

Trends in Shaken Baby Syndrome Diagnoses Among Young Children Hospitalized for Abuse

Aislinn Conrad (✉ aislinn-conrad@uiowa.edu)

University of Iowa <https://orcid.org/0000-0002-9446-9410>

Brandon Butcher

University of Iowa

Resmiye Oral

Dartmouth College Geisel School of Medicine

Megan Ronnenberg

University of Iowa

Corinne Peek-Asa

University of Iowa

Original Contribution

Keywords: shaken baby syndrome, abusive head trauma, child abuse, trends, secondary data

DOI: <https://doi.org/10.21203/rs.3.rs-22246/v2>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Objective To investigate national trends of SBS diagnosis codes and how trends varied among patient and hospital characteristics.

Methods We examined possible SBS, confirmed SBS, total SBS, and non-SBS abuse diagnoses among children age three and younger who were hospitalized for abuse between 1998 and 2014 using a secondary analysis of the National Inpatient Sample, the largest US all-payer inpatient care database ($N = 66,854$). A baseline category logit model was used based on a quasi-likelihood approach (QIC) with an independent working correlation structure.

Results The rate (per 100,000 census population) of total SBS diagnoses was 5.4 (± 0.3) between 1998 and 2014, whereas the rate of non-SBS abuse was 19.6 (± 1.0). The rate of confirmed SBS diagnoses increased from 3.8 (± 0.3) in 1998 to 5.1 (± 0.9) in 2005, and decreased to 1.3 (± 0.2) in 2014. Possible SBS diagnoses were 0.6 (± 0.2) in 1998, increasing to 2.4 (± 0.4) in 2014. Confirmed SBS diagnoses have declined since 2002, while possible SBS diagnoses have increased. All abuse types were more frequent among infants, males, children from low-income homes, and urban teaching hospitals.

Conclusions We investigated seventeen-year trends of SBS diagnoses among young children hospitalized for abuse. The discrepancy between trends in possible and confirmed SBS suggests differences in norms for diagnosing SBS, which has implications for which cases are considered AHT. Future research should investigate diagnostic processes for SBS and whether all codes associated with abusive head injuries in young children are classified as AHT. Our findings also highlight the relativity defining and diagnosing SBS. Medical professionals find utility in diagnosing SBS, though may be more apt to apply possible SBS diagnoses to abusive head injuries in children. Clarifying norms for SBS diagnosis and refining definitions for AHT will ensure that young children presenting with abusive head injuries are included in overall counts of AHT. This baseline data, an essential component of child abuse surveillance, will enable ongoing efforts to track, prevent, and reduce child abuse.

1. Introduction

Every year, 30 per 100,000 infants are diagnosed with abusive head trauma in US hospitals,^[1] leading to mild to moderate behavioral and cognitive problems among abuse survivors, and lifelong disability or death in severe instances.^[2] Pediatric abusive head trauma (AHT) includes injuries to children's skulls or intracranial contents that occur when perpetrators throw, drop, suffocate, choke, and violently shake young children.^[3] The actual incidence of AHT remains unknown due to the secrecy, stigma, and shame associated with child abuse,^{[4];[5]} eliciting researchers to surveil AHT using 15 diagnosis codes recommended by the Centers for Disease Control (CDC).^[6] Though the annual incidence of AHT likely exceeds the use of AHT diagnosis codes within hospitals, inpatient data are ideal for public health surveillance; hospital datasets provide consistent and reliable sampling frames (i.e., all children

hospitalized for AHT), and uniform measures of AHT (i.e., diagnosis codes from International Classification of Disease, Clinical Modification [ICD-CM]).^[7]

AHT is the official term for intentional abusive head injuries in children, yet researchers and medical professionals formerly ascribed these injuries to *shaken baby syndrome* (SBS). SBS is difficult to substantiate, relying on a specific mechanism for injury, i.e., shaking. The narrow definition of SBS along with legal and medical controversies surrounding SBS contributed to the American Academy of Pediatrics (AAP) and CDC's decision to adopt AHT terminology instead of SBS.^{6,8]} SBS is often framed as a questionable diagnosis in both mainstream media and research,^{[9]-¹⁰[11]} although nearly 40% of AHT hospitalizations include a diagnosis code for shaken baby syndrome (SBS).^[12]

The continued reliance on SBS codes suggests that medical professionals find utility in the diagnosis, yet little is known about the incidence of SBS diagnosis codes per year or over time. These knowledge gaps are problematic for two reasons. First, researchers do not know whether trends in SBS diagnoses correspond with trends in AHT diagnoses, which have stabilized or declined over time, depending on the study.^{12,13]} Evidence that SBS diagnoses are changing over time would provide AAP and CDC confidence about the effectiveness and accuracy of their messaging about AHT. Second, researchers do not know the extent to which SBS is diagnosed every year nor the hospital and patient characteristics associated with the diagnosis. Such evidence would highlight inconsistencies between current and desired diagnostic practices and help policymakers align current practices with their guidelines. In response, we examined trends in SBS diagnoses (ICD-9 code 995.55) between 1998 and 2014.

Another issue related to SBS diagnosis pertains to accuracy. Medical professionals who diagnose SBS rely largely on a unique pattern of injuries they attribute to shaking, including subdural hematoma, retinal hemorrhages and encephalopathy, otherwise known as the so-called "triad".^{[14].^{15]} However, researchers do not know whether the SBS diagnostic code (995.55) captures all abusive head injuries related to the "triad." In absence of this information, some pediatric abusive head injuries may remain unclassified as either SBS or AHT. The CDC definitions for both probable and definite AHT, for example, exclude retinal hemorrhages and convulsions without a seizure disorder, two symptoms typically associated with SBS.^[16] This is problematic considering that up to 40% of AHT hospitalizations with an SBS diagnosis would be considered non-AHT abuse without the SBS diagnostic code.¹² In response, we used diagnostic codes from ICD-9 to develop measures of possible and confirmed SBS. For possible SBS, we included ICD-9 codes for retinal hemorrhages and convulsions without a seizure disorder, whereas our measure of confirmed SBS included only the ICD-9 code for shaken baby syndrome (995.55) among young children hospitalized for child abuse.}

In all, few, if any, researchers have examined the prevalence of SBS diagnosis codes or how the use of codes are trending over time. In the absence of this data, researchers will not know the extent to which SBS is diagnosed, or the patient and hospital characteristics associated with SBS diagnosis. Therefore, the purpose of our study was to investigate trends in SBS diagnosis codes among a nationally representative sample of children age three and younger who were hospitalized for abuse. Using 1998-

2014 data from the National Inpatient Sample (NIS),^[17] we described the demographic characteristics of children hospitalized for both possible and confirmed SBS, calculated the annual rate of non-SBS abuse and possible and confirmed SBS diagnosis codes, and investigated how trends varied among patient and hospital characteristics.

Through our findings on trends in SBS diagnosis, we can determine whether the use of the SBS code (995.55) has declined since the AAP's recommendation in 2009, and whether the SBS code accounts for all possible SBS diagnoses, which are not currently captured within the 15 AHT diagnosis codes.

2. Method

2.1 Sample

Data from 1998-2014 from the National Inpatient Sample (NIS)¹⁷ were used for this retrospective study. The NIS is the largest all-payer, inpatient care database in the US and is maintained by the Healthcare Utilization project. We identified our sample of children three years of age or younger who were hospitalized for abuse using the following ICD-9 diagnosis and external cause of injury codes, which describe the intent, mechanism, and circumstances of an injury: Abuse by father/step-father/boyfriend (E967.0), abuse by mother/step-mother/girlfriend (E967.2), abuse by all other relatives (E967.3 – E967.7), abuse by non-relative (E967.8), neglect (995.52), physical abuse (995.54), psychological abuse (995.51), shaken baby syndrome (995.55), sexual abuse (995.53), and other child abuse not specified (995.50, 995.59, E967.1, & E967.9). We examined SBS diagnoses among young children hospitalized for any form of abuse for two reasons. First, though associations between physical abuse (e.g. SBS) and non-physical forms of abuse may seem surprising, physical and non-physical abuse co-occurs among 30 to 90% of abused children.^{[18]⁻[19][20][21]} Boxer and Terranova found that 50% of hospitalized children experienced more than one abuse type, with physical abuse, emotional abuse, neglect, and sexual abuse sharing modest to moderate correlations.^[22] Second, healthcare providers may misdiagnose or fail to diagnose earlier instances of child physical abuse preceding severe incidences of abuse.^{[23][]][24]} These findings suggest that young children with SBS diagnoses may also present to the hospital with a non-physical form of abuse.

Although data from 2015 and 2016 are available, we did not use these data due to the switch from ICD-9-CM to ICD-10-CM diagnosis standards in 2015. This change led to substantive shifts in abuse coding, meaning that changes in abuse frequency could not be discerned from changes in the coding standard. All analyses incorporated sampling weights to provide nationally representative estimates.

2.2 Measures

Our analysis included four measures of child abuse within our sample: Non-SBS abuse, confirmed SBS, possible SBS, and total SBS. We defined these three categories as follows:

- *Confirmed SBS Abuse*: The presence of diagnosis code 995.55.

- *Possible SBS Abuse*: The absence of diagnosis code 995.55 and the presence of physical abuse (995.54), Type 1 internal traumatic brain injury (TBI; 800,801,803,804(.1–.4,.6–.9,.03–.05,.53–.55), 850(.2–.4), 851–854, 950(.1–.3)), retinal hemorrhage (362.81), and/or convulsions not associated with a seizure disorder (780.39).
- *Non-SBS Abuse*: Remaining cases that did not meet the criteria of Confirmed or Possible SBS.
- *Total SBS Abuse*: The sum of confirmed and possible incidences of SBS.

Per the Barell injury matrix,^[25] Type 1 TBI diagnoses include primary intracranial injury, moderate to prolonged loss of consciousness, shaken infant syndrome, or injuries to the optic nerve pathways. We included retinal hemorrhage and convulsions not related to a seizure disorder because they indicate acceleration/deceleration of the head,¹⁶ yet are not included in the CDC’s recommended codes for AHT.⁶ While traumatic brain injury from impact is not precluded, this combination of codes indicates that children were subjected to high-force acceleration injury, characteristic of SBS.

2.3 Analytic strategy

We calculated the annual prevalence of SBS hospital diagnoses from 1998 through 2014 for confirmed SBS, possible SBS, and total SBS. Our primary objective was to estimate trends in the probability of confirmed and possible SBS diagnoses. A Chi-square test was used to test for independence of possible and confirmed SBS diagnoses from patient and hospital characteristics. Differences between non-SBS abuse and total SBS were also estimated.

Trends were estimated overall and within categories of age and hospital size. Hospital size is categorized as large, medium, and small, although the NIS does not provide detailed information on how these categories are constructed. A baseline category logit model^[26] was used based on a quasi-likelihood approach (QIC) with an independent working correlation structure in which non-SBS abuse is the reference category. The primary sampling unit in the NIS is the hospital; there are repeated observations within each hospital and across time. To account for the misspecification of the correlation structure, robust standard errors were used (i.e., “sandwich” estimators). Since there is a lack of research on SBS time trends, QIC was used to determine the form of the time trend: linear, quadratic, cubic, or treating time as categorical. A reduction in QIC of two-units was chosen a priori to indicate model preference. All statistical analyses were performed using SAS version 9.4.

3. Results

3.1 Sample characteristics

From 1998-2014, there were an estimated 66,854 total hospital admissions for child abuse among children three years of age and younger, with 52,562 hospital admissions for non-SBS abuse and 14,292 for SBS abuse, of which 10,083 were confirmed and 4,209 were possible SBS. Both possible SBS and non-SBS abuse admissions had significantly older age distributions than confirmed SBS or total SBS

admissions, respectively ($p < 0.0001$; Table 1). Although not statistically significant, 63.6% of possible SBS admissions were male compared to 59.7% of confirmed SBS admissions ($p = 0.0749$). In contrast, 60.8% of total SBS admissions were male as compared and 57.2% of non-SBS abuse admissions ($p < 0.001$). There were statistically significant differences in the racial distributions and hospital deaths of total SBS and non-SBS abuse admissions ($p < 0.0001$), yet no significant differences for possible and confirmed SBS admissions by racial distribution ($p = 0.2402$) or hospital deaths ($p = 0.4673$). We used the default racial categories provided by NIS (Asian or Pacific Islander, Black, Hispanic, Native American, Other, White).

The NIS categorizes patient income into quartiles based on the estimated median household income of residents in the patient's ZIP code. Lower income families (1st and 2nd income quartiles) had a higher representation among possible SBS and total SBS admissions than confirmed SBS admissions (62.1% & 56.0% vs. 54.2%, respectively; $p = 0.0005$). Moderate to higher income families (2-4th quartile) had greater representation among total SBS admissions compared to non-SBS abuse admissions ($p < 0.001$). Confirmed SBS was most common in large hospitals, while possible SBS was more frequent in medium and small-sized hospital ($p = 0.0082$). There were no statistically significant differences for total SBS and non-SBS abuse by hospital size. Possible SBS and total SBS were also more frequent than confirmed SBS and non-SBS abuse in urban teaching hospitals when compared to urban non-teaching and rural hospitals ($p = 0.0054$, $p < 0.0001$).

3.2 Time trends in rate of SBS

In Table 1, we summarize the rates (per 100,000 census population^{[27],[28],[29]}) for non-SBS abuse, possible SBS, confirmed SBS, and total SBS. The overall rate of total SBS diagnoses was 5.4 (± 0.3) for every 100,000 children 3 years of age or younger from 1998–2014, whereas the rate of non-SBS abuse was 19.6 (± 1.0). The overall rate of confirmed SBS and possible SBS admissions was 3.8 (± 0.3) and 1.6 (± 0.1), respectively. The annual rate of non-SBS abuse admissions remained fairly stable, with the lowest rate of admissions in 2000 (16.6 ± 2.0) and the highest rate of admissions in 2010 (25.8 ± 4.2). However, the rate of admissions for confirmed SBS abuse increased from 3.6 (± 0.6) in 1998 to 5.1 (± 0.9) in 2005, at which point the rate steadily decreased to 1.3 (± 0.2) in 2014. Conversely, the rate of admissions for possible SBS increased gradually per year. In 1998, the rate of possible SBS admissions was 0.6 (± 0.2) and steadily increased to 2.4 (± 0.4) in 2014. Total SBS fluctuated but remained relatively stable, beginning at 4.1 (± 0.7) in 1998 and ending at 3.7 (± 0.4) in 2014.

Time trends in probability of type of abuse diagnosis. We conducted a baseline category logit model to examine whether the difference in trends for confirmed SBS, possible SBS, and the reference category, non-SBS abuse, were statistically significant. Figures 1 – 3 indicate the results from these analyses (solid line and 95% confidence band). Non-SBS abuse includes all abuse cases not meeting criteria of confirmed or possible SBS. A statistically significant difference was found in the overall trends of the probability of possible SBS versus confirmed SBS (Figure 1). Possible SBS gradually increased over time, whereas confirmed SBS slightly increased until 2001 and then decreased from 2002 to 2014 with the

trends crossing over in 2011. In 1998, the estimated probability of possible SBS was 2.8% (95% CI: 1.7, 4.6), whereas the chance of confirmed SBS was 18.5% (95% CI: 12.5, 26.4). In 2014, the estimates for possible SBS and confirmed SBS were 9.4% (95% CI: 7.7, 11.3) and 5.3% (95% CI: 3.4, 8.2), respectively.

Figure 2 shows the statistically significant trends for possible SBS versus confirmed SBS by age group: < 1 year old, 1 year old, and 2 or 3 years old. The decrease in the probability of confirmed SBS was largest for infants (< 1 year old), declining from 29.9% (95% CI: 23.2, 37.4) in 1998 to 3.2% (95% CI: 1.4%, 7.3%) in 2014, a decrease of 26.7%. Confirmed SBS diagnosis trends for infants (< 1 year old) overlapped with possible SBS in 2011. The decrease in confirmed SBS diagnosis trends was more attenuated for young toddlers (1 year old) than for older toddlers (2 or 3 years old) between 1998 and 2014, decreasing by 8.3% for young toddlers (15.5% [95%: 9.4%, 24.4%] v. 7.2% [95% CI: 3.7%, 13.6%], respectively), and decreasing by 4.0% for older toddlers (11.2% [95%: 5.9%, 20.4%] v. 7.2% [95% CI: 3.2%, 13.9%], respectively). The probability of possible SBS increased for all age groups in the same time period.

The trends for confirmed and possible SBS among females and males (Figure 3) were similar to the overall trend (Figure 1). For males, the probability of confirmed SBS increased from 20.5% (95% CI: 13.4%, 30.1%) in 1998 to 21.8% (95% CI: 16.8%, 27.7%) in 2000, and then decreased to 5.0% (95% CI: 2.9%, 8.5%) in 2014. In contrast, the probability of a male receiving a possible SBS diagnosis increased gradually between 1998 to 2014 (3.1% [95% CI: 1.9, 4.8] v. 11.3% [95% CI: 9.3, 13.5], respectively). For females, the probability of a confirmed SBS diagnosis increased from 15.7% (95% CI: 9.2%, 25.4%) in 1998 to 19.2% (95% CI: 14.7%, 24.6%) in 2002, and then decreased to 5.6% (95% CI: 2.9%, 10.2%) in 2014, whereas the probability of a female receiving a possible SBS diagnosis increased gradually by 4.3% from 1998 to 2014 (2.4% [95% CI: 1.1%, 5.2%] v. 6.7% [95% CI: 4.8%, 9.3%], respectively).

Figure 4 shows the statistically significant trends for possible SBS versus confirmed SBS by hospital size (based on bed count). The most pronounced decrease in the probability of confirmed SBS was for large hospitals between 1998 and 2014 (26.9% [95% CI: 19.4, 35.9] v. 8.7% [95% CI: 5.7%, 13.0%]). This decrease in confirmed SBS was less attenuated among medium-sized hospitals (17.8% [95%: 9.6%, 30.6%] v. 8.7% [95% CI: 4.6%, 15.4%]) than small hospitals (23.7% [95%: 13.6%, 37.3%] v. 6.8% (95% CI: 3.0%, 14.4%)) between 1998 and 2014. In contrast, the probability of possible SBS increased for each hospital size during the same time period.

4. Discussion

AHT is a serious form of child physical abuse that happens when caregivers throw, drop, choke, and violently shake young children.³ These abusive head injuries were classified as SBS until 2009, when the AAP and CDC recommended AHT diagnoses instead of SBS.⁸ Though non-fatal AHT diagnoses have stabilized or declined over time,^{12,13} little is known about SBS diagnosis trends. This knowledge gap is problematic considering that 40% of AHT hospitalizations with an SBS diagnosis would not be classified as AHT without an SBS diagnosis.¹² Without knowing trends in SBS diagnosis codes, we cannot determine the extent to which medical professionals follow the diagnosis recommendations of CDC and

AAP. Further, the patient and hospital characteristics associated with SBS diagnoses remain unknown. Having this data could help researchers and policymakers identify the factors associated with SBS diagnosis. In response, we investigated seventeen-year trends in possible SBS, confirmed SBS, total SBS, and non-SBS abuse diagnoses among young children. We also examined the patient and hospital characteristics associated with these diagnoses.

In our study, we found support for the following: 1) Non-SBS abuse is the most common form of abuse in our study; 2) Confirmed SBS diagnosis trends have declined while possible SBS diagnosis trends have increased; 3) All abuse diagnoses were more common among infant, male, or low-income children and urban teaching hospitals. Taken together, our findings contribute to literature on SBS and non-SBS abuse diagnoses within hospitals, including diagnosis trends and characteristics associated with each abuse category. Policymakers can use our findings to develop plans for aligning current diagnostic practices with CDC and AAP guidelines.

According to our estimates, possible and confirmed SBS cases represent a fraction of the overall abuse young children experience. Our results are similar to reports on overall child maltreatment investigations, in which only 10.7% of cases comprise physical abuse.^[30] Hospitalizations often represent the most severe incidences of non-fatal child abuse, which are disproportionately experienced by young children.³⁰ Two research teams reported unchanging rates of child abuse hospitalizations among children ages 0 to 18, with young children facing the largest share of hospitalizations between 1998 and 2016,^[31] and stable overall trends in child maltreatment hospitalization among young children ages 0 to 3 from 1997 to 2009.^[32] Along with these study findings, our results provide evidence that child abuse hospitalizations remain a significant problem in the US.

Of our four abuse diagnosis categories, only confirmed SBS diagnoses declined between 2002 to 2014. This finding aligns with AHT literature indicating that AHT diagnoses decreased during overlapping time periods (2003 – 2008;¹² 2000 – 2009¹³). There may be various explanations for reductions to confirmed SBS diagnoses over time, including declines in the actual incidence of SBS. Unfortunately, our findings on the decreasing use of SBS code 995.55 most likely does not reflect shifts in abusive caregiver practices. Given that possible SBS diagnoses increased steadily over the study period, a likelier explanation relates to changing diagnostic practices of medical professionals. Though AAP and CDC recommendations likely impacted the decline in confirmed SBS diagnosis, confirmed SBS diagnoses began decreasing in 2002, seven years before AAP's recommendation in 2009. It is possible that medical and legal controversy surrounding SBS also contributed to the decline. Numerous papers have questioned SBS as a reputable diagnosis, citing inadequate scientific evidence that the injuries typically associated with SBS are caused solely by shaking.^{[33]-[34][35]}

Whereas confirmed SBS diagnoses have decreased, possible SBS diagnoses have increased. By 2011, the rate of possible SBS diagnoses exceeded the rate of confirmed SBS diagnoses. This finding suggests that medical professionals are not diagnosing retinal hemorrhage and/or convulsions not associated with a seizure disorder, as confirmed SBS, even in the presence of physical abuse and Type 1 internal

traumatic brain injury. If these diagnosis codes represent SBS yet are not coded as SBS, there are implications for diagnostic norms for both SBS and AHT. At present, CDC-recommended AHT codes do not include retinal hemorrhage and/or convulsions without seizure disorder (i.e. possible SBS). The implication is that our possible SBS diagnosis may capture cases that would not meet the CDC's definition of AHT,⁶ perhaps being misclassified as non-AHT abuse, as previously indicated by Parks and colleagues.¹²

In the future, researchers should investigate the overlap between possible SBS and AHT, and compare trends in confirmed SBS, possible SBS, and AHT diagnoses over time. This research would help determine whether current definitions of AHT capture all diagnoses associated with abusive head injuries in young children. If current AHT definitions exclude instances of abusive head injuries, including retinal hemorrhage and/or convulsions not associated with a seizure disorder in the presence of physical abuse and Type 1 internal traumatic brain injury, policymakers could consider adding codes to measure AHT

Our finding on increasing possible SBS diagnoses may also provide context to the overall process for diagnosing SBS, which Narang and Greeley describe as a complex, context-driven process without reputable diagnosis guidelines.^[36] Through our findings, there are a few directions researchers, policymakers, and medical professionals could take. If medical professionals find utility in diagnosing SBS, it appears that clearer diagnostic guidelines are needed, especially in light of the hospital characteristics associated with possible versus confirmed SBS diagnosis. According to our study, possible SBS diagnoses were more frequent in urban teaching hospitals and large hospitals, suggesting different diagnostic protocols in these institutions. Findley and colleagues recommend the development of a national registry on SBS and protocols for diagnosing SBS along with alternative explanations for SBS-like injuries.^[37] Likewise, we propose that researchers and pediatric medical providers agree to a standardized definition and diagnostic guidelines for possible and confirmed SBS, much like the AHT guidelines proposed by CDC, which may help reduce discrepancies in diagnosis and treatment and improve options for surveillance.^{[38],[39]}

Finally, our findings on the patient and hospital characteristics associated with SBS diagnoses align with what is known about AHT in the literature. Like AHT, our findings indicate that all abuse types were diagnosed more frequently among infants (<1-year-old), boys, and children from low-income households than toddlers, girls, and children from higher-income households.^{12,13,[40]} The prevalence of SBS and AHT of infants under the age of 1 has been attributed to infant crying and subsequent parental or caregiver stress. Perpetrators are often caregivers who shake children to stop persistent crying during the first few months after birth.^[41] The age distribution of SBS and AHT follow what is referred to as the "normal crying curve", or typical periods of increased infant crying that peaks between 6 to 10 weeks of age.^[42] ^[43] Explanations for the prevalence of SBS among male infants may include the acoustic characteristics of male cries, societal norms related to crying in boys, and gender stereotypes. Some research suggests that male infant cries may aggravate caregivers more than female cries and that caregivers may tolerate male cries less than female cries due to societal norms around crying;^[44] in the US, crying is more acceptable for girls and is considered a weakness for boys. Gender stereotypes held by physicians and

medical professionals may influence their diagnoses of abuse related injuries. For example, Ravichandiran and colleague reported that physicians initially miss the abuse of boys more often than girls,[45] suggesting that physicians may perceive injuries differently among boys and girls, possibly because boys are socialized for rough-and-tumble play and are more prone to accidental injury.[46]

In all, we contribute to the literature by examining seventeen-year trends of SBS among young children hospitalized for abuse, yet there are limitations. First, our possible SBS measure may not account for all SBS victims who are hospitalized. Physicians use a variety of tools, including constellations of injuries consistent with SBS and a child's history of injuries, to diagnose SBS. We chose a combination of codes highly indicative of acceleration/deceleration injury to avoid false-positive diagnoses, but these codes are not exhaustive. Second, our analysis includes no correction for confounders in the estimation of time trends. The lack of research on these trends, however, warranted our approach of estimating simple time trends by subgroup. Third, because our estimates rely on in-patient data, they do not include victims of SBS who were not hospitalized and therefore may misrepresent the actual incidence of SBS. This surveillance issue is a common problem for all studies on child maltreatment. Finally, SBS-related diagnosis codes only describe how medical professionals code abusive head injuries and cannot describe trends related to abusive parenting practices. Surveillance of child abuse itself remains a significant challenge in literature on child maltreatment, and is an issue our study cannot address.⁴

5. Conclusion

Our study findings demonstrated that while confirmed SBS has decreased since 2002, possible SBS has increased. The discrepancy between trends in possible and confirmed SBS suggests differences in norms for diagnosing SBS, which has implications for which cases are considered AHT and which are not. Future research should investigate diagnostic processes for SBS and whether all codes associated with abusive head injuries in young children are being classified as AHT. Our findings also highlight the relativity defining and diagnosing SBS. According to our findings on confirmed SBS diagnoses, medical professionals find utility in the diagnosis, though may be more apt to apply possible SBS diagnoses to abusive head injuries in children given AAP and CDC recommendations and controversy surrounding SBS diagnoses. Clarifying norms for SBS diagnosis and refining definitions for AHT will ensure that all young children presenting with abusive head injuries included in overall counts of AHT. This baseline data, an essential component of child abuse surveillance, will enable ongoing efforts to track, prevent, and reduce child abuse.

Abbreviations

AAP: American Academy of Pediatrics; AHT: Abusive head trauma; CDC: Center for Disease Control and Prevention; CI: Confidence interval; ICD9-CM: International classification of diseases, clinical modification, ninth revision; NIS: National Inpatient Sample; SBS: Shaken baby syndrome; TBI: Traumatic brain injury; QIC: Quasi-likelihood information criterion.

Declarations

Availability of data and materials

The data that support the findings of this study are available for purchase from the Healthcare Utilization Project. Data are available, however, from the authors upon reasonable request and with permission of the Healthcare Utilization Project.

Authors' contributions

AC, RO, BB, and CPA contributed significantly to the study conceptualization and design. AC contributed to manuscript writing. CPA and BB acquired the data, performed data cleaning and analysis, and contributed to manuscript writing. RO provided editing and guidance throughout manuscript revisions. MR conducted the literature review and contributed to manuscript writing. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Not applicable. NIS is a publicly available dataset.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Acknowledgements

Not applicable.

References

[1] Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinal SH. A population-based study of inflicted traumatic brain injury in young children. *Jama*. 2003; 290(5): 621-626.

[2] Duhaime AC, Christian CW. Abusive head trauma: evidence, obfuscation, and informed management: JNSPG 75th Anniversary Invited Review Article. *Journal of Neurosurgery: Pediatrics*. 2019; 24(5): 481-

488.

- [3] Joyce T, Huecker MR. Pediatric Abusive Head Trauma (Shaken Baby Syndrome). In: StatPearls [Internet]: StatPearls Publishing; 2020. PMID: 29763011.
- [4] Fallon B, Trocme N, Fluke J, MacLaurin B, Tonmyr L, Yuan Y. Methodological challenges in measuring child maltreatment. *Child Abuse & Neglect*. 2010; 34: 70-79.
- [5] Sedlak AJ, Mettenburg J, Basena M, Petta I, McPherson K, Greene A, Li S. *Fourth National Incidence Study of Child Abuse and Neglect (NIS-4): Report to Congress, Executive Summary*. Washington, DC: U.S. Department of Health and Human Services, Administration for Children and Families; 2010.
- [6] Center for Disease Control and Prevention (2012). Pediatric abusive head trauma: Recommended definitions for public health surveillance and research. Retrieved from <https://www.cdc.gov/violenceprevention/pdf/pedheadtrauma-a.pdf>.
- [7] Wirtz SJ, Trent RB. Passive surveillance of shaken baby syndrome using hospital inpatient data. *American Journal of Preventive Medicine*. 2008; 34(4): S134-S139.
- [8] Christian CW, Block R. Abusive head trauma in infants and children. *Pediatrics*. 2010; 123(5): 1409-1411.
- [9] Hennink-Kaminski HJ, Dougall EK. Myths, mysteries, and monsters: When shaken babies make the sews. *Social Marketing Quarterly*. 2009;15(4):25-48.
- [10] Schiks L, Dankelman J, Loeve A. Thresholds for the assessment of inflicted head injury by shaking trauma in infants: A systematic review. *Forensic Science International*. 2020; 306.
- [11] Lynøe N, Elinder G, Hallberg B, Rosen M, Sundgren P, Eriksson A. Insufficient evidence for 'shaken baby syndrome'- A systematic review. *Acta Paediatrica*. 2017;106:1021-1027.
- [12] Parks S, Sugerman D, Xu L, Coronado V. Characteristics of non-fatal abusive head trauma among children in the USA, 2003–2008: Application of the CDC operational case definition to national hospital inpatient data. *Injury Prevention*. 2012; 18(6): 392-398.
- [13] Shanahan ME, Zolotor AJ, Parrish JW, Barr RG, Runyan DK. National, regional, and state abusive head trauma: Application of the CDC algorithm. *Pediatrics*. 2013; 132(6): e1546-e1553.
- [14] Squier W. Shaken baby syndrome: The quest for evidence. *Developmental Medicine & Child Neurology*. 2008; 50(1): 10-14.
- [15] Squier W. The “Shaken Baby” Syndrome: Pathology and mechanisms. *Acta Neuropathologica*. 2011; 122(5): 519.

- [16] Hymel KP, Bandak F, Partington M, Winston K. Abusive head trauma? A biomechanics-based approach. *Child Maltreatment*. 1998; 3(2):116-128.
- [17] Agency for Healthcare Research and Quality (AHRQ). *Healthcare cost and utilization project – national inpatient sample*. 2012. Rockville, Maryland.
- [18] Claussen AH, Crittenden PM. Physical and psychological maltreatment: Relations among types of maltreatment. *Child Abuse & Neglect*. 1991; 15: 5–18.
- [19] Kim K, Mennen FE, Trickett PK. Patterns and correlates of co-occurrence among multiple types of child maltreatment. *Child & Family Social Work*. 2017; 22(1): 492-502.
- [20] McGee RA, Wolfe DA, Yuen SA, Wilson SK, Carnochan J. The measurement of maltreatment: A comparison of approaches. *Child Abuse & Neglect*. 1995; 19(2): 233–249.
- [21] Lau AS, Leeb RT, English D, Craham JC, Briggs EC, Brody KE, Marshall JM. What's in a name?: A comparison of methods for classifying predominant type of maltreatment. *Child Abuse & Neglect*. 2005; 29: 553–551.
- [22] Boxer P, Terranova AM. Effects of multiple maltreatment experiences among psychiatrically hospitalized youth. *Child Abuse & Neglect*. 2008; 32: 637– 647.
- [23] Christian CW, Committee on Child Abuse and Neglect. The Evaluation of Suspected Child Physical Abuse. *Pediatrics*. 2015; 135(5): e1337-e1354.
- [24] King WK, Kiesel EL, Simon HK. Child abuse fatalities: are we missing opportunities for intervention?. *Pediatr Emerg Care*. 2006;22(4):211-214. doi:10.1097/01.pec.0000208180.94166.dd
- [25] Bergen G, Chen LH, Warner M, Fingerhut LA. Injury in the United States: 2007 Chartbook. Hyattsville, MD: National Center for Health Statistics. 2008. <https://www.cdc.gov/nchs/data/misc/injury2007.pdf>. Accessed May 21, 2019.
- [26] Agresti, Alan. *Categorical Data Analysis / Alan Agresti*. Third ed. Wiley Series in Probability and Statistics. Hoboken, NJ: Wiley, 2013.
- [27] U.S. Census Bureau (2016). 1990s: National Population Datasets. Retrieved from <https://www.census.gov/data/datasets/time-series/demo/popest/1990s-national.html>.
- [28] U.S. Census Bureau (2016). National Intercensal Datasets: 2000-2010. Retrieved from <https://www.census.gov/data/datasets/time-series/demo/popest/intercensal-2000-2010-national.html>.
- [29] U.S. Census Bureau. Annual Estimates of the Resident Population by Single year of Age and Sex for the United States: April 1, 2010 to July 1, 2017. 2018. <https://www2.census.gov/programs-surveys/popest/datasets/2010-2017/national/asrh/nc-est2017-alldata-r-file18.csv>.

- [30] U.S. Department of Health & Human Services, Administration for Children and Families, Administration on Children, Youth and Families, Children's Bureau. (2020). Child Maltreatment 2018. <https://www.acf.hhs.gov/cb/research-data-technology/statistics-research/child-maltreatment>.
- [31] Wojciak, A. S., Butcher, B., Conrad, A., Coohy, C., Oral, R., & Peek-Asa, C. (2020). National trends in child abuse and neglect hospitalization rates and costs. Iowa City, IA: University of Iowa.
- [32] Farst K, Ambadwar PB, King AJ, Bird TM, Robbins JM. Trends in hospitalization rates and severity of injuries from abuse in young children, 1997–2009. *Pediatrics*. 2013; 131(6): e1796-e1802.
- [33] Findley KA, Risinger DM, Barnes PD, Mack J, Moran DA, Scheck B, Bohan T. Feigned Consensus: Usurping the Law in Shaken Baby Syndrome/Abusive Head Trauma Prosecutions. Wisconsin Law Review 1211, Univ. of Wisconsin Legal Studies Research Paper No. 1461. 2019. <http://dx.doi.org/10.2139/ssrn.3328996>
- [34] Choudhary AK, Narang SK, Moreno JA, Christian CW, Servaes S, Palusci VJ, Hedlund GL, Dias MS, Nelson MD, Silvera VM, Palasis S, Raissaki M, Rossi A, Offiah AC. A consensus response on the complete picture: Reply to Lynøe and Eriksson. *Pediatric Radiology*. 2019; 49(3): 424-428.
- [35] Lyons G. Shaken baby syndrome: A questionable scientific syndrome and a dangerous legal concept. *Utah L Rev*. 2003; 1109(3): 1109-1132.
- [36] Narang SK, Fingarson A, Lukefahr J, AAP Council on Child Abuse and Neglect. Abusive Head Trauma in Infants and Children. *Pediatrics*. 2020; 145(4): e20200203
- [37] Findley KA, Barnes PD, Moran DA, Squier W. Shaken baby syndrome, abusive head trauma, and actual innocence: Getting it right. *Hous J Health L & Pol'y*. 2011; 12(2): 209-312.
- [38] Kim PT, Mccagg J, Dundon A, Ziesler Z, Moody S, Falcone RA. Consistent screening of admitted infants with head injuries reveals high rate of nonaccidental trauma. *Journal of Pediatric Surgery*. 2017; 52(11): 1827-1830.
- [39] Paine CW, Scribano PV, Localio R, Wood JN. Development of guidelines for skeletal survey in young children with intracranial hemorrhage. *Pediatrics*. 2016; 137(4).
- [40] Leventhal JM, Martin KD, Gaither JR. Using US data to estimate the incidence of serious physical abuse in children. *Pediatrics*. 2012; 129(3): 458-464.
- [41] Barr RG. Preventing abusive head trauma resulting from a failure of normal interaction between infants and their caregivers. Proceedings of the National Academy of Sciences. 2012; 109: 17294-17301.
- [42] Barr RG, Trent RB, Cross J. Age-related incidence curve of hospitalized Shaken Baby Syndrome cases: Convergent evidence for crying as a trigger to shaking. *Child Abuse & Neglect*. 2006; 30(1): 7-16.

[43] Lee C, Barr RG, Catherine N, Wicks A. Age-related incidence of publicly reported shaken baby syndrome cases: Is crying a trigger for shaking? *Journal of Developmental & Behavioral Pediatrics*. 2007; 28(4): 288-293.

[44] Richey L, Li T, Rilling JK. Perception of male and female infant cry aversiveness by adult men. *Journal of Reproductive and Infant Psychology*. 2020: 1-15.

[45] Ravichandiran N, Schuh S, Bejuk M, et al. Delayed identification of pediatric abuse-related fractures. *Pediatrics*. 2009; 125(1): 60-66.

[46] Hagan LK, Kuebli J. Mothers and fathers socialization of preschoolers physical risk taking. *Journal of Applied Developmental Psychology*. 2007; 28(1): 2-14.

Table

Table 1. National hospital admissions for children up to three years, 1998 - 2014 (N = 66,854), patient- and hospital-level descriptive statistics, N (%), by type of abuse.

Variable	Possible SBS	Confirmed SBS	Chi-square	Total SBS	Non-SBS Abuse	Chi-square
	4,209 (29.4)	10,083 (70.6)	P value	14,292 (21.4)	52,562 (79.2)	P value
<i>Rates (per 100,00 population)</i>						
Total rate of abuse	1.6 (± 0.1)	3.8 (± 0.3)	—	4.5 (± 0.3)	19.6 (± 1.0)	—
Rate of abuse per year						
1998	0.6 (± 0.2)	3.6 (± 0.6)	—	4.1 (± 0.7)	17.8 (± 2.5)	—
1999	1.1 (± 0.3)	6.4 (± 1.0)	—	7.5 (± 1.2)	20.1 (± 2.3)	—
2000	0.6 (± 0.2)	4.6 (± 0.8)	—	5.2 (± 0.9)	16.6 (± 2.0)	—
2001	1.0 (± 0.3)	4.5 (± 0.8)	—	5.5 (± 1.1)	19.1 (± 3.1)	—
2002	0.7 (± 0.2)	4.3 (± 0.8)	—	5.0 (± 0.9)	17.5 (± 2.3)	—
2003	1.1 (± 0.3)	5.0 (± 0.8)	—	6.1 (± 1.0)	18.2 (± 2.6)	—
2004	1.3 (± 0.4)	4.8 (± 0.9)	—	6.1 (± 1.2)	18.1 (± 2.7)	—
2005	2.0 (± 0.6)	5.1 (± 0.9)	—	7.1 (± 1.3)	22.7 (± 3.6)	—
2006	1.3 (± 0.4)	4.5 (± 0.8)	—	5.9 (± 1.0)	17.9 (± 2.5)	—
2007	2.0 (± 0.6)	3.8 (± 0.7)	—	5.8 (± 1.1)	18.7 (± 3.5)	—
2008	1.2 (± 0.4)	3.8 (± 0.6)	—	5.0 (± 0.9)	17.3 (± 2.9)	—
2009	1.9 (± 0.5)	3.1 (± 0.6)	—	5.0 (± 1.0)	17.3 (± 2.8)	—
2010	1.9 (± 0.5)	3.6 (± 0.6)	—	5.6 (± 0.9)	25.8 (± 4.2)	—
2011	2.6 (± 0.7)	1.5 (± 0.3)	—	4.1 (± 0.9)	18.8 (± 3.8)	—
2012	2.3 (± 0.4)	2.2 (± 0.3)	—	4.4 (± 0.5)	21.4 (± 2.0)	—

2013	2.5 (± 0.4)	2.0 (± 0.3)	—	4.5 (± 0.5)	23.0 (± 2.0)	—
2014	2.4 (± 0.4)	1.3 (± 0.2)	—	3.7 (± 0.4)	22.5 (± 2.0)	—
<i>Patient Characteristics</i>						
Age						
Mean	0.57	0.29	—	0.37	0.62	—
Median	0	0	—	0	0	—
< 1	2,744 (65.2)	8,162 (80.9)	< 0.0001	10,906 (76.3)	33,428 (63.6)	< 0.0001
1	700 (16.6)	1,160 (11.5)		1,860 (13)	8,705 (16.6)	
2/3	765 (18.2)	761 (7.5)		1,526 (10.7)	10,429 (19.8)	
Died in Hospital						
Yes	571 (13.6)	1,271 (8.9)	0.4673	1,842 (12.9)	1,597 (3.0)	< 0.0001
No	3,637 (86.4)	8,812 (61.7)		12,450 (87.1)	50,964 (97.0)	
Sex						
Female	1,530 (36.4)	4,067 (40.3)	0.0749	5,597 (39.2)	22,486 (42.8)	0.0007
Male	2,679 (63.6)	6,016 (59.7)		8,695 (60.8)	30,075 (57.2)	
Race						
Asian or Pacific Islander	63 (1.5)	260 (2.6)	0.2402	323 (2.3)	467 (0.9)	< 0.0001
Black	853 (20.3)	1,992 (19.8)		2,845 (19.9)	12,774 (24.3)	
Hispanic	718 (17.1)	1,614 (16)		2,332 (16.3)	9,261 (17.6)	
Native American	58 (1.4)	84 (0.8)		142 (1)	500 (1)	
Other	310 (7.4)	574 (5.7)		884 (6.2)	2,632 (5)	
White	2,206 (52.4)	5,559 (55.1)		7,765 (54.3)	26,928 (51.2)	
Income						

1st Quartile	1,262 (30)	2,558 (25.4)	0.0005	3,820 (26.7)	18,216 (34.7)	< 0.0001
2nd Quartile	1,349 (32.1)	2,906 (28.8)		4,255 (29.8)	15,490 (29.5)	
3rd Quartile	1,037 (24.6)	2,572 (25.5)		3,609 (25.3)	11,703 (22.3)	
4th Quartile	560 (13.3)	2,047 (20.3)		2,607 (18.2)	7,153 (13.6)	
<i>Hospital Characteristics</i>						
Hospital Type (since 2008)						
Government, nonfederal	331 (14.4)	413 (14.9)	0.0677	744 (15.9)	3,641 (14.6)	0.6438
Private, investor-owned	98 (4.3)	243 (8.7)		341 (6.7)	1,541 (6.7)	
Private, not-for-profit	1,874 (81.4)	2,123 (76.4)		3,997 (77.4)	17,700 (78.6)	
Hospital Size (bed count)						
Large	2,380 (57.4)	6,704 (66.7)	0.0082	9,084 (64.0)	32,545 (62.5)	0.4798
Medium	1,111 (26.8)	1,944 (19.3)		3,055 (21.5)	12,063 (23.2)	
Small	656 (15.8)	1,398 (13.9)		2,054 (14.5)	7,455 (14.3)	
Hospital Location / Teaching						
Rural	45 (1.1)	328 (3.3)	0.0054	373 (2.6)	3,294 (6.3)	< 0.0001
Urban Non-Teaching	263 (6.2)	1,258 (12.5)		1,521 (10.6)	6,808 (13)	
Urban Teaching	3,901 (92.7)	8,497 (84.3)		12,398 (86.7)	42,460 (80.8)	
Hospital Region						
Midwest	1,210 (28.7)	2,707 (26.8)	0.1281	3,917 (27.4)	13,928 (26.5)	0.2049
Northeast	436 (10.4)	1,518 (15.1)		1,954 (13.7)	8,459 (16.1)	

South	1,675 (39.8)	4,177 (41.4)	5,852 (40.9)	20,144 (38.3)
West	888 (21.1)	1,681 (16.7)	2,569 (18)	10,029 (19.1)