Published in final edited form as:
Child Maltreat. 2015 August ; 20(3): 162–169. doi:10.1177/1077559515583549.

Annual Cost of U.S. Hospital Visits for Pediatric Abusive Head Trauma

Cora Peterson[1], **Likang Xu**[1], **Curtis Florence**[1], and **Sharyn E. Parks**[1]

[1]Centers for Disease Control and Prevention (CDC), National Center for Injury Prevention and Control, Atlanta, GA, USA

Abstract

We estimated the frequency and direct medical cost from the provider perspective of U.S. hospital visits for pediatric abusive head trauma (AHT). We identified treat-and-release hospital emergency department (ED) visits and admissions for AHT among patients aged 0–4 years in the Nationwide Emergency Department Sample and Nationwide Inpatient Sample (NIS), 2006–2011. We applied cost-to-charge ratios and estimated professional fee ratios from Truven Health MarketScan® to estimate per-visit and total population costs of AHT ED visits and admissions. Regression models assessed cost differences associated with selected patient and hospital characteristics. AHT was diagnosed during 6,827 (95% confidence interval [CI] [6,072, 7,582]) ED visits and 12,533 (95% CI [10,395, 14,671]) admissions (28% originating in the same hospital's ED) nationwide over the study period. The average medical cost per ED visit and admission were US$2,612 (error bound: 1,644–3,581) and US$31,901 (error bound: 29,266–34,536), respectively (2012 USD). The average total annual nationwide medical cost of AHT hospital visits was US$69.6 million (error bound: 56.9–82.3 million) over the study period. Factors associated with higher per-visit costs included patient age <1 year, males, coexisting chronic conditions, discharge to another facility, death, higher household income, public insurance payer, hospital trauma level, and teaching hospitals in urban locations. Study findings emphasize the importance of focused interventions to reduce this type of high-cost child abuse.

Keywords

child abuse; shaken baby syndrome; costs and cost analysis; economics; hospital

---

While the severity and public health significance of shaken baby syndrome, or pediatric abusive head trauma (AHT), has long been recognized, an administrative code-based definition of AHT with demonstrated accuracy from the Centers for Disease Control and Prevention (CDC) recently made it possible to investigate the health and financial impact of AHT on a consistent basis using U.S. nationwide data (Berger, Parks, Fromkin, Rubin, & Pecora, 2013; S. Parks, Annest, Hill, & Karch, 2012). Population-based studies using that

---

Corresponding Author: Cora Peterson, CDC National Center for Injury Prevention and Control, Mailstop F-62, 4770 Buford Highway, Atlanta, GA 30341, USA. cora.peterson@cdc.hhs.gov.

Declaration of Conflicting Interests
The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

definition have since separately reported the statewide or nationwide frequency of AHT mortality (S. E. Parks, Kegler, Annest, & Mercy, 2012), hospital inpatient admissions (Niederkrotenthaler, Xu, Parks, & Sugerman, 2013; S. Parks, Sugerman, Xu, & Coronado, 2012; Shanahan, Zolotor, Parrish, Barr, & Runyan, 2013), or emergency department (ED) visits (Selassie, Borg, Busch, & Russell, 2013; Xiang et al., 2013). However, no previous study has reported annual nationwide estimates of comprehensive hospital services (emergency and inpatient) for AHT and associated costs using the CDC definition.

Rigorous estimates of medical costs and resource use related to AHT are limited. A recent multistate study retrospectively assessed a large sample of AHT patients' individual medical costs from a payer perspective over several years, although that study was limited to patients with specific insurance types and could not assess nationwide frequency of AHT medical services (Peterson et al., 2014). In this study, we estimated the U.S. nationwide annual frequency of hospital emergency and inpatient visits for AHT, related direct medical costs from the provider perspective, and associations between AHT patient characteristics and hospital visit costs.

Methods

We identified treat-and-release hospital ED visits and inpatient admissions during which AHT was diagnosed (hereafter referred to as AHT ED visits or admissions, or collectively as AHT hospital visits) among patients aged 0–4 years in the 2006–2011 Nationwide Emergency Department Sample (NEDS) and Nationwide Inpatient Sample (NIS) from the Healthcare Cost and Utilization Project (HCUP). ED visits and admissions were included in this analysis if a combination of International Classification of Diseases, Ninth Revision, Clinical Modification, and External Cause of Injury (E-codes) diagnosis codes indicated definite or probable AHT based on a recent CDC definition (S. Parks, Annest, et al., 2012). AHT is defined by that source as an 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, excluding unintentional injuries resulting from neglectful supervision, as well as penetrating trauma such as gunshot or stab wounds (S. Parks, Annest, et al., 2012). The primary outcome measures in this study were the total number of AHT ED visits and admissions annually, the total direct medical cost from the provider perspective of AHT ED visits and admissions annually, and the average costs per AHT ED visit and admission over the study period. Secondary end points were the proportion of AHT admissions by source (i.e., ED, another facility, etc.) and estimated associations between per-visit costs and selected patient characteristics. This study used publicly available data.

Data

NEDS and NIS are the largest publicly available, all-payer, hospital-based ED and inpatient care databases, respectively, in the United States (Healthcare Cost and Utilization Project, 2013b, 2013c). These databases consist of stratified samples of discharge information, representative of the U.S. population, for patients with all health care payer types, including public insurance (i.e., Medicare and Medicaid), private insurance, and no insurance. The annual NEDS data assessed for this study were based on 26–29 million ED visits annually (representing 120–129 million visits, with survey weights) to 955–961 hospitals in 24–28 states (Healthcare Cost and Utilization Project, 2013b). The annual NIS data assessed for this study included approximately 8 million inpatient admissions annually (representing 38–39 million admissions, with survey weights) to 1,045–1,049 hospitals in 38–46 states (Healthcare Cost and Utilization Project, 2013c). NEDS and NIS report one discharge record per ED visit or admission and patients are not uniquely identified; therefore, analyses of these databases are presented in terms of per-visit and per-admission results, rather than per-patient results.

In this study, we used NEDS data to assess ED-only visits, defined as visits by patients routinely discharged, transferred to other facilities, leaving against medical advice, and those who died. Our methods for classifying ED treat-and-release and inpatient visits and inpatient admissions ensured nonoverlapping, comprehensive visit count and cost estimates. NEDS reports ED-only hospital charges for ED visits. We included patients who were transferred to other facilities in our ED treat-and-release estimates because this approach was required to comprehensively capture nationwide AHT hospital costs (i.e., if a patient was transferred from an ED to separate inpatient facility, the NIS data set would only report that patient's inpatient costs, excluding the ED costs from the originating facility). NIS reports inpatient admissions originating from all sources and reports total hospital charges per admission. In the NIS data set, ED charges are included only for ED services provided within the same facility.

Cost Estimates

NEDS and NIS report hospitals' facility-only charges (i.e., room and board) submitted to health care payers; physician, or professional, fees (i.e., payments to attending physicians, not directly employed by the hospital) are not included (Healthcare Cost and Utilization Project, 2011, 2012). The price that a hospital charges for its services is often greater than the amount the hospital is actually paid, or reimbursed, by an insurance company or individual. However, unlike hospital charges data, which are available from a number of publicly available, aggregated sources such as HCUP, hospital reimbursement data are commonly captured in proprietary data sets held by individual insurance companies and hospital organizations. Accepted methods are available to estimate hospitals' costs from charges data; the cost perspective in this case is referred to as the provider perspective. If instead insurance reimbursement data are used to estimate the cost of hospital services, the cost perspective is referred to as the payer perspective. Although different data and methods are used to estimate medical costs under these two perspectives, these approaches should yield similar cost estimates. Limited recent research directly comparing these approaches suggests that methods used to estimate hospital costs from charges data can produce a reasonable proxy for payments hospitals receive (Levit, Friedman, & Wong, 2013).

We applied two conversions to reported facility-only charges in the NEDS and NIS to estimate total costs for AHT ED visits and admissions: a cost-to-charge ratio (CCR; published by HCUP for this purpose) used to estimate facility costs based on facility charges and a professional fee ratio (PFR) used to estimate the cost of professional services when only facility costs are known. All estimated costs are reported as 2012 USD, inflated using the U.S. Producer Price Index for hospitals (U.S. Bureau of Labor Statistics).

Annual, all-payer, hospital-specific, inpatient CCR are calculated by the U.S. Centers for Medicare and Medicaid Services and published by HCUP for use with the NIS data (Healthcare Cost and Utilization Project, 2013a). When the annual, hospital-specific CCR was not available (*n* = 61/400, or 15% of unique annual hospital records with AHT admissions), we applied the annual, hospital group-average CCR, as recommended by HCUP (Healthcare Cost and Utilization Project, 2013a). When both hospital-specific and group-average CCR were unavailable (*n* = 13/400, or 3% of annual hospital records), we used multiple imputation based on selected characteristics (i.e., admission year and hospitals' regional location, urban/rural location, teaching status, and bed size—hospital ownership was ambiguous for 88% of hospitals in our sample and was not used for imputation) to estimate hospitals' annual, hospital-specific CCR based on reported CCR among similar hospitals (Healthcare Cost and Utilization Project, 2013a). While this type of imputed CCR is not specifically prescribed by HCUP, this approach was deemed preferable to alternatives such as eliminating observations for which no hospital CCR was available or using a general average CCR for missing values. After these steps were undertaken, the average inpatient CCR applied to AHT facility-only inpatient charges over the entire study period was 0.376 (standard error [*SE*] = 0.013), suggesting that hospitals' facility cost to provide services were, on average, just 38% of facility-only charges submitted to payers for AHT admissions.

HCUP does not publish CCR for NEDS data and hospitals in the NEDS data are not identified for linking to NIS data (Friedman & Owens, 2007). There is limited evidence that CCR for inpatient admissions is correlated with CCR for ED visits, although inpatient CCR may underestimate ED CCR (Friedman & Owens, 2007). With available data, we applied average inpatient CCR from hospitals with AHT admissions we had identified in the NIS data (including imputed CCR) to AHT ED visits in the NEDS data based on visit year, hospitals' regional location, urban/rural location, and teaching status (i.e., an AHT ED visit at an urban teaching hospital in the Midwest was assigned the average inpatient CCR for all hospitals matching those criteria with AHT admissions that year in our inpatient sample). For ED visits that could not be matched in this way (*n* = 276/6,827, or 4% of AHT ED visits), we assigned the annual average inpatient CCR for all hospitals that year with AHT admissions. The average CCR applied to NEDS facility-only charges for AHT ED visits over the entire study period was 0.380 (*SE* = 0.004).

To account for professional fees during AHT ED visits and admissions reported in NEDS and NIS, we applied PFR estimated from AHT ED visits and inpatient admissions identified in the 2006–2011 Truven Health MarketScan® database for a separate study (Peterson et al., 2014). MarketScan is a multi-state health insurance claims database that reports patient-level payments (or reimbursements) to health care providers for patients with selected employer-based and Medicaid health insurance (Truven Health Analytics, 2013). MarketScan is not nationally representative, and Medicaid data from approximately a dozen states are included. MarketScan separately reports facility and physician payments to hospitals for ED visits and inpatient admissions. Using MarketScan data for AHT patients with noncapitated health insurance plans, we calculated the average annual, payer-specific (i.e., commercial or Medicaid) PFR per AHT ED visit and admission. We found statistically significant group differences in PFR for AHT ED visits based on payer type in the MarketScan data; therefore, we applied payer-specific PFR (mean commercial insurance PFR for ED visits: 1.49, 95% confidence interval [CI] [1.33, 1.66], *n* = 205; mean Medicaid PFR for ED visits: 2.10, 95% CI [1.89, 2.32], *n* = 93) to estimate total costs per AHT ED visit reported in NEDS. There was no significant payer difference in inpatient PFR for AHT admissions as estimated with the MarketScan data; therefore, we uniformly applied an average PFR of 1.24, regardless of payer type, to estimate total costs per AHT admission reported in NIS.

Analysis

We first estimated the annual nationwide number of AHT ED visits, admissions, and associated total and per-visit average costs. We then used multivariable, survey-weighted, generalized linear models with gamma variance and the log link function to estimate associations between estimated per-visit costs and selected patient characteristics (Manning, Basu, & Mullahy, 2005). The statistical variation reported with our cost results is based only on the 95% CIs around HCUP survey weights (i.e., the count and cost of a particular AHT visit was assigned a statistical weighting based on standard HCUP sample methods) and not the additional elements we used to estimate hospital costs from HCUP's hospital charge data (i.e., CCR, which was applied to each observation as a hospital-specific, group-average, or imputed single value, as described previously, and PFR, which was applied to each observation as a payer-specific average for ED visits or a general average for inpatient admissions, as also described previously); therefore, the variation around the cost estimates is referred to as an error bound, rather than a 95% CI descriptive analysis was conducted with SAS 9.3 (Cary, NC) and regression models were estimated with Stata 13® (College Station, TX) software.

Results

The survey-weighted estimated annual number of AHT treat-and-release ED visits 2006–2011 ranged from 1,009 (2010; 95% CI [824, 1,193]) to 1,223 (2007; 95% CI [963, 1,482]), with an annual average of 1,138 (95% CI [1,012, 1,264]) over the study period (Table 1). The estimated number of AHT admissions ranged from 1,790 (2011; 95% CI [1,050, 2,531]) to 2,688 (2010; 95% CI [1,884, 3,492]) annually, with an annual average of 2,089 (95% CI [1,732, 2,445]) over the study period. AHT was diagnosed during a total of 6,827 (95% CI [6,072, 7,582]) ED visits and 12,533 (95% CI [10,395, 14,671]) admissions nationwide over the study period (data for total visits not shown; the total number of visits during the study period does not reflect the sum of all years due to rounding). Based on overlapping CIs, there were no significant temporal trends in ED visits, admissions, or costs over the study period. In total, 28% (*n* = 3,563/12,533) of total AHT admissions over the period originated in the same hospital's ED (data not shown).

The estimated average annual costs per ED visit and inpatient admission were US$2,612 (error bound: 1,644–3,581) and US$31,901 (error bound: 29,266–34,536), respectively, over the study period (2012 USD; Table 1). The estimated combined cost of all AHT ED visits and admissions over the study period ranged from US$58.9 million annually (2011; error bound: 35.0–82.9 million) to US$98.5 million (2010; error bound: 65.3–131.6 million), with an annual average of US$69.6 million (error bound: 56.9–82.3 million; Table 1).

In multivariable models, AHT patients' discharge to another facility for continued medical care after an ED visit or death during an ED visit were each associated with over 3 times the cost of an ED visit from which a patient was routinely discharged, exp(β) = 3.04, 95% CI [2.49, 3.71] and 3.70, 95% CI [1.97, 6.97], respectively (Table 2). AHT inpatients' discharge to another facility or death during an admission were also associated with higher costs. Other factors associated with higher per-visit costs included patient age <1 year (ED visits only), male sex (admissions only), coexisting chronic conditions (both ED visits and admissions), higher household income (admissions only), public insurance payer (ED visits only), hospitals with trauma-level ED (ED visits only, not reported for admissions), and teaching hospitals in urban locations (ED visits only; Table 2).

Discussion

To our knowledge, this analysis is the first to describe the combined annual frequency of emergency and inpatient hospital visits and associated costs for AHT at the nationwide level. Over the study period, the cost of AHT hospital care amounted to tens of millions of dollars annually. We used multiple nationwide data sets to create nonoverlapping, comprehensive estimates of AHT emergency and inpatient hospital visits. We used recommended methods to estimate hospital facility costs from publicly available data on hospital facility charges and derived estimates of professional fees from a separate data source to achieve comprehensive hospital visit cost estimates.

Consistent with a previous study of AHT inpatient admissions (over nonconsecutive years; Shanahan et al., 2013), we observed no significant temporal trends in the number of AHT visits, nor costs, over the study period. It is difficult to directly compare the AHT hospital visit frequency estimates we reported here to previous population-based studies—previous nationwide studies variously assessed a combination of narrower patient age ranges (such as <1 or <2 years; Niederkrotenthaler et al., 2013; Shanahan et al., 2013) or included different categories of inpatient admissions (i.e., limited to nonfatal admissions; S. Parks, Sugerman, et al., 2012) and ED visits (Xiang et al., 2013) over earlier study periods.

Clinicians might be surprised at the number of AHT patients treated and released from an ED without admission reported in our results. One study using only NEDS data previously reported over a third of patients treated for AHT in an ED were treated and released (Xiang et al., 2013). The only other study we are aware of that examined both ED and inpatient experiences for AHT patients reported 17% of such patients were not treated as inpatients within 2 days of their first AHT diagnosis (Peterson et al., 2014). Neither this study nor previous studies offered opportunities to further examine the experiences of AHT patients who were not admitted.

In a previous study of per-patient AHT direct medical costs using MarketScan provider reimbursement data from selected insurance payers (i.e., payer cost perspective), we examined the average reimbursement for a patient's initial ED visit or admission during which AHT was diagnosed (Peterson et al., 2014). The estimated cost of an initial AHT admission from that study (US$29,791; 95% CI [25,612, 33,971]) overlapped the error bound of the nationwide estimate for AHT admissions among patients with all insurance payer types we reported in this study (i.e., provider cost perspective; US$31,901, error bound: 29,266–34,536; both 2012 USD), where we could not observe whether the AHT admission was related to an initial AHT diagnosis, a subsequent AHT event, or follow-up AHT treatment. The average insurance reimbursement for a patient's initial AHT ED visit in the previous study (US$685; 95% CI [567, 802]) was significantly lower than the average AHT ED visit cost reported in this study (US$2,612, error bound: 1,644–3,581). The previous study included earlier study years (i.e., 2003–2011) and it is possible that changes over time beyond medical cost inflation affected the average cost of AHT ED visits we reported in the previous study. The previous study included only initial ED visits for AHT patients, while in this study, we could not observe whether children were returning to the ED for multiple AHT injuries; it is possible that children with multiple AHT injuries and ED visits could sustain more severe injuries, requiring more costly ED treatment. The previous study included only selected health insurance payer types, while this study included all payer types.

Peterson et al. (2014) also reported a per-person total attributable medical cost of AHT in the 4 years following patients' initial diagnosis, including inpatient, outpatient, and drugs costs (US$47,952, 95% CI [US$40,219, US$55,685]; 2012 USD; Peterson et al., 2014). Despite many advantages of the MarketScan data used for that estimate, its limitations are that it reflects only selected health insurance payers and that it cannot provide nationwide estimates of the number of children treated for AHT; neither of those limitations apply to the HCUP data we used for the present analysis. On the other hand, HCUP provides only hospital financial data (i.e., not outpatient or drugs data), various estimates are required to convert HCUP's reported hospital facility charges to estimated total hospital visit costs, and HCUP data cannot be used to track patients' health care experiences and costs over time. Further, this analysis estimated the total cost of hospital visits during which AHT was diagnosed, and the cost estimates reported here do not cleanly estimate the attributable, or excess, hospital cost of AHT. Estimates of the attributable cost of a health condition require eliminating medical costs that would have occurred to affected patients even in the absence of the condition under investigation. Such estimates usually require patient-level data and a patient control group, which is not consistent with what is available in the HCUP nationwide NEDS and NIS samples (Brown, Fang, & Florence, 2011).

Unfortunately, we are not aware of any nationwide data set that would allow us to examine total attributable health care costs for a relatively rare condition like AHT. Aside from the benefits and drawbacks of the data sources used to derive the different AHT medical cost estimates reported in Peterson et al. (2014) and the present analysis, the reported cost estimates can have different research and communication purposes: Studies of long-term per-patient medical costs of health conditions (i.e., Peterson et al., 2014) can be used in economic evaluations to assess the cost-effectiveness of proven interventions, while population-based annual medical cost estimates of those conditions (i.e., the present analysis) are relevant to examine population trends and contextualize public health issues.

Other recent studies have estimated the average medical and lifetime cost of all types of child maltreatment, including physical abuse, sexual abuse, emotional abuse, and neglect (Fang, Brown, Florence, & Mercy, 2012; Florence, Brown, Fang, & Thompson, 2013). Perhaps not surprising given that AHT is an extremely severe form of physical abuse, our study suggests AHT has high average acute care costs per child (on average, US$2,612 for a single ED visit and US$31,901 for a single hospitalization) compared to the entire average per-child annual medical cost (including payments to providers for inpatient services, outpatient services, and drugs) of maltreated children documented in those papers (approximately US$2,600, 2009 USD). A 2011 systematic literature review on the medical cost of all types of child maltreatment identified just one previous financial study of AHT (Brown et al., 2011; Ettaro, Berger, & Songer, 2004). That study, however, reported only hospital charges, which are not a meaningful indicator of medical costs and are not comparable to the cost estimates we reported here.

This study estimated higher per-visit AHT hospital costs based on a number of sociodemographic factors. It is possible that many of the significant estimated associations between AHT hospital costs and patient-level factors such as age, sex, and discharge status were driven by injury severity, which we could not directly observe for this analysis. The estimated significant associations between household income and admission costs, and health insurance payer and ED visit cost, could be related to hospital-level characteristics that we also could not observe for this analysis. The significantly higher per-ED visit costs for AHT patients with public payers could also be related to differences in care-seeking behavior between publicly and privately insured populations, such as deferred care for conditions unrelated to AHT that was administered during ED visits in our sample, resulting in higher total visit costs. Our models attempted to control for the cost of non-AHT care by controlling for AHT patients with specific chronic conditions, although this approach clearly does not address all types of additional care that AHT patients might have received. Differences in care-seeking behavior might also explain why the PFR for ED visits among Medicaid AHT patients was higher than the PFR for privately insured patients as measured in the MarketScan sample of AHT patients. Alternatively, higher PFR for Medicaid AHT visits could be related to charging and reimbursement differences between Medicaid and private insurers for ED care, which we could not observe in this analysis. This study observed significantly higher AHT ED visit costs among trauma hospitals. This could be related to several factors, including higher capital costs in such hospitals, or selection bias that resulted in more severely injured patients being routed to such facilities.

This analysis had a number of limitations. The statistical variation reported for our cost results underestimates the true variation because it was based only on HCUP survey weights and did not include variation around the contributing cost elements. We used the accepted method for estimating hospital costs from hospital charges data—hospital-wide CCR for individual centers published by HCUP. But CCR varies within hospitals by department; therefore, a single hospital-wide CCR applied to total hospital charges for each AHT hospital visit is an imprecise measure of hospitals' true cost to treat AHT patients. Using average annual inpatient CCR to estimate ED visit costs from hospital facility only charges is also a limitation. For 3% of inpatient records, we lacked both hospital-specific and group-average CCR and we used an imputation method. We used a data source—MarketScan—

that is not nationally representative to estimate professional fees for AHT hospital visits. The cost of professional fees for AHT hospital visits is not zero; therefore, using feasible methods to estimate such fees seems preferable to ignoring such fees altogether. MarketScan includes both private and Medicaid payment information from multiple regions of the United States, and provides as defensible a data source as any we are aware of to estimate PFR for this analysis. Some professional charges may be included in hospitals' facility bill. We applied estimated PFR to all AHT ED visits and admissions; therefore, we might have overestimated the total cost of some ED visits and admissions by double-counting some professional fees.

Our regression analyses suggested significantly higher ED visit and inpatient admission costs among patients with co-occurring chronic conditions (Table 2). It was not possible to assess whether that apparent cost difference was due to patients receiving treatment that should not have been attributed to AHT, in which case our results might have overestimated the cost of AHT hospital care. We were not able to distinguish initial AHT hospital visits from subsequent visits for the same type of abuse. It may be that due to the severe nature of AHT injuries, AHT is more accurately coded for acute, directly attributable medical treatment, and not as well coded for follow-up hospital-based treatment for related sequelae. If that is the case, our results might instead underestimate the total attributable annual cost of AHT hospital care. The total estimates of AHT hospital costs presented here likely underestimate the true total AHT hospital cost burden due to a separate issue, which is the documented underreporting of AHT in medical records (Jenny, Hymel, Ritzen, Reinert, & Hay, 1999; S. Parks, Annest, et al., 2012). Prospective, longitudinal patient studies could provide robust estimates of AHT patients' long-term medical needs and associated costs. Information on AHT patients' out of pocket costs, caregiver costs, and long-term costs such as special education could improve understanding of the total burden on individuals affected by this type of abuse.

Despite limitations, this study benefited from nationwide representativeness and several adjustments to estimate total per-visit hospital costs based on available financial data in two well-recognized sample data sets. This research contributes to the growing number of studies documenting nationwide information on AHT, made possible through a uniform code-based definition recently published by the CDC (S. Parks, Annest, et al., 2012). Total annual direct AHT hospital cost estimates can be used by researchers, practitioners, and policy makers to describe AHT in a public health context. The cost estimates presented here did not include the cost of nonhospital medical care or the long-term associated costs of special education and developmental services that many AHT patients require. But the total cost of hospital care alone for AHT on a nationwide level is substantial. Given these high costs, population-wide intervention programs that reduce AHT occurrence could potentially be cost effective.

Acknowledgments

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

Berger RP, Parks S, Fromkin J, Rubin P, Pecora PJ. Assessing the accuracy of the International Classification of Diseases codes to identify abusive head trauma: A feasibility study. Injury Prevention. 2015; 21:e133–e137. [PubMed: 24167034]

Brown DS, Fang X, Florence CS. Medical costs attributable to child maltreatment a systematic review of short-and long-term effects. American Journal of Preventive Medicine. 2011; 41:627–635.10.1016/j.amepre.2011.08.013 [PubMed: 22099241]

Ettaro L, Berger RP, Songer T. Abusive head trauma in young children: Characteristics and medical charges in a hospitalized population. Child Abuse & Neglect. 2004; 28:1099–1111. [PubMed: 15519438]

Fang X, Brown DS, Florence CS, Mercy JA. The economic burden of child maltreatment in the United States and implications for prevention. Child Abuse & Neglect. 2012; 36:156–165.10.1016/j.chiabu.2011.10.006 [PubMed: 22300910]

Florence C, Brown DS, Fang X, Thompson HF. Health care costs associated with child maltreatment: Impact on Medicaid. Pediatrics. 2013; 132(2):312–318. [PubMed: 23821692]

Friedman, B.; Owens, P. The cost of ‘‘treat and release’’ visits to hospital emergency departments, 2003 (HCUP Methods Series Report # 2007-05). Rockville, MD: Healthcare Cost and Utilization Project (HCUP), Agency for Healthcare Research and Quality; 2007. Retrieved from http://www.hcup-us.ahrq.gov/reports/methods.jsp

Healthcare Cost and Utilization Project. NEDS description of data elements. 2011 Sep 14. Retrieved December 15, 2013, from http://www.hcup-us.ahrq.gov/db/nation/neds/nedsdde.jsp

Healthcare Cost and Utilization Project. NIS description of data elements. 2012 Dec 6. Retrieved December 15, 2013, from http://www.hcup-us.ahrq.gov/db/nation/nis/nisdde.jsp

Healthcare Cost and Utilization Project. Cost-to-charge ratio files: 2011 nationwide inpatient sample user guide. 2013a Aug 7. Retrieved December 5, 2013, from http://www.hcup-us.ahrq.gov/db/state/costtocharge.jsp

Healthcare Cost and Utilization Project. Overview of the nationwide emergency department sample. 2013b Jun 20. Retrieved July 15, 2013, from http://www.hcup-us.ahrq.gov/nedsoverview.jsp

Healthcare Cost and Utilization Project. Overview of the nationwide inpatient sample. 2013c Jul 8. Retrieved July 15, 2013, from http://www.hcup-us.ahrq.gov/nisoverview.jsp

Jenny C, Hymel KP, Ritzen A, Reinert SE, Hay TC. Analysis of missed cases of abusive head trauma. JAMA. 1999; 281:621–626. [PubMed: 10029123]

Levit KR, Friedman B, Wong HS. Estimating inpatient hospital prices from state administrative data and hospital financial reports. Health Services Research. 2013; 48:1779–1797. [PubMed: 23662642]

Manning WG, Basu A, Mullahy J. Generalized modeling approaches to risk adjustment of skewed outcomes data. Journal of Health Economics. 2005; 24:465–488.10.1016/j.jhealeco.2004.09.011 [PubMed: 15811539]

Niederkrotenthaler T, Xu L, Parks SE, Sugerman DE. Descriptive factors of abusive head trauma in young children-United States, 2000–2009. Child Abuse & Neglect. 2013; 37:446–455.10.1016/j.chiabu.2013.02.002 [PubMed: 23535075]

Parks, S.; Annest, J.; Hill, H.; Karch, D. Pediatric abusive head trauma: Recommended definitions for public health surveillance and research. Atlanta, GA: Centers for Disease Control and Prevention; 2012.

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; 18:392–398.10.1136/injuryprev-2011-040234 [PubMed: 22328632]

Parks SE, Kegler SR, Annest JL, Mercy JA. Characteristics of fatal abusive head trauma among children in the USA: 2003–2007: An application of the CDC operational case definition to national vital statistics data. Injury Prevention. 2012; 18:193–199.10.1136/injuryprev-2011-040128 [PubMed: 22015935]

Peterson C, Xu L, Florence C, Parks SE, Miller TR, Barr RG, Steinbeigle R. The medical cost of abusive head trauma in the United States. Pediatrics. 2014; 134:91–99.10.1542/peds.2014-0117 [PubMed: 24936000]

Selassie AW, Borg K, Busch C, Russell WS. Abusive head trauma in young children: A population-based study. Pediatric Emergency Care. 2013; 29:283–291.10.1097/PEC.0b013e31828503ea [PubMed: 23426240]

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:e1546–e1553.10.1542/peds.2013-2049 [PubMed: 24276842]

StataCorp. Stata Statistical Software: Release 13. College Station, TX: StataCorp LP; 2013.

Truven Health Analytics. Truven health analytics Market-Scan® databases. 2013. Retrieved July 15, 2013, from http://www.tru-venhealth.com/your_healthcare_focus/pharmaceutical_and_medical_device/data_databases_and_online_tools.aspx

US Bureau of Labor Statistics. Producer price index–Hospital series (PCU622). Retrieved June 27, 2013, from http://www.bls.gov/data/#prices

Xiang J, Shi J, Wheeler KK, Yeates KO, Taylor HG, Smith GA. Paediatric patients with abusive head trauma treated in US emergency departments, 2006–2009. Brain Injury. 2013; 27:1555–1561.10.3109/02699052.2013.831126 [PubMed: 24102484]

Table 1

Estimated Annual Number and Cost of Hospital Visits by Type for Pediatric Abusive Head Trauma, 2006–2011.

	2006	2007	2008	2009	2010	2011	Annual Average
Number (95% CI) of visits[a]							
ED treat and release[b]	1,094 [814, 1,375]	1,223 [963, 1,482]	1,161 [867, 1,455]	1,154 [868, 1,441]	1,009 [824, 1,193]	1,186 [990, 1,381]	1,138 [1,012, 1,264]
Inpatient[c]	1,961 [1,369, 2,553]]	2,075 [1,234, 2,916]	1,983 [1,332, 2,633]	2,036 [1,315, 2,757]	2,688 [1,884, 3,492]	1,790 [1,050, 2,531]	2,089 [1,732, 2,445]
Admission source							
Routine	1,185 [819, 1,551]	1,007 [620, 1,393]	1,164 [743, 1,586]	1,118 [688, 1,548]	928 [625, 1,230]	220 [0, 471]	937 [771, 1,103]
ED (same facility)	408 [225, 591]	408 [219, 597]	581 [311, 850]	637 [345, 928]	927 [578, 1,276]	604 [251, 956]	594 [443, 745]
Another facility	364 [175, 554]	655 [178, 1,132]	233 [149, 318]	275 [125, 426]	828 [538, 1,119]	952 [582, 1,322]	551 [414, 689]
Unknown	5 [0, 14]	5 [0, 14]	5 [0, 13]	5 [0, 16]	5 [0, 15]	14 [0, 31]	6 [2, 11]
Average cost (error bound) per visit[d]							
ED treat-and- release	US$2,161 [1,484, 2,839]	US$2,006 [1,643, 2,369]	US$1,845 [1,358, 2,333]	US$2,018 [1,600, 2,436]	US$1,949 [1,517, 2,380]	US$5,549 [326, 10,771]	US$2,612 [1,644, 3,581]
Inpatient	US$32,147 [26,638, 37,657]	US$31,664 [24,538, 38,791]	US$29,830 [22,976, 36,685]	US$30,963 [23,503, 38,423]	US$35,908 [30,566, 41,251]	US$29,250 [25,697, 32,803)	US$31,901 [29,266, 34,536)
Total cost (error bound) by visit type and overall[e]							
ED treat and release	US$2,365,279 [US$1,330,784, US$3,399,775]	US$2,452,920 [1,644,562,3,261,277]	US$2,143,018 [1,407,261,2,878,775]	US$2,329,767 [1,434,629,3,224,904]	US$1,965,701 [1,301,164,2,630,238]	US$6,578,185 [0, 13,318,483]	US$2,972,478 [1,770,704,4,174,253]
Inpatient	US$63,049,756 [40,514,325, 85,585,187]	US$65,694,517 [32,083,466,99,305,569]	US$59,148,205 [31,964,956,86,331,455]	US$63,027,998 [34,507,355,91,548,642]	US$96,516,054 [63,298,974,129,733,134]	US$52,371,378 [29,342,551,75,400,206]	US$66,634,652 [53,955,955,79,313,349]
Total cost (95% CI)	US$65,415,035 [42,918,081, 87,911,989]	US$68,147,437 [34,619,476,101,675,398]	US$61,291,224 [34,173,077,88,409,370]	US$65,357,765 [36,901,826,93,813,705]	US$98,481,755 [65,349,753,131,613,757]	US$58,949,563 [35,017,278,82,881,848]	US$69,607,130 [56,906,560,82,307,700]

Note. Costs are 2012 USD. Reported statistical variation for cost estimates (error bound) is based only on the 95% confidence intervals around Healthcare Cost and Utilization Project (HCUP) survey weights and not the additional elements we used to estimate hospital costs from HCUP's hospital charge data. ED = emergency department.

[a] Visit number estimates are survey weighted.

[b] ED treat-and-release visits in the Nationwide Emergency Department Sample (NEDS), where disposition of the patient from the ED was routine, transfer to short-term hospital, other transfers (including skilled nursing facility, intermediate care, and another type of facility), home health care, against medical advice, died in ED, discharged/transferred to court/law enforcement, or destination unknown.

[c] Inpatient admissions in Nationwide Inpatient Sample (NIS). Admission source of ''ED'' includes admissions only from the same hospital's ED; ''another facility'' includes hospitals and long-term care facilities; ''routine'' includes birth and unspecified admissions. Data based on combined information from ''admission source'' and ''point of origin'' data.

[d] Per-visit cost estimates by visit type were calculated from as survey reweighted total costs by visit type (see next footnote) divided by survey-weighted number of visits by type.

[e] Total cost estimates by visit type were based on survey weights, with reweighting to account for missing cost data as recommended by the HCUP; Health care Cost and Utilization Project, 2013a). Survey-weighted missing cost data: ED treat and release, n = 889/6,827 (13%); inpatient: n = 88/12,533 (<1%).

Table 2

Factors Associated With Per-Visit Hospital Costs for Pediatric Abusive Head Trauma, 2006–2011.

		Emergency Department Treat and Release Visits (N = 6,827)		Inpatient Admissions (N = 12,533)	
Category	**Factor**	***n* (%) survey weighted**[a]	**exp(β),95% CI**	***n* (%) survey weighted**[a]	**exp(β),95% CI**
Age	<1 year	3,004 (44)	(Reference)	9,263 (74)	(Reference)
	1–4 years	3,823 (56)	0.77 [0.65, 0.90]*	3,270 (26)	1.09 [0.89, 1.33]
Sex	Female	3,005 (44)	(Reference)	5,098 (41)	(Reference)
	Male	3,822 (56)	1.11 [0.93, 1.32]	7,435 (59)	1.13 [1.02, 1.26]*
Race	White	NR	—	4,732 (38)	(Reference)
	Black	NR	—	1,856 (15)	1.07 [0.86, 1.34]
	Hispanic	NR	—	2,059 (16)	1.12 [0.92, 1.36]
	Other	NR	—	988 (8)	1.09 [0.85, 1.39]
	Unknown	NR		2,897 (23)	1.13 [0.90, 1.43]
Chronic condition[b]	No	6,291 (92)	(Reference)	9,486 (76)	(Reference)
	Yes	536 (8)	2.63 [1.52, 4.57]*	3,047 (24)	1.66 [1.43, 1.94)**
Admission source	Routine[c]	NA	—	3,278 (26)	(Reference)
	ER	NA	—	5,640 (45)	1.02 [0.84, 1.25]
	Another facility	NA	—	3,576 (29)	1.19 [0.96, 1.47]
	Unknown	NA		39 (0)	0.30 [0.14, 0.62])*
Discharge status	Routine[d]	5,711 (84)	(Reference)	9,824 (78)	(Reference)
	Another facility	1,081 (16)	3.04 [2.49, .71]**	1,379 (11)	2.20 [1.78, 2.73]**
	Died	35 (1)	3.70 [1.97, 6.97]**	1,330 (11)	1.59 [1.25, 2.03]**
Household income quartile	1	2,543 (37)	0.97 [0.74, 1.25]	4,349 (35)	0.78 [0.61, 0.99]*
	2	2,102 (31)	1.01 [0.77, 1.31]	3,594 (29)	0.83 [0.64, 1.07]
	3	1,233 (18)	0.84 [0.65, 1.10]	2,672 (21)	0.87 [0.69, 1.10]
	4 (Highest income)	844 (12)	(Reference)	1,585 (13)	(Reference)
	Unknown	105 (2)	0.80 [0.56, 1.15]	332 (3)	0.70 [0.51, 0.97]*
Primary payer	Private	1,889 (28)	(Reference)	2,149 (17)	(Reference)
	Public (Medicare/Medicaid)	4,093 (60)	1.33 [1.09, 1.61)*	9,474 (76)	1.11 [0.92, 1.34)

		Emergency Department Treat and Release Visits (N = 6,827)		Inpatient Admissions (N = 12,533)	
Category	**Factor**	***n* (%) survey weighted[a]**	**exp(β),95% CI**	***n* (%) survey weighted[a]**	**exp(β),95% CI**
	Self-pay	571 (8)	0.91 [0.69, 1.22]	298 (2)	1.05 [0.61, 1.83]
	Unknown	274 (4)	1.12 [0.77, 1.64]	611 (5)	1.20 [0.86, 1.68]
ED trauma level	Nontrauma	3,238 (47)	(Reference)	—	—
	Trauma	3,589 (53)	1.34 [1.07, 1.69]*	—	—
Hospital size	Small	NR	—	1,487 (12)	1.3 [0.93, 1.80]
	Medium	NR	—	2,233 (18)	1.07 [0.86, 1.33]
	Large	NR	—	8,497 (68)	(Reference)
	Unknown	NR	—	317 (3)	0.84 [0.59, 1.19]
Hospital location and teaching status	Rural	1,213 (18)	0.61 [0.45, 0.83]*	311 (2)	0.61 [0.33, 1.13]
	Urban, nonteaching	2,078 (30)	0.65 [0.51, 0.84]*	1,167 (9)	0.88 [0.66, 1.19]
	Urban, teaching	3,536 (52)	(Reference)	10,738 (86)	(Reference)
	Unknown	0	NA	317 (3)	NR
Hospital region	Northeast	1,674 (25)	(Reference)	1,858 (15)	(Reference)
	Midwest	1,914 (28)	0.97 [0.69, 1.38]	3,037 (24)	0.89 [0.62, 1.28]
	South	2,792 (41)	1.33 [0.94, 1.89]	4,997 (40)	0.8 [0.57, 1.13]
	West	448 (7)	1.04 [0.67, 1.63]	2,641 (21)	0.94 [0.66, 1.35]
Year	2006	1,094 (19)	(Reference)	1,961 (19)	(Reference)
	2007	1,223 (18)	0.91 [0.72, 1.15]	2,075 (17)	0.98 [0.70, 1.37]
	2008	1,161 (17)	0.86 [0.67, 1.11]	1,983 (16)	0.91 [0.66, 1.27]
	2009	1,154 (17)	1.03 [0.80, 1.32]	2,036 (16)	0.84 [0.65, 1.09]
	2010	1,009 (15)	0.81 [0.61, 1.09]	2,688 (21)	1.08 [0.82, 1.44]
	2011	1,186 (17)	1.24 [0.75, 2.06]	1,790 (14)	0.96 [0.72, 1.3]

Note. Data are results from multivariable generalized linear models with log link, gamma variance, and survey design. In the calculation of standard errors, strata with single sample units (ED: n = 23/111 strata; inpatient: 19/46 strata) used an average of the variances from other strata with multiple sampling units (StataCorps, 2013). Models included all listed variables. ED = emergency department, exp(β) = exponentiated coefficient (interpreted as a multiplicative change in the dependent variable—total cost per visit—associated with a unit change in an independent variable), NA = not applicable, NR = not reported, 95% CI = confidence interval.

[a] Survey data reweighted to accommodate missing cost data: ED: n = 889/6,827 (13%); inpatient: n = 88/12,533 (<1%; Healthcare Cost and Utilization Project, 2013a).

[b] Chronic conditions defined as the following conditions (ICD-9-CM codes) documented on discharge records: epilepsy/recurrent seizures (345), developmental delays (315), other nervous symptoms (781), congenital anomalies (740–759), conditions originating in the perinatal period (760–779), and other chronic conditions (299, 343, 317–319, 677, 369, and 389) (Niederkrotenthaler et al. 2013).

[c] Includes birth and unspecified admissions.

[d]Includes patients discharged: against medical advice; alive, destination unknown; to court or law enforcement; and to home health care.

*$p < .05$.

**$p < .001$.