

Demographics of abusive head trauma in the Commonwealth of Pennsylvania

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Object. The aim of this study was to characterize the prevalence and demographic features of abusive head trauma (AHT) among infants and children < 36 months of age in Pennsylvania.

Methods. The authors included all cases of substantiated AHT involving children < 36 months of age in Pennsylvania between 1996 and 2002 that had been reported to a statewide registry. Demographic information was derived from child abuse reports and birth certificates; the study cohort was contrasted with all infants born in Pennsylvania during the same period.

Results. The study identified 327 cases. The incidence was 14.7 cases (95% confidence interval 13.1–16.5) per 100,000 person-years for the first 2 years of life with a higher incidence during the 1st year (26.0 cases per 100,000 person-years) than the 2nd year (3.4 cases per 100,000 person-years). The incidence was similar among metropolitan, non-metropolitan, and rural counties. Significantly more cases occurred during the holiday months (October–December). The median age of victims was 4.1 months. Both victims and perpetrators were more commonly male (58.4% of victims, and 70% of identified perpetrators). Compared with the entire population of Pennsylvania parents, the parents of the study cohort were more likely to be younger, less educated, and unmarried. Both mothers and fathers were more often African-American and fathers more often Hispanic. Finally, mothers more often smoked during pregnancy, sought prenatal care later in the pregnancy, and delivered low birth weight infants.

Conclusions. This population-based study of abusive head injuries throughout an entire state adds significantly to the growing knowledge about this condition. The results suggests that families of infants with abusive head injuries have significantly different demographic features compared with the general population, although which of these variables is independently significant cannot be ascertained from this study and require further investigation.

(DOI: 10.3171/PED/2008/1/5/351)

KEY WORDS • abusive head trauma • shaken baby syndrome • shaken impact syndrome

ABUSIVE head trauma in children less than 36 months of age remains a significant cause of death and neurological morbidity. Most cases are thought to involve angular acceleration of the brain brought about by violent infant shaking, with or without impact injury, and have been collectively described as shaken baby or shaken impact syndrome.^{1,2,10} The mortality rate ranges from 15 to 35%,^{7,14,18,22} and 50% of survivors suffer permanent neurological and visual sequelae.^{9,13} Abusive head trauma is a leading cause of death due to child abuse with an estimated annual incidence of between 17 and 19 cases per 100,000 person-years for children 0–2 years of age.^{3,8,16}

Unfortunately, very little is known about the demographics of either the perpetrators or the victims and their families.

What little is known is derived largely from case series from single institutions with a significant potential for selection bias; only a few population-based studies have been reported.^{3,16} The Commonwealth of Pennsylvania maintains a statewide database of all cases of reported child abuse, providing an opportunity to study the demographics of AHT. We sought to identify all children < 36 months with substantiated AHT throughout the Commonwealth of Pennsylvania to analyze the demographic features and social makeup of these families, and to contrast these demographic features with those of the total population of infants in the state. We hypothesized that there would be significant demographic differences in the makeup of victims' families compared with other infants.

Clinical Materials and Methods

The Pennsylvania Department of Public Welfare maintains a statewide registry of reported cases of suspected

Abbreviations used in this paper: AHT = abusive head trauma; CI = confidence interval; ICD-10 = International Classification of Diseases, 10th Revision; OCYF = Office of Children, Youth and Families.

child abuse throughout Pennsylvania. All cases reported to this registry are divided into 2 broad categories: unfounded and substantiated. Unfounded cases are largely those in which a thorough investigation by the OCYF fails to identify a credible suspicion of abuse after a medical and social investigation by OCYF staff. However, there are a few unfounded cases having a credible suspicion of abuse but no identifiable perpetrator. All unfounded reports are expunged after 485 days if no further information is brought to light to warrant a further investigation or change in status. Substantiated reports are those in which there is a credible finding of abuse by either the OCYF (in which the case is referred to as indicated) or the judiciary (in which the case is referred to as founded). The state registry captures most cases of AHT, although a small number of unidentified cases may have been reported only to local rather than state authorities.

All cases of substantiated abusive head injury (as designated by the OCYF) between January 1996 and December 2002 involving children < 36 months of age were extracted from the state registry (cases reported after 2002 were not included in this analysis as a statewide AHT prevention program began at this time). All reports referencing any brain injury or intracranial hemorrhage (epidural, subdural, intraventricular, or subarachnoid), with or without skull fracture or retinal hemorrhages, were included. The ICD-10 codes could not be used because this is a nonmedical database. Additionally, no external medical review was performed to further differentiate the extent or types of cranial injuries. Information extracted from the registry included the child's age, sex, and county of residence at the time of the report; the age, sex, and relationship of the alleged perpetrator or perpetrators; the types of injuries; and the case mortality.

Each of the identified children's names was submitted to the Pennsylvania Department of Health's Bureau of Vital Statistics to obtain additional information from each infant's birth certificate. Information from the birth certificates included the parent and family composition; parents' ethnic origin (as defined by US Census Bureau categories) and highest educational attainment; circumstances involved in the pregnancy and birth; health follow-up during the pregnancy; and medical conditions and complications of labor and/or delivery. Incidence rates were calculated per 100,000 person-years for the entire cohort; for the 1st and 2nd years of life combined; and separately for children in the 1st, 2nd, and 3rd years of life according to the methods of Keenan et al.¹⁶ Variations in the incidence rates were calculated by month and season.

For those infants for whom a birth certificate was identified, information on the birth certificate was contrasted with aggregate demographic birth certificate information from the entire Commonwealth (144,850 live births per year during the study period) to identify differences. Comparisons between case data and the Pennsylvania population were made using chi-square goodness-of-fit tests for categorical outcomes and one-sample t-tests or Wilcoxon signed-rank tests for continuous outcomes. Poisson regression analysis was used to compare incidence per 100,000 live births by year and by season (winter [December–February], spring [March–May], summer [June–August], and autumn [September–November]) with results expressed as risk ratios and corresponding 95% CIs. All statistical analyses were performed using SAS Version 9 (SAS Institute, Inc.) using a 0.05 level of statistical significance. Because the birth cer-

tificate information from the entire Commonwealth was provided only in the aggregate, a multivariate analysis could not be performed to identify independently significant variables.

This research was conducted with approval by the Human Subjects Protection Office of the Pennsylvania State University College of Medicine.

Results

A total of 327 cases of AHT were identified during the 7-year study period (Fig. 1). The incidence of AHT (Table 1) was 14.7 cases per 100,000 person-years (95% CI 13.1–16.5 cases) for children 0–2 years old and 10.7 cases per 100,000 person-years (95% CI 9.6–11.9) for children 0–3 years old. The incidence rate was higher during the 1st year (26.0 cases per 100,000 person-years; 95% CI 23.1–29.4) compared with the 2nd (3.4 cases per 100,000 person-years; 95% CI 2.4–4.7) and 3rd (2.8 cases per 100,000 person-years; 95% CI 2.0–4.1) years. The overall case mortality rate was 21.4%. There was no significant variation from year to year during the study period. There was evidence for a seasonal effect with more cases occurring during the holiday months (October–December) compared with the rest of the year ($p = 0.04$; 95% CI 1.01–1.64). Identified cases of AHT were distributed among the rural, nonmetropolitan, metropolitan, and central city areas in proportion to the number of live births in these areas. In other words, there was no predilection for urban areas in this study beyond their population density.

The median age of the victims at the time of the abuse was 4.1 months (Fig. 2). Boys were victims more frequently than girls, representing 58.4% of cases. The sex of the perpetrator was identified in 248 cases (76%); male perpetrators accounted for 173 (70%) of these cases. Parents were perpetrators in 81% of cases, with father figures (biological or stepfathers) accounting for 49% and biological mothers accounting for 16% (in an additional 16% one or the other parent was the perpetrator, although a specific parent could not be identified). Other perpetrators included paramours (6%), babysitters (6%), and other relatives (6%) (Fig. 3).

Birth certificates were identified for 306 of the 327 cases. Each of the variables is listed in Table 2 and is contrasted with the aggregate data for families of newborn infants in the entire Commonwealth. Compared with the Commonwealth's aggregate demographic information, both mothers

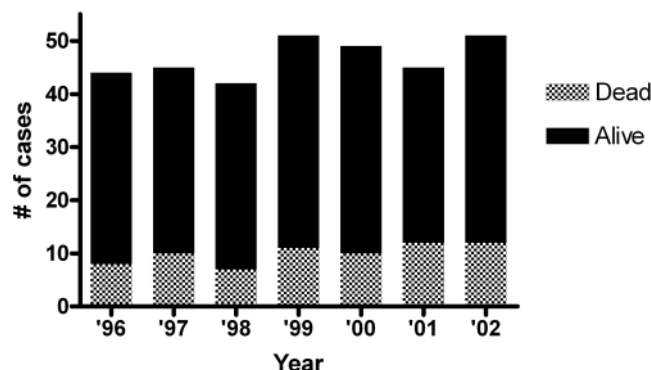


FIG. 1. Bar graph showing the number of cases of AHT per year in Pennsylvania between 1996 and 2002.

Demographics of abusive head trauma in Pennsylvania

TABLE 1
Incidence of AHT per 100,000 person-years

| Authors & Year | Incidence | | |
|----------------------------|--------------|---------------|--------------|
| | 0 to <12 mos | 12 to <24 mos | 0 to <24 mos |
| Barlow & Minns, 2000 | 24.6 | | |
| Keenan et al., 2003 | 29.7 | 3.8 | 17.0 |
| Dias et al., 2005* | 36.5 | 2.5 | 19.4 |
| Ellingson et al., in press | 24.3† | | |
| present study | 26.0 | 3.4 | 14.7 |
| mean | 28.2 | 3.2 | 17.0 |

* Children 24–36 months old were excluded. Incidence rates per 100,000 person-years were recalculated for the first 2 years and individually for Years 1 and 2 of life according to the methods of Keenan et al.

† Data averaged from Kids In-Patient Databases for 1997, 2000, and 2003.

and fathers of infant victims of AHT were significantly younger and significantly less likely to be married at the time of the victims' births. Both mothers and fathers of children with AHT also had fewer years of formal education. This difference held true even among older parents, suggesting that the differences in education are not due solely to the younger age of the study cohort. There were also a disproportionate number of African-American parents and Hispanic fathers (but not mothers) in the study group. Additional maternal factors that were statistically associated with AHT included a delay in seeking prenatal care, low infant birth weight, and mother's tobacco use (but not alcohol use) during pregnancy. In contrast, the frequency of prenatal and perinatal medical conditions such as congenital anomalies, medical complications of labor and delivery, method of delivery, and maternal medical conditions were comparable to the control group.

A subgroup analysis that included only cases identified in the Child Line database as "Shaken Baby Syndrome" revealed the same demographic features as for the study cohort as a whole. A final analysis that excluded cases in which the perpetrator was a babysitter or other family member also demonstrated the same significant demographic differences with the sole exception that Hispanic fathers were

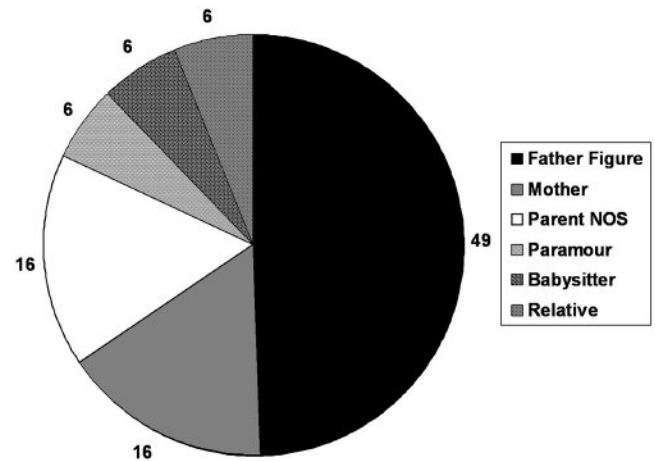


FIG. 3. Pie graph showing the relationship of perpetrators to infant victims of AHT. NOS = not otherwise specified.

no longer significantly overrepresented among the study cohort.

Discussion

This is a large population-based comparative study regarding the demographics of infant AHT in a single state. The measured incidence of AHT in this study, which identifies cases through OCYF reports rather than hospital admission or discharge codes, is remarkably similar to reported incidence rates in other studies (Table 1). For example, Barlow and Minns³ reported an incidence of 24.6 cases per 100,000 person-years for infants 0–1 years old in the United Kingdom. In a population-based study of children with AHT in South Carolina who were either admitted to pediatric intensive care units or died, Keenan et al.¹⁶ reported an incidence of 17.0 per 100,000 person-years for the first 2 years of life with a significantly higher incidence during the 1st year compared with the 2nd year (29.7 vs 3.8 cases per 100,000 person-years, respectively). Dias et al.⁸ reported an incidence of 41.5 cases per 100,000 live births among infants < 36 months of age in western New York. Recalculated incidence rates from this study (unpublished results) for infants and children < 24 months, and expressed per 100,000 person-years according to the methods of Keenan et al.,¹⁶ yields an incidence of 19.4 cases per 100,000 person-years for the first 2 years of life with higher incidence rates in the 1st year compared with the 2nd year (36.5 cases vs 2.5 cases per 100,000 person-years, respectively). Finally, Ellingson et al.¹¹ studied only infants < 12 months of age with AHT identified from the Kids In-Patient Database (Agency for Healthcare and Research Quality) and calculated respective incidence rates of 23.2, 23.6, and 26.1 cases per 100,000 person-years for the 1997, 2000, and 2003 data sets. The incidence rates averaged from all studies (Table 1) were 17.0 (range 14.7–19.4) per 100,000 person-years for the first 2 years of life, 28.2 (range 24.3–36.5) for the 1st year of life and 3.2 (range 2.5–3.8) per 100,000 person-years for the 2nd year of life. There was little year-to-year variation in the present study.

A previous study found an increase in both AHT incidence and death during the winter months.⁶ The present

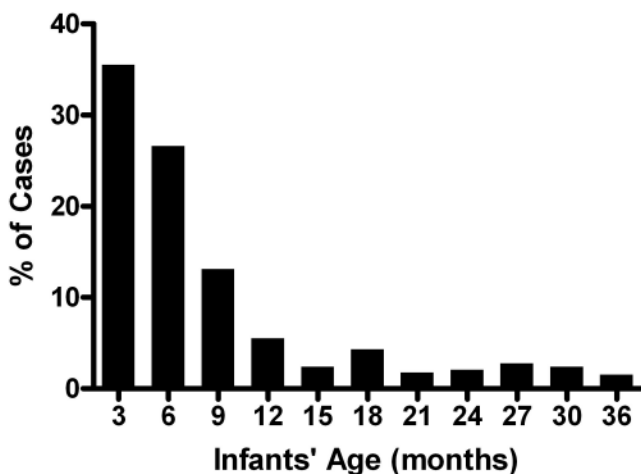


FIG. 2. Bar graph showing distribution of infant victims of AHT. The median age was 4.1 months.

TABLE 2

Demographic features in 306 cases of AHT in Pennsylvania

| Descriptor | % Study Case Group | % Pennsylvania Population* | p Value |
|----------------------------|--------------------|----------------------------|---------|
| child's sex† | | | 0.0091 |
| male | 58.41 | 51.20 | |
| female | 41.59 | 48.80 | |
| mother's age (yrs) | | | <0.0001 |
| <18 | 11.11 | 3.82 | |
| 18–19 | 17.97 | 6.43 | |
| 20–24 | 43.79 | 21.62 | |
| 25–29 | 16.01 | 28.06 | |
| 30–34 | 7.19 | 26.20 | |
| ≥35 | 3.59 | 13.85 | |
| unknown | 0.33 | 0.01 | |
| father's age (yrs)‡ | | | <0.0001 |
| <18 | 3.59 | 0.93 | |
| 18–19 | 11.44 | 3.01 | |
| 20–24 | 33.66 | 14.84 | |
| 25–29 | 22.55 | 22.42 | |
| 30–34 | 12.09 | 27.63 | |
| ≥35 | 6.54 | 25.80 | |
| unknown | 10.13 | 5.36 | |
| mother of Hispanic origin‡ | | | 0.1377 |
| no | 90.52 | 93.22 | |
| yes | 8.50 | 5.87 | |
| unknown | 0.98 | 0.91 | |
| father of Hispanic origin‡ | | | 0.0008 |
| no | 83.01 | 89.42 | |
| yes | 8.82 | 6.04 | |
| unknown | 8.17 | 4.54 | |
| mother's race‡ | | | <0.0001 |
| Caucasian | 74.18 | 81.45 | |
| African-American | 23.53 | 13.80 | |
| other | 1.31 | 3.45 | |
| unknown | 0.98 | 1.30 | |
| father's race‡ | | | <0.0001 |
| Caucasian | 60.46 | 76.96 | |
| African-American | 29.74 | 14.55 | |
| other | 1.31 | 3.26 | |
| unknown | 8.50 | 5.23 | |
| mother's education (yrs)§ | | | <0.0001 |
| ≤8 | 2.94 | 2.88 | |
| 9–11 | 32.35 | 11.80 | |
| 12 | 40.20 | 34.78 | |
| 13–15 | 16.99 | 20.75 | |
| ≥16 | 3.92 | 27.28 | |
| unknown | 3.59 | 2.51 | |
| father's education (yrs)‡ | | | <0.0001 |
| ≤8 | 1.63 | 2.68 | |
| 9–11 | 23.53 | 8.86 | |
| 12 | 43.46 | 36.54 | |
| 13–15 | 9.48 | 15.75 | |
| ≥16 | 4.90 | 27.26 | |
| unknown | 16.99 | 8.91 | |
| mother's marital status | | | <0.0001 |
| married to father | 23.53 | 66.82 | |
| not married to father | 76.14 | 32.81 | |
| unknown | 0.33 | 0.37 | |
| birth weight (g) | | | <0.0001 |
| <1500 | 4.90 | 1.49 | |
| 1500–2499 | 16.99 | 6.17 | |
| 2500–3499 | 52.61 | 52.18 | |
| 3500–4499 | 24.18 | 38.39 | |
| ≥4500 | 0.98 | 1.68 | |
| unknown | 0.33 | 0.09 | |

(continued)

TABLE 2 (continued)

Demographic features in 306 cases of AHT in Pennsylvania

| Descriptor | % Study Case Group | % Pennsylvania Population* | p Value |
|------------------------------------|--------------------|----------------------------|---------|
| trimester prenatal care | | | <0.0001 |
| began | | | |
| 1st | 67.97 | 81.14 | |
| 2nd | 18.95 | 11.95 | |
| 3rd | 4.25 | 2.59 | |
| no care | 2.94 | 1.02 | |
| unknown | 5.88 | 3.29 | |
| method of delivery | | | 0.2936 |
| cesarean section | 20.59 | 20.58 | |
| vaginal | 78.76 | 77.56 | |
| unknown | 0.65 | 1.86 | |
| plurality | | | 1.0000 |
| single birth | 96.73 | 96.99 | |
| twin birth | 2.94 | 2.83 | |
| triplet or more | 0.33 | 0.18 | |
| medical risk factors | | | 0.0894 |
| present‡ | | | |
| no | 59.15 | 62.89 | |
| yes | 39.87 | 34.94 | |
| unknown | 0.98 | 2.18 | |
| obstetric procedures‡ | | | 0.0691 |
| no | 5.56 | 6.47 | |
| yes | 94.12 | 91.39 | |
| unknown | 0.33 | 2.14 | |
| complication(s) of labor/delivery‡ | | | 0.0874 |
| no | 53.27 | 55.97 | |
| yes | 46.08 | 41.88 | |
| unknown | 0.65 | 2.15 | |
| abnormal condition(s) of newborn‡ | | | 0.3784 |
| no | 85.62 | 86.57 | |
| yes | 13.07 | 11.27 | |
| unknown | 1.31 | 2.16 | |
| congenital anomaly(ies) of infant‡ | | | 0.1305 |
| no | 95.42 | 95.81 | |
| yes | 3.27 | 1.93 | |
| unknown | 1.31 | 2.26 | |
| maternal tobacco use** | | | <0.0001 |
| no | 65.03 | 80.40 | |
| yes | 33.66 | 17.23 | |
| unknown | 1.31 | 2.38 | |
| maternal alcohol use‡†† | | | 0.2015 |
| no | 96.73 | 95.59 | |
| yes | 2.29 | 1.30 | |
| unknown | 0.98 | 3.12 | |
| any live births now living‡ | | | 0.0001 |
| no | 50.65 | 40.00 | |
| yes | 49.35 | 60.00 | |
| any live births now dead‡ | | | 0.8279 |
| no | 98.04 | 97.50 | |
| yes | 1.63 | 1.90 | |
| unknown | 0.33 | 0.60 | |

*Data are based on Pennsylvania population data from 1993 to 2002, unless otherwise indicated.

† Population data from 1993 to 2001.

‡ Population data from 2001 to 2002.

§ Population data from 1996 to 2002.

|| Induction or stimulation of labor and tocolysis are not included.

** Population data from 1995 to 2001.

†† Unknowns were removed to make statistical comparison.

study did not find a strict seasonal incidence, although there was an increased incidence during the holiday months of October–December suggesting that the added stress of the holidays may lead to more parental and caregiver frustration and a greater frequency of AHT during this time. Although a previous study²¹ found a decrease in overall physical abuse during April (Child Abuse Prevention Month), no such decline in AHT was seen in the present study.

Somewhat surprisingly, the incidence of AHT was no greater among major metropolitan areas such as Philadelphia and Pittsburgh than in suburban or rural regions beyond the differences in the regional birthrates. Boys were more commonly victims than girls, as previously reported.¹⁹ Consistent with several previous studies,^{7,8,19,20} perpetrators were more commonly male; fathers and boyfriends accounted for more than half of cases in which a perpetrator's sex could be identified, whereas mothers accounted for only 16%. This study cannot assess the relative frequency of AHT by biological fathers, stepfathers, or boyfriends because the frequency with which these types of males are present in the home (the denominator in these calculations) is unknown and since fathers and stepfathers were not differentiated in the OCYF database.

This study provides strong evidence that although AHT can occur in every socioeconomic group, there are significant demographic differences between the general population and those families in which AHT occurs. An increased incidence of AHT is found among parents who are younger, less well educated, or unmarried. Both mothers and fathers were more often African-American, and fathers were more often Hispanic. Mothers were more likely to smoke during the pregnancy, delay seeking medical care during the pregnancy, and deliver low birth weight infants. However, the independent or relative importance of each of these factors is impossible to establish in the absence of a multivariate analysis. In New Zealand, the incidence of AHT among the native Maori (who have historically been impoverished as a consequence of European colonization and, as a group, have a socioeconomic status similar to African-Americans in the US) is also significantly higher than the rate among either the European or other Pacific Islander populations living in New Zealand (P. Kelley, unpublished data, 2007). Recent studies from the United Kingdom also suggest that parents of children with AHT are younger and more frequently from laboring classes than the general population.^{4,5,12}

One must be very cautious in interpreting these data, as there are at least 2 different interpretations. One interpretation is that infants in these families are actually more likely to suffer AHT. Another interpretation is that these families are more likely to be reported for AHT (or, conversely, that families conforming to other demographics are less likely to be reported) under the same or similar circumstances and therefore these results represent an ascertainment bias. Although the present study includes only cases of substantiated AHT, it is not possible, with the information provided, to know with absolute certainty whether these injuries were all, in fact, abusive, nor do we have any information about unfounded or unreported cases of AHT as this information is clearly unknowable. One previous study found that “missed” cases of AHT (those that were previously overlooked by health care providers) more frequently involved “intact” and Caucasian families.¹⁵ A more recent study of children with bone fractures also concluded that African-

American children were not only more likely to sustain abusive bone fractures but also were more likely to be reported as having been abused even after controlling for type of insurance and the likelihood that the injuries were abusive after an independent review was undertaken.¹⁷

A number of limitations are inherent in the study design, the first and foremost of which is that case identification relies on a state registry compiled from child abuse reports rather than more traditional medical tracking mechanisms such as ICD-10 hospital discharge codes, raising concerns about the fidelity and consistency of the submitted information. Second, the lack of access to individual demographic information from all birth certificates statewide precludes any multivariate analysis to determine which of the identified variables is independently associated with AHT. Third, a small number of cases may have been reported to local child abuse agencies rather than to the state registry, although there is no reason to suspect that this leads to a selection bias. A final limitation is that the registry omits cases of substantiated abuse that were instead unfounded for lack of an identified perpetrator. Unfortunately this is a limitation of the registry since unfounded cases are expunged from the database (and the data lost) after 485 days. The registry manager (oral communication) estimates only 1–2 such cases per year, which does not significantly impact the results of the study. For example, adding 2 more cases each year would change the incidence rate by only 4%.

Conclusions

This study provides comprehensive, population-based information about the incidence, seasonal variation, mortality rates, and family demographics of children who have sustained AHT that may prove useful both to those who care for these infants as well as those who are designing ways to prevent it.⁸ However, as stated earlier, one must be very cautious about generalizing these data to individual cases, especially within the context of the judicial system, given that independent associations cannot be identified nor ascertainment bias excluded from these results.

Acknowledgment

The principal investigator, Mark S. Dias, M.D., had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Manuscript submitted October 2, 2007.

Accepted January 22, 2008.

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