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Increased severity of abusive head trauma during the first year of the COVID-19 pandemic☆

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ABSTRACT

Background: Abusive head trauma (AHT) is the leading cause of death from physical abuse in children. Reports regarding the impact of the COVID-19 pandemic on rates and severity of AHT are limited and with conflicting results.

Objective: To determine the number and clinical characteristics of AHT cases presenting to a pediatric tertiary care center during the first year of the COVID-19 pandemic compared to the two prior years.

Participants and setting: We performed a retrospective cohort study of patients <5 years old diagnosed with AHT at a single pediatric tertiary care center over a three-year period.

Methods: Data were obtained for the pandemic year and two years before, including demographics, length of stay, physical and retinal examination findings, radiologic studies, electroencephalogram results, and mortality.

Results: There were 27 cases of AHT during the first year of the pandemic and 55 during the two pre-pandemic years. Length of stay was similar for the two cohorts. The mortality rate was higher during the pandemic (29.6 % vs. 3.6 %; \( p < .01 \)), as were the proportion of patients with retinal hemorrhages (84.6 % vs. 41.5 %; \( p < .01 \)) and abnormal cervical spine imaging (52.6 % vs. 21.2 %; \( p = .02 \)). There were no differences in age, sex, race, abnormalities on dermatological exam, skeletal surveys, and electroencephalograms.

Conclusions: We did not observe an increase in the number of patients with AHT during the pandemic but did see an increase in mortality, patients with retinal hemorrhages, and patients with abnormalities on cervical spine imaging. These data suggest a higher severity of AHT presenting to a pediatric tertiary care center during the pandemic.

Abbreviations: AHT, abusive head trauma; CPS, child protective services; CT, computed tomography; EEG, electroencephalogram; ICD, International Classification of Diseases; ICI, intracranial injury; IQR, interquartile range; LOS, length of stay; MRI, magnetic resonance imaging; PHIS, Pediatric Health Information System; RH, retinal hemorrhages; SDH, subdural hemorrhage; SS, skeletal survey; WHO, World Health Organization.

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1. Introduction

Abusive head trauma (AHT) is the leading cause of death from physical abuse in children (Keenan et al., 2003; Parks, Annest, Hill, & Karch, 2012). AHT is associated with detrimental long-term sequelae and substantial health care costs (Parks et al., 2012). In March 2020, the World Health Organization (WHO) declared COVID-19 to be a global pandemic (Walker & Tolentino, 2020). In Pennsylvania, social distancing measures and non-essential business closures started March 13, 2020, with stay-at-home orders for certain counties starting March 23, 2020. A statewide stay-at-home order was implemented April 1, 2020 and lasted until June 5, 2020. School closures started March 13, 2020 and continued through the remainder of the 2019–2020 academic year (City of Pittsburgh, n.d.). Lifestyle disruptions during the COVID-19 pandemic, including work, childcare, and school closures, along with elevated unemployment rates, added to family stressors, posing potential increased risk for family violence (Campbell, 2020; Griffith, 2020; Lawson, Piel, & Simon, 2020). Several studies suggested an increase in physical abuse frequency (Kovler et al., 2021) or severity (Massiot et al., 2022) during the period of lockdown.

Studies regarding the impact of the COVID-19 pandemic on rates of AHT are few and have conflicting results. An early case series report from a single institution in the United Kingdom showed a marked increase in AHT cases (10 vs. 0.67 cases/month) during the first month of national self-isolation due to the COVID-19 pandemic compared to the same month in the three prior years (Sidpra, Abomeli, Hameed, Baker, & Mankad, 2021). However, subsequent large database reviews yielded variable results. In the U.S., an initial review of the Pediatric Health Information System (PHIS) database reported no change in the rates or severity of physical abuse during the first five months of the pandemic compared to the three prior years (Kaiser et al., 2021). This report was followed by another review of the same PHIS database focused specifically on children with AHT, which reported a decrease in mean monthly admissions for children with AHT during the first six months of the pandemic compared to the three prior years, and a similar mortality rate (Maassel, Asnes, Leventhal, & Solomon, 2021). Intriguingly, an additional analysis of the same PHIS database by another group reported increased odds of AHT during the first three months of the pandemic (De Boer et al., 2022). A review of the French national hospital registry reported a similar incidence of hospital admissions for subdural hemorrhages and mortality in the context of child abuse during the first year of the pandemic compared to the two prior years (Caron et al., 2022). The authors of these four database studies recognize the limitations of their methodology, including reliance on International Classification of Diseases (ICD) codes, reliance on limited recorded data, and absence of case-specific information.

A detailed assessment of the severity and clinical characteristics of AHT cases during and prior to the pandemic would help in understanding how to target prevention efforts. Therefore, in this study we aim to determine the number and specific clinical characteristics of patients with AHT presenting to a tertiary children’s hospital during the first year of the COVID-19 pandemic compared to the previous two pre-pandemic years.

2. Methods

2.1. Participants

We performed a retrospective, single-center cohort study of patients <5 years of age presenting with AHT to a single pediatric tertiary care center from March 11, 2018, through March 10, 2021. The March 11 start date was in accordance with the WHO declaration of COVID-19 as a pandemic in 2020 (Walker & Tolentino, 2020). Patients were identified using an existing Child Advocacy Center database which tracks all consults to the hospital-based Child Protection Team. Additionally, to identify patients who may have died prior to admission, we performed a review of emergency department mortalities during the study time period. AHT was defined as any intracranial injury or skull fracture deemed highly concerning or definitive for physical abuse by our institution’s Child Protection Team. Patients with intracranial injuries due to neglectful supervision or penetrating brain injuries were excluded. This study was approved by the University of Pittsburgh Institutional Review Board.

2.2. Data collection and outcomes

Data obtained included patient demographics (age, sex, race), admission date, zip code, length of stay (LOS), computed tomography (CT) head or magnetic resonance imaging (MRI) brain results, skeletal survey results, cervical spine imaging results including CTs and MRIs, presence of retinal hemorrhages on fundoscopic exam, dermatological physical exam findings, electroencephalogram (EEG) results, and mortality. Intensive care unit admission rate was not included in this study as all patients with intracranial injuries are admitted to the intensive care unit at our institution.

The primary outcome was the number of AHT cases during the first year of the pandemic (March 11, 2020–March 10, 2021) compared to the two previous years (March 11, 2018-March 10, 2020). Secondary outcomes were LOS, mortality, presence of retinal hemorrhages, abnormal skeletal survey, abnormal cervical spine imaging, abnormal dermatologic findings, and abnormal EEG.

To assess if the geographical origin of patients with AHT changed during the pandemic, we used the patients’ residence zip codes and computed the percentage of patients coming from a previously defined encatchment area of 23 counties in Western Pennsylvania from which our institution would expect to receive patients, and compared these percentages for during and prior to the pandemic (Berger et al., 2011).
2.3. Definitions

An abnormal skeletal survey was defined as having any fracture(s) excluding skull fractures. Abnormal cervical spine imaging was defined as any bone, soft tissue, or ligamentous injury identified on CT or MRI. An abnormal dermatologic exam was defined as the presence of any bruise, burn, or oral injury consistent with physical abuse excluding scalp swelling. An abnormal EEG was defined as epileptic abnormalities or slowing identified on the initial EEG. Prior injury was defined as any healing fracture(s) on skeletal survey. Prior child protective services involvement included any documentation from social work or the Child Protection Team regarding a referral to child protective services prior to the admission for AHT.

2.4. Statistical analysis

Descriptive statistics were presented as a number and percentage or median and interquartile range (IQR). For continuous variables, the Mann-Whitney U test was used for analysis of two groups. For categorical variables, the Chi-Square test or Fisher's exact test were used. SPSS (IBM SPSS Statistics, Version 26.0. Armonk, NY: IBM Corp) was used for all statistical analyses.

We compared data for the first year of the pandemic (March 11, 2020–March 10, 2021) to the two previous years (March 11, 2018–March 10, 2020). Additionally, to assess if the severity of AHT was higher in the early months of the pandemic, we performed a secondary analysis and compared patients who presented in the first three months of the COVID-19 pandemic to those who presented in the subsequent nine months.

We also performed a sensitivity analysis to evaluate the impact of mortality on LOS prior to and during the COVID-19 pandemic. An analysis to compare the proportion of patients who underwent advanced cervical spine imaging with CT or MRI during and prior to the pandemic was performed.

3. Results

A total of 82 patients presenting with AHT met inclusion criteria during the three years: 27 during the COVID-19 pandemic and 55 during the two previous years. The median (IQR) age of patients was similar for the two cohorts: 4.3 (2.3–11.2) months, pandemic and pre-pandemic group, respectively. The two cohorts had similar age distribution, sex, and race (Table 1). The majority of patients came from our institution’s 23 county encatchment area during both time periods (n = 23, 85.2 % vs. n = 49, 89.1 %, pandemic vs. pre-pandemic group, respectively, p = .72).

LOS was similar for patients during and prior to the COVID-19 pandemic (5.6 days, IQR 2.8–19.9 vs. 4.9 days, IQR 2.9–10.4; p = .35). Sensitivity analysis excluding children who died during and prior to the pandemic also showed a similar LOS (4.2 days, IQR 2.4–18.0 vs. 4.9 days, IQR 2.9–10.9; p = .54). The proportion of patients with dermatological abnormalities, abnormal skeletal surveys, abnormal EEGs, skull fractures, and subdural hemorrhages were also similar in the two cohorts (Table 2).

Mortality was higher during the pandemic compared to prior years: 29.6 % (8/27) vs. 3.6 % (2/55); p < .01. The proportion of patients with retinal hemorrhages was also higher during the pandemic (n = 22, 84.6 % vs. n = 22, 41.5 %; p < .01). There was a higher proportion of patients with abnormal cervical spine imaging during the pandemic compared to prior (n = 10, 52.6 % vs. n = 7, 21.2 %; p = .02) (Table 2). Proportion of patients who underwent cervical spine imaging with CT or MRI during the pandemic compared to prior did not change (n = 19, 70.4 % vs. n = 33, 60.0 %; p = .36). Among patients with spine imaging, use of cervical spine MRI was similar during and prior to the pandemic (n = 15, 79.0 % vs. n = 28, 84.8 %; p = .56).

For the ten children who died during both time periods, median age was 6.4 months during the pandemic vs. 17.9 months pre-pandemic. Table 3 presents demographics and clinical details of these patients. Of these 10 patients, 5 either had healing fractures on skeletal survey or documentation of prior child protective services involvement.

To assess if the severity of AHT was higher early in the pandemic, we compared the severity indices during the first three months of the pandemic to the subsequent nine months. Six of 27 (22 %) patients presented in the first three months. When the patients who presented in the first three months were compared to those in the following nine months, there were no differences in mortality (n = 2, 7, 21.2 %; p = .72).

### Table 1

Patient demographics.

| Variables     | Pre-pandemic (2 years; n = 55) | COVID-19 pandemic (1 year; n = 27) |
|---------------|---------------------------------|-----------------------------------|
| Age distribution |                                |                                   |
| <6 months     | 65.5 (36)                       | 59.3 (16)                         |
| 6-12 months   | 9.1 (5)                         | 18.5 (5)                          |
| 1-2 years     | 9.1 (5)                         | 11.1 (3)                          |
| 2-5 years     | 16.4 (9)                        | 11.1 (3)                          |
| Male sex      | 63.6 (35)                       | 59.3 (16)                         |
| Race          |                                 |                                   |
| White         | 69.1 (38)                       | 66.7 (18)                         |
| African American | 21.8 (12)                    | 14.8 (4)                          |
| Other         | 9.1 (5)                         | 18.5 (5)                          |
4. Discussion

In this retrospective cohort study, we report a similar number of children diagnosed with AHT during the first year of the COVID-19 pandemic compared to the two previous years. During the pandemic there was a higher mortality rate along with a higher proportion of patients with retinal hemorrhages and abnormalities on cervical spine imaging compared to pre-pandemic, suggesting increased severity of AHT for patients presenting to a pediatric tertiary care center during the pandemic. While our hospital is a tertiary care center, nearly all cases of non-fatal AHT are admitted to our hospital, as there are no secondary care centers in our region that care for AHT patients (Berger et al., 2011). In addition, <10% of cases of AHT are fatal prior to presentation to the hospital (Berger et al., 2011; Keenan et al., 2003), so we believe that these data represent overall rates of AHT in our region.

The increased mortality rate among children with AHT during the pandemic period is consistent with some prior studies that report an increased severity of physical abuse during the pandemic (De Boer et al., 2022; Massiot et al., 2022). Two studies, however, did not find an increase in mortality in children with AHT. In an analysis of the U.S. based PHIS database during the first six months of the pandemic, Maassel et al. found no change in mortality for AHT patients compared to the three prior years (Maassel et al., 2021). Similarly, Caron et al., who analyzed a nationwide French database, found no change in mortality among children 0–24 months old admitted for abusive subdural hemorrhage in the first 12 months of the COVID-19 pandemic compared to the two prior years (Caron et al., 2022).

Both of these previous studies employed analysis of large databases and rely on ICD diagnosis codes for identification of AHT cases. ICD diagnosis codes have been shown to both under and overcount abuse cases (Ellingson, Leventhal, & Weiss, 2008; Hooft et al., 2015). Moreover, in the U.S. the 2015 transition to ICD-10 and the introduction of diagnosis codes for suspected and confirmed abuse led to volatile changes in coding practices and may have decreased the sensitivity and specificity of ICD-10 codes as compared to ICD-9 diagnosis codes (Hughes Garza, Piper, Barczyk, Pérez, & Lawson, 2021). The use of a prospectively collected database of children evaluated and diagnosed by a Child Protection Team, as was used in this study, allows for providing case specific information and decreases the risk of including miscategorized patients (Berger, Parks, Fromkin, Rubin, & Pecora, 2015).

The increased mortality rate and severity of injury found in our study in the context of a similar number of patients with AHT during both time periods could be due to either a) a true increase in mortality, b) a decreased number of AHT cases brought to medical attention during the pandemic, or c) an increased number of missed AHT cases during the pandemic. In the last two scenarios, the artificially small denominator could lead to an increase in the mortality rate due to a difference in the population being evaluated. These two scenarios are plausible, as it is well documented that a lower number of patients sought care during the COVID-19 pandemic (Radhakrishnan, Carey, Hartnett, et al., 2022). Moreover, it is possible that children with less severe AHT would have less severe symptoms which would have resolved over time if they were not brought for medical evaluation, either due to hesitancy to seek care during the pandemic or due to decreased opportunities for identification of abuse by non-medical care providers, such as extended family or daycare personnel. One might expect that if this were the case, the proportion of children with evidence of previous injury (e.g., healing fracture) would increase over time. While we did not see that, our numbers are small and difficult to interpret. In future studies, it will be important to expand the time period beyond the first year after the start of the pandemic. It is also possible that there was an increase in missed AHT which would have resulted in a lower denominator; two large studies separated by 15 years demonstrated almost identical rates of missed AHT suggesting that the rates of missed AHT are stable (Jenny, Hymel, Ritzen, Reinert,
Table 3
Clinical characteristics of AHT mortalities.

| Patient | Age (months) | Sex | Race | LOS (days) | SDH | Skull fracture | Abnormal C-spine | Abnormal SS | Dermatologic abnormality | RH | Prior injury | Prior CPS involvement |
|---------|--------------|-----|------|------------|-----|----------------|------------------|-------------|-------------------------|----|--------------|-----------------------|
| Pre-pandemic | | | | | | | | | | | | | |
| 1 | 34.2 | M | White | 1.0 | Yes | No | No | No | None | | Yes | No | Yes |
| 2<sup>a</sup> | 1.6 | M | White | 0.0 | – | Yes | – | Yes | Multiple bruises | | – | No | No |
| Pandemic | | | | | | | | | | | | | |
| 3 | 0.8 | F | Other | 21.2 | Yes | No | Yes | No | None | | Yes | No | No |
| 4 | 35.5 | M | White | 29.3 | Yes | Yes | No | Yes | Multiple bruises | | Yes | Yes | Yes |
| 5 | 0.9 | F | White | 5.6 | Yes | No | Yes | Yes | None | | Yes | No | Yes |
| 6 | 8.9 | M | White | 2.8 | Yes | No | No | No | Bruise of left foot | | Yes | No | No |
| 7 | 22.0 | M | Black | 2.8 | Yes | No | No | No | Multiple bruises | | Yes | No | No |
| 8 | 3.9 | M | White | 44.9 | Yes | Yes | No | Yes | Bruise of left eyelid | | Yes | Yes | No |
| 9 | 3.5 | M | Other | 6.2 | Yes | No | Yes | Yes | Multiple bruises | | Yes | Yes | Yes |
| 10 | 39.0 | M | Other | 1.1 | Yes | No | Yes | Yes | Multiple bruises | | Yes | No | No |

Abbreviations: LOS, length of stay; SDH, subdural hemorrhage; SS, skeletal survey; RH, retinal hemorrhages; CPS, Child Protective Services.

<sup>a</sup> Patient 2 died in the ED and did not have dedicated head imaging or an eye exam.
<sup>b</sup> LOS defined as time between admission date and death.
<sup>c</sup> Prior injury defined as healing fracture(s) on skeletal survey.
<sup>d</sup> Documentation of prior CPS involvement from hospital social work team or Child Protection Team.
& Hay, 1999; Letson et al., 2016). Any of these three scenarios, however, would signify increased incidence or severity of abuse, and thus the increased mortality rate that our study revealed is important to note.

The increased proportion of patients with cervical spine injuries during the pandemic suggest that shaking may have been the mechanism of injury (Choudhary, Ishak, Zacharia, & Dias, 2014). This mechanism could also account for the increased proportion of patients with retinal hemorrhages, a finding independently associated with increased risk of mortality (Christian et al., 2018; Levin, 2010; Shein et al., 2012). The increase in cervical spine injuries was not related to an increase in use of MRI vs. CT as the proportion of patients undergoing MRI remained stable through the study time period.

The lack of a change in LOS despite the increased severity was surprising particularly given that the lack of change persisted even when children who died, and might be expected to have a shorter length of stay, were removed from the analysis. We evaluated overall hospital LOS as opposed to intensive care unit length of stay. It is possible that intensive care unit LOS, which is likely driven more by medical condition, was increased, while overall hospital LOS, which can be driven by social factors such as locating a foster home, was stable.

There are several limitations to this study. While patient identification for the Child Protection Team database was prospective, patient level data was obtained retrospectively, and subject to expected limitations of reporter bias, recorder bias, and missing data. While all included patients were diagnosed with AHT and underwent head imaging, not all patients underwent cervical spine imaging or EEG. Just over half of the patients from both time periods underwent cervical spine MRI, a rate of cervical spine imaging consistent with prior studies (Henry & Wood, 2018; Kadom et al., 2014; Rabbitt et al., 2020). Provider decision making in obtaining these studies was not regulated during the study period and indications were not routinely documented, however, this was similar in both cohorts. Other patient factors, including socioeconomic status, parental unemployment, parental education, relationship of the child to the alleged perpetrator, number of other children in the home, and setting where death occurred which could affect risk of physical abuse or injury severity (Fingarson et al., 2019) may have been different between the two time periods and might account for differences in injury severity in individual cases; these data were not routinely available and could not be analyzed in this study.

5. Conclusion

During the COVID-19 pandemic, the number of AHT cases remained stable while mortality and concomitant measures of injury severity increased at a pediatric tertiary care center. It is unclear whether these results represent a true increase in severity of AHT or a decrease in the identification of milder AHT in the context of decreased use of health care overall during the first part of the pandemic. Future research is needed to differentiate these possibilities since the public health response would need to be different. Given the limited time interval of this study and the ongoing societal impact of the COVID-19 pandemic, expanding the study period and increasing the number of institutions collecting data would help to answer this question.

Declarations of competing interests

None.

Data availability

Data will be made available on request.

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