Pediatric Abusive Head Trauma Trends in Alaska (2005 – 2019)

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Abstract:
Background: Pediatric abusive head trauma (AHT) is a severe form of child maltreatment, often resulting in extensive health consequences or death. Methods: Using a multi-source identification approach based on International Classification of Disease 9th revision (ICD-9) codes, prior estimates of AHT in Alaska were reported for 2005 – 2010. Adoption of ICD-10 codes in 2015 required a modernization and standardization of coding algorithms to trend AHT. This analysis describes the distribution and trends of AHT in Alaska between 2005 – 2019 using a modified CDC algorithm. Results: Over the 15-year observation period, the annual incidence remained flat but with large year-to-year variability. Children < 1 year old are overrepresented. Likewise, children born to low socioeconomic status families, unmarried mothers, and mothers with < 12 years education experienced significantly elevated risk of AHT compared to their counterparts. Disparities originally observed by race and maternal age were not significantly predictive of risk of AHT when adjusted for the above maternal risk factors. Conclusion: AHT has continued to occur in Alaska at a consistent rate overall, with some sub-populations experiencing higher incidences than others. Families with limited resources or supports and other household challenges who are welcoming a new child should be prioritized for prevention efforts, such as home visiting or other AHT specific prevention programs.

Background:

Pediatric abusive head trauma (AHT) accounts for approximately one-third of child maltreatment fatalities in the United States.[1] Victims of non-fatal AHT are often left with long lasting health consequences, such as developmental delays and physical disabilities.[2] Monitoring trends in AHT incidence rates is critical for detecting unexpected changes, characterizing persons at risk, and evaluating prevention efforts.

In response to historical definition variability between researchers, the Centers for Disease Control and Prevention (CDC) created a coding algorithm to define AHT using International Classification of Diseases diagnosis and cause of injury codes (ICD-9-CM for morbidity coding and ICD-10 for mortality coding).[3] The algorithm developed by CDC enables standardized systematic identification of AHT over time and valid comparisons between jurisdictions.

The CDC AHT algorithm encompasses children younger than 5 years. However, the highest incidence of AHT is reported among children younger than one-year old[4] and higher AHT-related mortality has been documented in children between one and two years old.[5,6] Therefore, it is common for researchers and program leaders to focus prevention and detection efforts among children at greatest risk (< 1 year old or < 2 years old).

Based on the CDC definition, a recent national study using hospital discharge records estimated 39 per 100,000 children < 1 year of age during 2000-2009 experienced AHT.[7] A multi-source study in Alaska estimated 34.4 per 100,000 children < 2 years of age during 2005-2010 experienced AHT.[8] The estimate observed in Alaska was approximately 42 cases per 100,000 children when limited to children < 1 year of age and to the singular hospital discharge data

Table 1. ICD-9-CM and ICD-10-CM coding. AHT cases must have both a clinical diagnosis and injury/abuse code, unless otherwise specified.

AHT Categorization	Clinical Diagnosis Code	Injury or Abuse Code
	ICD-9-CM Coding	
Definite or Presumptive AHT	781.0-781.4, 781.8, 800, 800.1-800.4, 800.6-800.9, 801, 801.1-801.9, 803, 803.1-803.4, 803.6-803.9, 804.1-804.4, 804.6-804.9, 850, 850.0-850.9, 851, 851.0-851.99, 852.0-852.59, 853.0-853.19, 854.0-854.19, 925.1, 950.0-950.3, 959.01, 995.55**	E960.0, E967, E968.1, E968.2, E968.8, E968.9, 995.50*, 995.54, 995.59*
Probable AHT	All of those above except 995.55	E987, E988.8, E988.9
	ICD-10-CM Coding	
Definite or Presumptive AHT	S02.0-S02.1, S02.7-S02.9, S04.0, S06.0-S06.9, S07.1, S07.8-S07.9, S09.7-S09.8, T74.4**[a], T90.2, T90.5, T90.8-T90.9	Y00, Y01, Y04, Y07.0-Y07.3, Y07.8-Y07.9, Y08, Y08.8[a], Y09, Y87.1, T74.1, T74.8-T74.9
Probable AHT	All of those above except T74.4	Y29, Y30, Y33, Y34, T76.1[a], T76.9[a], Y87.2

AHT: Abusive head trauma
* Exclude case in the presence of a fall or accident code
** Does not require an injury or abuse code
[a] Codes added to original CDC definitions

source to enable more direct comparison with the national estimate.

On October 1, 2015, the healthcare community dropped the use of ICD-9-CM and transitioned to the exclusive use of ICD-10-CM diagnosis and procedure codes. Surveillance systems reliant on ICD-9-CM codes required cross-walking and updating definitions to facilitate trend analyses post-2015. Therefore, updated trend analyses of AHT incidence rates required modification to the established CDC AHT classification algorithm.

Using multi-source detection, the current study describes updated trends of AHT incidence rates in Alaska among children aged < 2 years between 2005-2019 using the CDC definition guidelines modified to account for the ICD code system update. The study population of children aged < 2 years was chosen because this population is at increased risk of AHT compared to other ages and the age range encompasses a majority of reported AHT cases. In addition, the timeframe enables a shorter reporting lag period and improves capturing of unique cases.

Method:
We extracted first instance AHT cases for children < 2 years of age residing in Alaska during 2005 to 2019 using data from the Alaska Maternal Child Death Review (MCDR), Medicaid, Health Facilities Data Reporting System (HFDR; formerly referred to as the Hospital Discharge Database), and the Alaska Trauma Registry (ATR). All sources are described in detail elsewhere.[8] AHT was defined using CDC Pediatric Abusive Head Trauma research guidelines (PAHT)[3] with additional code specifications added based on a recent publication defining AHT hospital admissions[9] (Table 1).

We applied the modified PAHT definition to each contributing source independently due to limitations in data elements available in each system. Detected cases from each source were subsequently compared to identify unique cases. AHT cases identified between sources that shared identical or near identical admission dates, demographic information, and diagnoses codes were considered duplicates and merged. Identifying information for each case was taken from the source of detection, if available. Each of the remaining cases were identified using Vital Statistics birth and death records provided by the Section of Health Analytics and Vital Records and Alaska Office of Children's Services case records to identify any remaining duplicates. Cases already discovered from our prior publication[8] were verified through this process.

To calculate incidence rates, annual denominators for children < 2 years of age in Alaska were calculated as (annual births + [previous year's births - previous year's infant deaths]). The total period and annual incidence of AHT among children < 2 years of age were calculated per 100,000 population (per convention) and by subgroups.

Subgroup incidence was calculated for infant sex (male, female), geographical maternal residence (urban, rural), maternal years of education (< 12 years, 12+ years), maternal marital status (married, not married), maternal race (any mention of Alaska Native, White, Other), and family Medicaid status all at time of birth (enrolled, not enrolled). Subgroups were chosen based on factors identified in prior research.[8,10] Urban versus rural status was classified by county of residence using the US Census Bureau's definition. Subgroup analyses were constrained by availability of demographic variables identified through linkage to birth records.

A multivariable logistic regression model was constructed with children born between 2004 – 2019 to investigate the independent relationships between AHT and all maternal characteristics, apart from Medicaid status. Medicaid status was not included in the model due to potential bias resulting from Medicaid being a primary source of case identification.

Trends were assessed using a Generalized Linear Model with quasi-Poisson distribution. All analyses were conducted in R, version 4.1.0.[11]

Results:

We identified 163 unique cases of AHT among children aged < 2 years during 2005 – 2019 in Alaska, yielding an annual average incidence of 49.3 cases per 100,000 children aged < 2 years (95% CI: 41.7, 56.9). The AHT incidence among children aged < 2 years ranged from 28.0 (95% CI: 5.6, 50.4) in 2006 to 79.4 (95% CI: 42.7, 116.0) in 2015. Over the 15-year period, on average each year, approximately 11 children aged < 2 years experienced AHT (Table 2), and the case fatality ratio was 13%. The AHT trend remained flat over time (Trend Estimate = 0.01, $p = 0.435$; Figure 1).

Table 2. Abusive head trauma cases among children aged < 2 years in Alaska, 2005-2019

Year	Cases	Population*
2005	10	20,793
2006	6	21,446
2007	12	22,022
2008	13	22,482
2009	7	22,743
2010	13	22,771
2011	11	22,932
2012	9	22,632
2013	11	22,620
2014	12	22,835
2015	18	22,680
2016	8	22,493
2017	13	21,682
2018	14	20,561
2019	6	19,923

* Population = annual births + (previous year's births – previous year's infant deaths).

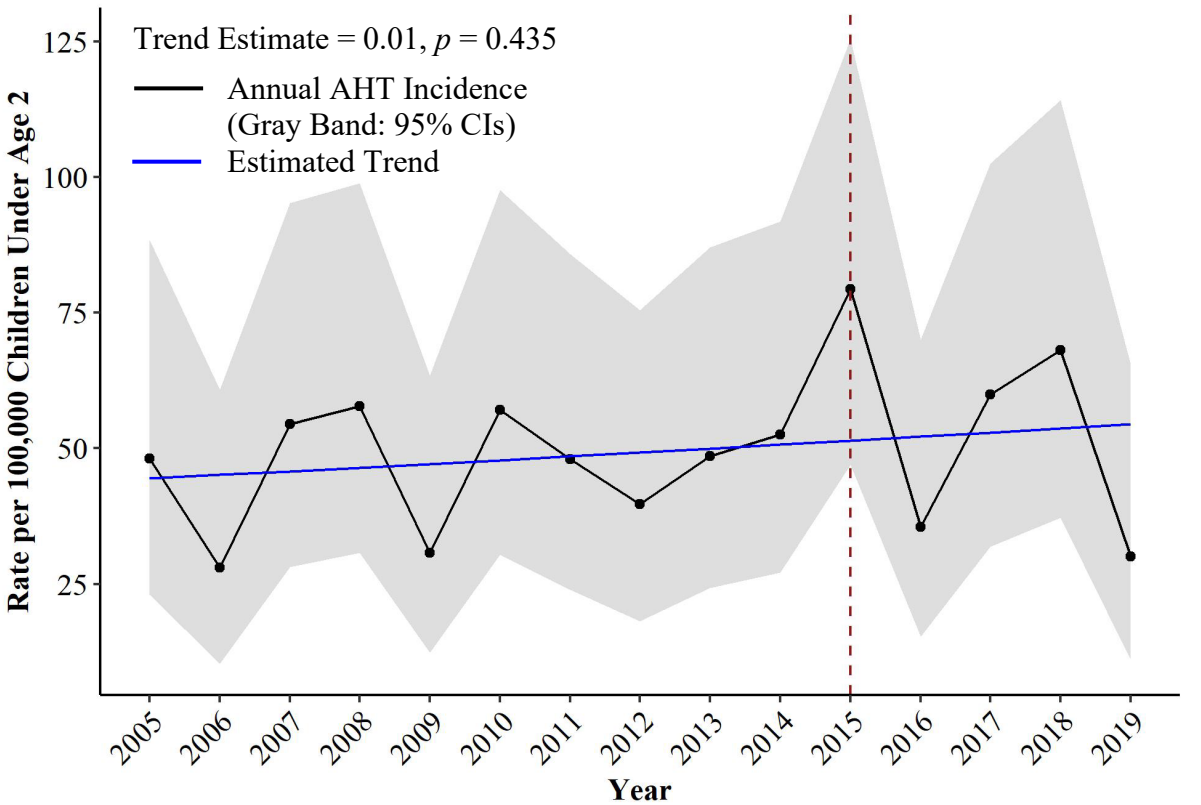

Figure 1. Abusive head trauma (AHT) rates 2005 – 2019 in children < 2 years of age, Alaska. Red dashed line indicates year ICD-9 codes were dropped and the algorithm was updated.

Infants (< 12 months of age) had statistically elevated rates of AHT relative to older children (Table 3). Children born to birthing parents who were young (< 20 years of age), had less than 12 years of education, were Alaskan Native, were not married, or enrolled in Medicaid had significantly higher incidences of AHT compared to their low-risk counterparts (Table 3).

After adjusting for maternal characteristics, we only observed two significant independent associations. We found that children born to unmarried birthing parents and birthing parents with less than 12 years of education were 3.6 (95% CI: 2.4, 5.4) and 1.6 (95% CI: 1.0, 2.4) times as likely to experience AHT relative to married birthing parents and those with higher education, respectively (Table 4).

Finally, no single data system identified all AHT cases. Among the sources, the MCDR captured 13% (21/163), Medicaid captured 66% (108/163), the HFDR captured 24% (39/163), and ATR captured 38% (62/163) of the total cases. Of note, MCDR only captures fatal events. Unique case capture counts by source are shown in Figure 2.

Discussion:

The Alaska incidence of AHT during 2005 – 2019 was 49.3 cases per 100,000 children aged < 2 years. We observed large year-to-year variability and did not detect a statistically significant trend during the 15-year period (p = 0.435; Figure 1).

While explicitly predicting AHT is difficult, certain populations experience a disproportionate burden of identified cases. Research suggests that caregiver factors such as mental health issues, substance misuse, historical trauma, isolation, and increased

stressors (such as losing a job) may produce scenarios that increase the risk of AHT,[2,4] especially when exacerbated by stressful infant and child behavior such as excessive and inconsolable crying. Consistent with prior research, we observed that infants (relative to 1-year-olds) were significantly more likely to experience AHT. However, divergent from national research,[7,12] we did not observe a difference by sex of the child or region of birth.

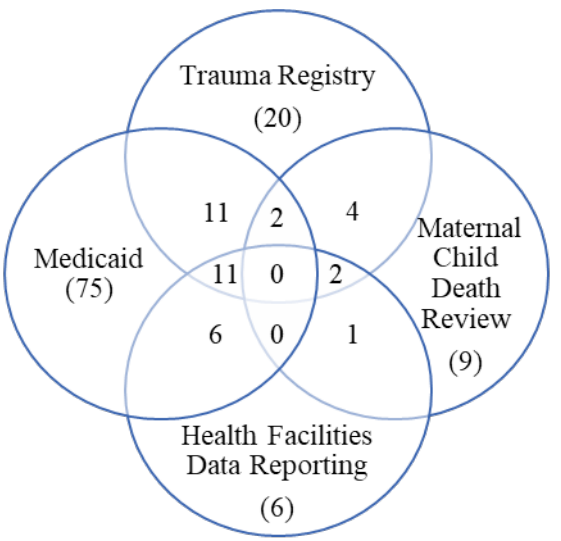

Figure 2. Venn diagram of number of abusive head trauma cases detected by each Alaska state source. Not pictured: Health Facilities Data Reporting and Trauma Registry had 13 cases overlap, and Maternal Child Death Review and Medicaid had 3 cases overlap.

Disparities:
Congruent with prior research,[10] certain maternal characteristics reported on the birth certificate were associated with elevated unadjusted rates of AHT and included: Less than 20 years of age, less then high school education, unmarried, Alaska Native maternal race, and being enrolled in Medicaid. After adjustment, unmarried marital status and low education were the two significant independent indicators associated with elevated odds of AHT. It is critical, however, that these observed unadjusted and adjusted associations are not misinterpreted as causal but rather a detection of a population experiencing a differential distribution of underlying modifiable risk factors. By identifying populations experiencing disparities, resources can be allocated and targeted. For example, 64% of all AHT cases occurred among children of unmarried birthing parents. This association may indicate that factors tied to single parenting – such as a lack of additional social supports, isolation, reduced economic resources, use of unrelated caregivers, and elevated stressors – increase the risk of AHT. As such, increasing access to social supports, education, and financial services for birthing parents could act as protective measures against risk of AHT.

Although the use of race to classify largely heterogenous populations is common in public health descriptive epidemiology, it can result in further stigmatization of already marginalized populations and does not consider the unique culture and public health challenges of individuals and communities. In this analysis, we demonstrate that after adjusting for a minimal number of other maternal characteristics, race is not predictive of AHT. This underscores the point that no biological predisposition exists among different racial groups. Furthermore, prior research suggests the potential for differential detection and classification bias by race that may also contribute to observed unadjusted differences.[13,14] Additional research should attempt to quantify and qualify both potential implicit bias and underlying factors driving these observed disparities through systematic investigation. Future research should also identify and highlight supportive individual, familial, community, and cultural practices that protect against AHT occurrence to ensure that individual and community identity is a source of strength and prevention as opposed to stigmatization.

Prevention:
To remedy some of these risk factors, providers of pregnant and/or delivering persons should universally educate new parents on child development, milestones, and provide strategies for dealing with infant and early childhood behavior. Use of care coordination and programs such as Help Me Grow should be a key resource for providers. Additionally, for populations with elevated rates, home visiting (e.g., Parents as Teachers, Nurse-Family Partnership) and other more intensive prevention efforts such as mental health treatment and support are likely required to address underlying challenges.

Detection:
The use of multiple data systems to extract AHT cases was a strength of this study, as no one source identified all detected AHT cases. Distribution of case detection by source matched our prior publication.[8] However, it should still be noted that Medicaid captured the most unique and overall number of cases out of the four sources. Therefore, subgroup analyses documenting increased AHT risk for children born to mothers who were eligible for Medicaid should be interpreted with caution.

Limitations:
This descriptive study has limitations that should be noted and understood. First: There is currently no official standard for trending AHT incidence rates beyond the CDC definition,[3] which became outdated at the end of 2015. While we remain confident in the choices of ICD-10-CM code inclusions, there is still a need to standardize an updated research and clinical guideline to measure the sensitivity and specificity of the specified algorithm. Second: We were unable to control for all possible confounders and therefore present only crude associations and a limited regression model. Third: Due to the small annual numbers, we had low statistical power to detect a trend diverging from a slope of zero.

Conclusion:
While welcoming a new baby into a family is often filled with joy, it is also an intensely stressful event. Families and individuals already experiencing multiple stressors may be at a critical disadvantage to respond to new stressors effectively. Predicting individual behavior, however, is difficult because of the multiple external influences and internal capacities that may trigger an AHT event. Due to this difficulty in individual prediction, and in consideration of our findings and prior literature, there is a need for both universal and targeted prevention efforts focused on reducing household stress loads, increasing caregiver social supports, and treating health factors such as substance misuse and mental health issues. In addition, there is a need to raise awareness for and support developed programs that focus on increasing caregiver knowledge about appropriate child behavior and training them with skills to empower and increase their self-efficacy.

While rare, the impact of AHT on the health and development of a child is considerable. Health care, childcare, and other providers have a unique opportunity to engage with birthing parents and caregivers during critical developmental and impressionable periods. Those engaging with expectant parents can initiate prevention efforts prior to the birth of a child, and follow-up prevention efforts can promote supportive and confirming messages throughout early childhood.

Recommendations:

- Visit the CDC website to learn about current AHT prevention efforts and best practices. https://www.cdc.gov/violenceprevention/childabuseandneglect/Abusive-Head-Trauma.html
- Health care providers and others who interface with new parents should provide evidence based AHT prevention strategies early and often, such as home visiting and

connecting them with care coordination programs such as Help Me Grow https://helpmegrowak.org/

- The current CDC AHT definition and detection guideline should be updated and standardized for consistent use by researchers and health care providers.
- Providers should focus on building strengths within new birthing parents experiencing multiple challenges, especially among those experiencing resource needs and limited supports.
- Observed racial disparities are not causal. Providers should avoid language that could further stigmatize racial groups but rather leverage culture and community to build strengths.

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Table 3. Abusive head trauma characteristics among children aged <2 years in Alaska, 2005-2019

Characteristic	Population*	Cases (%)	Incident Rate (95% CI)[a]	Incidence Rate Ratio (95% CI)	*p*-Value[b]
Total	330,615	163	49.30 (41.73,56.87)		
		Child Characteristics			
Age					
1 year	165,091	37 (23)	22.41 (15.19, 29.63)	1	
< 1 year	165,524	126 (77)	76.12 (62.83, 89.41)	3.39 (2.37, 4.95)	<0.001
Missing		0			
Sex					
Male	170,191	85 (52)	49.94 (39.33, 60.56)	1	
Female	160,416	78 (48)	48.62 (37.83, 59.41)	0.97 (0.71, 1.32)	0.865
Missing		0			
Birth Region					
Urban	259,704	122 (75)	46.98 (38.64, 55.31)	1	
Rural	66,958	31 (19)	46.30 (30.00, 62.60)	0.99 (0.66, 1.45)	0.958
Missing		10 (6)			
		Maternal Characteristics			
Age					
20+	305,558	120 (74)	39.27 (32.25, 46.30)	1	
< 20	24,909	28 (17)	112.41 (70.77, 154.05)	2.88 (1.87, 4.27)	<0.001
Missing		15 (9)			
Education					
12+ years	280,805	101 (62)	35.97 (28.95, 42.98)	1	
< 12 years	36,613	41 (25)	111.98 (77.70, 146.26)	3.12 (2.15, 4.45)	<0.001
Missing		21 (13)			
Marital Status					
Married	210,315	42 (26)	19.97 (13.93, 26.01)	1	
Not Married	118,524	104 (64)	87.75 (70.88, 104.61)	4.38 (3.09, 6.34)	<0.001
Missing		17 (10)			
Medicaid					
Not Enrolled	161,131	19 (12)	11.79 (6.49, 17.09)	1	
Enrolled	169,484	129 (79)	76.11 (62.98, 89.25)	6.41 (4.06, 10.72)	<0.001
Missing		15 (9)			
Race					
White	195,763	78 (47)	39.84 (31.00, 48.69)	1	
AN/AI	74,217	56 (34)	75.45 (55.69, 95.22)	1.90 (1.34, 2.67)	<0.001
Other	56,071	22 (13)	39.24 (22.84, 55.63)	0.99 (0.60, 1.56)	0.967
Missing		7 (4)			

* Population = annual births + (previous year's births – previous year's infant deaths).
[a] Incidence rates per 100,000 children <2 years of age.
[b] *p*-value and 95% CIs calculated by median unbiased estimation exact methods.
AN/AI: Alaska Native/American Indian

Table 4. Logistic regression model of maternal characteristic predictors of pediatric abusive head trauma among children aged < 2 years in Alaska, 2005-2019

Maternal Characteristic	β (95% CI)	SE β	*Wald Z*	*p*	OR (95% CI)
Age					
20+	Reference				
< 20	0.39 (-0.09, 0.85)	0.24	1.65	0.100	1.48 (0.91, 2.33)
Education					
12+ years	Reference				
< 12 years	0.46 (0.03, 0.87)	0.21	2.13	0.033	1.58 (1.03, 2.39)
Marital Status					
Married	Reference				
Not Married	1.28 (0.89, 1.69)	0.20	6.29	< 0.001	3.61 (2.43, 5.42)
Race					
White	Reference				
AN/AI	-0.06 (-0.47, 0.35)	0.21	-0.29	0.775	0.94 (0.62, 1.41)
Other	0.11 (-0.36, 0.54)	0.23	0.46	0.646	1.11 (0.69, 1.72)

SE β = Standard error of β coefficient
OR = Odds ratio

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