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ORIGINAL PAPER

Early clinical indicators of developmental outcome in abusive head trauma

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Abstract
Purpose The purpose of the study was to determine the developmental prognostic significance of early clinical indicators in abusive head trauma.
Methods Seventy-one children were diagnosed with abusive head trauma and followed in a post-injury growth and development clinic. A retrospective chart review was completed to gather clinical features at the time of injury, including presence or absence of early post-traumatic seizures, presence or absence of intubation, and presence or absence of pediatric intensive care unit admission. Children then underwent developmental testing with use of the Capute Scales of the Cognitive Adaptive Test (CAT) and the Clinical Linguistic and Auditory Milestone Scale (CLAMS) during follow-up clinic visits. Clinical features at initial injury were compared to developmental outcome.
Results Thirty-four of 71 patients with seizures during their admission hospitalization scored significantly lower on follow-up developmental testing than patients who did not have seizures. Twenty-one of 71 patients who required intubation scored lower on developmental testing than patients who did not require intubation. Thirty-five of 71 patients who required pediatric intensive care unit admission scored lower on developmental testing than patients who did not require pediatric intensive care unit admission.
Conclusions This study demonstrates that clinical factors at the time of injury, such as early post-traumatic seizures and intubation requirement, are associated with poorer developmental outcome. This study also suggests that close developmental follow-up should be obtained for all children with abusive head trauma, regardless of whether or not the child was admitted to the PICU.

Keywords Abuse · Developmental outcome · Head trauma · Intensive care · Seizure

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Introduction

Abusive head trauma (AHT) is the leading cause of traumatic injury and death to young children and infants [1, 2]. AHT accounts for nearly two-thirds of infant homicides [3]. The incidence of AHT is high at 24–29 per 100,000 children younger than 1 year of age [4, 5]. Recent data suggest that the incidence of AHT may be much higher than previously reported. A study from North and South Carolina used anonymous telephone calls to survey mothers about potentially abusive behaviors towards children. The results were surprising and suggested that for every child younger than 2 years of age diagnosed with AHT, another 152 may suffer a subclinical AHT that goes undetected [6].

The outcomes of infants and children suffering AHT are poor. Infants and children who survive AHT suffer brain injury, eye injuries, and fractures in the acute stage. The majority of survivors suffer developmental delays, seizures, motor impairments, feeding difficulties and later behavioral and educational dysfunctions [7]. Childhood victims of non-

accidental trauma have been shown to have worse outcome than victims of accidental head trauma [8, 9]. A review of 24 articles over 27 years showed that the majority of patients with abusive head trauma had poor outcomes [7]. Almost one-fifth of the patients died, half of the children had some impairment, and only 22% reportedly had no impairments. The most recent outcomes study found that greater than 50% of children with abusive head trauma had some deficits 1 year after injury [10]. A review of outcomes of infants and children with AHT from Scotland showed that 68% of children had some neurological abnormality at an average length of follow-up of 59 months. These neurological abnormalities include motor, language, cognitive, and behavioral deficits. Thirty-six percent of the patients had severe deficits that required significant care therapies [11, 12].

After a diagnosis of abusive head trauma, family and primary physicians often inquire about long-term prognosis. There is reluctance to make predictions of outcome following AHT in children due to the perceived potential for brain remodeling [8, 9, 13]. There have been some efforts to correlate outcome with scales performed at admission or at discharge; however, the results have not demonstrated good prediction of long-term development [14, 15]. This study correlates developmental outcome of children with AHT to the following objective predictors: presence or absence of seizures, presence or absence of intubation, and presence or absence of a pediatric intensive care admission.

Patients and methods

This study was approved by the Cincinnati Children's Hospital Medical Center Institutional Review Board. From the period of March 2002 to May 2009, 71 children were diagnosed with abusive head trauma at Cincinnati Children's Hospital by a child abuse pediatrician with a multidisciplinary team review and enrolled and seen for at least one visit in the Mayerson Center's Post-Injury Growth and Development Clinic at Cincinnati Children's Hospital Medical Center. The Post-Injury Clinic is a voluntary multidisciplinary clinic for the evaluation and long-term developmental monitoring of children with a history of AHT with the goal of early identification of needs. These children ranged in age from 0.5 months to 29 months at the time of injury. Data were gathered on their hospitalization course at the time of injury, including the presence or absence of seizures, the presence or absence of intubation, and the presence or absence of a pediatric intensive care admission.

Developmental testing was done at the follow-up visit in Post-Injury Clinic by a physician trained in administration of the Capute Scales. This scale includes two domains, the Cognitive Adaptive Test (CAT) for visual–motor development and the Clinical Linguistic and Auditory Milestone Scale (CLAMS) for language development. These tests have been shown to demonstrate good predictive validity and within-test validity [16–28]. The Capute Scales have previously been utilized to track development up to age 36 months in a wide range of patient populations, including preterm infants, children with genetic conditions, and children with HIV exposure [24, 29, 30]. It has also been shown to be well correlated to the Bayley Scales of Infant Development-II [31]. The advantage of utilizing the Capute Scales is the time and ease of administration, as it can be completed in about 15–20 min by a physician or nurse. It involves both parent report and items completed directly by the infant or toddler. The resulting score is given as a developmental quotient. A developmental quotient is considered in the normal range when it is within one standard deviation from the mean, ranging from 85 to 115. According to the principles of the Capute Scales, a developmental delay is a slower rate of developmental milestone acquisition, which is determined by a developmental quotient of less than 70–75 in one or more areas [32]. A developmental quotient less than 70 was chosen to represent developmental delay in this study. Developmental quotients ranging from 70 to 84 were defined as borderline results. Disparate developmental quotients refer to an uneven rate of developmental milestone acquisition between the two domains being tested [32]. This could indicate that the child has either a communication disorder (CLAMS) or a visual motor disorder (CAT).

Follow-up testing was done between 2 months and 35 months from the time of injury, with an average follow-up time of 12 months and a mean follow-up time of 10.5 months. Children who had more than one visit to the Post-Injury Follow-up Clinic had their last obtained developmental scores used for analysis (Table 1).

Logistic regression was performed where the response was either the CAT, CLAM, or Full Scale category. The explanatory variables considered in the models were age at injury, time of evaluation, seizure status, intubation status, and PICU status (yes or no), and their second order interactions. The backward variable selection procedure was used to identify only those variables that were significant predictors in the model. Statistical significance was set at $p<0.05$.

Results

Of the 71 patients, 34 (48%) had early onset seizures, 21 (30%) were intubated, and 35 (49%) were admitted to the

Table 1 Timing of injury and follow-up evaluations

	Range	Average	Median
Age at injury (months)	0.5–29	5.7	3
Time from injury to testing (months)	2–35	12.4	10.5

PICU (Fig. 1). At the time of follow-up and developmental testing in Post-Injury Clinic, 20 (28%) had full Capute Scale developmental quotients less than normal, 26 (37%) had CAT developmental quotients less than normal, and 17 (24%) had CLAMS developmental quotients less than normal (Table 2).

Borderline developmental outcomes

Of the 71 patients with abusive head trauma, irrespective of seizure, intubation or PICU status, 13 (18%) had scores in the 70–84 range on at least one of the CAT or CLAMS components. In patients with either a CAT developmental quotient or a CLAMS developmental quotient above 70, the CAT developmental quotient score was more likely to be in the lower category (McNemar's test, $p=0.0117$).

Outcomes with respect to seizures

Presence of seizures at initial presentation resulted in poorer developmental outcome. Of the 37 patients with a diagnosis of abusive head trauma without seizures at time of injury, only eight (22%) had CAT developmental quotient scores less than normal, two (6%) had CLAMS developmental quotient scores less than normal, and five (13%) had a full-scale developmental quotient less than normal. One patient (3%) had a cognitive adaptive delay (CAT DQ<70), one patient (3%) had a language delay (CLAMS DQ<70), and two patients (5%) had a full-scale developmental quotient<70. However, in the 34 patients with seizures at the time of injury, 18 (53%) had CAT developmental quotients less than normal, 15 (44%) had CLAMS developmental quotients less than normal, and 15 (44%) had full-scale developmental quotient less than normal. Twelve patients (35%) had a cognitive adaptive delay (CAT DQ<70), 11 patients (32%) had a language delay (CLAMS DQ<70), and 12 patients (35%) had a full-scale developmental quotient<70. *p*-Values for all three tests were<0.003 using Fisher's exact test on the distribution of the three score categories (< 70, 70–84, and≥85) vs. the presence or absence of seizure (Fig. 2).

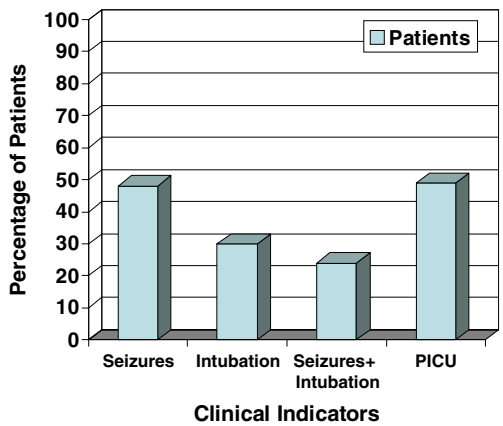

Fig. 1 Frequency of seizures, intubation, and PICU admission in AHT victims

Outcomes with respect to intubation

Presence of intubation resulted in a poorer developmental outcome. Of the 50 patients with a diagnosis of abusive head trauma without intubation at time of injury, only ten (20%) had CAT developmental quotient scores less than normal, five (10%) had CLAMS developmental quotient scores less than normal, and seven (14%) had a full-scale developmental quotient less than normal. One patient (2%) had a cognitive adaptive delay (CAT DQ<70), one patient (2%) had a language delay (CLAMS DQ<70), and two patients (4%) had a full-scale developmental quotient<70. However, in the 21 patients with intubation at the time of injury, 16 (76%) had CAT developmental quotients less than normal, 12 (57%) had CLAMS developmental quotients less than normal, and 13 (62%) had full-scale developmental quotient less than normal. Twelve patients (57%) had a cognitive adaptive delay (CAT DQ<70), 11 patients (52%) had a language motor delay (CLAMS DQ<70), and 12 patients (57%) had a full-scale developmental quotient<70. *p*-Values for all three tests were<0.0001 using Fisher's exact test on the distribution of the three score categories (< 70, 70–84, and≥85) vs. the presence or absence of intubation (Fig. 3).

Outcomes with respect to seizures with intubation

Patients that had early onset seizures and also required intubation had even worse developmental outcomes. Of the 17 patients with seizures who also required intubation at the time of injury, 15 (88%) had CAT developmental quotients less than normal, 12 (71%) had CLAMS developmental quotients less than normal, and 13 (76%) had full-scale developmental quotient less than normal. Eighteen percent had CAT developmental quotients in the 70–84 range, 6% had CLAMS developmental quotients in the 70–84 range, and 6% had a full-scale developmental quotient in the 70–84 range. Twelve patients (71%) had a cognitive adaptive delay (CAT DQ<70), 11 patients (65%) had a language motor delay (CLAMS DQ<70), and 12 patients (71%) had a full-scale developmental quotient <70. *p*-Values for all three tests were<0.0001 using Fisher's exact test on the distribution of the three score categories (< 70, 70–84, and≥85) vs. the presence or absence of seizure with intubation (Fig. 4).

Outcomes with respect to intensive care unit admission

Presence of intensive care unit admission was associated with worse developmental outcome. Of the 36 patients with

Table 2 CAT, CLAMS, and full-scale developmental outcomes by clinical indicator

Clinical indicator		CAT			CLAMS			Full scale		
		Normal > 84 (%)	Borderline 70–84 (%)	< 70 (%)	Normal > 84 (%)	Borderline 70–84 (%)	< 70 (%)	Normal > 84 (%)	Borderline 70–84 (%)	< 70 (%)
Seizures	Present 34	16 (47)	6 (18)	12 (35)	19 (56)	4 (12)	11 (32)	19 (56)	3 (9)	12 (35)
	Absent 37	29 (78)	7 (19)	1 (3)	35 (95)	1 (3)	1 (3)	32 (86)	3 (8)	2 (5)
Intubation	Present 21	5 (24)	4 (19)	12 (57)	9 (43)	1 (5)	11 (52)	8 (38)	1 (5)	12 (57)
	Absent 50	40 (80)	9 (18)	1 (2)	45 (90)	4 (8)	1 (2)	43 (86)	5 (10)	2 (4)
PICU admission	Present 35	16 (46)	7 (20)	12 (34)	21 (60)	3 (9)	11 (31)	20 (57)	3 (9)	12 (34)
	Absent 36	29 (81)	6 (17)	1 (3)	33 (92)	2 (6)	1 (3)	31 (86)	3 (8)	2 (6)

a diagnosis of abusive head trauma who were not admitted to the pediatric intensive care unit at the time of injury, only seven (20%) had CAT developmental quotient scores less than normal, three (9%) had CLAMS developmental quotient scores less than normal, and five (14%) had a full-scale developmental quotient less than normal. One patient (3%) had a cognitive adaptive delay diagnosed by CAT DQ<70, one patient (3%) had a language motor delay diagnosed by CLAMS DQ<70, and two patients (6%) had a full-scale developmental quotient<70. However, in the 35 patients who were admitted to the pediatric intensive care unit at the time of injury, 19 (54%) had CAT developmental quotients less than normal, 14 (40%) had CLAMS developmental quotients less than normal, and 15 (43%) had a full-scale developmental quotient less than normal. Twelve patients (34%) had a cognitive adaptive delay (CAT DQ<70), 11 patients (31%) had a language delay (CLAMS DQ<70), and 12 patients (34%) had a full-scale developmental quotient<70 (Fig. 5). This relationship between intensive care and developmental outcome appears significant; however, if the intubated patients are removed from the equation, the picture changes. There were 14 patients who were admitted to the PICU but not intubated. Eleven had a normal developmental outcome, and three had a developmental outcome in the 70–84 range. None were diagnosed with developmental delay.

Outcomes with respect to age

Logistic regression was used where the response was one of the three full-scale DQ categories described previously in the article. The results of this model showed a significant interaction between age of injury and intubation status. Of the children who did not require intubation at admission, age of injury was associated with a worse developmental outcome, meaning that the older the child at time of injury, the worse the developmental outcome. Of the children who did require intubation at admission, age of injury was associated with a better developmental outcome, meaning that the older the child at the time of injury, the better the developmental outcome (Fig. 6).

Discussion

Because AHT has such poor outcomes, there is a desire to predict outcome for particular patients. Outcome prediction scales performed during the initial hospitalization have not

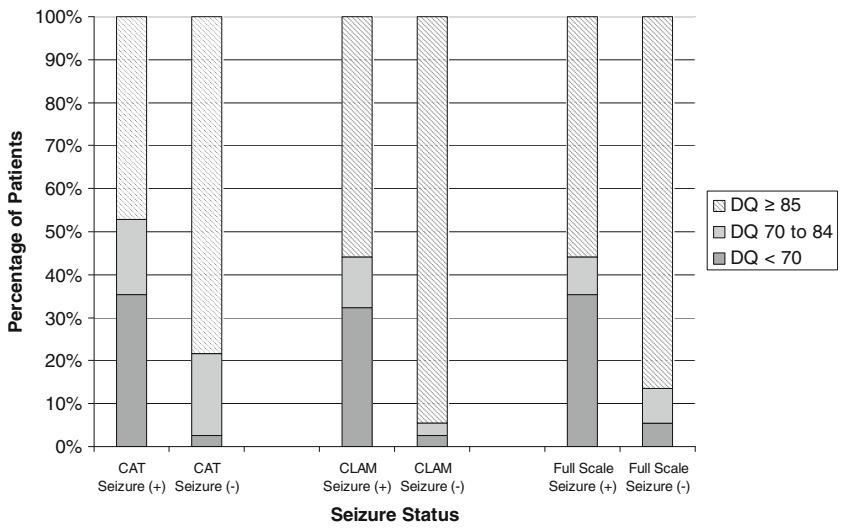

Fig. 2 CAT/CLAMS outcomes with respect to seizure status

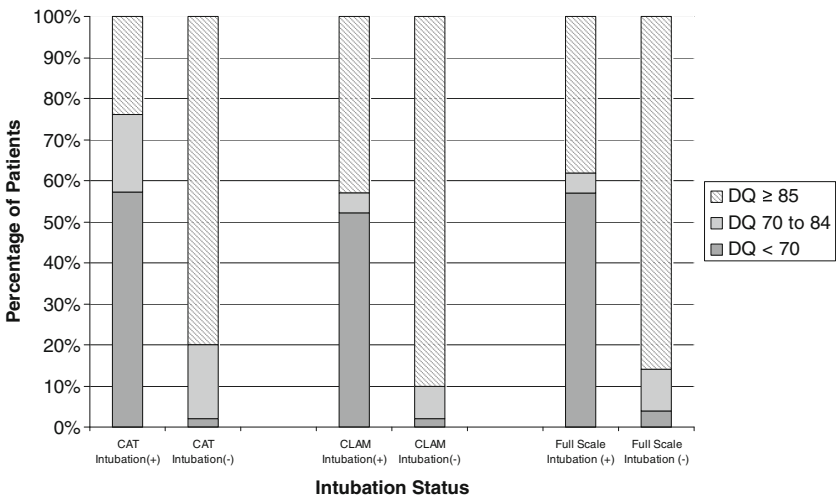

Fig. 3 CAT/CLAMS outcomes with respect to intubation status

been successful in predicting long-term outcome for children. The Glasgow Coma Scale, although shown to have correlation with mortality and some measures of outcome, has shown very limited utility due to a lack of scores obtained in the first 24 h after injury and poor inter-observer agreement [14, 33–35]. The Glasgow Coma Outcome Scale has outcome measures that are not applicable to children, such as return to work [36]. The King's Outcome Scale for Childhood Head Injury predicted early outcome well but did not correlate well with long-term outcome, including developmental follow-up [15].

This study is unique because it does not rely on scales that are subject to administration difficulty or inter-rater reliability, but instead examines specific clinical factors. In this study, the presence of seizures and the need for intubation were found to correlate with poor developmental outcome.

This study did not find as strong an association between PICU admission and developmental outcome. In particular, of the patients who were not intubated but were admitted to the PICU, none were diagnosed with developmental delay. It is possible that these children were admitted to the PICU for reasons other than their head injury, such as other bodily injury. Conversely, there were eight patients who did not require admission to the PICU who did not have normal developmental outcome: seven with developmental quotients in the 70–84 range and one diagnosed with developmental delay (developmental quotient<70). These patients highlight the need for close developmental follow-up, regardless of level of care while in the hospital.

A group of children that may be at particular risk for developing later sequelae affecting their educational achievement are those children who are initially scoring with a developmental quotient in the 70–84 range since their learning problems may not be as apparent and their functional deficits may not prompt screening. Children whose developmental quotients are<70 frequently have their educational needs identified early and are found eligible for special education services to meet their particular needs.

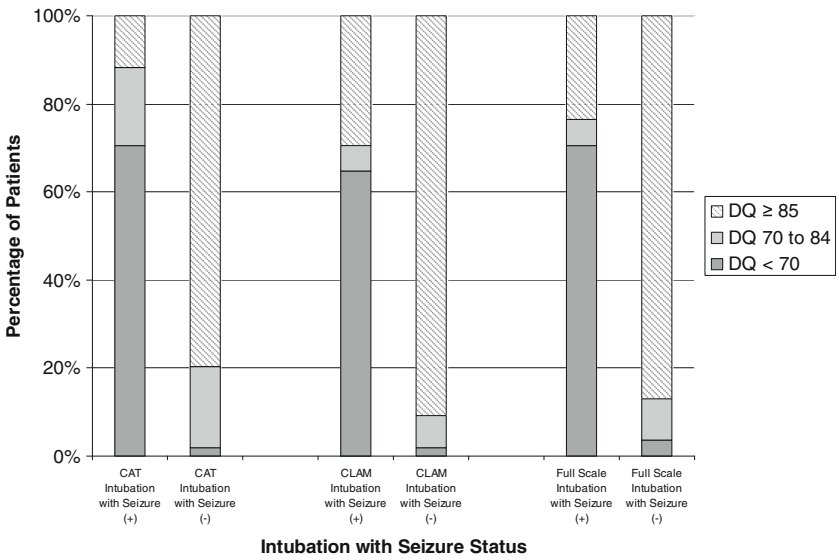

Fig. 4 CAT/CLAMS outcomes with respect to intubation with seizure status

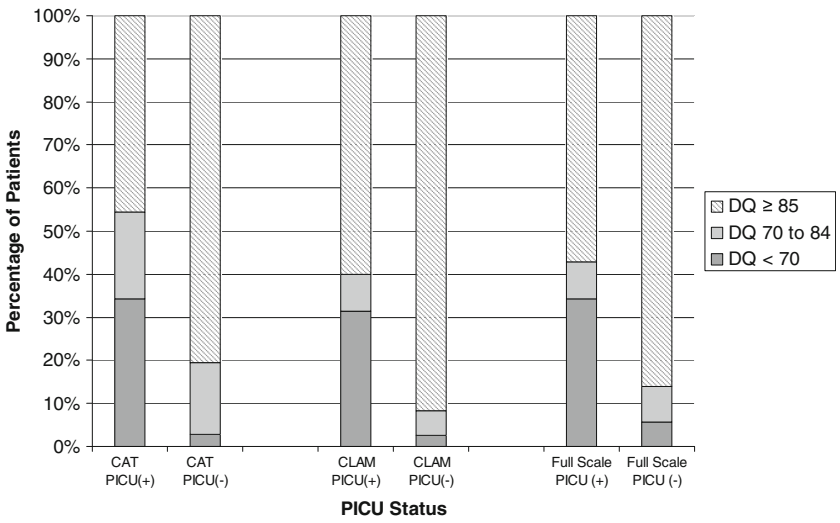

Fig. 5 CAT/CLAMS outcomes with respect to PICU status

Since the children whose developmental quotients are in the 70–84 range are often not identified early, they may be at risk for having special needs overlooked. Systemized developmental testing in this population would identify this group of patients and uncover any needs potentially before they enter school.

Another interesting finding in this study is that in the children who had only one area of developmental delay as demonstrated by the CAT or CLAMS, it was much more likely to be a cognitive–adaptive delay (visual motor). Visual–motor diagnoses can have a profound impact on the child's ability to achieve academically and can often be missed [32]. This demonstrates the importance of close developmental follow-up.

Historically, the young age of the AHT victims was believed to offer the potential for improved outcome due to potential for brain remodeling; however, more recent studies have actually demonstrated worse outcome for younger age patients [37, 38]. This study demonstrated that when injury occurred at a younger age, full-scale developmental outcomes were significantly lower. An exception to this was when the child required intubation. Younger children who required intubation showed better outcomes than older children requiring intubation. It is unclear why this effect was observed, but it should be considered for future research.

There are several limitations to this study. The sample size was adequate to find significance in the outcomes but should be expanded in further research. Because clinic is voluntary for families, there could be some question as to whether patients who follow up in Post-Injury Clinic represent the general abusive head trauma population and therefore whether results are fully generalizable. Finally, it is unknown which children would have had developmental disabilities from another etiology, irrespective of the head injury.

Conclusion

Determining prognosis for children with AHT is very difficult due to the multiple factors contributing to outcome. The presence of seizures, need for intubation, and admission to the PICU are easily determined characteristics. In our

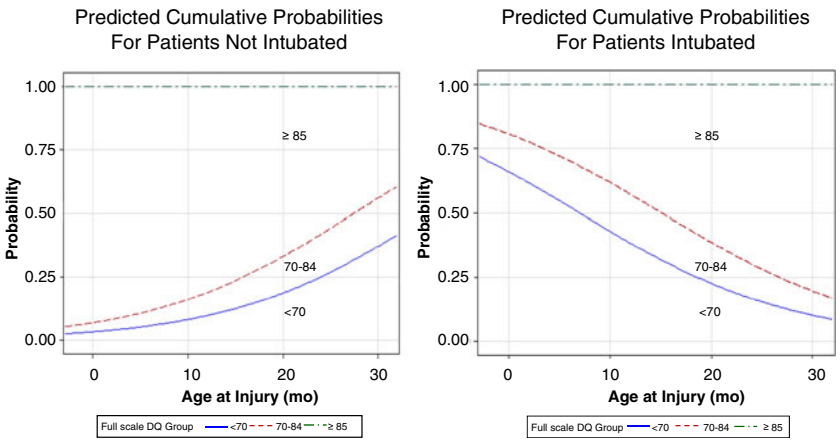

Fig. 6 Predicted cumulative probabilities for full-scale developmental quotient by age of injury

patient sample, presence of seizures and intubation requirement during admission hospitalization showed a statistically significant relationship with low scores on follow-up CAT and CLAMS testing. While not being appropriate for treatment decisions, these findings are useful in discussing expected prognosis with family, primary physicians, and courts. Furthermore, these findings indicate that close developmental follow-up should be obtained for all children with AHT, regardless of whether or not the child was admitted to the PICU.

The current literature lacks prospective data correlating early clinical features of AHT and developmental outcome. This topic should be investigated in a prospective fashion. While a simple clinical tool is valuable, the role of neuroimaging in prognostication figures to be more prominent as imaging techniques advance in the future. Future studies should include neuroradiology to correlate with clinical features and developmental testing.

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