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Abusive Head Trauma

A Bibliography

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Scope

This bibliography lists publications covering a variety of topics related to abusive head trauma/shaken baby syndrome including medical evaluation, diagnosis, prevention, economic impact, & investigation.

Organization

Publications include articles, book chapters, reports, and research briefs and are arranged in date descending order. Links are provided to full text publications when possible. However, this collection may not be complete. More information can be obtained in CALiO™, the Child Abuse Library Online.

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Abusive Head Trauma

A Bibliography

Concato, M., Mihic, A. G., Petrovic, T., Alempijevic, D. M., Radaelli, D., & D'Errico, S. (2026). Guidance for a clinical and forensic diagnosis of pediatric abusive head trauma: A narrative review. *Frontiers in Pediatrics*, *14*, 1706089. DOI:10.3389/fped.2026.1706089

The term Shaken Baby Syndrome, now largely replaced by the more general term abusive head trauma (AHT), poses significant challenges for forensic assessment and investigation. The clinical assessment of these cases remains a complex process that necessarily involves collecting a complete medical history, taking into account the caregivers and the child's socio-economic and family context, a thorough physical examination, and additional diagnostic investigations. In cases where the child has died, the autopsy—whether performed for investigative or purely diagnostic purposes—remains an essential step requiring a rigorous methodological approach, technical expertise, and in-depth knowledge of the subject. Guided by previously conducted instrumental examinations, the autopsy includes a fundamental macroscopic evaluation followed by the essential histological assessment of the injuries. Given the importance of the topic, and the implications of an erroneous conclusion for both the young patient and their family, this work aims to compile methodological updates from the last ten years, in order to promote greater uniformity in the medico-legal practice.

Smith-Dewey, R., Bachim, A., Bressler, C., Campbell, K., Frasier, L., Greeley, C., Horton, D., Johnson, N., Leonard, J., Letson, M. M., McNamara, C., Sherman, A., Nienow, S., Sommers, S., Wood, J. N., & Anderst, J. (2026). AHT diagnoses: The influences of clinical presentation and evidence of impact. *Child Abuse & Neglect*, *174*, 107978. DOI:10.1016/j.chiabu.2026.107978

The frequency of abusive head trauma (AHT) diagnoses by child abuse pediatricians (CAPs), especially regarding external evidence of head impact, has been questioned. We

aimed to describe subjects with SDH and concomitant suspicious injuries (CSI) without evidence of head impact as well as compare CAP diagnoses in subjects with subdural hemorrhage (SDH) across clinical presentations, including subgroups with and without external evidence of head impact Subjects were from a multicenter retrospective study including subjects <24 months old with SDH divided into groups based on clinical presentations: Ill SDH only, Non-ill SDH only, and SDH + CSI. Groups were subcategorized based on presence/absence of external evidence of head impact. AHT diagnoses were compared across groups. Of the 492 study subjects, 386 (78%) were diagnosed with abuse. Of the 266 subjects without evidence of head impact, 206 (77%) were diagnosed with abuse. In both the total group and the subgroup without evidence of head impact, SDH + CSI subjects were significantly more likely to be diagnosed with abuse than Ill-SDH only and Non-ill SDH only subjects, with odds ratios ranging from 2.6 (95% CI 1.2–5.6) to 10.4 (95% CI 5.0–21.8). Of the 147 SDH + CSI subjects without evidence of head impact, 33% had severe non-retinal injury, such as high specificity and/or multiple fractures or abdominal injury. In young children with SDH, many of whom are ill and/or have other concerning injuries, CAPs often do not diagnose abuse. Lack of evidence of head impact does not eliminate trauma as a cause of SDH.

Vollmer-Sandholm, M. J., Myhre, A. K., Myhre, M., Albæk, A. U., & Stray-Pedersen, A. (2026). Characteristics of pediatric cases presenting for concerns of abusive head trauma in Norway. *Child Protection and Practice*, *9*, 100296. DOI:10.1016/j.chipro.2026.100296

Abusive head trauma (AHT) is a frequent cause of severe and fatal head injury in young children. There are few published studies on AHT from Scandinavia. A mixed-methods retrospective chart review was conducted of children aged <4 years admitted with head injury and reported to the police for suspected AHT between 2003–2019 to describe the characteristics of AHT in Norway and examine whether documented prior concerns could have enabled earlier identification and prevention. Based on medicolegal investigation,

cases were classified as deemed inflicted or indeterminate. Case files included medical records and police investigation reports, focusing on demographics, medical and social history, and circumstances around the time of presentation to care. Of 77 children (median age 4 months; 64% male), 55 were deemed inflicted and 22 indeterminate. Inflicted cases had typically more severe injuries and poorer outcomes, with low GCS on admission and 15% mortality. In 78% of all cases no history of trauma was initially offered and in 65% there was delay before seeking care. At least one prior concern related to illness, injuries or parental coping was documented before the head injury in 55% of cases, more often in inflicted (62%) than indeterminate AHT (36%; P = 0.04). In 32% of cases there appeared to have been opportunities to intervene prior to the injury. Most AHT cases present without a reported trauma history and with delay in seeking care. Prior concerns about the child's well-being are common, indicating potential for prevention.

Adachi, K., Srivatsa, A., Raymundo, A., Bhargava, D., & Mehta, A. I. (2025). Risk factors for abusive head trauma in the pediatric population. *Journal of Neurosurgery: Pediatrics*, *35*(2), 111-117. DOI:10.3171/2024.8.PEDS24205

Abusive head trauma (AHT) is the leading cause of death from physical child abuse in children younger than 5 years of age in the United States. The mortality rate among patients with AHT is 25%, and the recurrence rate of child abuse rises to 35% when there is a lack of intervention. Thus, identifying child abuse is crucial yet especially challenging for infants and toddlers as they are preverbal. Current guidelines for child abuse do not sufficiently address the specific needs of a younger population. This study aimed to evaluate clinical factors associated with abuse among such populations. The National Trauma Data Bank was queried from 2017 to 2019 for patients younger than 3 years with acute head trauma. Patients who were suspected of having experienced child abuse (suspected child abuse [SCA] group) were propensity score matched with patients who were not suspected of having experienced child abuse (non-SCA group) based on demographics, comorbidities, and Glasgow Coma Scale (GCS) scores. Paired Student t-

test and chi-square tests were used to compare differences in hospital outcomes between the two groups. Multivariable regression analysis was used to determine factors associated with SCA ($p < 0.05$). The authors identified 10,844 patients in the SCA group and 27,912 in the non-SCA group. Regression analysis results showed that patients in the SCA group had higher rates of prematurity (OR 2.30, $p < 0.001$), GCS scores < 13 (OR 1.79, $p < 0.001$), congenital disorders (OR 1.56, $p < 0.001$), and public insurance use (68.38% vs 52.88% $p < 0.001$). Black and Hispanic patients were more likely to be in the SCA group (OR 1.56, $p < 0.001$ and OR 1.35, $p < 0.001$, respectively). Following propensity score matching, SCA patients had a longer length of hospital stay (3.17 vs 1.34 days, $p < 0.001$) and higher mortality rate (4.89% vs 3.58%, $p < 0.001$). Acute head injuries in the SCA group were associated with prematurity, congenital disorder, low GCS score, and public insurance use. As such, the current guidelines should implement clinical history and insurance type to better reflect the at-risk patient population when evaluating infants and toddlers for potential abuse. There could be overidentification of child abuse among Black and Hispanic patients, and further research is warranted.

Berthold, O., Blangis, F., & Greeley, C. S. (2025). From pachymeningitis hemorrhagica to abusive head trauma: A journey through the centuries. *Child Maltreatment, 30*(4), 751-759. DOI:10.1177/10775595251361930

The development of medical knowledge follows specific principles. These also apply to abusive head trauma. The seminal literature from the early 20th century is based on earlier research from Europe, which is fundamental to understand the evolution of understanding and nomenclature of abusive head trauma. A review of original medical literature on intracranial injuries in children, published in German, English, and French, was conducted using PubMed and Google Scholar for articles before 1950. The primary search focused on subdural hemorrhages and pachymeningitis in children, followed by a snowball search of references. Full texts of available manuscripts were reviewed. Primary literature as early as 1839 was reviewed by native language speakers, referring to

intracranial collections of blood that underwent an evolution in nomenclature and understanding of causation. Initially termed *pachymeningitis hemorrhagica*, implying an inflammatory cause, the nomenclature evolved to subdural hematoma, as traumatic causes aligned with clinical experience. Advances in diagnostic imaging further enhanced understanding and nomenclature. The clinical findings associated with abusive head trauma have been described for centuries, with consistent signs and symptoms until the present day. As the understanding of the disease evolved due to modern diagnostic techniques, changes in nomenclature became necessary.

Lynøe, N., & Eriksson, A. (2025). Policy critique: The conflation of shaken baby syndrome and abusive head trauma–a measure with several negative effects. *Forensic Science International: Synergy*, *10*, 100585. DOI:10.1016/j.fsisyn.2025.100585

The amalgamizing of shaken baby syndrome (SBS) with the much broader and heterogeneous abusive head trauma (AHT) diagnosis is problematized. We suggest that the reason why American Academy of Pediatrics (AAP) took this step in 2009 was a response to another theory being presented and discussed from 2001 and onwards. This theory had completely different legal consequences as it suggested that the medical findings on which the SBS diagnosis were based, i.e. "the triad" (subdural hemorrhages/SDH, retinal hemorrhages/RH, and encephalopathy) were non-traumatic. If such an explanation was accepted, this would reveal not only that serious legal abuses had occurred in the past and that the pediatricians should be held responsible for this, but also that it would in the future be more difficult to protect the child by claiming abuse in cases of unclear diagnosis. We present also other steps, taken by other pediatric organizations, having similar effects upon the current SBS controversy. We suggest that these value-based considerations were the underlying reasons why SBS was integrated in the AHT concept, and why competing theories and evidence-based criticism is ignored, allowing to always interpret triad findings as the result of abuse. If the ethical principle to protect the child is more important to AAP than the scientific ambition to develop

evidence-based diagnostic procedures, we encourage AAP to be honest and admit this prioritization. Or at least to admit that in this ethical dilemma, AAP finds that the least bad choice is *First of all, protect the child!* despite the price is that many infants and its siblings may be separated on wrong grounds from their family, and that caregivers might be falsely accused and convicted of child abuse.

Narang, S. K., Haney, S., Duhaime, A. C., Martin, J., Binenbaum, G., de Alba Campomanes, A. G., Barth, R., Bertocci, G., Care, M., McGuone, D., Council on Child Abuse & Neglect, Section on Ophthalmology, Section on Radiology, Section on Neurological Surgery, Society for Pediatric Radiology, American Association of Certified Orthoptists, American Association for Pediatric Ophthalmology & Strabismus, & American Academy of Ophthalmology. (2025). Abusive head trauma in infants and children: Technical report. *Pediatrics*, *155*(3), e2024070457. DOI:10.1542/peds.2024-070457

Abusive head trauma (AHT) in infants and children is a complex and challenging clinical diagnosis. Because of its clinical, social, and legal implications, few pediatric diagnoses evoke as much cognitive difficulty and emotional distress as AHT. Over the past several decades, considerable literature has been published on various aspects of the AHT diagnosis including epidemiology, historical features, clinical findings, biomechanics, differential diagnoses, outcomes, and prevention. To date, the American Academy of Pediatrics (AAP) has not promulgated, in the form of a technical report, a comprehensive review of the evidence-based literature surrounding AHT. Although the AAP has addressed the subject matter in other treatises, a scientific review in the form of a technical report offers the benefit of openly available, readily accessible, and more frequently updatable scientific information. Each area of this technical report, authors or groups of authors performed a wide review of peer-reviewed publications within each subtopic (generally limited to articles published in English), emphasizing those sources with the highest quality of evidence but not eliminating sources for which descriptive methods nonetheless provide useful and relevant information. The overall manuscript was reviewed several times by multiple participants with source documents reviewed for

content when appropriate. References are provided for statements and conclusions so that the reader can access the sources directly.

Shouldice, M., Ward, M. G., Nolan, K., & Cory, E. (2025). Medical assessment of suspected traumatic head injury due to child maltreatment (THI-CM). *Paediatrics & Child Health*, *30*(3), 184-188. DOI:10.1093/pch/pxae073

Traumatic head injury due to child maltreatment (THI-CM) is a serious form of child abuse with significant morbidity and mortality, particularly in infants and young children. Healthcare providers have important roles to play, including identifying and treating these children, reporting concerns of child maltreatment to child welfare authorities, assessing for associated injuries and medical conditions, supporting children and their families, and communicating medical information clearly to families and other medical, child welfare, and legal professionals. Symptoms associated with head trauma often overlap with those of other common childhood illnesses, and external signs of injury may be subtle or absent. As a result, THI-CM is frequently overlooked and its identification is often delayed, leading to a risk of ongoing injury. Assessing for head trauma in cases of possible child maltreatment includes considering medical causes for clinical findings and assessment for occult injuries. This practice point provides health care providers with guidance for identifying and medically assessing suspected THI-CM in infants and children.

Thiblin, I., Wingren, C. J., Emad, J. A., & Tamsen, F. (2025). Pathophysiological hypotheses of the triad in abusive infant shaking: A systematic review and analysis of corroborated cases. *Forensic Science International: Synergy*, *11*, 100618. DOI:10.1016/j.fsisyn.2025.100618

Subdural hemorrhage, retinal hemorrhages, and encephalopathy are associated with the medical diagnosis of abusive head trauma. These findings have also been observed in children exposed to admitted or witnessed shaking. There are various suggested

mechanisms behind these findings. One mechanism is exclusive to intentional shaking, while the other suggested mechanisms are compatible with both intentional and accidental violence as well as an underlying illness. We performed a systematic literature review of case reports on triad findings with subsequent analysis on the empirical consequences of three mechanistic hypotheses: (1) the outcome components arise independently following acceleration-deceleration forces during shaking; (2) the outcome components are partially dependent and caused by pathophysiological mediators following hypoxia caused by damage to the brainstem or cervical spinal cord by shaking; (3) the outcome factors are partially dependent and are caused by re-bleeding triggered by shaking in chronic subdural hematoma. From a total of 9628 articles, we identified twelve publications including in total 100 cases that met the inclusion criteria. We identified no sufficiently detailed case report, but nine cases had information that allowed for tentative testing of the hypotheses. Three cases had findings consistent with that triad findings are partially dependent and related to chronic subdural re-bleeding (hypothesis 3), whereas no case provided support for the other hypotheses. Thus, published cases do not provide the information needed to understand the mechanism underlying triad findings in infants subjected to shaking.

Tibballs, J., & Bhatia, N. (2025). Shaken baby syndrome/abusive head injury: The role of expert witness testimony and a recent case development. *Journal of Bioethical Inquiry*, *22*(3), 483-491. DOI:10.1007/s11673-025-10422-x

The triad of clinical signs, (extensive bilateral retinal haemorrhages, subdural haematoma, and encephalopathy) is regarded by some expert witnesses as pathognomonic proof that an infant was deliberately shaken and head injured (shaken baby syndrome / abusive head injury). However, that view is controversial since scientific evidence does not support the diagnostic accuracy of the triad. In contrast to previous cases, a Victorian Supreme Court jury found an accused not guilty of homicide of a one-month-old infant afflicted with the triad. Prosecution witnesses were heavily criticized for

failing to provide impartial testimony and to abide by Supreme Court expert evidence rules. We argue that there is a need to reassess the manner in which expert witness testimony is considered by the courts in shaken baby cases where injury has caused the death of the infant.

Berthold, O., Fegert, J. M., Brähler, E., Jud, A., & Clemens, V. (2024). Abusive head trauma: The body of the iceberg–A population-based survey on prevalence and perpetrators. *Child Abuse & Neglect*, *149*, 106660. DOI:10.1016/j.chiabu.2024.106660

Research on abusive head trauma (AHT) is usually research on clinically identified cases, while population-based studies, having the potential to identify cases of shaking that did not end with hospital admission, are missing to date. Thus, we aimed to assess the prevalence of AHT and associated risk factors in a representative sample of the German population. We conducted a cross-sectional, observational study in Germany from July to October 2021. Using different sampling steps including a random route procedure, a probability sample of the German population was generated. The final sample consisted of 2503 persons (50.2 % female, mean age: 49.5 years). Participants were asked about sociodemographic information in a face-to-face interview and whether they had been ever responsible for the care of an infant and whether they had ever performed potential harmful methods including shaking to calm it, intimate partner violence (IPV) and adverse childhood experiences (ACEs) using a questionnaire. In total, 1.4 % of women (*N* = 18) and 1.1 % of men (*N* = 13) reported to have at least once shaken an infant to calm it. Ever having used a potential harmful parenting method in calming an infant was reported by 4.9 % of women (*N* = 61) and 3.1 % (*N* = 39) of men. No gender differences were seen. A low income, living with someone under 16 in the household and victimization and perpetration of IPV and ACEs are associated with increased risks of shaking and other potential harmful methods to calm an infant. Our data suggest that despite better knowledge on the dangers of shaking, the percentage of women that shake infants might be higher than previously thought. Also, intimate partner violence

and ACEs are key risk factor for shaking and harmful parenting behaviors in general. This has important implications for future prevention programs.

Brook, C. (2024). Witnessing abusive head trauma: Accidents show higher rates of intracranial pathologies than shaking. *Annals of the Child Neurology Society, 2*(3), 206-211. DOI:10.1002/cns3.20084

This study aims to determine whether intracranial injuries, such as seizures, encephalopathy, bilateral subdural hematoma (SDH), and severe bilateral retinal hemorrhage (RH), are indicators of abusive head trauma (AHT), particularly in cases involving shaking. Data comprising 54 witnessed shaking cases were drawn from two studies in the literature. Data of 100 witnessed accidents comes from the pediBIRN collaboration. Rates of intracranial injuries in cases of unconflicted witnessed accidents are compared to rates in cases of witnessed shaking and also to cases of unconflicted witnessed shaking. Unconflicted is defined as observed by an independent, unbiased witness, or by a potentially biased witness (such as partner) if reported prior to medical examinations. When all witnessed shaking cases were considered, including potentially biased witnesses, there are higher rates of findings commonly associated with AHT in witnessed accidents than in cases of witnessed shaking, although the difference is only statistically significant for seizures and encephalopathy. When restricted to cases when the witness was unconflicted, the rates of all findings are significantly more common in accidents than in shaking. Accidents result in more severe intracranial pathologies than shaking, aligning with biomechanical studies that have shown that impact exerts greater force on the brain than violent shaking.

Chang, H.-Y., Chang, Y.-C., Chang, Y.-T., Chen, Y.-W., Wu, P.-Y., & Feng, J.-Y. (2024). The effectiveness of parenting programs in preventing abusive head trauma: A systematic review and meta-analysis. *Trauma, Violence, & Abuse*, *25*(1), 354-368. DOI:10.1177/1524838023115169

Parenting programs are the most common intervention for preventing the lethal form of child maltreatment, abusive head trauma (AHT). However, certain results of the effects of these programs have not yet been compared across studies. A systematic review with meta-analysis is warranted to quantitively synthesize the available evidence to identify effective elements and strategies of the programs for preventing AHT. This review aims to estimate AHT preventive parenting programs' pooled effect on the reduction of AHT incidence, the improvement of parental knowledge, and the increased use of safe strategies in response to infants' inconsolable crying. Studies published in English and Mandarin were searched and retained if they were randomized control trials (RCTs) or with a quasi-experimental design, included an AHT preventive parenting program, and provided data that quantified targeted outcomes. Eighteen studies were included in this review. AHT preventive parenting programs had a pooled effect on improving parents' knowledge and increasing the use of safe coping strategies in response to inconsolable crying but not on the incidence of AHT and parents' emotional self-regulation. Subgroup analyses showed that the intervention effects were mostly present across study designs or measurements and emerged in the reduction of AHT incidence compared with historical controls. The findings suggest that AHT preventive parenting programs enhance parenting knowledge and skills to provide safe care for infants. Further efforts to evaluate AHT parenting programs on the reduction of AHT incidence are necessary for decision-making on allocating and disseminating interventions.

Sokoloff, M., Feldman, K. W., Levin, A. V., Rockter, A., Armijo-Garcia, V., Musick, M., Weeks, K., Haney, S. B., Marinello, M., Herman, B. E., Frazier, T. N., Carroll, C. L., Hymel, K. P., & Pediatric Brain Injury Research Network (PediBIRN) Investigators. (2024). Retinal hemorrhage variation in inertial versus contact head injuries. *Child Abuse & Neglect*, *149*, 106606. DOI:10.1016/j.chiabu.2023.106606

Abusive head trauma (AHT) is frequently accompanied by dense/extensive retinal hemorrhages to the periphery with or without retinoschisis (complex retinal hemorrhages, cRH). cRH are uncommon without AHT or major trauma. The study objectives were to determine whether cRH are associated with inertial vs. contact mechanisms and are primary vs. secondary injuries. This retrospective study utilized a de-identified PediBIRN database of 701 children <3-years-old presenting to intensive care for head trauma. Children with motor vehicle related trauma and preexisting brain abnormalities were excluded. All had imaging showing head injury and a dedicated ophthalmology examination. Contact injuries included craniofacial soft tissue injuries, skull fractures and epidural hematoma. Inertial injuries included acute impairment or loss of consciousness and/or bilateral and/or interhemispheric subdural hemorrhage. Abuse was defined in two ways, by 1) predetermined criteria and 2) caretaking physicians/multidisciplinary team's diagnostic consensus. PediBIRN subjects with cRH frequently experienced inertial injury (99.4 % (308/310, OR = 53.74 (16.91–170.77)) but infrequently isolated contact trauma (0.6 % (2/310), OR = 0.02 (0.0004–0.06)). Inertial injuries predominated over contact trauma among children with cRH sorted AHT by predetermined criteria (99.1 % (237/239), OR = 20.20 (6.09—67.01) vs 0.5 % (2/339), OR = 0.04 (0.01–0.17)). Fifty-nine percent of patients with cRH, <24 h altered consciousness, and inertial injuries lacked imaging evidence of brain hypoxia, ischemia, or swelling. cRH are significantly associated with inertial angular acceleration forces. They can occur without brain hypoxia, ischemia or swelling suggesting they are not secondary injuries.

Squier, W. (2024). Retinodural haemorrhage of infancy, abusive head trauma, shaken baby syndrome: The continuing quest for evidence. *Developmental Medicine & Child Neurology*, *66*(3), 290-297. DOI:10.1111/dmcn.15676

The shaken baby syndrome was originally proposed in the 1970s without any formal scientific basis. Once data generated by scientific research was available, the hypothesis became controversial. There developed essentially two sides in the debate. One side claimed that the clinical triad of subdural haemorrhage, retinal haemorrhage, and encephalopathy, or its components, is evidence that an infant has been shaken. The other side stated this is not a scientifically valid proposal and that alternative causes, such as low falls and natural diseases, should be considered. The controversy continues, but the contours have shifted. During the last 15 years, research has shown that the triad is not sufficient to infer shaking or abuse and the shaking hypothesis does not meet the standards of evidence-based medicine. This raises the issue of whether it is fit for either clinical practice or for the courtroom; evidence presented to the courts must be unassailable.

Watson, A. E., Oliver, C., Wilson, R. F., & Self-Brown, S. (2024). Abusive head trauma in child maltreatment-related homicide cases in the United States: An analysis of the National Violent Death Reporting System data-2012–2017. *Journal of Family Violence, 39*(2), 339-346. DOI:10.1007/s10896-022-00489-0

In the U.S., there are approximately 1,300 abusive head trauma (AHT) cases reported annually, with 25% of them fatal. This is a descriptive study of child maltreatment (CM)-related homicides resulting from AHT. Data from the National Violent Death Reporting System (NVDRS) for 2012–2017 were used to describe child homicide cases resulting from AHT of children aged 0–17 years. During 2012–2017, among the 1,957 deaths from CM-related homicides, 230 resulted from AHT. More than half of the victims of AHT were male children, and greater than half of the AHT-related deaths were perpetrated by males, with fathers as the perpetrator in 43% of the cases. In addition, more than one-third of AHT victims (44%), as well as perpetrators (36%), were White, non-Hispanic. Almost half of AHT

victims had a previous history of abuse, 37% had a nonfatal injury prior to their death, and 22% of their deaths were precipitated by child's crying behavior. This paper describes the prevalence of AHT deaths from 2012 to 2017 data, along with multiple risk factors that are associated with victim death AHT and perpetration of this type of maltreatment. These findings can inform targeted prevention strategies for the most extreme forms of AHT, those that result in child death.

Cercone, D. J., Berger, R. P., Manole, M. D., Soung, J. K., Coombs, C. M., & Noorbakhsh, K. A. (2023). Increased severity of abusive head trauma during the first year of the COVID-19 pandemic. *Child Abuse & Neglect*, *135*, 105971. DOI:10.1016/j.chiabu.2022.105971

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. 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 in order 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. 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. 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. 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.

Lynoe, N., & Eriksson, A. (2023). An overview of the scientific controversy regarding the diagnostic accuracy of Shaken Baby Syndrome. *Medicine & Law*, *42*, 763-780.

The process used to diagnose Shaken Baby Syndrome (SBS), a subgroup of Abusive Head Trauma (AHT) without signs of relevant trauma, is not reliable and remains uncertain. There is insufficient scientific evidence for any doctor or medical expert to conclude that if a child has three medical findings, the "triad", then the infant *must* have been shaken or abused. All studies showing a 'strong' association between the triad and the diagnostic accuracy of the SBS diagnosis rely on circular reasoning., There is *insufficient* scientific evidence that the *isolated* triad can predict traumatic shaking, as there is a high risk of bias. There is an ongoing scientific controversy within the area. The aim of the present article is to facilitate a better understanding of this scientific controversy for those who are not themselves medical scientists -, such as lawyers, prosecutors, and judges. The legal and medical consequences of the current scientific controversy is that an incorrect diagnosis may delay the correct diagnosis, harm the infant and its family, and jeopardize rule of law.

Schiks, L. A. H., Dankelman, J., & Loeve, A. J. (2023). Inflicted head-injury by shaking-trauma in infants: The importance of spatiotemporal variations of the head's rotation center. *Scientific Reports*, *13*(1), 15226. DOI:10.1038/s41598-023-42373-x

Inflicted head injury by shaking trauma (IHI-ST) in infants is a type of abusive head trauma often simulated computationally to investigate causalities between violent shaking and injury. This is commonly done with the head's rotation center kept fixed over time. However, due to the flexibility of the infant's neck and the external shaking motion imposed by the perpetrator it is unlikely that the rotation center is static. Using a test-

dummy, shaken by volunteers, we demonstrated experimentally that the location of the head's rotation center moves considerably over time. We further showed that implementation of a spatiotemporal-varying rotation center in an improved kinematic model resulted in strongly improved replication of shaking compared to existing methods. Hence, we stress that the validity of current infant shaking injury risk assessments and the injury thresholds on which these assessments are based, both often used in court cases, should be re-evaluated.

Boos, S. C., Wang, M., Karst, W. A., Hymel, K. P., & Pediatric Brain Injury Research Network (PediBIRN) Investigators. (2022). Traumatic head injury and the diagnosis of abuse: A cluster analysis. *Pediatrics*, *149*(1), e2021051742. DOI:10.1542/peds.2021-051742

Data guiding abusive head trauma (AHT) diagnosis rest on case-control studies that have been criticized for circularity. We wished to sort children with neurologic injury using mathematical algorithms, without reference to physicians' diagnoses or predetermined diagnostic criteria, and to compare the results to existing AHT data, physicians' diagnoses, and a proposed triad of findings. Unsupervised cluster analysis of an existing data set regarding 500 young patients with acute head injury hospitalized for intensive care. Three cluster algorithms were used to sort (partition) patients into subpopulations (clusters) on the basis of 32 reliable ($\kappa > 0.6$) clinical and radiologic variables. *P* values and odds ratios (ORs) identified variables most predictive of partitioning. The full cohort partitioned into 2 clusters. Variables substantially ($P < .001$ and OR > 10 in all 3 cluster algorithms) more prevalent in cluster 1 were imaging indications of brain hypoxemia, ischemia, and/or swelling; acute encephalopathy, particularly when lasting >24 hours; respiratory compromise; subdural hemorrhage or fluid collection; and ophthalmologist-confirmed retinoschisis. Variables substantially ($P < .001$ and OR < 0.10 in any cluster algorithm) more prevalent in cluster 2 were linear parietal skull fracture and epidural hematoma. Postpartitioning analysis revealed that cluster 1 had a high prevalence of

physician-diagnosed abuse. Three cluster algorithms partitioned the population into 2 clusters without reference to predetermined diagnostic criteria or clinical opinion about the nature of AHT. Clinical difference between clusters replicated differences previously described in comparisons of AHT with non-AHT. Algorithmic partition was predictive of physician diagnosis and of the triad of findings heavily discussed in AHT literature.

Feldman, K. W., Melville, J. D., Johnson, K. L., Valvano, T. J., Piper, A. C., Lakin, K. L., & Petrak, C. S. (2022). Abusive head trauma follows witnessed infant shaking. *Child Abuse Review, 31*(3), e2739. DOI:10.1002/car.2739

Abuse is a frequent cause of infant subdural haemorrhages, retinal haemorrhages and neurological dysfunction. Confessed shaking, without impact, is one reported injury cause. However, this remains legally controversial. We evaluated whether witnessed shaking alone can cause typical abusive head trauma (AHT). Cases were collected by Helfer Society list-serve solicitation for infants who developed signs and symptoms of AHT after independently witnessed shaking. We also reviewed a cross-sectional observational, multi-centre study (Examining Siblings to Recognize Abuse (ExSTRA)) of 2890 children evaluated for abuse between January 2010 and April 2011 who experienced independently witnessed shaking. Four children identified by the Helfer Society experienced witnessed shaking and developed clinical and radiological evidence of AHT, including subdural and retinal haemorrhages. Another two had neurological symptoms, but normal imaging. Nineteen (0.7%) ExSTRA subjects experienced witnessed shaking without impact injuries. Among them, one (5.9%) of the 17 subjects who were neuroimaged had AHT findings and additional abusive injuries. Three had neurologic symptoms but normal neuroimaging. Although shaking is rarely witnessed, these cases support that shaking alone can cause typical AHT injuries, including, but not limited to, acute neurological impairment, subdural haemorrhages and retinal haemorrhages. This information is important to the legal management of abused children.

Karmazyn, B., Reher, T. A., Supakul, N., Streicher, D. A., Kiros, N., Diggins, N., Dennings, S. G., Exkert, G. J., Hibbard, R. A., & Radhakrishnan, R. (2022). Whole-spine MRI in children with suspected abusive head trauma. *American Journal of Roentgenology, 218*(6), 1074-1087. DOI:10.2214/AJR.21.26674

Abusive head trauma (AHT) in children has recently been associated with findings on cervical spine MRI. The purpose of this study was to evaluate whether whole-spine MRI in children with suspected AHT shows additional abnormalities not identified on cervical spine MRI. This retrospective study included 256 children younger than 3 years old (170 boys, 86 girls; mean age, 5.9 months) who underwent skeletal survey and head MRI for suspected child abuse from January 2019 to December 2020. Per institutional protocol, children with suspected AHT also underwent whole-spine MRI. AHT diagnoses were established by a combination of clinical information from medical record review and injuries described in reports from skeletal survey, head MRI, and head CT (if performed). Two pediatric neuroradiologists independently reviewed whole-spine MRI examinations for presence and level of intraspinal hemorrhage (classified as subarachnoid, subdural, or epidural), ligamentous injury, spinal cord edema, and vertebral fractures; subdural hematoma, epidural hematoma, ligamentous injury, and fracture unidentified by skeletal survey were considered major findings. Interobserver agreement was assessed; a third radiologist resolved discrepancies. Findings were summarized with attention to injuries isolated to the thoracolumbar spine. A total of 148 of 256 (57.8%) children underwent whole-spine MRI. AHT was diagnosed in 79 of 148 (53.4%) children who underwent whole-spine MRI versus in 2 of 108 (1.9%) who did not undergo whole-spine MRI ($p < .001$). Interobserver agreement, expressed as kappa coefficient, was 0.90 for intraspinal hemorrhage, 0.69 for ligamentous injury, 0.66 for spinal cord edema, and 0.95 for fracture. A total of 57 of 148 (38.5%) whole-spine MRI examinations showed injuries, and 34 of 148 (23.0%) showed injuries localized to the thoracolumbar spine. A total of 47 of 148 (31.8%) whole-spine MRI examinations showed major findings, of which 24 (51.1%) were localized to the thoracolumbar spine. Isolated thoracolumbar injuries included 23 of 34 spinal subdural hematomas, 2 of 3 spinal epidural hematomas, and 9 of 11 vertebral fractures,

including five fractures not identified by skeletal survey. Diagnosis of AHT was more common in children with positive, versus negative, whole-spine MRI examinations (76.8% vs 39.1%; $p < .001$). In children with suspected AHT, whole-spine MRI commonly shows isolated thoracolumbar injuries.

Song, H. H., Thoreson, W. B., Dong, P., Shokrollahi, Y., Gu, L., & Suh, D. W. (2022). Exploring the vitreoretinal interface: A key instigator of unique retinal hemorrhage patterns in pediatric head trauma. *Korean journal of Ophthalmology, 36*(3), 253–263. DOI:10.3341/kjo.2021.0133

Various types of trauma can cause retinal hemorrhages in children, including accidental and nonaccidental head trauma. We used animal eyes and a finite element model of the eye to examine stress patterns produced during purely linear and angular accelerations, along with stresses attained during simulated repetitive shaking of an infant. Using sheep and primate eyes, sclerotomy windows were created by removing the sclera, choroid, and retinal pigment epithelium to expose the retina. A nanofiber square was glued to a 5 mm^2 area of retina. The square was pulled and separated from vitreous while force was measured. A finite element model of the pediatric eye was used to computationally measure tension stresses during shaking. In both sheep and primate eyes, tension stress required for separation of retina from vitreous range from 1 to 5 kPa. Tension stress generated at the vitreoretinal interface predicted by the computer simulation ranged from 3 to 16 kPa during a cycle of shaking. Linear acceleration generated lower tension stress than angular acceleration. Angular acceleration generated maximal tension stress along the retinal vasculature. Linear acceleration produced more diffuse force distribution centered at the poster pole. The finite element model predicted that tension stress attained at the retina during forcible shaking of an eye can exceed the minimum threshold needed to produce vitreoretinal separation as measured in animal eyes. Furthermore, the results show that movements that involve significant angular acceleration produce strong stresses localized along the vasculature, whereas linear

acceleration produces weaker, more diffuse stress centered towards the posterior pole of the eye.

Cartocci, G., Fineschi, V., Padovano, M., Scopetti, M., Rossi-Espagnet, M. C., & Giannì, C. (2021). Shaken baby syndrome: Magnetic resonance imaging features in abusive head trauma. *Brain Sciences, 11*(2), 179. DOI:10.3390/brainsci11020179

In the context of child abuse spectrum, abusive head trauma (AHT) represents the leading cause of fatal head injuries in children less than 2 years of age. Immature brain is characterized by high water content, partially myelinated neurons, and prominent subarachnoid space, thus being susceptible of devastating damage as consequence of acceleration–deceleration and rotational forces developed by violent shaking mechanism. Diagnosis of AHT is not straightforward and represents a medical, forensic, and social challenge, based on a multidisciplinary approach. Beside a detailed anamnesis, neuroimaging is essential to identify signs suggestive of AHT, often in absence of external detectable lesions. Magnetic resonance imaging (MRI) represents the radiation-free modality of choice to investigate the most typical findings in AHT, such as subdural hematoma, retinal hemorrhage, and hypoxic-ischemic damage and it also allows to detect more subtle signs as parenchymal lacerations, cranio-cervical junction, and spinal injuries. This paper is intended to review the main MRI findings of AHT in the central nervous system of infants, with a specific focus on both hemorrhagic and non-hemorrhagic injuries caused by the pathological mechanisms of shaking. Furthermore, this review provides a brief overview about the most appropriate and feasible MRI protocol to help neuroradiologists identifying AHT in clinical practice.

Gjerde, H., & Mantagos, I. S. (2021). Charting the globe: How technologies have affected our understanding of retinal findings in abusive head trauma/shaken baby syndrome. *Seminars in Ophthalmology*, *36*(4), 205-209. DOI:10.1080/08820538.2021.1890150

It is sometimes difficult to isolate the cause of a medical finding, especially when the origins and pathogenesis are unknown and there is only a statistical association between empirical phenomena. In 1965, the English epidemiologist Austin Bradford Hill presented 9 criteria to indicate possible causality.1 The eighth criterion states that if a preventive program has a significant effect on a certain condition, there might be a causal relationship between the intervention and the condition it is intended to prevent.

Lynøe, N., & Eriksson, A. (2021). Why programs for managing colicky crying fail to prevent abusive head trauma and suggestions for improvement. *JAMA Pediatrics*, *175*(7), 671–672. DOI:10.1001/jamapediatrics.2021.0455

It is sometimes difficult to isolate the cause of a medical finding, especially when the origins and pathogenesis are unknown and there is only a statistical association between empirical phenomena. In 1965, the English epidemiologist Austin Bradford Hill presented 9 criteria to indicate possible causality.1 The eighth criterion states that if a preventive program has a significant effect on a certain condition, there might be a causal relationship between the intervention and the condition it is intended to prevent.

Maiese, A., Iannaccone, F., Scatena, A., Del Fante, Z., Oliva, A., Frati, P., & Fineschi, V. (2021). Pediatric abusive head trauma: A systematic review. *Diagnostics, 11*(4), 734. DOI:10.3390/diagnostics11040734

Abusive head trauma (AHT) represents a commonly misdiagnosed condition. In fact, there is no pathognomonic sign that allows the diagnosis in children. Therefore, it is such an important medico-legal challenge to evaluate reliable diagnostic tools. The aim of this review is to evaluate the current scientific evidence to assess what the best practice

is in order to diagnose AHT. We have focused particularly on evaluating the importance of circumstantial evidence, clinical history, the use of postmortem radiological examinations (such as CT and MRI), and the performance of the autopsy. After autopsy, histological examination of the eye and brain play an important role, with attention paid to correlation with symptoms found in vivo.

Narang, S. K., Sachdev, K. K., Bertocci, K., Pierre-Wright, M. J., Kaczor, K., Bertocci, G., & Pierce, M. C. (2021). Overturned abusive head trauma and shaken baby syndrome convictions in the United States: Prevalence, legal basis, and medical evidence. *Child Abuse & Neglect*, *122*, 105380. DOI:10.1016/j.chiabu.2021.105380

Media reports and the Innocence Network assert that wrongful Abusive Head Trauma (AHT)/Shaken Baby Syndrome (SBS) convictions pervade the United States (U.S.) criminal justice system. Yet, no empirical evaluation of overturned AHT/SBS convictions has been conducted. In order to evaluate the prevalence, legal basis, and characteristics of appellate rulings of AHT/SBS convictions, a retrospective review of U.S. appellate cases in a legal database, Westlaw that had appellate rulings from January 2008 through December 2018 was conducted. Multiple search terms ensured all potential AHT/SBS cases were included. A mixed-methods analysis was conducted on overturned AHT/SBS convictions. We identified a total of 1431 unique AHT/SBS criminal convictions that had appellate rulings since 2008. Of those, 49 convictions (3%) were overturned, and 1382 (97%) were affirmed/upheld. Of those overturned, 20 cases (1% overall) were overturned on medical evidence-related grounds. The most common themes from the medical evidence-related reversals were controversy over the AHT/SBS diagnosis (n = 12) and accidental injury mechanism (n = 11). After being overturned on appeal, upon retrial, 42% of defendants either re-plead guilty to or were convicted again of the same offense. AHT/SBS convictions are rarely overturned on medical evidence-related grounds. When overturned, medical evidence-related themes seldom reflect new scientific or clinical discoveries, but rather are alternative or differing medical opinions from those offered at

the original trial. Our data tends to support the concerns of other authors regarding irresponsible communication of medical information in AHT/SBS cases.

Shaffer, S., Compo, N. S., Klemfuss, J. Z., Peplak, J., & Mejias, J. (2021). Law enforcement investigation of non-sexual child abuse: Physical abuse, neglect and abusive head trauma. *The International Journal of Evidence & Proof, 25*(2), 75-92. DOI:10.1177/13657127211002284

This study examined the experiences of law enforcement in investigating physical abuse, neglect and Abusive Head Trauma (AHT). Law enforcement (N = 388) in the United States were surveyed regarding case characteristics, investigative strategy, interrogative approaches, frequency/content of perpetrator admissions and interagency interaction across cases of physical abuse, neglect and AHT. Results revealed that exposure rates matched those of national statistics. AHT perpetrators reported to admit guilt less often than suspects of physical abuse and neglect. Participants reported that suspects explain physical abuse and AHT by referencing poor self-control as a common cause. Lack of financial resources was commonly reported as the explanation for neglect. Potentially coercive interviewing techniques were reported across abuse types but were more frequent in cases of AHT. AHT cases were reportedly hardest to prove/prosecute partially due to conflicting medical diagnoses. Potential implications for law enforcement investigative (interviewing) policies and future research are discussed.

Stray-Pedersen, A., Strisland, F., Rognum, T. O., Schiks, L. A. H., & Loeve, A. J. (2021). Violent infant surrogate shaking: Continuous high-magnitude centripetal force and abrupt shift in tangential acceleration may explain high risk of subdural hemorrhage. *Neurotrauma Reports*, *2*(1), 224–231. DOI:10.1089/neur.2021.0013

Violent shaking is believed to be a common mechanism of injury in pediatric abusive head trauma. Typical intracranial injuries include subdural and retinal hemorrhages. Using a laboratory surrogate model we conducted experiments evaluating the head

motion patterns that may occur in violent shaking. An anthropomorphic test device (ATD; Q0 dummy) matching an infant of 3.5 kg was assembled. The head interior was equipped with accelerometers enabling assessment of three-axial accelerations. Fifteen volunteers were asked to shake the surrogate vigorously holding a firm grip around the torso. We observed the volunteers performing manual shaking of the surrogate at a median duration of 15.5 sec (range 5–54 sec). Typical acceleration/deceleration patterns were produced after 2–3 shakes with a steady-state shaking motion at a pace of 4–6 cycles (back and forth) per second. Mean peak sagittal tangential accelerations at the vertex were 45.7*g* (range 14.2–105.1*g*). The acceleration component in the orthogonal direction, the radial acceleration, fluctuated around a negative mean of more than 4*g* showing that the surrogate head was continuously subjected to centripetal forces caused by rotations. This surrogate experiment showed that violent shaking may induce high peak tangential accelerations and concomitantly a continuous high-magnitude centripetal force. We hypothesize that the latter component may cause increased pressure in the subdural compartment in the cranial roof and may cause constant compression of the brain and possibly increased stretching or shearing of the bridging veins. This may contribute to the mechanism accountable for subdural hematoma in abusive head trauma.

Chen, Y. W., & Feng, J. Y. (2020). Development and validation of a paediatric abusive head trauma awareness questionnaire for healthcare professionals: A two-stage questionnaire development study. *Child Abuse Review*, *29*(3), 218-230. DOI:10.1002/car.2610

This two-stage study aimed to develop and validate a paediatric abusive head trauma (AHT) awareness questionnaire for healthcare professionals. In stage one, an item pool was created for the AHT awareness questionnaire. Four experts assessed the content validity. Test–retest reliability and internal consistency were examined using a pilot study of 24 healthcare professionals. In stage two, 302 healthcare professionals from a medical centre in southern Taiwan were recruited to establish the questionnaire's psychometric

properties. The final version of the questionnaire comprised 81 items, including demographics, attitudes towards childrearing and four sub-concepts on AHT awareness (infant crying, soothing skills, clinical manifestations and consequences of AHT, and risk factors of AHT). The content validity of the questionnaire was satisfactory with a score of 0.91 to 1.0 for the scale content validity index. The test–retest reliability was 0.51–0.71. Cronbach's alphas for the final sample were 0.52–0.93 for the four subscales. Exploratory factor analysis extracted two factors as risk factors of AHT with a total explained variance of 55.9 per cent. This questionnaire is useful in understanding AHT awareness with identified aspects among healthcare professionals and other professionals working in child protection fields. Items and subscales of the AHT awareness questionnaire could act as a reference guide for future training programmes.

Eismann, E. A., Theuerling, J., Cassedy, A., Curry, P. A., Colliers, T., & Makoroff, K. L. (2020). Early developmental, behavioral, and quality of life outcomes following abusive head trauma in infants. *Child Abuse & Neglect, 108*, 104643. DOI:10.1016/j.chiabu.2020.104643

Developmental delays following pediatric abusive head trauma are common. The objective was to assess early developmental, behavioral, and quality of life outcomes following infant abusive head trauma and evaluate injury severity and early therapeutic intervention as potential predictors. Infants under 12 months old who were admitted to a large pediatric hospital with abusive head trauma between October 2010 and October 2017 and followed at a multidisciplinary post-injury clinic were included. Injury severity groups were classified based on days in the Pediatric Intensive Care Unit. Participation in early intervention services and/or physical or occupational therapy by the first clinic visit was documented. Development was assessed using the Mullen Scales of Early Learning, which 47 patients completed at approximately 6 month intervals up to 3 years of age (an average of 19 months post-injury). Behavior and quality of life were assessed around age 2 using the Child Behavior Checklist (n = 24) and PedsQL™ (n = 27), respectively. Overall

cognitive development, fine motor function, and expressive language significantly declined with age up to 3 years ($p < 0.05$). The changes in these developmental scales with age differed significantly between injury severity groups ($p < 0.05$). Internalizing behaviors were also greater in patients with moderate than mild injuries ($t = 2.37$, $p = 0.037$). Quality of life was comparable to healthy populations. Early therapeutic intervention was not significantly associated with developmental, behavioral, or quality of life outcomes ($p > 0.05$). Long-term comprehensive follow-up is recommended for children following abusive head trauma, as developmental delays and behavioral problems may present at later ages.

Edwards, G. A., Maguire, S. A., Gaither, J. R., & Leventhal, J. M. (2020). What do confessions reveal about abusive head trauma? A systematic review. *Child Abuse Review, 29*(3), 253-268. DOI:10.1002/car.2627

Although confessions related to abusive head trauma (AHT) are reported, no detailed analysis exists. Therefore, we systematically reviewed studies of AHT confessions and examined the details, including country of origin, mechanisms and perpetrators' characteristics. Employing 36 search terms across three search engines, we searched Medline and CINAHL from 1963 to 2018. All relevant studies underwent two independent reviews and data extraction. Descriptive statistics were used to characterise the sample; chi square and Fisher's exact tests were used to assess differences in demographic and clinical characteristics. Of 6759 identified studies, 157 full texts were reviewed and 55 articles from 15 countries spanning four continents were included. Included articles contained 434 confessions. The mechanisms of abuse and other (0.9%). There was no statistically significant difference in the percentage of confessions reporting shaking alone when comparing continents: North America (64.0%), Europe (64.2%) and Oceania (60.0%; $p = 0.92$), or when comparing circumstances in which the confession was obtained: medical evaluation (74.6%) vs police or judicial investigations (63.4%; $p = 0.11$). Of 119 cases with identified perpetrators, 67.2 per cent were cases with males alone.

Confessions reveal striking similarities in the mechanism of AHT (predominantly shaking) that occur across the globe.

Hung, K. (2020). Pediatric abusive head trauma. *Biomedical Journal, 43*(3), 240-250. DOI:10.1016/j.bj.2020.03.008

Abusive head trauma (AHT), used to be named shaken baby syndrome, is an injury to the skull and intracranial components of a baby or child younger than 5 years due to violent shaking and/or abrupt impact. It is a worldwide leading cause of fatal head injuries in children under 2 years. The mechanism of AHT includes shaking as well as impact, crushing or their various combinations through acceleration, deceleration and rotational force. The diagnosis of AHT should be based on the existence of multiple components including subdural hematoma, intracranial pathology, retinal hemorrhages as well as rib and other fractures consistent with the mechanism of trauma. The differential diagnosis must exclude those medical or surgical diseases that can mimic AHT such as traumatic brain injury, cerebral sinovenous thrombosis, and hypoxic-ischemic injury. As for the treatment, most of the care of AHT is supportive. Vital signs should be maintained. Intracranial pressure, if necessary, should be monitored and controlled to ensure adequate cerebral perfusion pressure. There are potential morbidity and mortality associated with AHT, ranging from mild learning disabilities to severe handicaps and death. The prognosis of patients with AHT correlates with the extent of injury identified on CT and MRI imaging. The outcome is associated with the clinical staging, the extent of increased intracranial pressure and the existence of neurological complications such as acquired hydrocephalus or microcephalus, cortical blindness, convulsive disorder, and developmental delay. AHT is a potentially preventable disease, therefore, prevention should be stressed in all encounters within the family, the society and all the healthcare providers.

O'Meara, A. M. I., Sequeira, J., & Ferguson, N. M. (2020). Advances and future directions of diagnosis and management of pediatric abusive head trauma: A review of the literature. *Frontiers in Neurology, 11*, 118. DOI:10.3389/fneur.2020.00118

Abusive head trauma (AHT) is broadly defined as injury of the skull and intracranial contents as a result of perpetrator-inflicted force and represents a persistent and significant disease burden in children under the age of 4 years. When compared to age-matched controls with typically single occurrence accidental traumatic brain injury (TBI), mortality after AHT is disproportionately high and likely attributable to key differences between injury phenotypes. This article aims to review the epidemiology of AHT, summarize the current state of AHT diagnosis, treatment, and prevention as well as areas for future directions of study. Despite neuroimaging advances and an evolved understanding of AHT, early identification remains a challenge for contemporary clinicians. As such, the reported incidence of 10–30 per 100,000 infants per year may be a considerable underestimate that has not significantly decreased over the past several decades despite social campaigns for public education. This may reflect caregivers in crisis for whom education is not sufficient without support and intervention, or dangerous environments in which other family members are at risk in addition to the child. Acute management specific to AHT has not advanced beyond usual supportive care for childhood TBI, and prevention and early recognition remain crucial. Moreover, AHT is frequently excluded from studies of childhood TBI, which limits the precise translation of important brain injury research to this population. Repeated injury, antecedent abuse or neglect, delayed medical attention, and high rates of apnea and seizures on presentation are important variables to be considered. More research, including AHT inclusion in childhood TBI studies with comparisons to age-matched controls, and translational models with clinical fidelity are needed to better elucidate the pathophysiology of AHT and inform both clinical care and the development of targeted therapies. Nevertheless, recognition of warning signs and intervention before irreversible harm occurs remains the current best strategy for medical professionals to protect vulnerable infants and toddlers.

Laurent-Vannier, A., Bernard, J. Y., & Chevignard, M. (2020). High frequency of previous abuse and missed diagnoses prior to abusive head trauma: A consecutive case series of 100 forensic examinations. *Child Abuse Review, 29*(3), 231-241. DOI:10.1002/car.2638

This study describes the frequency of signs and symptoms of abuse and missed diagnoses prior to the diagnosis of abusive head trauma (AHT) in infants. Data were from a retrospective observational study of 100 consecutive cases of infants diagnosed with AHTover a seven-year period. The most frequent symptom leading to the diagnosis was a loss of consciousness (68%) that always occurred inside a home (parents' or nanny's), never outside. Diagnosis was established using criteria based on the child's lesions and the alleged history. Lesions leading to diagnosis were described: 99 per cent had multifocal subdural haematoma (SDH) located in four areas including lateral space, interhemispheric, tentorium cerebelli and vertex; 60 per cent had a rupture of bridging veins. Previous abuse was found in 79 per cent of cases, of whom 75 per cent underwent medical consultations that did not result in a diagnosis of abuse. The main signs and symptoms of previous abuse were repeated vomiting without fever or diarrhoea (62%), abnormal head circumference increase (49%) and bruises (38%). These results suggest a higher frequency of repeated abuse than previous studies and highlight the great challenges most professionals encounter to evoke and set the diagnosis of abuse.

Narang, S. K., Fingarson, A., Lukefahr, J., Council on Child Abuse and Neglect, Sirotnak, A. P., Flaherty, E. G., Gavril, A. R., Gilmartin, A. B. H., Haney, S. B., Idzerda, S. M., Laskey, A., Legano, L. A., Messner, S. A., Mohr, B., Moles, R. L., Nienow, S., & Palusci, V. J. (2020). Abusive head trauma in infants and children. *Pediatrics, 145*(4), e20200203. DOI:10.1542/peds.2020-0203

Abusive head trauma (AHT) remains a significant cause of morbidity and mortality in the pediatric population, especially in young infants. In the past decade, advancements in research have refined medical understanding of the epidemiological, clinical, biomechanical, and pathologic factors comprising the diagnosis, thereby enhancing

clinical detection of a challenging diagnostic entity. Failure to recognize AHT and respond appropriately at any step in the process, from medical diagnosis to child protection and legal decision-making, can place children at risk. The American Academy of Pediatrics revises the 2009 policy statement on AHT to incorporate the growing body of knowledge on the topic. Although this statement incorporates some of that growing body of knowledge, it is not a comprehensive exposition of the science. This statement aims to provide pediatric practitioners with general guidance on a complex subject. The Academy recommends that pediatric practitioners remain vigilant for the signs and symptoms of AHT, conduct thorough medical evaluations, consult with pediatric medical subspecialists when necessary, and embrace the challenges and need for strong advocacy on the subject.

Paek, D., & Kwon, D. I. (2020). A review on four different paths to respiratory arrest from brain injury in children: Implications for child abuse. *Journal of Forensic and Legal Medicine*, *71*, 101938. DOI:10.1016/j.jflm.2020.101938

Child abuse was suspected in a case of out-of-hospital arrest with minor brain injuries. Confronted with continued disputes on pathophysiologic correlates even after autopsy, to assist the differentiation of potential causes of sudden cardiopulmonary arrest in children, we tried to identify the mechanism of cardiopulmonary arrest in brain injuries from different causes. Systematic review was carried out in two stages. First, major external causes of cardiopulmonary arrest among children and infants were identified from Pubmed and Google Scholar search, and then the exact sequence of cardiopulmonary arrest, and their pathophysiologic features were identified based on articles of animal models of brain injury. From the review, we have identified four major groups of external circumstances for rather sudden cardiopulmonary arrest from brain damage in children, after excluding congenital and other unrelated diseases; 1) impact brain apnea, 2) anoxic insults, 3) drug or other substance induced central nervous system depression, and 4) traumatic brain damage. Each group has different features in the

course of cardiac and respiratory arrests. Based on this review of pathophysiologic features of cardio-respiratory responses from external causes, we have presented a suspected, but unlikely, child abuse case of respiratory arrest from brain injury. The social consequences of both unknowingly missing, and falsely incriminating the abuse can be grave, and the identification of the mechanisms of cardiopulmonary arrest from brain injury can be important for the differentiation of various potential causes.

Rey-Salmon, C., de Boissieu, P., Teglas, J.-P., & Adamsbaum, C. (2020). Abusive head trauma in day care centers. *Pediatrics, 146*(6), e2020013771. DOI:10.1542/peds.2020-013771

Abusive head trauma (AHT) warrants particular attention in terms of prevention. One of the key questions asked is how often AHT occurs in infant day care centers compared with private parental or nonparental homes. To investigate this, we studied the caretaking arrangement and child's location at the time of injury in a cohort of cases involving AHT from the courts. This multicenter retrospective study covering an 18-year period included all medical and court records of 323 children (2.5 months to 3 years) with AHT, confirmed by the authors acting as medical experts. All markers for abuse and forensic written reports were analyzed by using a standardized data collection tool. The usual child care arrangement and the child's location at the time of injury were noted. The percentage of day care centers found in the study was compared to the expected rate in the French population (19.5%) by using the χ 2 test. In 317 AHT cases (98.5%), the assault occurred in a private home (4 in other indoor settings and 1 with missing data). In only 1 case, shaking occurred in a day care center when the nurse was alone with the infant for a few minutes. In 317 cases (98.5%), the usual child care arrangement was by a single adult in charge of 1 or more children. The fact that AHT is an unusual occurrence in day care centers could help social service agencies make decisions in terms of prevention. Recent government policies regarding stay-at-home orders during a pandemic have given this issue new relevance.

Sayrs, L. W., Ortiz, J. B., Notrica, D. M., Kirsch, L., Kelly, C., Stottlemyre, R., Cohen, A., Misra, S., Green, T. R., Adelson, P. D., Lifshitz, J., & Rowe, R. K. (2020). Intimate partner violence, clinical indications, and other family risk factors associated with pediatric abusive head trauma. *Journal of Interpersonal Violence, 37*(9-10), NP6785-NP6812. DOI:10.1177/0886260520967151

Over half of fatal pediatric traumatic brain injuries are estimated to be the result of physical abuse, i.e., abusive head trauma (AHT). Although intimate partner violence (IPV) is a well-established risk for child maltreatment, little is known about IPV as an associated risk factor specifically for AHT. We performed a single-institution, retrospective review of all patients (0-17 years) diagnosed at a Level 1 pediatric trauma center with head trauma who had been referred to an in-hospital child protection team for suspicion of AHT between 2010 and 2016. Data on patient demographics, hospitalization, injury, family characteristics, sociobehavioral characteristics, physical examination, laboratory findings, imaging, discharge, and forensic determination of AHT were extracted from the institution's forensic registry. Descriptive statistics (mean, median), chi-square and Mann-Whitney U tests were used to compare patients with fatal head injuries to patients with nonfatal head injuries by clinical characteristics, family characteristics, and forensic determination. Multiple logistic regression was used to estimate adjusted odds ratios for the presence of IPV as an associated risk of AHT while controlling for other clinical and family factors. Of 804 patients with suspicion for AHT in the forensic registry, there were 240 patients with a forensic determination of AHT; 42 injuries were fatal. There were 101 families with a reported history of IPV; 64.4% of patients in families with reported IPV were <12 months of age. IPV was associated with a twofold increase in the risk of AHT (Exp(β) = 2.3 [p = .02]). This study confirmed IPV was an associated risk factor for AHT in a single institution cohort of pediatric patients with both fatal and nonfatal injuries. Identifying IPV along with other family factors may improve detection and surveillance of AHT in medical settings and help reduce injury, disability, and death.

Sirmai, N., Garside, L., & Tzioumi, D. (2020). Abusive head trauma in infants: Incidence and detection of prior brain injury. *Child Abuse Review, 29*(3), 242-252. DOI:10.1002/car.2621

Diagnosis of abusive head trauma (AHT) is challenging; clinical signs are non-specific and perpetrator confessions are rare. Moreover, many infants sustain multiple episodes of abuse before presenting to medical practitioners. The objective of this study was to quantify the incidence of prior presentations with features of brain injury in AHT, and to compare these figures to those in non-abusive head trauma (non-AHT). Data on children under the age of two years who were assessed for AHT by the Child Protection Unit of Sydney Children's Hospital between 2008 and 2017 were collected, and AHT cases were compared with non-abusive cases. Of the 167 cases assessed for head trauma, 26 per cent had at least one prior presentation to medical care. This was 42 per cent of the AHT cases, and 11 per cent of the non-AHT cases. Odds ratio calculations revealed infants with AHT were 5.7 times more likely to have had a prior presentation than children with non-AHT (CI = 2.4–13.17, $p < 0.001$. Infants with AHT are much more likely than infants with non-AHT to have presented previously to medical practitioners. This difference suggests that there is an early diagnostic window within which abuse can be detected before it continues or escalates. Careful evaluation of an infant is of paramount importance, and may save a life.

Steinbeigle, R., Barr, M., Barr, R. G., & Miller, T. R. (2020). Financial impact of abusive head trauma to age 17. *Child Abuse Review*, *29*(3), 208-217. DOI:10.1002/car.2626

In order to illustrate the medical and financial impact arising from the care of a severely injured victim of abusive head trauma (AHT) from incident through to adulthood, a complete review of all medical financial files for the injured child beginning at the time custody of the child was transferred to the paternal grandparents (2.5 months of age) through to age 17 was conducted. Cost data were extracted from the insurance explanation of benefits or the family's bank statements. Costs were divided into seven

categories and adjusted for inflation. Medical costs from 2.5 months to 18 years of age totaled $261,499, with $106,607 of out-of-pocket expenditures by the child's paternal grandparents and $154,892 covered by insurance. Costs were highly variable from year to year as reflected in the standard deviation of annual costs of $16,877. The cost of caring for a seriously injured victim of AHT is substantial & may be highly variable and unpredictable from year to year making it difficult for families to plan financially.

Beaulieu, E., Rajabali, F., Zheng, A., & Pike, I. (2019). The lifetime costs of pediatric abusive head trauma and a cost-effectiveness analysis of the Period of Purple crying program in British Columbia, Canada. *Child Abuse & Neglect, 97*, 104133. DOI:10.1016/j.chiabu.2019.104133

Abusive head trauma (AHT) is a severe form of child abuse causing devastating outcomes for children and families, but its economic costs in Canada has yet to be determined. The Period of PURPLE crying program (PURPLE) is an AHT prevention program implemented in British Columbia for which success in reducing AHT events was recently reported. This study estimated the lifetime costs to society of incidental AHT events and compared the benefits and associated costs of AHT before and after the implementation of the PURPLE program. Children aged 0–24 months old with a definite diagnosis of AHT between 2002 and 2014 in British Columbia were included in this study. An incidence-based cost-of-illness analysis, using the human capital approach was used to quantify the lifetime costs of AHT events according to their severity (least severe, severe and fatal). A cost-effectiveness analysis of the PURPLE program was conducted from both a societal and a health services' perspectives using decision tree models. There were 64 AHT events between 2002–2014, resulting in a total cost of $354,359,080 to society. The costs associated with fatal, severe and least severe AHT averaged $7,147,548, $6,057,761 and $1,675,099, respectively. The investment of $5 per newborn through the PURPLE program resulted in a $273.52 and $14.49 per child cost avoidance by society and by the healthcare system. This study provides evidence to policymakers and health practitioners that

investing upstream in well-developed AHT prevention programs, such as PURPLE, not only promote child safety and health, but also translates into avoided costs to society.

Beaulieu, E., Jiang, A., Zheng, A., Rajabali, F., & Pike, I. (2019). Inequities in pediatric abusive head trauma according to neighborhood social and material deprivation: A population-level study in British Columbia, Canada. *Child Maltreatment, 25*(3), 300-307. DOI:10.1177/1077559519892332

To explore the relationship between neighborhood social and material deprivation and the rates of abusive head trauma (AHT), and whether it differs according to sex, and following the implementation of the Period of PURPLE Crying (PURPLE) program, a cross-sectional study design was applied to data from children 0 to 24 months old with a confirmed AHT diagnosis between 2005 and 2017 in British Columbia. Dissemination area–based social and material deprivation scores were assigned to residential areas, where AHT cases were recorded. Poisson regression models tested the relationship between deprivation scores and AHT rates, adding sex and pre–post program implementation as interaction terms. With each increase in material and social deprivation quintiles, AHT rates increased by 42% (95% CI) and 25% (95% CI), respectively, following a social gradient. AHT rate disparities between neighborhoods did not change following the PURPLE program implementation. This study stresses the need to provide additional AHT prevention services proportionately to the levels of neighborhood disadvantage, in addition to universal AHT programs, to successfully protect all children.

Anderst, J. D., Carpenter, S. L., Presley, R., Berkoff, M. C., Wheeler, A. P., Sidonio, R. F., & Soucie, J. M. (2018). Relevance of abusive head trauma to intracranial hemorrhages and bleeding disorders. *Pediatrics, 141*(5), e20173485. DOI:10.1542/peds.2017-3485

Bleeding disorders and abusive head trauma (AHT) are associated with intracranial hemorrhage (ICH), including subdural hemorrhage (SDH). Because both conditions often

present in young children, the need to screen for bleeding disorders would be better informed by data that include trauma history and are specific to young children. The Universal Data Collection database contains information on ICH in subjects with bleeding disorders, including age and trauma history. Study objectives were to (1) characterize the prevalence and calculate the probabilities of any ICH, traumatic ICH, and nontraumatic ICH in children with congenital bleeding disorders; (2) characterize the prevalence of spontaneous SDH on the basis of bleeding disorder; and (3) identify cases of von Willebrand disease (vWD) that mimic AHT. We reviewed subjects <4 years of age in the Universal Data Collection database. ICH was categorized on the basis of association with trauma. Prevalence and probability of types of ICH were calculated for each bleeding disorder. Of 3717 subjects, 255 (6.9%) had any ICH and 206 (5.5%) had nontraumatic ICH. The highest prevalence of ICH was in severe hemophilia A (9.1%) and B (10.7%). Of the 1233 subjects <2 years of age in which the specific location of any ICH was known, 13 (1.1%) had spontaneous SDH (12 with severe hemophilia; 1 with type 1 vWD). The findings in the subject with vWD were not congruent with AHT. In congenital bleeding disorders, nontraumatic ICH occurs most commonly in severe hemophilia. In this study, vWD is not supported as a "mimic" of AHT.

Barr, R. G., Barr, M., Rajabali, F., Humphreys, C., Pike, I., Brant, R., Hlady, J., Colbourne, M., Fujiwara, T., & Singhal, A. (2018). Eight-year outcome of implementation of abusive head trauma prevention. *Child Abuse & Neglect, 84,* 106-114. DOI:10.1016/j.chiabu.2018.07.004

Low incidence rates and economic recession have hampered interpretation of educational prevention efforts to reduce abusive head trauma (AHT). Our objective was to determine whether the British Columbia experience implementing a province-wide prevention program reduced AHT hospitalization rates. A 3-dose primary, universal education program (the Period of PURPLE Crying) was implemented through maternal and public health units and assessed by retrospective/prospective surveillance. With

parents of all newborn infants born between January 2009 and December 2016 (n=354,477), nurses discussed crying and shaking while delivering a booklet and DVD during maternity admission (dose 1). Public health nurses reinforced Talking Points by telephone and/or home visits post-discharge (dose 2) and community education was instituted annually (dose 3). During admission, program delivery occurred for 90% of mothers. Fathers were present 74.4% of the time. By 2–4 months, 70.9% of mothers and 50.5% of fathers watched the DVD and/or read the booklet. AHT admissions decreased for<12-month-olds from 10.6 (95% CI: 8.3–13.5) to 7.1 (95% CI: 4.8–10.5) or, for<24-month-olds, from 6.7 (95% CI: 5.4–8.3) to 4.4 (95% CI: 3.1–6.2) cases per 100,000 person-years. Relative risk of admission was 0.67 (95% CI: 0.42–1.07, P=0.090) and 0.65 (95% CI: 0.43-0.99, P=0.048) respectively. We conclude that the intervention was associated with a 35% reduction in infant AHT admissions that was significant for<24-month-olds. The results are encouraging that, despite a low initial incidence and economic recession, reductions in AHT may be achievable with a system-wide implementation of a comprehensive parental education prevention program.

Cowley, L. E., Maguire, S., Farewell, D. M., Quinn-Scoggins, H. D., Flynn, M. O., & Kemp, A. M. (2018). Factors influencing child protection professionals' decision making and multidisciplinary collaboration in suspected abusive head trauma cases: A qualitative study. *Child Abuse & Neglect, 82*, 178-191. DOI:10.1016/j.chiabu.2018.06.009

Clinicians face unique challenges when assessing suspected child abuse cases. The majority of the literature exploring diagnostic decision-making in this field is anecdotal or survey-based and there is a lack of studies exploring decision-making around suspected abusive head trauma (AHT). We aimed to determine factors influencing decision-making and multidisciplinary collaboration in suspected AHT cases, amongst 56 child protection professionals. Semi-structured interviews were conducted with clinicians (25), child protection social workers (10), legal practitioners (9, including 4 judges), police officers (8), and pathologists (4), purposively sampled across southwest

United Kingdom. Interviews were recorded, transcribed and imported into NVivo for thematic analysis (38% double-coded). We identified six themes influencing decision making: 'professional', 'medical', 'circumstantial', 'family', 'psychological' and 'legal' factors. Participants diagnose AHT based on clinical features, the history, and the social history, after excluding potential differential diagnoses. Barriers to decision-making include lack of experience, uncertainty, the impact on the family, the pressure of making the correct diagnosis, and disagreements between professionals. Legal barriers include alternative theories of causation proposed in court. Facilitators include support from colleagues and knowledge of the evidence-base. Participants' experiences with multidisciplinary collaboration are generally positive, however child protection social workers and police officers are heavily reliant on clinicians to guide their decision-making, suggesting the need for training on the medical aspects of physical abuse for these professionals and multidisciplinary training that provides knowledge about the roles of each agency.

Lopes, N. R. L., & Williams, L. C. D. A. (2018). Pediatric abusive head trauma prevention initiatives: A literature review. *Trauma, Violence, & Abuse, 19*(5), 555-566. DOI:10.1177/1524838016675479

Abusive head trauma (AHT) is a serious form of child maltreatment that needs to be prevented. The aim of this study was to summarize the main AHT prevention strategies described in literature, aiming to identify evidence of their efficiency, as well as strengths and limitations. International databases were reviewed from 2005 to 2015 using the key words Shaken Baby Syndrome or abusive head trauma or nonaccidental head trauma or abusive head injury or nonaccidental head injury and prevention. A total of 1,215 articles were found and 34 complete articles were selected for this study. Five initiatives with the main objective of reducing infant 12 aimed at raising parents and shaking a baby stands out for its empirical evidence.

Pfeiffer, H., Smith, A., Kemp, A. M., Cowley, L. E., Cheek, J. A., Dalziel, S. R., Borland, M. L., O'Brien, S., Bonisch, M., Neutze, J., Oakley, E., Crowe, L., Hearps, S. J. C., Lyttle, M. D., Bressan, S., & Babl, F. E. (2018). External validation of the PediBIRN clinical prediction rule for abusive head trauma. *Pediatrics, 141*(5), e20173674. DOI:10.1542/peds.2017-3674

A 4-variable abusive head trauma (AHT) clinical prediction rule (CPR) for use in the PICU was derived and validated for children <3 years of age by the Pediatric Brain Injury Research Network (PediBIRN). We aimed to externally validate PediBIRN as designed (PICU only) as well as using broader inclusion criteria (admitted children with head injuries). This was a secondary analysis of a prospective multicenter study of pediatric head injuries at 5 Australian and New Zealand tertiary pediatric centers. Possible AHT was identified by clinician suspicion, epidemiology codes, or a high-risk group (<3 years of age, admitted, abnormal neuroimaging results). We designated patients as positive for AHT, negative for AHT, or having indeterminate outcome after multidisciplinary review and applied the PediBIRN CPR, blinded to outcome, to PICU admissions only, and any head injury admissions. CPR accuracy was calculated by using 95% confidence intervals. One hundred and forty-one patients were admitted with abnormal neuroimaging results. Twenty-eight (20%) were positive for AHT, 94 (67%) were negative for AHT, and 19 (13%) had indeterminate outcome. Excluding indeterminate cases, in the PICU, the CPR was 100% (75%–100%) sensitive and 11% (0%–48%) specific; in all admitted patients sensitivity was 96% (82%–100%) and specificity of 43% (32%–53%). This validation revealed high sensitivity and low specificity for PICU patients.

Berger, R. P., Fromkin, J., Herman, B., Pierce, M. C., Saladino, R. A., Flom, L., Tyler Kabara, E. C., McGinn, T., Richichi, R., & Kochanek, P. M. (2016). Validation of the Pittsburgh infant brain injury score for abusive head trauma. *Pediatrics*, *138*(1), e20153756. DOI:10.1542/peds.2015-3756.

Abusive head trauma is the leading cause of death from physical abuse. Misdiagnosis of abusive head trauma as well as other types of brain abnormalities in infants is common

and contributes to increased morbidity and mortality. We previously derived the Pittsburgh Infant Brain Injury Score (PIBIS), a clinical prediction rule to assist physicians deciding which high-risk infants should undergo computed tomography of the head. Well-appearing infants 30 to 364 days of age with temperature <38.3°C, no history of trauma, and a symptom associated with an increased risk of having a brain abnormality were eligible for enrollment in this prospective, multicenter clinical prediction rule validation. By using a predefined neuroimaging paradigm, subjects were classified as cases or controls. The sensitivity, specificity, and negative and positive predictive values of the rule for prediction of brain injury were calculated. A total of 1040 infants were enrolled: 214 cases and 826 controls. The 5-point PIBIS included abnormality on dermatologic examination (2 points), age ≥3.0 months (1 point), head circumference >85th percentile (1 point), and serum hemoglobin <11.2g/dL (1 point). At a score of 2, the sensitivity and specificity for abnormal neuroimaging was 93.3% (95% confidence interval 89.0%–96.3%) and 53% (95% confidence interval 49.3%–57.1%), respectively. Our data suggest that the PIBIS accurately identifies infants who would benefit from neuroimaging to evaluate for brain injury. An implementation analysis is needed before the PIBIS can be integrated into clinical practice.

Boop, S., Axente, M., Weatherford, B., & Klimo, P. (2016). Abusive head trauma: An epidemiological and cost analysis. *Journal of Neurosurgery: Pediatrics, 18*(5), 542-549. DOI:10.3171/2016.1.PEDS15583

Research on pediatric abusive head trauma (AHT) has largely focused on clinical presentation and management. The authors sought to review a single-institution experience from a public health perspective to gain a better understanding of the local population affected, determine overall incidence and seasonal trends, and provide details on the initial hospitalization, including extent of injuries, neurosurgical interventions, and hospital charges. All cases of AHT involving patients who presented to Le Bonheur Children's Hospital (LBCH) from 2009 through 2014 were identified. AHT was

defined as skull fracture or intracranial hemorrhage in a child under the age of 5 years with a suspicious mechanism or evidence of other intentional injuries, such as retinal hemorrhages, old or new fractures, or soft-tissue bruising. Injuries were categorized as Grade I (skull fracture only), Grade II (intracranial hemorrhage or edema not requiring surgical intervention), or Grade III (intracranial hemorrhage requiring intervention or death due to brain injury). Two hundred thirteen AHT cases were identified. The demographics of the study population are similar to those reported in the literature: the majority of the patients involved were 6 months of age or younger (55%), male (61%), African American (47%), and publicly insured (82%). One hundred one neurosurgical procedures were performed in 58 children, with the most common being bur hole placement for treatment of subdural collections (25%) and decompressive hemicraniectomy (22%). The annual incidence rate rose from 2009 (19.6 cases per 100,000 in the population under 5 years of age) to 2014 (47.4 cases per 100,000) and showed seasonal peaks in January, July, and October (6-year average single-month incidence, respectively, 24.7, 21.7, and 24.7 per 100,000). The total hospital charges were $13,014,584, with a median cost of $27,939. Treatment costs for children who required surgical intervention (i.e., those with Grade III) were up to 10 times those of children with less severe injuries. In the authors' local population, victims of AHT are overwhelmingly infants, are more often male than female, and are disproportionately from lower socioeconomic ranks. The incidence is increasing and initial hospitalization charges are substantial and variable. The authors introduce a simple 3-tiered injury classification scheme that adequately stratifies length of hospital stay and cost**.**

Christian, C. W., AAP Committee on Child Abuse and Neglect, & AAP Section on Child Abuse and Neglect. (2016). *Understanding abusive head trauma in infants and children: Answers from America's pediatricians*. American Academy of Pediatrics.

Letson, M. M., Cooper, J. N., Deans, K. J., Scribano, P. V., Makoroff, K. L., Feldman, K. W., & Berger, R. P. (2016). Practice implications: Prior opportunities to identify abuse in children with abusive head trauma. *Child Abuse & Neglect, 60*, 36-45. DOI:10.1016/j.chiabu.2016.09.001

Infants with minor abusive injuries are at risk for more serious abusive injury, including abusive head trauma (AHT). Our study objective was to determine if children with AHT had prior opportunities to detect abuse and to describe the opportunities. All AHT cases from 2009-2011 at 4 tertiary care children's hospitals were included. A prior opportunity was defined as prior evaluation by either a medical or child protective services (CPS) professional when the symptoms and/or referral could be consistent with abuse but the diagnosis was not made and/or an alternate explanation was given and accepted. 232 children with AHT were identified; median age (IQR) was 5.40 months. 10% (22/232) died. Of the 232 patients diagnosed with AHT, 31% had a total of 120 prior opportunities. Fifty-nine children (25%) had at least one prior opportunity to identify abuse in a medical setting, representing 98 prior opportunities. An additional 14 (6%) children had 22 prior opportunities through previous CPS involvement. There were no differences between those with and without a prior opportunity based on age, gender, race, insurance, mortality, or institution. Children with prior opportunities in a medical setting were more likely to have chronic subdural hemorrhage (48 vs. 17%) and healing fractures (31 vs. 19%). The most common prior opportunities included vomiting 31.6% (38/120), prior CPS contact 20% (24/120), and bruising 11.7% (14/120). Improvements in earlier recognition of AHT and subsequent intervention might prevent additional injuries and reduce mortality.

Lind, K., Toure, H., Brugel, D., Meyer, P., Laurent-Vannier, A., & Chevignard, M. (2016). Extended follow-up of neurological, cognitive, behavioral and academic outcomes after severe abusive head trauma. *Child Abuse & Neglect, 51*, 358-367. DOI:10.1016/j.chiabu.2015.08.001

Studies about long-term outcome following abusive head trauma (AHT) are scarce. The aims of this study were to report long-term neurological, cognitive, behavioral and

academic outcomes, ongoing treatments and/or rehabilitation, several years after AHT diagnosis, and rehabilitation unit following AHT between 1996 and 2005, with subsequent follow-up exceeding 3 years, were included. Medical files were reviewed and a medical interview was performed with parents on the phone when possible. The primary outcome measure was the Glasgow Outcome Scale (GOS). Forty-seven children (out of 66) met the inclusion criteria (mean age at injury 5.7 months; SD = 3.2). After a median length of follow-up of 8 years (range 3.7–12), only seven children (15%) had "good outcome" (normal life – GOS I) and 19 children (40%) presented with severe neurological impairment (GOS III and IV). Children sustained epilepsy (38%), motor deficits (45%), visual deficit (45%), sleep disorders (17%), language abnormalities (49%), attention deficits (79%) and behavioral disorders (53%). Most children (83%) had ongoing rehabilitation. Only 30% followed a normal curriculum, whereas 30% required special education services. Children with better overall outcome (GOS I and II) had significantly higher educated mothers than those with worse outcomes (GOS III and IV): graduation from high school 59% and 21% respectively (p = 0.006). This study highlights the high rate of severe sequelae and health care needs several years post AHT, and emphasizes the need for extended follow-up of medical, cognitive and academic outcomes.

Burkhart, Z. N., Thurber, C. J., Chuang, A. Z., Kumar, K. S., Davis, G. H., & Kellaway, J. (2015). Risk factors associated with retinal hemorrhage in suspected abusive head trauma. *Journal of American Association for Pediatric Ophthalmology and Strabismus*, *19*(2), 119–123. DOI:10.1016/j.jaapos.2014.12.007

In order to determine risk factors associated with retinal hemorrhage (RH) in pediatric abusive head trauma (AHT) suspects, records of children aged 0–3 years hospitalized for suspected AHT from January 2007 to November 2011 were retrospectively reviewed in this case–control study. Children were classified into case and control groups based on RH presence. Medical history, presenting symptoms, reasons, and characteristics of injury were recorded. Logistic regression analysis was performed to identify risk factors. A total

of 168 children (104 males) were included. Of these, 103 were classified as cases and 65 as controls. The mean age (with standard deviation) was 9.3 ± 8.3 months (range, 1 day-36 months). Of the 103 cases, 22 (21%) had subretinal hemorrhage, 9 (9%) had retinoschisis, and 1 (1%) had vitreous hemorrhage. Children presenting with lethargy or altered mental status (P < 0.0001), subdural hemorrhage (P < 0.0001), and other radiologic findings (eg, cerebral ischemia, diffuse axonal injury, hydrocephalus, or solid organ injury; P = 0.01546) were likely to have RH. All 23 children with skull or nonskull fracture without intracranial hemorrhage did not have RH (P < 0.0001 both categories). Retinal hemorrhages were almost never found in the absence of intracranial hemorrhage and not found in the setting of fracture without intracranial hemorrhage.

Colbourne, M. (2015). Abusive head trauma: Evolution of a diagnosis. *British Columbia Medical Journal*, *57*(8), 331-335.

Over the past 60 years, the diagnosis of abuse in children has been challenged within both the medical and the legal communities. Nowhere has this been more apparent than in the literature addressing abusive head trauma in infants and children. The diagnostic terminology used currently, while more encompassing than terminology used in the past, has contributed to confusion about the strength of scientific evidence for inflicted injuries. Fortunately, a variety of medical disciplines, including pediatrics, emergency medicine, radiology, ophthalmology, pathology, biomechanics, neurosurgery, and neurology, have contributed to an unprecedented growth in our understanding of inflicted head trauma in children. We can now confirm that abusive head trauma does occur, that it is a leading cause of traumatic death in children under 2 years of age, that it has a characteristic clinical presentation and injury pattern, and that it can involve a variety of different injury mechanisms. Awareness of these mechanisms and rigorous efforts to ensure comprehensive clinical assessments will best inform the diagnostic process. Being able to identify abusive head trauma and finding answers to the challenging questions that

remain, including how to mitigate damage when a young patient presents with head trauma, will lead ultimately to improvements in both outcomes and prevention.

Cowley, L. E., Morris, C. B., Maguire, S. A., Farewell, D. M., & Kemp, A. M. (2015). Validation of a prediction tool for abusive head trauma. *Pediatrics*, *136*(2), 290-298. DOI:10.1542/peds.2014-3993

Abusive head trauma (AHT) may be missed in the clinical setting. Clinical prediction tools are used to reduce variability in practice and inform decision-making. From a systematic review and individual patient data analysis we derived the Predicting Abusive Head Trauma (PredAHT) tool, using multilevel logistic regression to predict likelihood of AHT. This study aims to externally validate the PredAHT tool. Consecutive children aged ,36 months admitted with an intracranial injury, confirmed as abusive or nonabusive, to 2 sites used in the original model were ascertained. Details of 6 influential features were recorded (retinal hemorrhage, rib and long -bone fractures, apnea, seizures, and head or neck bruising). We estimated the likelihood of an unrecorded feature being present with multiple imputation; analysis included sensitivity, specificity, and area under the curve, with 95% confidence intervals (CIs). Data included 133 non-AHT cases and 65 AHT cases, 97% of children were ,24 months old. Consistent with original predictions, when 3 features were present in a child ,36 months old with intracranial injury, the estimated probability of AHT was .81.5% (95% CI). The sensitivity of the tool was 72.3% (95% CI), the specificity was 85.7% (95% CI), area under the curve 0.88 (95% CI). When tested on novel data, the PredAHT tool performed well. This tool has the potential to contribute to decision-making in these challenging cases but an implementation study is needed to explore its performance and utility within the child protection process.

Edwards, G. A. (2015). Mimics of child abuse: Can choking explain abusive head trauma?. *Journal of Forensic and Legal Medicine, 35,* 33-37. DOI:10.1016/j.jflm.2015.06.012

Choking is one of the alternative explanations of abusive head trauma in children that have been offered in courtroom testimony and in the media. Most of these explanations — including choking — are not scientifically supported. This article highlights four points. (1) The origins of choking as an explanation for intracranial and retinal hemorrhages are speculative. (2) Choking has been used in high profile court testimony as an explanation for the death of a child thought to have been abused. (3) A case report that proposes choking as an alternative explanation for the death of a child diagnosed with abusive head trauma includes omissions and misrepresentations of facts. (4) There was a decision by the editor of the journal that published the case report that it was not necessary to include all the facts of the case; moreover, the editor indicated that facts are not required when presenting an alternative explanation. The use of scientifically unsupported alternative explanations for abusive head trauma based on inaccurate and biased information constitutes further victimization of the abused child and represents a travesty of justice.

Kelly, P., John, S., Vincent, A. L., & Reed, P. (2015). Abusive head trauma and accidental head injury: A 20-year comparative study of referrals to a hospital child protection team. *Archives of Disease in Childhood, 100*(12), 1123-1300. DOI:10.1136/archdischild-2014-306960

In order to describe children referred for suspected abusive head trauma (AHT) to a hospital child protection team in Auckland, New Zealand, a comparative review of demographics, histories, injuries, investigations and diagnostic outcomes for referrals under 15 years old from 1991 to 2010 was conducted. Records were available for 345 children. Referrals increased markedly (88 in the first decade, 257 in the second), but the diagnostic ratio was stable: AHT 60%, accidental or natural 29% and uncertain cause 11%. The probability of AHT was similar regardless of socio-economic status or ethnicity. In

children under 2 years old with accidental head injuries (75/255, 29%) or AHT (180/255, 71%), characteristics of particular interest for AHT included no history of trauma (88/98, 90%), no evidence of impact to the head (84/93, 90%), complex skull fractures with intracranial injury (22/28, 79%), subdural haemorrhage (160/179, 89%) and hypoxic ischaemic injury (38/39, 97%). In children over 2 years old, these characteristics did not differ significantly between children with accidental head injuries (21/47, 45%) and AHT (26/47, 55%). The mortality of AHT was higher in children over 2 years old (10/26, 38%) than under 2 years (19/180, 11%). The striking increase in referrals for AHT probably represents increasing incidence. The decision to refer a hospitalised child with a head injury for assessment for possible AHT should not be influenced by socio-economic status or ethnicity. Children over 2 years old hospitalised for AHT are usually injured by mechanisms involving impact and should be considered at high risk of death.

Morrill, A. C., McElaney, L., Peixotto, B., VanVleet, M., & Sege, R. (2015). Evaluation of All Babies Cry, a second generation universal abusive head trauma prevention program. *Journal of Community Psychology, 43*(3), 296-314. DOI:10.1002/jcop.21679

Child maltreatment results in significant individual, family, and societal costs. This study assessed the efficacy of All Babies Cry (ABC), a media-based infant maltreatment prevention program, using a mixed-method, quasi-experimental staged evaluation design. ABC's messaging, designed and tested through a series of focus groups, provides strategies for reducing parental stress and soothing infants. Participants (n = 423) were first-time parents, 70% fathers, recruited at two hospitals. The first 211 were controls; the next 212 received ABC. Participants were interviewed 3 times: at baseline in hospital, and by telephone 5 weeks (n = 359; 85%) and 17 weeks (n = 326; 77%) later. Researchers measured parents' perceptions, intentions, and use of strategies to calm crying and manage caregiver stress. Outcomes were based on the Strengthening Families Model

and the Theory of Planned Behavior. The intervention was well received, appears effective in improving mediators of behavior, and may change parental behavior.

Peterson, C., Xu, L., Florence, C., & Parks, S. E. (2015). Annual cost of US hospital visits for pediatric abusive head trauma. *Child Maltreatment*, *20*(3), 162-169. DOI:10.1177/1077559515583549

We estimated the frequency and direct medical cost from the provider perspective of U.S. hospital visits for pediatric abusive head trauma (AHT). We identified treat-and-release hospital emergency department (ED) visits and admissions for AHT among patients aged 0–4 years in the Nationwide Emergency Department Sample and Nationwide Inpatient Sample (NIS), 2006–2011. We applied cost-to-charge ratios and estimated professional fee ratios from Truven Health MarketScan1 to estimate per-visit and total population costs of AHT ED visits and admissions. Regression models assessed cost differences associated with selected patient and hospital characteristics. AHT was diagnosed during 6,827 (95% confidence interval [CI] [6,072, 7,582]) ED visits and 12,533 (95% CI [10,395, 14,671]) admissions (28% originating in the same hospital's ED) nationwide over the study period. The average medical cost per ED visit and admission were US$2,612 (error bound: 1,644–3,581) and US$31,901 (error bound: 29,266–34,536), respectively (2012 USD). The average total annual nationwide medical cost of AHT hospital visits was US$69.6 million (error bound: 56.9–82.3 million) over the study period. Factors associated with higher per-visit costs included patient age <1 year, males, coexisting chronic conditions, discharge to another facility, death, higher household income, public insurance payer, hospital trauma level, and teaching hospitals in urban locations. Study findings emphasize the importance of focused interventions to reduce this type of high-cost child abuse.

Stephens, A., & Oates, K. (2015). The placement of children following non-accidental head injuries: Are they protected from further harm?. *Child Abuse Review*, *24*(1), 67-76. DOI:10.1002/car.2335

Few studies have examined the social outcomes for these children – their trajectories through child protection systems and their placements (Cobley and Sanders, 2007; Kelly et al., 2009). This paper provides descriptive data on a cohort of 68 children with suspected NAHI seen at a large paediatric hospital in Sydney, Australia, and discusses the outcomes for these children in terms of placements and re-notifications to the statutory authority and the implications for potential future harm. This paper is part of a retrospective study that followed 68 suspected NAHI cases from hospital presentation through the child protection and criminal justice systems of New South Wales (NSW), Australia.

Wood, J. N., French, B., Song, L., & Feudtner, C. (2015). Evaluation for occult fractures in injured children. *Pediatrics*, *136*(2), 232-240. DOI:10.1542/peds.2014-3977

Objectives: To examine variation across US hospitals in evaluation for occult fractures in (1) children <2 years old diagnosed with physical abuse and (2) infants <1 year old with injuries associated with a high likelihood of abuse and to identify factors associated with such variation. Methods: We performed a retrospective study in children <2 years old with a diagnosis of physical abuse and in infants <1 year old with non-motor vehicle crash–related traumatic brain injury or femur fractures discharged from 366 hospitals in the Premier database from 2009 to 2013. We examined across-hospital variation and identified child- and hospital-level factors associated with evaluation for occult fractures. Results: Evaluations for occult fractures were performed in 48% of the 2502 children with an abuse diagnosis, in 51% of the 1574 infants with traumatic brain injury, and in 53% of the 859 infants with femur fractures. Hospitals varied substantially with regard to their rates of evaluation for occult fractures in all 3 groups. Occult fracture evaluations were more likely to be performed at teaching hospitals than at nonteaching hospitals (all P < .001).

The hospital-level annual volume of young, injured children was associated with the probability of occult fracture evaluation, such that hospitals treating more young, injured patients were more likely to evaluate for occult fractures (all P < .001). Conclusions: Substantial variation in evaluation for occult fractures among young children with a diagnosis of abuse or injuries associated with a high likelihood of abuse highlights opportunities for quality improvement in this vulnerable population.

Allen, K. A. (2014). The neonatal nurse's role in preventing abusive head trauma. *Advances in Neonatal Care: Official Journal of the National Association of Neonatal Nurses*, *14*(5), 336-342. DOI:10.1097/ANC.0000000000000117

Background: Abusive head trauma in infants occurs in 24.6 to 39.8 per 100,000 infants in developed countries. Abusive head trauma refers to any type of intentional head trauma an infant sustains, as a result of an injury to the skull or intracranial contents from a blunt force and/or violent shaking. Clinical Question: What evidence-based interventions have been implemented by neonatal nurses to prevent abusive head trauma in infants? Search Strategy: PubMed was search to obtain English language publications from 2005 to May 2014 for interventions focused on preventing abusive head trauma using key terms 'shaken baby syndrome'. Search Yield: A total of 10 studies were identified that met the inclusion criteria. All of the interventions targeted prevention of abusive head trauma with information about abusive head trauma/shaken baby syndrome and the 'normal' infant crying behaviors. Main Findings: Interventions taught parents why infants cried, how to calm the infants, ways to cope with inconsolable infants, and how to develop a plan for what to do if they could not cope anymore. Parents who participated in the interventions were consistently able to explain the information and tell others about the dangers of shaking infants compared to the control parents. Only two studies calculated the pre-intervention abusive head trauma rate and the post-intervention frequency of abusive head trauma. Each found significant differences in abusive head trauma.

Imagawa, K. K., Hamilton, A., Ceschin, R., Tokar, E., Pham, P., Bluml, S., Wisnowski, J., & Panigrahy, A. (2014). Characterization of microstructural injury: A novel approach in infant abusive head trauma—initial experience. *Journal of Neurotrauma, 31*(19), 1632-1638. DOI:10.1089/neu.2013.3228

Abusive head trauma (AHT) is the leading cause of morbidity and mortality among abused children, yet the neuroanatomical underpinnings of AHT outcome is incompletely understood. The aim of this study was to characterize white matter (WM) abnormalities in infants with AHT using diffusion tensor imaging (DTI) and determine which microstructural abnormalities are associated with poor outcome. Retrospective DTI data from 17 infants (>3 months) with a diagnosis of AHT and a comparison cohort of 34 term infants of similar post-conceptual age (PCA) were compared using a voxel-based DTI analysis of cerebral WM. AHT cases were dichotomously classified into mild/moderate versus severe outcome. Clinical variables and conventional imaging findings were also analyzed in relation to outcome. Outcomes were classified in accordance with the Pediatric Cerebral Performance Category Score (PCPCS). Reduced axial diffusivity (AD) was shown in widespread WM regions in the AHT infants compared with controls as well as in the AHT severe outcome group compared with the AHT mild/moderate outcome group. Reduced mean diffusivity (MD) was also associated with severe outcome. Radial diffusivity (RD), conventional magnetic resonance findings, brain metric measurements, and clinical/laboratory variables (with the exception of Glascow Coma Scale) did not differ among AHT outcome groups. Findings support the unique role of DTI techniques, beyond conventional imaging, in the evaluation of microstructural WM injury of AHT. Reduced AD (likely reflecting axonal damage) and MD were associated with poor clinical outcome. DTI abnormalities may uniquely reflect AHT patterns of axonal injury that are not characterized by conventional imaging, which may have both therapeutic and prognostic implications.

Levin, A. V., Cordovez, J. A., Leiby, B. E., Pequignot, E., & Tandon, A. (2014). Retinal hemorrhage in abusive head trauma: Finding a common language. *Transactions of the American Ophthalmological Society, 112,* 1-10.

In order to assess the performance of a refined Web-based tool for documenting retinal hemorrhage characteristics in suspected abusive head trauma (AHT), 4 pediatric ophthalmologists performed pilot testing with 80 images for tool refinement using a comprehensive tabular secure platform, with access to digital images in color, black and white, and 4-zone system schematic overlay. In a second phase, retinal hemorrhages were documented by number, zone, and type. Interobserver agreement was calculated using the Fleiss kappa coefficient & the Intraobserver agreement was calculated using Cohen's kappa statistic. Interobserver agreement was good (kappa 0.4–0.6) and very good (kappa 0.6–0.8) for all questions in Zone A (peripapillary). For zones C (midperiphery) and D (peripheral retina), agreement was very good for all questions except number of hemorrhages, for which agreement was good. Zone B (macula) showed good and fair agreement except for superficial hemorrhage, for which agreement was poor. There was very good intraobserver agreement for number (kappa 0.68, 0.65, 0.67) and type of hemorrhages in zones A, B, and C. Surface area mapping results revealed no significant differences between zones A and B. Zones C and D had significantly less hemorrhage than A and B. Our tool performed with good or very good interobserver and intraobserver agreement in almost all domains. We attribute zone B underperformance to the significant increased area covered by hemorrhages compared to zones C and D and the lack of contrast with normal anatomical structures in zone A.

Peterson, C., Xu, L., Florence, C., Parks, S. E., Miller, T. R., Barr, R. G., Barr, M., & Steinbeigle, R. (2014). The medical cost of abusive head trauma in the United States. *Pediatrics*, *134*(1), 91-99. DOI:10.1542/peds.2014-0117

Objectives: Health consequences of shaken baby syndrome, or pediatric abusive head trauma (AHT), can be severe and long-lasting. We aimed to estimate the multiyear

medical cost attributable to AHT. Methods: Using Truven Health MarketScan data, 2003-2011, we identified children 0 to 4 years old with commercial or Medicaid insurance and AHT diagnoses. We used exact case-control matching based on demographic and insurance characteristics such as age and health plan type to compare medical care between patients with and without AHT diagnoses. Using regression models, we assessed service use (ie, average annual number of inpatient visits per patient) and inpatient, outpatient (including emergency department), drug, and total medical costs attributable to an AHT diagnosis during the 4-year period after AHT diagnosis. Results: We assessed 1209 patients with AHT and 5895 matched controls. Approximately 48% of patients with AHT received inpatient care within 2 days of initial diagnosis, and 25% were treated in emergency departments. AHT diagnosis was associated with significantly greater medical service use and higher inpatient, outpatient, drug, and total costs for multiple years after the diagnosis. The estimated total medical cost attributable to AHT in the 4 years after diagnosis was $47,952 (95% confidence interval [CI], $40,219-$55,685) per patient with AHT (2012 US dollars) and differed for commercially insured ($38,231 [95% CI, $29,898-$46,564]) and Medicaid ($56,691 [95% CI, $4290-$69,092]) patients. Conclusions: Children continue to have substantial excess medical costs for years after AHT. These estimates exclude related nonmedical costs such as special education and disability that also are attributable to AHT.

Risen, S. R., Suskauer, S. J., DeMatt, E. J., Slomine, B. S., & Salorio, C. F. (2014). Functional outcomes in children with abusive head trauma receiving inpatient rehabilitation compared with children with nonabusive head trauma. *The Journal of Pediatrics, 164*(3), 613-619. DOI: 10.1016/j.jpeds.2013.10.075

In order to compare clinical features and functional outcomes of age and sex matched children with abusive and non-abusive head trauma receiving inpatient rehabilitation, children with abusive head trauma (n = 28) and age, sex matched children with non-abusive head trauma (n = 20) admitted to one inpatient pediatric rehabilitation unit from

1995–2012 were studied. Acute hospitalization and inpatient rehabilitation records were retrospectively reviewed for pertinent clinical data: initial GCS score, signs of increased intracranial pressure, neuroimaging findings, and presence of associated injuries. Functional status at admission to and discharge from inpatient rehabilitation was assessed using the Functional Independence Measure for Children (WeeFIM). Outcome at discharge and outpatient follow-up was described based on attainment of independent ambulation and expressive language. Children with abusive and non-abusive head trauma had similar levels of injury severity although associated injuries were greater in abusive head trauma. Functional impairment upon admission to inpatient rehabilitation was comparable and functional gains during inpatient rehabilitation were similar between groups. More children with non-abusive than abusive head trauma attained independent ambulation and expressive language after discharge from rehabilitation; the difference was no longer significant when only children greater than 12 months of age at injury were examined. There was variability in delay to obtain these skills and quality of gained skills in both groups. Despite more associated injuries, children with abusive head trauma make significant functional gains during inpatient rehabilitation comparable with an age and sex matched sample with non-abusive head trauma. Key functional skills may be gained by children in both groups following discharge from inpatient rehabilitation.

Simonnet, H., Laurent-Vannier, A., Yuan, W., Hully, M., Valimahomed, S., Bourennane, M., & Chevignard, M. (2014). Parents' behavior in response to infant crying: Abusive head trauma education. *Child Abuse & Neglect*, *38,* 1914-1922. DOI:10.1016/j.chiabu.2014.06.002

Abusive head trauma (AHT) is still too common, and probably underestimated. It is the leading cause of death from child abuse. Crying is thought to contribute to the act of shaking. Objectives of this study were to (a) assess parents' knowledge about infant crying, their ability to manage crying, and their knowledge about AHT; and (b) assess the

feasibility and the impact of a simple educational intervention about crying and AHT with parents shortly after their child's birth. A short questionnaire was completed orally by the parents of 190 consecutive newborns in a maternity hospital at day 2 of life. Then, during the routine examination of the child, the pediatrician gave parents a short talk about infant crying and AHT, and a pamphlet. Finally, parents were contacted by phone at 6 weeks for the post-intervention questionnaire assessing their knowledge about crying and AHT. Among 202 consecutive births, parents of 190 children were included (266 parents; 70% mothers) over a 1-month period and answered the pre-intervention questionnaire. The intervention was feasible and easy to provide. Twenty-seven percent of mothers and 36% of fathers had never heard of AHT. At 6 weeks, 183 parents (68% of the sample; 80% mothers) answered the post-intervention questionnaire. Parents' knowledge improved significantly post-intervention. Parents found the intervention acceptable and useful. Health care professionals such as pediatricians or nurses could easily provide this brief talk to all parents during systematic newborn examination.

Binenbaum, G., Christian, C. W., Ichord, R. N., Ying, G. S., Simon, M. A., Romero, K., Pollock, A. N., & Forbes, B. J. (2013). Retinal hemorrhage and brain injury patterns on diffusion weighted magnetic resonance imaging in children with head trauma. *Journal of American Association for Pediatric Ophthalmology and Strabismus, 17*(6), 603-608. DOI:10.1016/j.jaapos.2013.09.002

Purpose: To evaluate associations between retinal hemorrhage severity and hypoxic-ischemic brain injury (HII) patterns by diffusion-weighted magnetic resonance imaging (DW-MRI) in young children with head trauma. Methods: DW-MRI images of a consecutive cohort study of children under age 3 years with inflicted or accidental head trauma who had eye examinations were analyzed by two independent masked examiners for type, severity, and location of primary lesions attributable to trauma, HII secondary to trauma, and mixed injury patterns. Retinal hemorrhage was graded retrospectively on a scale from 1 (none) to 5 (severe). Results: Retinal hemorrhage score was 3–5 in 6 of 7 patients with predominantly post-traumatic HII pattern and 4 of 32 who had traumatic injury

without HII ($P < 0.001$) on DW-MRI imaging. Severe retinal hemorrhage was observed in absence of HII but only in inflicted injury. Retinal hemorrhage severity was correlated with HII severity ($\rho = 0.53$, $P < 0.001$) but not traumatic injury severity ($\rho = -0.10$, $P = 0.50$). HII severity was associated with retinal hemorrhage score 3–5 ($P = 0.01$), but traumatic injury severity was not ($P = 0.37$). Conclusions: During inflicted head injury, a distinct type of trauma occurs causing more global brain injury with HII and more severe retinal hemorrhages. HII is not a necessary factor for severe retinal hemorrhage to develop from inflicted trauma.

Gordy, C., & Kuns, B. (2013). Pediatric abusive head trauma. *Nursing Clinics of North America, 48*(2), 193-201. DOI:10.1016/j.cnur.2013.01.013

Pediatric abusive head trauma is a significant contributor to pediatric morbidity and mortality in the United States. Signs and symptoms can be vague, nonspecific, and difficult to recognize. This article increases the healthcare provider's level of suspicion and ability to recognize early warning signs of abuse. It also addresses evidence-based prevention strategies. This information is useful to nurses, advanced practice nurses, and physicians who work with children and families in any capacity.

Hasbani, D. M., Topjian, A. A., Friess, S. H., Kilbaugh, T. J., Berg, R. A., Christian, C. W., Dlugos, D. J., Huh, J., & Abend, N. S. (2013). Nonconvulsive electrographic seizures are common in children with abusive head trauma. *Pediatric Critical Care Medicine, 14*(7), 709-715. DOI:10.1097/PCC.0b013e3182917b83

In order to determine the prevalence of nonconvulsive seizures in children with abusive head trauma, a retrospective study of children with abusive head trauma undergoing clinically indicated continuous electroencephalographic monitoring was conducted in the PICU of a tertiary care hospital. Children less than or equal to 2 years old with evidence of abusive head trauma determined by neuroimaging, physical examination, and

determination of abuse by the Child Protection Team. Thirty-two children with abusive head trauma were identified with a median age of 4 months. Twenty-one of 32 children (66%) underwent electroencephalographic monitoring. Those monitored were more likely to have a lower admission Glasgow Coma Scale (8 vs 15, p = 0.05) and be intubated (16 vs 2, p = 0.002). Electrographic seizures occurred in 12 of 21 children (57%) and constituted electrographic status epilepticus in 8 of 12 children (67%). Electrographic seizures were entirely nonconvulsive in 8 of 12 children (67%). Electroencephalographic background category (discontinuous and slow-disorganized) and neuroimaging evidence of ischemia were associated with the presence of electrographic seizures. Subjects who had electrographic seizures were no more likely to have clinical seizures at admission, parenchymal imaging abnormalities, or extra-axial imaging abnormalities. Four of 21 (19%) children died prior to discharge; none had electrographic seizures, but all had attenuated-featureless electroencephalographic backgrounds. Follow-up outcome data were available for 16 of 17 survivors at a median duration of 9.5 months following PICU admission, and the presence of electrographic seizures or electrographic status epilepticus was not associated with the Glasgow Outcome Scale score. Electrographic seizures and electrographic status epilepticus are common in children with abusive head trauma. Most seizures have no clinical correlate. Further study is needed to determine whether seizure identification and management improves outcome.

Hymel, K. P., Willson, D. F., Boos, S. C., Pullin, D. A., Homa, K., Lorenz, D. J., Herman, B. E., Graf, J. M., Isaac, R., Armijo-Garcia, V., Narang, S. K., & Pediatric Brain Injury Research Network (PediBIRN) Investigators. (2013). Derivation of a clinical prediction rule for pediatric abusive head trauma. *Pediatric Critical Care Medicine, 14*(2), 210-220. DOI:10.1097/PCC.0b013e3182712b09

The objective was to reduce missed cases of pediatric abusive head trauma (AHT), Pediatric Brain Injury Research Network investigators derived a 4-variable AHT clinical prediction rule (CPR) with sensitivity of .96. Our objective was to validate the screening performance of this AHT CPR in a new, equivalent patient population. We conducted a

prospective, multicenter, observational, cross-sectional study. Applying the same inclusion criteria, definitional criteria for AHT, and methods used in the completed derivation study, Pediatric Brain Injury Research Network investigators captured complete clinical, historical, and radiologic data on 291 acutely head-injured children <3 years of age admitted to PICUs at 14 participating sites, sorted them into comparison groups of abusive and nonabusive head trauma, and measured the screening performance of the AHT CPR. In this new patient population, the 4-variable AHT CPR demonstrated sensitivity of .96, specificity of .46, positive predictive value of .55, negative predictive value of .93, positive likelihood ratio of 1.67, and negative likelihood ratio of 0.09. Secondary analysis revealed that the AHT CPR identified 98% of study patients who were ultimately diagnosed with AHT. Four readily available variables (acute respiratory compromise before admission; bruising of the torso, ears, or neck; bilateral or interhemispheric subdural hemorrhages or collections; and any skull fractures other than an isolated, unilateral, nondiastatic, linear, parietal fracture) identify AHT with high sensitivity in young, acutely head-injured children admitted to the PICU.

Maguire, S. A., Watts, P. O., Shaw, A. D., Holden, S., Taylor, R. H., Watkins, W. J., Mann, M. K., Tempest, V., & Kemp, A. M. (2013). Retinal haemorrhages and related findings in abusive and non-abusive head trauma: A systematic review. *Eye, 27*(1), 28-36. DOI:10.1038/eye.2012.213

Aim: To report the retinal signs that distinguish abusive head trauma (AHT) from non-abusive head trauma (nAHT). Methods: A systematic review of literature, 1950–2009, was conducted with standardised critical appraisal. Inclusion criteria were a strict confirmation of the aetiology, children aged <11 years and details of an examination conducted by an ophthalmologist. Post mortem data, organic disease of eye, and inadequate examinations were excluded. A multivariate logistic regression analysis was conducted to determine odds ratios (OR) and probabilities for AHT. Results: Of the 62 included studies, 13 provided prevalence data (998 children, 504 AHT). Overall, retinal

haemorrhages (RH) were found in 78% of AHT vs 5% of nAHT. In a child with head trauma and RH, the OR that this is AHT is 14.7 (95% confidence intervals 6.39, 33.62) and the probability of abuse is 91%. Where recorded, RH were bilateral in 83% of AHT compared with 8.3% in nAHT. RH were numerous in AHT, and few in nAHT located in the posterior pole, with only 10% extending to periphery. True prevalence of additional features, for example, retinal folds, could not be determined. Conclusions: Our systematic review confirms that although certain patterns of RH were far commoner in AHT, namely large numbers of RH in both the eyes, present in all layers of the retina, and extension into the periphery, there was no retinal sign that was unique to abusive injury. RH are rare in accidental trauma and, when present, are predominantly unilateral, few in number and in the posterior pole.

Niederkrotenthaler, T., Xu, L., Parks, S. E., & Sugerman, D. E. (2013). Descriptive factors of abusive head trauma in young children—United States, 2000–2009. *Child Abuse & Neglect*, *37,* 446-455. DOI:10.1016/j.chiabu.2013.02.002

Abusive head trauma (AHT) is a leading cause of severe injury in maltreated children in the United States. There is little research from nationally representative datasets available to characterize young children who had AHT compared to non-abusive head trauma (NAHT). Using the recent CDC AHT case definition, we performed a retrospective analysis of 2000, 2003, 2006 and 2009 hospitalization data using the Kids' Inpatient Database (KID) from the Healthcare Cost and Utilization Project. Logistic regression was used to compare AHT to NAHT patients <2 years of age. Socio-demographic data and indicators of socioeconomic status (i.e., insurance status and household income), presence of chronic conditions, injury severity (i.e., length of hospital stay and vital status), hospital specialization (i.e., hospital type), hospital region, and season of admission were used as independent variables. A weighted sample of 7,603 AHT and 25,339 NAHT patients was identified. National rates for AHT were 39.8 per 100,000 population for children <1 year and 6.8 per 100,000 population for children 1 year old. Compared to NAHT, children with AHT were more often <1 year of age (adjusted odds ratio [aOR]=2.66; 95% confidence interval

[CI]: 2.35–3.01), male (aOR=1.10; 95% CI: 1.01–1.20), enrolled in Medicaid (aOR=2.78; 95% CI: 2.49–3.11), hospitalized longer (aOR=8.26; 95% CI: 7.24–9.43), died during hospitalization (aOR=5.12; 95% CI: 4.01–6.53), and seen at children's hospitals (aOR=1.97; 95% CI: 1.63–2.38) and hospitals outside the Northeast [aOR=2.65 (95% CI: 2.10–3.33) for the Midwest, 1.90 (95% CI: 1.52–2.38) for the South and 1.93 (95% CI: 1.45–2.57) for the West, respectively]. The results confirm that injuries from AHT are more severe and more often lethal than other head injuries. Socioeconomically disadvantaged families with children <1 year are an important focus for primary prevention. The associations of AHT, compared to NAHT with hospital type and hospital region warrant further investigation. Referral or reporting patterns, or true differences in the incidence may contribute to the identified associations.

Scribano, P. V., Makoroff, K. L., Feldman, K. W., & Berger, R. P. (2013). Association of perpetrator relationship to abusive head trauma clinical outcomes. *Child Abuse & Neglect*, *37,* 771-777. DOI:10.1016/j.chiabu.2013.04.011

The diagnosis of abusive head trauma (AHT) remains a significant public health problem with limited prevention success. Providing protection from further harm is often challenged by the difficulty in identifying the alleged perpetrator (AP) responsible for this pediatric trauma. The objective of this study was to evaluate demographic and clinical characteristics of children with AHT and the relationship between APs and their victims in a large, multi-site sample. Understanding the AHT risks from various caregivers may help to inform current prevention strategies. A retrospective review of all cases of AHT diagnosed by child protection teams (CPT) from 1/1/04 to 6/30/09 at four children's hospitals was conducted. Clinical characteristics of children with AHT injured by non-parental perpetrators (NPP) were compared to parental perpetrators (PP). There were 459 children with AHT; 313 (68%) had an identified AP. The majority of the 313 children were <1 year of age (76%), Caucasian (63%), male (58%), receiving public assistance (80%), and presented without a history of trauma (62%); mortality was 19%. Overall, APs were: father (53%), parent partner (22%), mother (8%), babysitter (8%), other adult caregiver

(5%); NPP accounted for 39% of APs. NPPs were more likely to cause AHT in children ≥1 year (77% vs. 23%, p<0.001) compared to PP. Independent associations to NPP included: older child, absence of a history of trauma, retinal hemorrhages, and male perpetrator gender. While fathers were the most common AP in AHT victims, there is a significant association for increased risk of AHT by NPPs in the older child, who presents with retinal hemorrhages, in the hands of a male AP. Further enhancement of current prevention strategies to address AHT risks of non-parental adults who provide care to children, especially in the post-infancy age seems warranted.

Ward, M. K., King, W. J., & Bennett, S. (2013). From bruises to brain injury: The physician's role in the assessment of inflicted traumatic head injury. *Paediatrics & Child Health*, *18*(8), 423-424. DOI:10.1093/pch/18.8.423

The article presents a case study of a four-month-old boy with two small brown-yellow bruises on the right arm superior to the antecubital fossa. It mentions that the baby was in the emergency department because of vomiting due to each feed for 24 hours without diarrhea & also discusses computed tomography (CT) scan, diagnosis of viral gastroenteritis and baby's hydration status.

Barr, R. G. (2012). Preventing abusive head trauma resulting from a failure of normal interaction between infants and their caregivers. *Proceedings of the National Academy of* Sciences, 109(Supplement 2), 17294-17301. DOI:10.1073/pnas.1121267109

Head trauma from abuse, including shaken baby syndrome, is a devastating and potentially lethal form of infant physical abuse first recognized in the early 1970s. What has been less recognized is the role of the early increase in crying in otherwise normal infants in the first few months of life as a trigger for the abuse. In part, this is because infant crying, especially prolonged unsoothable crying, has been interpreted clinically as something wrong with the infant, the infant's caregiver, or the interactions between them.

Here, we review an alternative developmental interpretation, namely, that the early increase in crying is a typical behavioral development in normal infants and usually does not reflect anything wrong or abnormal. We also review evidence indicating that this normal crying pattern is the most common trigger for abusive head trauma (AHT). Together, these findings point to a conceptualization of AHT as the consequence of a failure in an otherwise common, iterative, and developmentally normal infant–caregiver interaction. They also imply that there is a window of opportunity for prevention of AHT, and potentially other forms of infant abuse, through a public health primary universal prevention strategy aimed at changing knowledge and behaviors of caregivers and society in general concerning normal development of infants and the significance of early increased infant crying. If effective, there may be important implications for prevention of infant abuse nationally and internationally.

Ellingson, C. C., Livingston, J. S., & Fanaroff, J. M. (2012). End-of-life decisions in abusive head trauma. *Pediatrics, 129*(3), 541-547. DOI:10.1542/peds.2011-1988

Abusive head trauma is a significant and tragic cause of morbidity and mortality in infants and its victims often have a poor prognosis. With such high rates of morbidity and mortality, health care providers and parents are often faced with the decision to continue or discontinue life support for an affected child. Sadly, however, this decision becomes complicated when parents are accused of causing the victim-child's current state. In this situation, if life support is withdrawn, criminal charges for the accused may escalate from assault to murder. This escalation of legal charges creates a conflict of interest for accused parents. As a result, parents have a strong incentive to avoid murder charges by using their parental decision-making rights to keep the child alive, even when treatment is deemed futile or inhumane. In this article, we discuss the legal challenges health care providers may face when parents place their interest above their child's. We also propose solutions that give greater deference to the rights and interest of these critically ill children while still preserving protected parental rights.

Friedman, J., Reed, P., Sharplin, P., & Kelly, P. (2012). Primary prevention of pediatric abusive head trauma: A cost audit and cost-utility analysis. *Child Abuse & Neglect, 36*(11-12), 760-770. DOI:10.1016/j.chiabu.2012.07.008

Objectives: To obtain comprehensive, reliable data on the direct cost of pediatric abusive head trauma in New Zealand, and to use this data to evaluate the possible cost–benefit of a national primary prevention program. Methods: A 5 year cohort of infants with abusive head trauma admitted to hospital in Auckland, New Zealand was reviewed. We determined the direct costs of hospital care (from hospital and Ministry of Health financial records), community rehabilitation (from the Accident Compensation Corporation), special education (from the Ministry of Education), investigation and child protection (from the Police and Child Protective Services), criminal trials (from the Police, prosecution and defence), punishment of offenders (from the Department of Corrections) and life-time care for moderate or severe disability (from the Accident Compensation Corporation). Analysis of the possible cost-utility of a national primary prevention program was undertaken, using the costs established in our cohort, recent New Zealand national data on the incidence of pediatric abusive head trauma, international data on quality of life after head trauma, and published international literature on prevention programs. Results: There were 52 cases of abusive head trauma in the sample. Hospital costs totaled $NZ2,433,340, child protection $NZ1,560,123, police investigation $NZ1,842,237, criminal trials $NZ3,214,020, punishment of offenders $NZ4,411,852 and community rehabilitation $NZ2,895,848. Projected education costs for disabled survivors were $NZ2,452,148, and the cost of projected lifetime care was $NZ33,624,297. Total costs were $NZ52,433,864, averaging $NZ1,008,344 per child. Cost-utility analysis resulted in a strongly positive economic with improved health outcomes. Conclusions: Pediatric abusive head trauma is very expensive, and on a conservative estimate the costs of acute hospitalization represent no more than 4% of lifetime direct costs. If shaken baby prevention programs are effective, there is likely to be a strong economic argument for their implementation. This study also provides robust data for future cost–benefit analysis in the field of abusive head trauma prevention.

Parks, S. E., Annest, J. L., Hill, H. A., & Karch, D. L. (2012). *Pediatric abusive head trauma: Recommended definitions for public health surveillance and research*. National Center for Injury Prevention and Control (U.S.). Division of Violence Prevention. https://stacks.cdc.gov/view/cdc/26243

The current report focuses on standard data elements for abusive head trauma—a specific category of child maltreatment that presents unique definitional and measurement challenges. These challenges are discussed followed by a presentation of recommended uniform operational definitions of fatal and nonfatal abusive head trauma based on International Classification of Diseases (ICD-9-CM for morbidity coding and ICD-10 for mortality coding) diagnosis and external- cause-of-injury codes (2001; 2005). Similar processes and formats to that of the Child Maltreatment Surveillance Uniform Definitions and Data Elements have been used in order to maintain consistency and facilitate ease of use.

Parks, S., Sugerman, D., Xu, L., & Coronado, V. (2012). Characteristics of non-fatal abusive head trauma among children in the USA, 2003–2008: Application of the CDC operational case definition to national hospital inpatient data. *Injury Prevention, 18*(6), 392-398. DOI:10.1136/injuryprev-2011-040234

An International Classification of Diseases code-based case definition for non-fatal abusive head trauma (AHT) in children <5 years of age was developed in March 2008 by an expert panel convened at the Centers for Disease Control and Prevention (CDC). This study presents an application of the CDC recommended operational case definition of AHT to US hospital inpatient data to characterise the AHT hospitalisation rate for children <5 years of age. Nationwide Inpatient Sample (NIS) data from the Healthcare Cost and Utilisation Project from 2003 to 2008 were examined. Inspection of the NIS data resulted in the identification of an estimated 10 555 non-fatal AHT hospitalisations with 9595 classified as definite/presumptive AHT and 960 classified as probable AHT. The non-fatal AHT rate was highest among children aged <1 year (32.3 per 100 000) with a peak in hospitalisations between 1 and 3 months of age. Non-fatal AHT hospitalisation rates for

children <2 years of age were higher for boys (21.9 per 100 000) than girls (15.3 per 100 000). The non-fatal AHT hospitalisation rate showed little variation across seasons. To reduce the burden of AHT in the USA, a preventable public health problem, concerted prevention efforts targeting populations at risk should be implemented. This report demonstrates a model procedure for using the new CDC definition for public health surveillance and research purposes. Such findings can be used to inform parents and providers about AHT (eg, dangers of shaking, strategies for managing infant crying) as well as to monitor better the impact of prevention strategies over time.

Piteau, S. J., Ward, M. G., Barrowman, N. J., & Plint, A. C. (2012). Clinical and radiographic characteristics associated with abusive and nonabusive head trauma: A systematic review. *Pediatrics*, *130*(2), 315-323. DOI:10.1542/peds.2011-1545

The objective was to systematically review the literature to determine which clinical and radiographic characteristics are associated with abusive head trauma (AHT) and nonabusive head trauma (nAHT) in children. We searched MEDLINE, EMBASE, PubMed, conference proceedings, and reference lists to identify relevant studies. Two reviewers independently selected studies that compared clinical and/or radiographic characteristics including historical features, physical exam and imaging findings, and presenting signs or symptoms in hospitalized children ≤6 years old with AHT and nAHT. Twenty-four studies were included. Meta-analysis was complicated by inconsistencies in the reporting of characteristics and high statistical heterogeneity. Notwithstanding these limitations, there were 19 clinical and radiographic variables that could be meta-analyzed and odds ratios were determined for each variable. In examining only studies deemed to be high quality, we found that subdural hemorrhage(s), cerebral ischemia, retinal hemorrhage(s), skull fracture(s) plus intracranial injury, metaphyseal fracture(s), long bone fracture(s), rib fracture(s), seizure(s), apnea, and no adequate history given were significantly associated with AHT. Epidural hemorrhage(s), scalp swelling, and isolated skull fracture(s) were significantly associated with nAHT. Subarachnoid

hemorrhage(s), diffuse axonal injury, cerebral edema, head and neck bruising, any bruising, and vomiting were not significantly associated with either type of trauma. Clinical and radiographic characteristics associated with AHT and nAHT were identified, despite limitations in the literature. This systematic review also highlights the need for consistent criteria in identifying and reporting clinical and radiographic characteristics associated with AHT and nAHT.

Robertson, B. D., McConnel, C. E., & Green, S. (2012). Charges associated with pediatric head injuries: A five-year retrospective review of 41 pediatric hospitals in the US. *Journal of Injury and Violence Research*, *5*(1), 51-60. DOI:10.5249/jivr.v5i1.205

Brain injuries are a significant public health problem, particularly among the pediatric population. Brain injuries account for a significant portion of pediatric injury deaths, and are the highest contributor to morbidity and mortality in the pediatric and young adult populations. Several studies focus on particular mechanisms of brain injury and the cost of treating brain injuries, but few studies exist in the literature examining the highest contributing mechanisms to pediatric brain injury and the billed charges associated with them. Data were extracted from the Pediatric Health Information System (PHIS) from member hospitals on all patients admitted with diagnosed head injuries and comparisons were made between ICU and non-ICU admissions. Collected data included demographic information, injury information, total billed charges, and patient outcome. Motor vehicle collisions, falls, and assaults/abuse are the three highest contributors to brain injury in terms of total numbers and total billed charges. These three mechanisms of injury account for almost $1 billion in total charges across the five-year period, and account for almost half of the total charges in this dataset over that time period. Research focusing on brain injury should be tailored to the areas of the most pressing need and the highest contributing factors. While this study is focused on a select number of pediatric hospitals located throughout the country, it identifies significant contributors to head injuries, and the costs associated with treating them.

Shein, S. L., Bell, M. J., Kochanek, P. M., Tyler-Kabara, E. C., Wisniewski, S. R., Feldman, K., Makoroff, K., Scribano, P. V. & Berger, R. P. (2012). Risk factors for mortality in children with abusive head trauma. *The Journal of Pediatrics, 161*(4), 716-722. DOI:10.1016/j.jpeds.2012.03.046

We sought to identify risk factors for mortality in a large clinical cohort of children with abusive head trauma. Bivariate analysis and multivariable logistic regression models identified demographic, physical examination and radiologic findings associated with in-hospital mortality of children with abusive head trauma at four pediatric centers. An initial Glasgow Coma Scale (GCS) ≤ 8 defined severe abusive head trauma. Data are shown as OR (95% CI). Analysis included 386 children with abusive head trauma. Multivariable analysis showed children with initial GCS either 3 or 4 – 5 had increased mortality versus children with GCS 12 – 15 and 15.6, respectively). Additionally, retinal hemorrhage (RH), intraparenchymal hemorrhage and cerebral edema were independently associated with mortality. In the subgroup with severe abusive head trauma and RH (n = 117), cerebral edema and initial GCS of 3 or 4 – 5 were independently associated with mortality. Chronic subdural hematoma was independently associated with survival. Low initial GCS score, RH, intraparenchymal hemorrhage and cerebral edema are independently associated with mortality in abusive head trauma. Knowledge of these risk factors may enable researchers and clinicians to improve the care of these vulnerable children.

Altman, R. L., Canter, J., Patrick, P. A., Daley, N., Butt, N. K., & Brand, D. A. (2011). Parent education by maternity nurses and prevention of abusive head trauma. *Pediatrics*, *128*(5), e1164-e1172. DOI:10.1542/peds.2010-3260

A consortium of the 19 community hospitals and 1 tertiary care children's hospital that provide maternity care in the New York State Hudson Valley region implemented a program to teach parents about the dangers of shaking infants and how to cope safely with an infant's crying. This study evaluated the effectiveness of the program in reducing the frequency of shaking injuries. The educational program, which was delivered by maternity nurses, included a leaflet explaining abusive head trauma ("shaken baby

syndrome") and how to prevent it, an 8-minute video on the subject, and a statement signed by parents acknowledging receipt of the information and agreeing to share it with others who will care for the infant. Poisson regression analysis was used to compare the frequency of shaking injuries during the 3 years after program implementation with the frequency during a 5-year historical control period. Sixteen infants who were born in the region during the 8-year study period were treated at the children's hospital for shaking injuries sustained during their first year of life. Of those infants, 14 were born during the 5-year control period and 2 during the 3-year postimplementation period. The decrease from 2.8 injuries per year (14 cases in 5 years) to 0.7 injuries per year (2 cases in 3 years) represents a 75.0% reduction. Parent education delivered in the hospital by maternity nurses reduces newborns' risks of sustaining an abusive head injury resulting from shaking during the first year of life.

Berger, R. P., Fromkin, J. B., Stutz, H., Makoroff, K., Scribano, P. V., Feldman, K., Tu, L. C., & Fabio, A. (2011). Abusive head trauma during a time of increased unemployment: A multicenter analysis. *Pediatrics*, *128*(4), 637-643. DOI:10.1542/peds.2010-2185

The objective was to evaluate the rate of abusive head trauma (AHT) in 3 regions of the United States before and during an economic recession and assess whether there is a relationship between the rate of AHT and county-level unemployment rates. Clinical data were collected for AHT cases diagnosed in children younger than 5 years from January 1, 2004 until June 30, 2009, by hospital-based child protection teams within 3 geographic regions. The recession was defined as December 1, 2007 through June 30, 2009. Quarterly unemployment rates were collected for every county in which an AHT case occurred. During the 5½-year study period, a total of 422 children were diagnosed with AHT in a 74-county region. The overall rate of AHT increased from 8.9 in 100 000 (95% confidence interval [CI]) before the recession to 14.7 in 100 000 (95% CI) during the recession. There was no difference in the clinical characteristics of subjects in the prerecession versus recession period. There was no relationship between the rate of AHT and county-level

unemployment rates. The rate of AHT increased significantly in 3 distinct geographic regions during the 19 months of an economic recession compared with the 47 months before the recession. This finding is consistent with our understanding of the effect of stress on violence. Given the high morbidity and mortality rates for children with AHT, these results are concerning and suggest that prevention efforts might need to be increased significantly during times of economic hardship.

Kemp, A. M. (2011). Abusive head trauma: Recognition and the essential investigation. *Archives of Disease in Childhood-Education & Practice Edition*, *96*(6), 202-208. DOI:10.1136/adc.2009.170449

Abusive head trauma (AHT) affects one in 4000–5000 infants every year and is one of the most serious forms of physical child abuse that has a high associated mortality and morbidity. Differentiating this form of abuse from another potential cause of brain injury is of utmost importance to the welfare of the child concerned and it is essential that the condition is correctly diagnosed. This article describes the evidence base behind the associated historical, clinical and neuroradiological features of AHT and spinal injury in physical abuse and sets out an algorithm of essential investigations that should be performed in any infant or young child where AHT is suspected.

Kemp, A. M., Jaspan, T., Griffiths, J., Stoodley, N., Mann, M. K., Tempest, V., & Maguire, S. A. (2011). Neuroimaging: What neuroradiological features distinguish abusive from non-abusive head trauma? A systematic review. *Archives of Disease in Childhood*, *96*(12), 1103-1112. DOI:10.1136/archdischild-2011-300630

The objective was to identify the evidence base behind the neuroradiological features that differentiate abusive head trauma (AHT) from non-abusive head trauma (nAHT). Literature search of 14 databases, websites, textbooks, conference abstracts and references (1970–February 2010). Studies had two independent reviews (three if disputed) and critical appraisal. Patients Primary comparative studies of children <11 years old

hospitalised with AHT and nAHT diagnosed on CT or MRI. Main outcome measures Neuroradiological features that differentiated AHT from nAHT. 21 studies of children predominantly <3 years old were analysed. Subdural haemorrhages (SDH) were significantly associated with AHT (OR 8.2, 95% CI 6.1 to 11). Subarachnoid haemorrhages were seen equally in AHT and nAHT and extradural haemorrhages (EDH) were significantly associated with nAHT (OR for AHT 0.1, 95% CI 0.07 to 0.18). Multiple (OR 6, 95% CI 2.5 to 14.4), interhemispheric (OR 7.9, 95% CI 4.7 to 13), convexity (OR 4.9, 95% CI 1.3 to 19.4) and posterior fossa haemorrhages (OR 2.5, 95% CI 1 to 6) were associated with AHT. Hypoxic-ischaemic injury (HII) (OR 3.7, 95% CI 1.4 to 10) and cerebral oedema (OR 2.2, 95% CI 1.0 to 4.5) were significantly associated with AHT, while focal parenchymal injury was not a discriminatory feature. SDH of low attenuation were more common in AHT than in nAHT. Multiple SDH over the convexity, interhemispheric haemorrhages, posterior fossa SDH, HII and cerebral oedema are significantly associated with AHT and should be considered together with clinical features when identifying the condition.

Maguire, S. A., Kemp, A. M., Lumb, R. C., & Farewell, D. M. (2011). Estimating the probability of abusive head trauma: A pooled analysis. *Pediatrics*, *128*(3), e550-e564. DOI:10.1542/peds.2010-2949

The objective was to determine which combinations of clinical features assist in distinguishing abusive head trauma (AHT) from nonabusive head trauma. Individual patient data from 6 comparative studies of children younger than 3 years with intracranial injury were analyzed to determine the association between AHT and combinations of apnea; retinal hemorrhage; rib, skull, and long-bone fractures; seizures; and head and/or neck bruising. An aggregate analysis of data from these studies used multiple imputation of combined clinical features using a bespoke hotdeck imputation strategy, which accounted for uncertainty arising from missing information. Analyzing 1053 children (348 had AHT), excluding nonsignificant variables (gender, age, skull fractures), for a child with an intracranial injury and 1 or 2 of the 6 features, the positive

predictive value (PPV) of AHT varies from 4% to 97% according to the different combinations. Although rarely recorded, apnea is significantly associated with AHT (odds ratio [OR]: 6.89 [confidence interval: 2.08–22.86]). When rib fracture or retinal hemorrhage was present with any 1 of the other features, the OR for AHT is >100 (PPV > 85%). Any combination of 3 or more of the 6 significant features yielded an OR of >100 (PPV for AHT > 85%). Probabilities of AHT can be estimated on the basis of different combinations of clinical features. The model could be further developed in a prospective large-scale study, with an expanded clinical data set, to contribute to a more refined tool to inform clinical decisions about the likelihood of AHT.

Narang, S. (2011). Daubert Analysis of Abusive Head Trauma/Shaken Baby Syndrome, Part II. An examination of the differential diagnosis. *Houston Journal of Health Law & Policy, 11*, 505.

For reasons inexplicable to many physicians, and unbeknownst to many others, the diagnosis of Abusive Head Trauma/Shaken Baby Syndrome (AHT/SBS) remains a lightning rod for controversy. Recent legal commentary has suggested that there is insufficient science girding this diagnosis. In Part I of the analysis on this topic, Dr. Narang presented a relatively comprehensive analysis of the current science surrounding AHT/SBS, and more specifically, surrounding two of the most common injuries found in AHT/SBS — subdural hemorrhages (SDHs) and retinal hemorrhages (RHs). Dr. Narang asserted that the diagnosis of AHT is supported by "at least 700 peer-reviewed, clinical medical articles comprising thousands of pages of medical literature, published by over one thousand different medical authors, from at least twenty-eight different countries." In response to this article, Findley et al reiterated an insufficient scientific basis for the diagnosis, citing, amongst other things, logical fallacies (such as "circularity" and "the prosecutor's fallacy") as premises for the fallacious literature. In Part II of this analysis, Narang et al swing the microscope in the opposite direction. Narang et al scrutinize the "differential diagnosis" of AHT, and the differential diagnosis methodology itself, to

ascertain whether the scientific process of coming to the AHT diagnosis meets reliability and relevancy criteria under Daubert.

Adamsbaum, C., Grabar, S., Mejean, N., & Rey-Salmon, C. (2010). Abusive head trauma: Judicial admissions highlight violent and repetitive shaking. *Pediatrics*, *126*(3), 546-555. DOI:10.1542/peds.2009-3647

Confessions are uncommon in abusive head trauma (AHT) cases, and there is debate over whether shaking alone can cause the injuries characteristic of AHT. The objective of this article is to correlate legal statements by perpetrators with medical documentation to offer insights into the mechanism of injury. In this retrospective observational study we examined forensic evidence from 112 cases referred for AHT over a 7-year period. We compared 29 cases in which a perpetrator confessed to violence toward the child with 83 cases in which there was no confession. Inclusion criteria were subdural hematoma (SDH) on computed tomography and perpetrator admission of a causal relationship between the violence inflicted and the child's symptoms. Groups were compared by using Student's *t* test for age and Fisher's exact test for gender, death, fractures, retinal hemorrhages, ecchymoses, symptoms, and SDH patterns. All medical records from birth to diagnosis, imaging studies, and written investigation reports were reviewed. All confessions came from forensic investigations. There was no statistically significant difference between the 2 groups for any of the variables studied. Shaking was described as extremely violent (100%) and was repeated (55%) from 2 to 30 times (mean: 10) because it stopped the infant's crying (62.5%). Impact was uncommon (24%). No correlation was found between repeated shaking and SDH densities. This unique forensic case series confirms the violence of shaking. The high frequency of habitual AHT is a strong argument for reporting suspected cases to judicial authorities and helps to explain the difficulty in dating the injuries.

Bhardwaj, G., Chowdhury, V., Jacobs, M. B., Moran, K. T., Martin, F. J., & Coroneo, M. T. (2010). A systematic review of the diagnostic accuracy of ocular signs in pediatric abusive head trauma. *Ophthalmology*, *117*(5), 983-992. DOI:10.1016/j.ophtha.2009.09.040

The objective was to review systematically the diagnostic accuracy of various ocular signs for pediatric abusive head trauma (AHT). Intraocular hemorrhages (IOH), perimacular retinal folds, traumatic retinoschisis and optic nerve sheath hemorrhages have been reported as cardinal signs of AHT. The evidence base supporting the accuracy of this interpretation, however, has not been systematically reviewed. A systematic keyword search of MEDLINE, EMBASE, and Evidence-Based Medicine Reviews was conducted for original studies reporting ocular findings in AHT. Articles were graded using a checklist for systematic reviews of diagnostic accuracy. The initial search yielded 971 articles, of which 55 relevant studies were graded, and 20 studies met inclusion criteria and were included in the review. The overall sensitivity of IOH for AHT was 75% and their specificity was 94%. Intraretinal hemorrhage at the posterior pole was the most common finding, although extensive, bilateral, and multilayered IOH were the most specific for AHT. Optic nerve sheath hemorrhages had a sensitivity and specificity for AHT of 72% and 71%, respectively. Traumatic retinoschisis and perimacular retinal folds were reported in 8% and 14% of AHT, respectively, but were not reported in other conditions. Prospective, consecutive studies confirm that IOH in infants—particularly bilateral, extensive, are highly specific for AHT. Optic nerve sheath hemorrhages are significantly more common in AHT than in other conditions, in autopsy studies. Traumatic retinoschisis and perimacular folds are present in a minority of AHT, but rarely seen in other conditions.

Levin, A. V. (2010). Retinal hemorrhage in abusive head trauma. *Pediatrics*, *126*(5), 961-970. DOI:10.1542/peds.2010-1220

Retinal hemorrhage is a cardinal manifestation of abusive head trauma. Over the 30 years since the recognition of this association, multiple streams of research, including

clinical, postmortem, animal, mechanical, and finite element studies, have created a robust understanding of the clinical features, diagnostic importance, differential diagnosis, and pathophysiology of this finding. The importance of describing the hemorrhages adequately is paramount in ensuring accurate and complete differential diagnosis. Challenges remain in developing models that adequately replicate the forces required to cause retinal hemorrhage in children. Although questions, such as the effect of increased intracranial pressure, hypoxia, and impact, are still raised, clinicians can confidently rely on a large and solid evidence base when assessing the implications of retinal hemorrhage in children with concern of possible child abuse.

Chiesa, A., & Duhaime, A. C. (2009). Abusive head trauma. *Pediatric Clinics of North America*, *56*(2), 317-331. DOI:10.1016/j.pcl.2009.02.001

Child physical abuse that results in injury to the head or brain has been described using many terms, including battered child syndrome, whiplash injuries, shaken infant or shaken impact syndrome, and nonmechanistic terms such as abusive head trauma or nonaccidental trauma. These injuries sustained by child abuse victims are discussed in detail in this article, including information about diagnosis, management and outcomes. The use of forensics, imaging studies, and associated injuries are also detailed.

Maguire, S., Pickerd, N., Farewell, D., Mann, M. K., Tempest, V., & Kemp, A. M. (2009). Which clinical features distinguish inflicted from non-inflicted brain injury? A systematic review. *Archives of Disease in Childhood*, *94*(11), 860-867. DOI:10.1136/adc.2008.150110

A systematic review of the scientific literature to define clinical indicators distinguishing inflicted (iBI) from non-inflicted brain injury (niBI). A literature search of 20 electronic databases, websites, references and bibliographies from 1970–2008 was carried out. Relevant studies were independently reviewed by two trained reviewers. Inclusion criteria

included primary comparative studies of iBI and niBI in children aged ,18 years, with high surety of diagnosis describing key clinical features. Multilevel logistic regression analysis was conducted, determining the positive predictive value (PPV) and odds ratios (OR) with p values for retinal haemorrhage, rib/long bone/skull fractures, apnoea, seizures and bruising to head/neck. 8151 studies were identified, 320 were reviewed and 14 included, representing 1655 children, 779 with iBI. Gender was not a discriminatory feature. In a child with intracranial injury, apnoea and retinal haemorrhage were the features most predictive of iBI. Rib fractures had a similar PPV to retinal haemorrhages, but there were less data for analysis. Seizures and long bone fractures were not discriminatory, and skull fracture and head/neck bruising were more associated with niBI, although not significantly so. This systematic review shows that apnoea and retinal haemorrhage have a high odds ratio for association with iBI. This review identifies key features that should be recorded in the assessment of children where iBI is suspected and may help clinicians to define the likelihood of iBI.

Oral, R., Yagmur, F., Nashelsky, M., Turkmen, M., & Kirby, P. (2008). Fatal abusive head trauma cases: Consequence of medical staff missing milder forms of physical abuse. *Pediatric Emergency Care*, *24*(12), 816-821. DOI:10.1097/PEC.0b013e31818e9f5d

Missed diagnosis of child abuse may lead to chronic abuse with potential for death. This paper reports 3 such cases. This is a retrospective chart review of 38 cases diagnosed as abusive head trauma between 2004 and 2006 at a university hospital. We sought to identify fatal cases with a past medical history of physical abuse that was missed by the medical staff. 3 cases (7.9%) had a past medical history of physical abuse that was missed by the medical staff. Infants were 2 males and 1 female. Their ages were 2.5, 3.5, and 6 months, respectively. Missed abuse episodes involved rib fractures, a tibial fracture, and a shaking episode, respectively. The intervals that had elapsed between the missed and the fatal abuse episodes were 24 hours, 12 days, and 6 weeks, respectively.

Perpetrators of fatal head trauma were all biological fathers. One pled guilty, and 2 were convicted of involuntary manslaughter. The infants were in the care of the perpetrators of the fatal abuse episodes at the time the missed abuse episodes occurred. Physicians assessing children, especially infants, should be alert to indicators of abusive trauma to recognize abuse early on. Including abusive trauma in the differential diagnostic list and taking appropriate steps to rule out or confirm the diagnosis are of paramount importance in establishing child protective services and preventing further abuse and neglect that may at times be fatal.

Salehi-Had, H., Brandt, J. D., Rosas, A. J., & Rogers, K. K. (2006). Findings in older children with abusive head injury: Does shaken-child syndrome exist? *Pediatrics*, *117*(5), e1039-e1044. DOI:10.1542/peds.2005-0811

Shaken-baby syndrome (SBS) has been hypothesized to occur after shaking by an adult during the first 2 years of life. We wondered whether it is possible to achieve rotational forces sufficient to cause SBS-like injuries in children >2 years of age. The present study describes cases of child abuse in older children who presented with the classic ophthalmologic and intracranial findings of SBS. In this case series, 4 cases of older children (2.5–7 years old) who died from abusive head injuries and who had diffuse retinal hemorrhages identified antemortem were selected for review. The cases were abstracted from hospital charts, records from autopsies, coroners' and district attorneys' offices, and court transcripts. In all 4 cases the history provided by the primary caregiver did not match the severity of the injuries. 3 case subjects presented with patterned bruises. Multilayered retinal hemorrhages and acute subdural hematoma were observed in all 4 cases. At autopsy, diffuse axonal injury was evident in 3 of the 4 cases; all 4 cases had optic nerve sheath hemorrhages. None of the victims had skeletal fractures on radiologic examination or at autopsy. This case series demonstrates that it is possible to observe SBS-like retinal and central nervous system findings in the older and heavier child. Our

findings underscore the need for providers to consider intentional shaking as a mechanism of injury in the evaluation of abusive head injury in older children.

Tung, G. A., Kumar, M., Richardson, R. C., Jenny, C., & Brown, W. D. (2006). Comparison of accidental and nonaccidental traumatic head injury in children on noncontrast computed tomography. *Pediatrics*, *118*(2), 626-633. DOI:10.1542/peds.2006-0130

Mixed-density convexity subdural hematoma and interhemispheric subdural hematoma suggest nonaccidental head injury. The purpose of this retrospective observational study is to investigate subdural hematoma on noncontrast computed tomography in infants with nonaccidental head injury and to compare these findings in infants with accidental head trauma for whom the date of injury was known. 2 blinded, independent observers retrospectively reviewed computed tomography scans with subdural hematoma performed on the day of presentation on 9 infant victims of nonaccidental head injury (mean age: 6.8 months; range: 1–25 months) and on 38 infants (mean age: 4.8 months; range: newborn to 34 months) with accidental head trauma. Homogeneous hyperdense subdural hematoma was significantly more common in children with accidental head trauma (28 of 38 [74%]; nonaccidental head trauma: 3 of 9 [33%]), whereas mixed-density subdural hematoma was significantly more common in cases of nonaccidental head injury (6 of 9 [67%]; accidental head trauma: 7 of 38 [18%]). Twenty-two (79%) subdural hematomas were homogeneously hyperdense on noncontrast computed tomography performed within 2 days of accidental head trauma, one (4%) was homogeneous and isodense compared to brain tissue, one (4%) was homogeneous and hypodense, and four (14%) were mixed-density. There was no statistically significant difference in the proportion of inter-hemispheric subdural hematoma, epidural hematoma, calvarial fracture, brain contusion, or subarachnoid hemorrhage. Homogeneous hyperdense subdural hematoma is more frequent in cases of accidental head trauma. Mixed-density subdural hematoma is more frequent in cases of

nonaccidental head injury but may be observed within 48 hours of accidental head trauma. Interhemispheric subdural hematoma is not specific for inflicted head injury.

Biron, D., & Shelton, D. (2005). Perpetrator accounts in infant abusive head trauma brought about by a shaking event. *Child Abuse & Neglect*, *29*(12), 1347-1358. DOI:10.1016/j.chiabu.2005.05.003

The objective was to analyze perpetrator and medical evidence collected during investigations of infant abusive head trauma (IAHT), with a view to identifying cases where injuries were induced by shaking in the absence of any impact and documenting the response of infant victims to a violent shaking event. A retrospective study was undertaken of IAHT cases investigated by the Queensland Police Service over a 10-year period. Cases of head trauma involving subdural and/or subarachnoid hematoma and retinal hemorrhages, in the absence of any evidence of impact, were defined as shaking-induced. Perpetrator statements were then examined for further evidence to support the shaking hypothesis and for descriptions of the victim's immediate response to a shaking event. From a total of 52 serious IAHT cases, 13 (25%) were found to have no medical or observer evidence of impact. In 5 of those 13 cases, there was a statement by the perpetrator to the effect that the victim was subjected to a shaking event. In several cases both with and without evidence of associated impact, perpetrator accounts described an immediate neurological response on the part of the victim. The study confirms that IAHT resulting in death or serious neurological impairment can be induced by shaking alone. In cases where the infant's medical condition was adequately described, the symptoms of head injury presented immediately.

Dias, M. S., Smith, K., Mazur, P., Li, V., & Shaffer, M. L. (2005). Preventing abusive head trauma among infants and young children: A hospital-based, parent education program. *Pediatrics*, *115*(4), e470-e477. DOI:10.1542/peds.2004-1896

Abusive head injuries among infants (shaken infant or shaken impact syndrome) represent a devastating form of child abuse. An effective prevention program that reduces the incidence of abusive head injuries could save both lives and the costs of caring for victims. We wished to determine whether a comprehensive, regional, hospital-based, parent education program, administered at the time of the child's birth, could be successfully implemented and to examine its impact on the incidence of abusive head injuries among infants <36 months of age. All hospitals that provide maternity care in an 8-county region of western New York State participated in a comprehensive regional program of parent education about violent infant shaking. The program was administered to parents of all newborn infants before the infant's discharge from the hospital. The hospitals were asked to provide mothers and, whenever possible, fathers or father figures with information describing the dangers of violent infant shaking and providing alternative responses to persistent infant crying and to have both parents sign voluntarily a commitment statement (CS) affirming their receipt and understanding of the materials. Program compliance was assessed by documenting the number of CSs signed by parents and returned by participating hospitals. Follow-up telephone interviews were conducted with a randomized 10% subset of parents, 7 months after the child's birth, to assess parents' recall of the information. Finally, the regional incidence of abusive head injuries among infants and children <36 months of age during the program (study group) was contrasted with the incidence during the 6 preceding years (historical control group). During the first 5.5 years of the program, 65 205 CSs were documented, representing 69% of the 94 409 live births in the region during that time; 96% of CSs were signed by mothers and 76% by fathers/father figures. Follow-up telephone surveys 7 months later suggested that >95% of parents remembered having received the information. The incidence of abusive head injuries decreased by 47%, from 41.5 cases during the 6-year control period to 22.2 cases during the 5.5-year study period. No

comparable decrease was seen in the Commonwealth of Pennsylvania during the years 1996–2002, which bracketed the control and study periods in western New York State. A coordinated, hospital-based, parent education program, targeting parents of all newborn infants, can reduce significantly the incidence of abusive head injuries among infants and children <36 months of age.

Bechtel, K., Stoessel, K., Leventhal, J. M., Ogle, E., Teague, B., Lavietes, S., Banyas, B.,Allen, K., Dziura, J., & Duncan, C. (2004). Characteristics that distinguish accidental from abusive injury in hospitalized young children with head trauma. *Pediatrics*, *114*(1), 165-168. DOI:10.1542/peds.114.1.165

The objective was to describe the clinical features that distinguish accidental from abusive head injury in hospitalized children <24 months of age.. Prospective study of children <24 months of age hospitalized for head injury between August 1, 2000, and October 31, 2002. During hospitalization, children had computed tomographic scans of the brain, serial neurologic examinations, dilated ophthalmoscopic eye examinations, evaluation by a social worker, and, in some cases, a child abuse specialist. The main outcome measure was the proportion of children in each group with retinal hemorrhages (RHs). Secondary outcome measures were the proportion of children in each group who had vitreous hemorrhage; abnormal mental status on presentation; seizures; scalp hematomas; need for anticonvulsants; and operative procedures such as subdural tap, craniotomy, ventriculostomy, tracheostomy, and gastrostomy. Eighty-seven children were prospectively enrolled. Fifteen children were classified as having abusive head injury, and 72 were classified as having accidental head injury. Five children, all in the accidental head injury group, were excluded from statistical analysis, because they did not have a dilated ophthalmoscopic examination during their hospitalization. Thus 82 children were included in the statistical analysis. There were no significant differences between the 2 groups with respect to mean age, gender, or ethnicity. RHs were more likely to be seen in children with abusive head injury (60% vs 10%) and were more likely to be

bilateral (40% vs 1.5%). Pre-RHs were more likely to be seen in children with abusive head injury (30% vs 0%). Premacular RHs and RHs that extended to the periphery of the retina were also more likely to be seen in children with abusive head injury (20% vs 0% and 27% vs 0%, respectively). Of the 7 children with accidental head injury who had RHs, 6 had unilateral RHs. Children with abusive head injury were more likely to have seizures (53% vs 6%) and an abnormal mental status on initial presentation (53% vs 1%). Children with accidental head injury were more likely to have scalp hematomas (6.7% vs 49%). RHs are seen more often in abusive head injury and often are bilateral and involve the preretinal layer. Children with abusive head injury were more likely to have RHs that cover the macula and extend to the periphery of the retina. Unilateral RHs can be seen in children with accidental head injury. Children with abusive head injury were more likely to present with abnormal mental status and seizures, whereas children with accidental head injury were more likely to have scalp hematomas. Such characteristics may be useful to distinguish accidental from abusive head trauma in children <24 months of age.

Keenan, H. T., Runyan, D. K., Marshall, S. W., Nocera, M. A., & Merten, D. F. (2004). A population-based comparison of clinical and outcome characteristics of young children with serious inflicted and noninflicted traumatic brain injury. *Pediatrics, 114*(3), 633-639. DOI:10.1542/peds.2003-1020-L

Diagnosing inflicted traumatic brain injury (TBI) in young children is difficult in practice. Comparisons of children with inflicted and non-inflicted TBI may help to identify markers of inflicted TBI. The objective of this study was to compare inflicted and noninflicted TBI in terms of presenting complaints, clinical features, and hospital outcomes. The presenting complaint, clinical finding, hospital course, and outcome of all children who were aged 2 years or younger in North Carolina and were admitted to a pediatric intensive care unit or died with a TBI in 2000 and 2001 were reviewed. Clinical presentation and injury types were compared between children with inflicted and noninflicted TBI. Risk ratios were used to compare clinical and outcome characteristics between the 2 groups. Among survivors,

multivariate binomial regression was used to examine the adjusted risk of a poor outcome dependent on injury type. A total of 80 (52.6%) children had inflicted and 72 (47.3%) children had noninflicted TBI. Children with noninflicted TBI were more likely to present to the emergency department asymptomatic (44.8% vs 8.3%) and to have a specific history of trauma than children with inflicted TBI. Retinal hemorrhage, metaphyseal fracture, rib fracture, and subdural hemorrhage were more commonly found in children with inflicted compared with noninflicted TBI. Skeletal survey and ophthalmologic examination combined would have missed 8 (10.0%) inflicted TBI cases. Clinicians should not rule out inflicted TBI on the basis of skeletal survey and ophthalmoscopy alone but should proceed to computed tomography and/or magnetic resonance imaging.

Altman, R. L., Brand, D. A., Forman, S., Kutscher, M. L., Lowenthal, D. B., Franke, K. A., & Mercado, V. V. (2003). Abusive head injury as a cause of apparent life-threatening events in infancy. *Archives of Pediatrics & Adolescent Medicine, 157*(10), 1011-1015. DOI:10.1001/archpedi.157.10.1011

An *apparent life-threatening event* (ALTE) refers to the sudden occurrence of a breathing abnormality, color change, or alteration in muscle tone or mental status in an infant. Several patients with ALTEs admitted to our institution were found to have sustained abusive head injuries. To systematically examine the possible causes of ALTEs and their relative frequencies. Prospective consecutive case series of 243 infants younger than 12 months admitted to a tertiary care academic medical center for evaluation of an ALTE during a 32-month interval. Thirty-five different causes of ALTEs were identified. Six subjects (2.5%) were diagnosed as having abusive head injuries, or 1 admission every 5 months. Three patients died in the hospital, 2 of whom were diagnosed as having abusive head injuries. A wide spectrum of diseases and disorders can precipitate an ALTE. Among them, abusive head injury, a recently recognized cause, occurs frequently enough to obligate its inclusion in the differential diagnosis. An ophthalmologic evaluation with

dilated fundus examination and cranial imaging should therefore be considered early in the investigation unless another cause becomes apparent soon after admission.

Donohoe, M. (2003). Evidence-based medicine and shaken baby syndrome: Part I: Literature review, 1966–1998. *The American Journal of Forensic Medicine and Pathology*, *24*(3), 239-242. DOI:10.1097/01.paf.0000083635.85457.97

Ricci, L., Giantris, A., Merriam, P., Hodge, S., & Doyle, T. (2003). Abusive head trauma in Maine infants: Medical, child protective, and law enforcement analysis. *Child Abuse & Neglect*, *27*(3), 271-283. DOI:10.1016/S0145-2134(03)00006-1

The objective was to collect and compare the results of medical, child protective, and law enforcement evaluation of a sample of Maine children who were victims of abusive head trauma (AHT) in order to describe the clinical and evaluative characteristics as they relate to victims, families and perpetrators of such trauma and to improve the professional response to AHT. Retrospective chart review of medical, child protective, and law enforcement records of all AHT victims admitted to 2 tertiary care hospitals in Maine or seen by the state medical examiner from 1991 to 1994. Nineteen children (age range 2 weeks to 17 months) were identified as victims of AHT (out of a total of 94 head trauma admissions) accounting for 20 hospitalizations during the study period. There was a history of prior injury in 30%, history of prior medical evaluations for possibly abuse related problems in 65%, while, on presentation, 75% had evidence or history of prior injury. The hospitals notified child protective services (CPS) in all 20 cases and correctly identified abuse in 18 (90%). Parental risk factors for abuse identified in CPS records included substance abuse (53%), domestic violence (42%), criminal history (32%), unrealistic expectations (42%), and attachment problems (32%). However, risk factors were inadequately assessed in 53% of homes. Law enforcement identified a likely perpetrator in 79% of cases and in the majority the identified suspect was the father. In the 15 cases where a perpetrator was identified by law enforcement, that person was alone with the

child at symptom onset in 14 (93%). The medical response, at least at the inpatient level, was generally well done with regard to suspicion and reporting. Cases are possibly being missed at the outpatient level. Child protective risk assessment was limited overall yet in a third of the homes where AHT occurred, few if any risk factors were present to aid in identification and prevention. Law enforcement results suggest that a primary suspect for AHT is the caretaker alone with the child at the time of symptom onset.

Hymel, K. P., Jenny, C., & Block, R. W. (2002). Intracranial hemorrhage and rebleeding in suspected victims of abusive head trauma: Addressing the forensic controversies. *Child Maltreatment*, *7*(4), 329-348. DOI:10.1177/107755902237263

Does an expanded subarachnoid space predispose to subdural bleeding? What does heterogeneity in the appearance of a subdural collection on CT or MRI imaging indicate? In some specific cases, answers to these questions have important forensic implications. To conclude objectively that an infant's intracranial hemorrhage or rebleeding resulted from inflicted injury or re-injury requires an in-depth understanding of the pathogenesis of posttraumatic subdural and subarachnoid collections. The authors present two cases of indoor, accidental, pediatric, closed-head trauma that resulted in intracranial rebleeding. Both accidental cranial impacts occurred in medical settings and were independently witnessed by medical personnel. In addition, the authors summarize the relevant medical literature regarding pediatric intracranial bleeding and rebleeding.

Case, M. E., Graham, M. A., Handy, T. C., Jentzen, J. M., Monteleone, J. A., & National Association of Medical Examiners Ad Hoc Committee on Shaken Baby Syndrome. (2001). Position paper on fatal abusive head injuries in infants and young children. *The American Journal of Forensic Medicine and Pathology*, *22*(2), 112-122.

This article represents the work of the National Association of Medical Examiners Ad Hoc Committee on shaken baby syndrome. Abusive head injuries include injuries caused by

shaking as well as impact to the head, either by directly striking the head or by causing the head to strike another object or surface. Because of anatomic and developmental differences in the brain and skull of the young child, the mechanisms and types of injuries that affect the head differ from those that affect the older child or adult. The mechanism of injury produced by inflicted head injuries in these children is most often rotational movement of the brain within the cranial cavity. Rotational movement of the brain damages the nervous system by creating shearing forces, which cause diffuse axonal injury with disruption of axons and tearing of bridging veins, which causes subdural and subarachnoid hemorrhages, and is very commonly associated with retinal schisis and hemorrhages. Recognition of this mechanism of injury may be helpful in severe acute rotational brain injuries because it facilitates understanding of such clinical features as the decrease in the level of consciousness and respiratory distress seen in these injured children. The pathologic findings of subdural hemorrhage, subarachnoid hemorrhage, and retinal hemorrhages are offered as "markers" to assist in the recognition of the presence of shearing brain injury in young children.

David, T. J. (1999). Shaken baby (shaken impact) syndrome: Non-accidental head injury in infancy. *Journal of the Royal Society of Medicine*, *92*(11), 556-561. DOI:10.1177/014107689909201105

The shaken baby syndrome has been a source of medical controversy for many years, and has been in the public eye since the trial of Louise Woodward in Boston in 1997. This paper outlines the condition and discusses some of the more controversial aspects.

Jenny, C., Hymel, K. P., Ritzen, A., Reinert, S. E., & Hay, T. C. (1999). Analysis of missed cases of abusive head trauma. *JAMA*, *281*(7), 621-626. DOI:10.1001/jama.281.7.621

Abusive head trauma (AHT) is a dangerous form of child abuse that can be difficult to diagnose in young children. The objective was to determine how frequently AHT was

previously missed by physicians in a group of abused children with head injuries and to determine factors associated with the unrecognized diagnosis. Retrospective chart review of cases of head trauma presenting between January 1, 1990, and December 31, 1995. One hundred seventy-three children younger than 3 years with head injuries caused by abuse. Characteristics of head-injured children in whom diagnosis of AHT was unrecognized and the consequences of the missed diagnoses. Fifty-four (31.2%) of 173 abused children with head injuries had been seen by physicians after AHT and the diagnosis was not recognized. The mean time to correct diagnosis among these children was 7 days (range, 0-189 days). Abusive head trauma was more likely to be unrecognized in very young white children from intact families and in children without respiratory compromise or seizures. In 7 of the children with unrecognized AHT, misinterpretation of radiological studies contributed to the delay in diagnosis. Fifteen children (27.8%) were reinjured after the missed diagnosis. Twenty-two (40.7%) experienced medical complications related to the missed diagnosis. Four of 5 deaths in the group with unrecognized AHT might have been prevented by earlier recognition of abuse. Although diagnosing head trauma can be difficult in the absence of a history, it is important to consider inflicted head trauma in infants and young children presenting with nonspecific clinical signs.

Hymel, K. P., Abshire, T. C., Luckey, D. W., & Jenny, C. (1997). Coagulopathy in pediatric abusive head trauma. *Pediatrics*, *99*(3), 371-375. DOI:10.1542/peds.99.3.371

Coagulopathy is a potential complication of head trauma that may be attributable to parenchymal brain damage. The objectives of this study were to assess the frequency of coagulation defects in pediatric *abusive* head trauma and to analyze their relationship to parenchymal brain damage. We reviewed the records of 265 pediatric patients hospitalized for head trauma. One hundred forty-seven patients met study inclusion criteria: (1) radiologic evidence of head trauma, (2) multidisciplinary validation that head trauma had been inflicted, and (3) coagulation screening performed within 2 days of

presentation. Using nonparametric analysis, initial coagulation test results were compared between study patients *without* parenchymal brain damage and those *with* parenchymal brain damage. Mild prothrombin time (PT) prolongations (median 13.1) occurred in 54% of study patients *with* parenchymal brain damage and only 20% of study patients *without* parenchymal brain damage. Among pediatric abusive head trauma patients with parenchymal brain damage *who died*, 94% displayed PT prolongations (median 16.3) and 63% manifested evidence of activated coagulation. PT prolongation and activated coagulation are common complications of pediatric abusive head trauma. In the presence of parenchymal brain damage, it is highly unlikely that these coagulation abnormalities reflect a preexisting hemorrhagic diathesis. These conclusions have diagnostic, prognostic, and legal significance.

Starling, S. P., Holden, J. R., & Jenny, C. (1995). Abusive head trauma: The relationship of perpetrators to their victims. *Pediatrics*, *95*(2), 259-262. DOI:10.1542/peds.95.2.259

Abusive head trauma is the most common cause of morbidity and mortality in physically abused infants. Effective prevention requires the identification of potential perpetrators. No study has specifically addressed the relationship of the perpetrators of abusive head trauma ("shaken baby syndrome") to their victims. The objectives of this study were to identify the abusers and their relationship to victims in these cases. We reviewed the medical charts of 151 infants who suffered abusive head trauma to determine the perpetrator of the abuse. Caretakers were classified by level of certainty: confession to the crime, legal actions taken, or strong suspicion by the staff. The relationship of abusers to victims was analyzed. Male victims accounted for 60.3% of the cases. Twenty-three percent of the children died, although death rates for boys and girls did not vary significantly. Male perpetrators outnumbered females 2.2:1, with fathers, step-fathers, and mothers' boyfriends committing over 60% of the crimes. Fathers accounted for 37% of the abusers, followed by boyfriends at 20.5%. Female baby-sitters, at 17.3%, were a large, previously unrecognized group of perpetrators. Mothers were responsible for only 12.6% of

our cases. All but one of the confessed abusers were with the child at the time of onset of symptoms. Our data suggest male caretakers are at greater risk to abuse infants. Baby-sitters are a concerning risk group, because they represent a significant proportion of abusers, and they more easily escape prosecution. In addition, no prevention efforts have been directed at baby-sitters. These statistics could help change the focus of efforts to prevent abusive head trauma.