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REVIEW

Mild abusive head injury: diagnosis and pitfalls

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Abstract
Clinicians often miss making the diagnosis of abusive head injury in infants and toddlers who present with mild, non-specific symptoms such as vomiting, fussiness, irritability, trouble sleeping and eating, and seizure. If abusive head injury is missed, the child is likely to go on to experience more severe injury. An extensive review of the medical literature was done to summarize what is known about missed abusive head injury and about how these injuries can be recognized and appropriately evaluated. The following issues will be addressed: the definition of mild head injury, problems encountered when clinicians evaluated mildly ill young children with non-specific symptoms, the risk of missing the diagnosis of mild abusive head trauma, the risks involved in subjecting infants and young children to radiation and/or sedation required for neuroimaging studies, imaging options for suspected neurotrauma in children, clinical prediction rules for evaluating mild head injury in children, laboratory tests than can be helpful in diagnosing mild abusive head injury, history and physical examination when diagnosing or ruling out mild abusive head injury, social and family factors that could be associated with abusive injuries, and interventions that could improve our recognition of mild abusive head injuries. Relevant literature is described and evaluated. The conclusion is that abusive head trauma remains a difficult diagnosis to identify in mildly symptomatic young children.

Keywords Child abuse · Craniocerebral trauma · Neuroimaging · Clinical prediction rules · Laboratory evaluation · Family risk factors

Mild head injury is generally defined as a patient having a Glasgow Coma Scale (GCS) rating of 14 or 15, although some investigators include GCS of 13 as well. The CDC and World Health Organization define mild head injury as an acute brain injury resulting from mechanical energy to the head from external forces resulting in confusion, loss of consciousness, post-traumatic amnesia, focal neurological findings, and/or seizures resulting in a GCS of 13 to 15 thirty minutes after injury or when presenting for care. For children, the definition of mild traumatic brain injury is GCS to 13 to 15 with or without intracranial injury on neuroimaging [1].

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Why is it so difficult to diagnose abusive head injury when children present with mild signs and symptoms?

Abusive head injury (AHI) can be difficult to diagnose, particularly if the infant's symptoms are mild. Several studies have found that the diagnosis of AHI in abused children can be missed [2–4].

There are many reasons for this. First, the history given by the caretaker is often false or misleading [5]. Hetler and Greenes found that no history was given in 69% of head injury cases determined to be abuse, and 25% gave a history of a short fall; together, the two histories had a high predictive value for AHI [6]. A Japanese study showed a negative correlation between the reported height of infant falls by the caretakers and the neurological outcome of the injury [7], implying that the caretakers' history was often unreliable. If the people presenting with the injured children in the emergency department are not the perpetrators, they might not be aware of the history or might be repeating false histories told to them.

Second, children with AHI can be neurologically normal. One study of children evaluated for other abusive injuries found occult head injury in 6.4% of the neurologically normal infants who had head imaging done and in nearly 10% of asymptomatic infants imaged who were less than 6 months of age [8]. Another study of abused children under 2 years of age found a rate of 37% with occult head injuries after imaging [9]. Alertness and no neurological deficits after an injury do not rule out intracranial pathology [10].

Children presenting after AHI can exhibit mild, non-specific symptoms such as vomiting, fussiness, lethargy, poor feeding, or trouble sleeping [11, 12]. A study of missed cases of AHI found misdiagnosis to be more common in children who were awake, alert, and breathing normally at presentation [1]. Many children with AHI will have no external signs of head trauma such as scalp swelling [13].

There is often a delay in seeking care after AHI, sometimes greater than 24 h [14–16]. Perpetrators might be reluctant to present the child for care, or sometimes caretakers become more concerned as a child's condition worsens over time. On the other hand, the child's status may have improved over time after the injury, leading the physician to not recognize a head injury.

Another factor that can make recognizing AHI is the infant's limited behavioral repertoires [12]. One cannot evaluate language skills, confusion, balance and coordination, memory, or the presence of post-traumatic amnesia. There are limited behavioral characteristics that can be relied on to determine the presence of brain dysfunction.

What is the risk of missing the diagnosis of a mild case of AHI?

The main concern for missing AHI is the possibility that another, more serious inflicted injury will occur. Many studies have found that AHI often happens repeatedly [2, 4]. Adamsbaum et al. studied confessed cases of AHI and episodes of violently shaking infants [17]. They found that 55% of the perpetrators of AHI shake their infants multiple times. Early recognition of mild AHI could save children from repeated, damaging, and painful episodes of trauma.

Another reason for recognizing mild AHI is that even after a period of minor symptoms, infants and children can then decompensate and develop serious signs and symptoms of brain injury [10, 18, 19]. Delayed decompensation can be related to the development of a space-occupying lesion, the development of cerebral edema, neuroinflammation caused by metabolic abnormalities [20], or the development of electrolyte abnormalities.

What is the downside of obtaining imaging studies when infants present with mild, non-specific symptoms that could be caused by AHI?

Computerized tomography scans of the head are effective in diagnosing intracranial injury. They can be obtained rapidly and are readily available. But there are concerns about the effects of radiation on children. Children are at increased risk from exposure to radiation. They are growing rapidly with a high mitotic rate and have a longer life span. The cumulative effects of radiation will develop over time. The lifetime risk of radiation-induced malignancies is a concern in children [21]. In all children from 0 to 15 years of age, the estimated risk of developing cancer is 2.5 per 1000, with leukemia being the most common [22].

The average child is exposed to 2.7 mSv background radiation per year [23]. A head CT imparts a radiation dose of approximately 1.5 to 1.9 mSv in children younger than 2 years of age. Two skeletal surveys (recommended in most cases of suspected child abuse in children under 2) provide 3.3–5.4 mSv of radiation. It is estimated that one child abuse radiological workup increases the lifetime cancer risk by 0.053% to 0.088% [24]. The risk of missing a case of AHI must be balanced with the risk imposed by diagnostic radiation.

Magnetic resonance imaging (MRI) of the head exposes the child to no excess radiation. Head MRI is better than CT at diagnosing brain ischemia, diffuse axonal injury, parenchymal injury, and cerebellar injury. It is also better at distinguishing benign extra-axial fluid from chronic subdural hematomas [25]. MRI is also less available than CT in many emergency departments and is more expensive. MRI also takes more time to perform, from 30 to 60 min. Because of the longer time in the scanner, brain MRIs usually require sedation in young infants to mitigate movement artifact. There has been some concern about the effects of anesthesia on the developing brain, but at this point, the data is preliminary and inconclusive [26]. Many factors need to be considered when determining the need for head imaging in infants and young children. The risk of missing AHI should be compared with the potential risks of MRI and CT [24, 27].

A third alternative has been proposed—that is, to use "fast MRI" scans of the head to image children in EDs to diagnose traumatic brain injuries [28]. Fast MRI uses modified protocols with faster acquisition times. They do not require sedation, and there is no exposure to ionizing radiation. Infants are fed and swaddled to induce sleep. While a complete MRI takes 30 min or more and head CTs take about one minute, fast MRI is done in about six minutes. The protocols for fast MRI vary by the manufacturer of the scanner. Most include one sagittal T1 sequence, two planes of a T2 sequence, a diffusion sequence, and a blood-sensitive sequence such as a GRE or an SWI sequence. The quality of the images is somewhat decreased compared to full MRIs.

One study comparing fast MRIs to head CTs in children under 6 years old with suspected head injury found that the MRIs detected 92.8% of the head injuries identified with CTs [29]. Another study of fast MRIs was done on 158 infants with various indications for neuroimaging [25]. 27% of the scans had motion artifact while only 2% were uninterpretable. Subarachnoid hemorrhages and skull fractures were not as well detected as on CT.

Clinical decision algorithms for the management of mild head trauma

The above concerns need to be considered when ordering neuroimaging in children. Several clinical prediction rules for the management of childhood head trauma of (varying quality) have been developed [30]. More recently, three high-quality decision rules have been developed to use in children based on large samples of subjects: the Pediatric Emergency Care Applied Research Network (PECARN) decision rules, widely used in the United States, the Canadian Assessment of Tomography for Childhood Head Injury (CATCH) rule, and the Children's Head Injury Algorithm for the Prediction of Important Clinical Events (CHALICE) developed in the United Kingdom. The PECARN rule uses six clinical variables to identify children with mild head injury who are at low risk of needing imaging studies. Qualifying patients have a GCS of 14 or 15 and present within 24 h after the injury. The CATCH rules include patients with a GCS of 13 to 15, again presenting within 24 h of injury. It is used for children with a history of loss of consciousness, amnesia, disorientation, persistent vomiting, or irritability. The CHALICE rules are used to evaluate children with head trauma of all severities to determine which children need imaging. The variables include six clinical history factors, five physical exam factors, and three descriptors of injury mechanisms. All three decision rules have been shown to be sensitive predictors of children needing or not needing imaging studies after head injury [21].

All three of these clinical prediction rules rely on the children's caretakers presenting accurate, reliable histories of injury mechanisms and course of clinical symptoms. The CHALICE rules specifically state that they are not to be used in cases of suspected AHI [31]. Given that the clinical history is likely to be unreliable in abuse cases, the three major prediction rules cannot be applied to AHI [32].

Clinical prediction rules for identifying AHI

Three clinical prediction rules to identify AHI have been developed and verified [33].

The predicting abusive head trauma tool (PredAHT) PredAHT was developed by comparing 133 cases of head trauma caused by proven accidents to 65 cases caused by proven abuse [34]. All children were less than 36 months of age. The tool consists of six clinical features: retinal hemorrhages, rib fractures, head or neck bruising, seizures, and apnea. The six factors were recorded as "absent," "present," or data missing. The model accurately identified 82% of the accidental injuries and 66% of the abusive injuries. When three or more of the six factors were present, the estimated probability of AHI was greater than 81.5% (95% CI, 63.3% to 91.8%). The sensitivity of the model was 72.3%, the specificity was 85.7%, the positive predictive value was 71.2%, and the negative predictive value was 86.3%. The authors proposed that the model be used as "an assistive clinical prediction tool" rather than a clinical decision rule. They conclude, "Knowledge of the results of this prediction tool may assist … clinicians in their discussions with child abuse specialists and social welfare, law enforcement, or other professionals involved in the child protection process."

The PredAHT uses clinical data that is obtained when abuse is suspected and cannot be used until the child abuse workup has been completed. In that regard, it is not helpful in deciding how to manage a mild head injury case when the child first presents for care.

The pediatric brain injury network clinical decision rule (PediBIRN CDR) The PediBIRN CDR was developed to direct pediatric intensive care unit physicians to complete a thorough evaluation for child abuse in young head-injured patients who present with one or more of five predictor variables [35]. Data were prospectively collected on 209 patients in 14 pediatric intensive care units (PICUs). Forty-five percent of the cases were determined to be caused by child abuse. Forty variables were originally collected. Five of the variables were found to be discriminating, reliable, and readily available to the PICU physicians at the time of admission. The variables were acute respiratory compromise, seizures or acute encephalopathy, bruising of the ears, neck, or torso, interhemispheric or bilateral subdural hematomas, and any skull fracture other than an isolated, unilateral, non-diastatic, linear, and parietal skull fracture. If at least one of the five variables was present, 97% of the abused children could be identified. The CDR was found to have a specificity of 0.95, a sensitivity of 0.95, a positive predictive value of 0.53, and a negative predictive value of 0.91.

The CDR was later refined to include four variables (PediBIRN 4-variable CDR), excluding the variable of seizures/encephalopathy [36]. The validation study was done prospectively at 14 PICUs and involved 291 head-injured children under 3 years, 43% of whom were determined to be abused. The 4-variable CDR had a sensitivity of 0.96 and a specificity of 0.43. Positive and negative predictive values were 0.55 and 0.93. 98% of the patients determined to be abused were identified by the CDR. 57% percent of patients who were not abused would have been identified as needing an abuse workup.

In a secondary analysis of a large series of children with head trauma evaluated in emergency departments, 78% of 116 children were found to be abused [37]. The sensitivity of the CDR in this population was similar to the PICU data but the specificity was low (0.29). 27 of the 38 patients who were not abused would have been determined to be "high risk" for abuse and a complete workup would have been recommended. If the skull fracture variable had been excluded, the specificity would have been raised to 0.84 without sacrificing sensitivity.

As with the PredAHT, the PediBIRN 4-variable decision rule uses results of the head CT to predict the likelihood of abuse. Thus, it is not helpful in deciding which children should undergo imaging and experience the risk of radiation or sedation. In that regard, it does not help in the management of mild head injury in the emergency department to assure AHI is not missed.

The Pittsburgh infant brain injury score clinical prediction rule (PIBIS CPR) The PIBIS CPR was derived from data collected from 150 infants without brain injury and 37 infants with mild AHI. Five predictor variables were identified as contributing to the diagnosis of mild AHI: age ≥ 3 months of age, enlarged head circumference, abnormal neurologic or dermatologic exam, and a history of a previous emergency department visit for a "high-risk symptom" such as vomiting or irritability.

The PIBIS CIS was then validated in a larger study of 1040 infants evaluated at pediatric emergency departments (EDs) of three different children's hospitals [11]. Children included in the study were 30 to 364 days of age and well-appearing. They presented to the ED with a temperature of < 38.3 °C, with no history of trauma, and with symptoms of possible head injury. The symptoms included apnea or apparent life-threatening events (now referred to as brief, resolved unexplained events (BRUE)) [38], vomiting without diarrhea, soft tissue swelling of the scalp, bruising, or non-specific neurologic symptoms such as lethargy, or fussiness.

Extensive clinical data on the infants were collected prospectively by ED physicians. Subjects were tracked for six months or up to one year of age to identify patients who had neuroimaging done after the initial ED visit. Cases were classified by abnormal imaging at the initial visit or at follow-up. Controls were children with no imaging done or normal imaging. Cases were also classified by results of neuroimaging as possible traumatic findings, definite traumatic findings, and atraumatic findings. Abuse was determined as definite or probable by each hospital's child protection team.

214 of the 1040 subjects (21%) were classified as "cases" based on neuroimaging. 168 (78%) were classified as definite or probable abuse. A 5-point PIBIS score was derived from the data. The five points were abnormal dermatologic exam (2 points), and one point each for age ≥ 3 months, head circumference > 85th percentile for age, and hemoglobin < 11.2 g/dL.

Abnormal neuroimaging was present in 93% of patients scoring 2 or more on the PIBIS. The specificity for abnormal imaging was 53%. A score of < 2 gave a negative predictive value of 96% for abnormal imaging. The authors concluded that a score of 2 or greater can help identify high-risk infants who would benefit from neuroimaging. They point out that the PIBIS should not be used in infants who need emergent neuroimaging based on their clinical presentation. The score did not diagnose abuse but did predict abnormal imaging studies. Abnormal skin exam (bruising) was the variable most predictive of possible abuse.

The PIBIS is the only clinical prediction rule that is helpful in identifying mild AHI. The factors can be useful for assessing the need for neuroimaging for "well-appearing" children.

Laboratory tests that could be helpful in diagnosing mild AHI

Hemoglobin As noted above, a low blood hemoglobin level can be a factor to consider when concerned about the diagnosis of mild AHI [11], particularly if the child has normal red blood cell indices, indicating acute blood loss instead of pre-existing anemia.

D-dimer The D-dimer antigen is a fibrin degradation product resulting from the breakdown of fibrin clots. During fibrinolysis, D-dimer antigens are created. Serum D-dimer results from hemostasis, thrombosis, and tissue repair [39]. Research has shown that D-dimer is increased after head injuries. A low level of D-dimer has been shown to indicate that a head CT is not likely to be positive for injury in children after head trauma [40–42]. Berger and colleagues tested D-dimer retrospectively on banked serum from head-injured children and prospectively on a small series of children under 4 years of age who were at high risk of mild AHI [43]. In the prospective study, 24 children who presented to the ED with non-specific symptoms such as vomiting, fussiness, or seizures were controls. Of the 20 cases with positive findings on head CT, all presented with non-specific symptoms but four had a history of head trauma and four had soft tissue swelling of the scalp. Nineteen had acute intracranial injury including nine cases of AHI, four with skull fractures, and one with a stroke. One other child had Sturge-Weber syndrome. D-dimer levels were much higher in the positive CT cases compared to the controls. The probability of correctly identifying cases versus controls was greater than 90%.

There are many different quantitative tests for D-dimer. They use different antibodies, methods of capture, instrumentation, and calibration standards [44]. D-dimer values increase with age, so using tests normed to adults can be a problem. Newborns also have higher D-dimer levels. Assays should be validated on relevant populations to determine specific cut-off values for elevation caused by head trauma.

Many medical conditions cause elevated D-dimer such as thromboses, inflammatory diseases, infections (including COVID-19), coagulopathies, malignancies, and diabetes [45]. Again, the test is not recommended to diagnose head trauma or abuse but can be helpful in deciding which child with non-specific symptoms should receive neuroimaging.

Biomarkers of brain injury Chemicals are released by brain tissue into the cerebrospinal fluid (CSF) after brain injury. The impermeability of the blood–brain barrier also is transiently decreased, allowing these chemicals to leak into the bloodstream [46]. Brain biomarkers have been used to diagnose brain injuries in adults. Brain biomarkers could be useful in the diagnosis of mild AHI, suggesting the need for neuroimaging studies. Ideally, brain markers for head injury would not be present in other tissue.

Several CSF markers have been found to be increased after inflicted head trauma in young child [47]:

- *Glutamate*—an excitatory neurotransmitter found in the central nervous system (CNS) that can trigger passive and active neuronal death;
- *Quinolinic acid*—a neurotoxin produced by activated microglia and macrophages;
- *p-Selectin*—a protein produced by activated platelets and endothelial cells that function as a cell-adhesion molecule;
- *ICAM*-1—an immunoglobulin that facilitates endothelial transmigration and possibly causes vasospasm;
- *Cytokines*—proteins involved in the inflammatory process;
- Cytochrome c—a marker of apoptotic cell death.

Other CSF markers have been shown to be increased after inflicted trauma but less so than in accidental trauma:

- *Bcl-2*—a protein that regulates cell apoptosis;
- *Adenosine*—a neuroprotective organic compound;
- *Procalcitonin*—an inflammatory biomarker.

After inflicted brain injury, concentrations of neurotoxins have been found to be higher than after accidental head injury, while concentrations of neuroprotective factors have been found to be lower. This could possibly contribute to the worse outcome that occurs after AHI. The problem with CSF biomarkers is that a spinal tap could be extremely dangerous in a head-injured child if the child has increased CSF pressure in the head. This will limit the usefulness of CSF markers to indicate the need for acute imaging in emergent cases.

Serum biomarkers occurring after abusive and accidental head injuries that have been studied include the following [48]:

- *Neuron-specific enolase (NSE)*—a glycolytic enzyme found in neuronal cytoplasm;
- *S-100B*—a calcium-binding protein located in the astroglia, an indicator of neuronal and astroglial death;
- *Myelin basic protein (MBP)*—a protein associated with white matter which peaks in the bloodstream 48 to 72 h post-injury and persists for weeks.

These markers are found to persist longer in both inflicted brain injury and hypoxic-ischemic brain injury, suggesting prolonged neuronal, axonal, and astroglial death is occurring.

Before serum biomarkers can become useful in the diagnosis of mild AHI, an effective "point of care" test needs to be developed for use in EDs. Berger et al. compared 44 biomarkers in the serum of children with no extracranial trauma, comparing biomarkers in those with and without mild head trauma [49]. Markers that were found to be higher in head-injured children included the following:

- *Matrix metalloproteinase-9* (*MMP-9)*—an extracellular enzyme involved in the degradation of extracellular matrix proteins that is thought to contribute to post-traumatic brain tissue and blood–brain barrier degradation;
- *Hepatocyte growth factor (HGF)*—a cytokine that regulates mobility, morphogenesis, and development of various types of cells;
- *Fibrinogen*—a glycoprotein complex that is converted to fibrin by thrombin;
- *Interleukin 6 (IL-6)*—a protein that acts as a proinflammatory cytokine.

Berger's group went on to develop a multiplex platform to rapidly measure multiple biomarkers of brain injury on 2 μL of serum to identify intracranial hemorrhage in well-appearing children at the point of care [50]. The platform supported a multivariable model including clinical factors. Three serum biomarkers are measured by the platform:

- *Matrix metallopeptidase-9 (MMP-9)*;
- *Neuron specific enolase (NSE)*;

- *Vascular cellular adhesion model-1 (VCAM-1)*—a cell adhesion molecule.

This data was incorporated into a logistic regression model along with serum hemoglobin values to derive a formula known as the Biomarker of Brain Injury Score (BIBIS). The sensitivity and specificity of BIBIS calculation for acute intracranial blood were 89.34% (95% CI, 98.7–90.4) and 48.0% (95% CI, 47.3–48.9). The negative predictive value was 95.6%, indicating the Score could be very useful in helping to decide which infants at high risk for mild AHI should receive neuroimaging. Unfortunately, the BIBIS has not been made available commercially as a point-of-care test, but further research and development are clearly indicated.

History and physical examination in children with symptoms of mild AHI

History Always inquire about the possibility of a traumatic event. A history of recent illness episodes and visits to health care facilities is warranted. Two small studies looked at specific factors in the history given by parents. One small study asked parents an open-ended question about how they would describe their children who were under 1 year of age [51]. A higher percentage of parents of abused children gave negative descriptors of their children such as “fussy,” “crier,” “needy,” or “spoiled”. Carers of non-abused children were likely to describe them positively using terms like “happy,” “sweet,” or “cute”. In another study of victims of AHI, parents reported frequently having expressed concerns to their primary care providers about the child being particularly fussy or crying a great deal [52]. Asking open-ended questions about babies’ personalities and crying behaviors would not likely be interpreted by parents as too intrusive.

Physical examination As noted above, measuring an infant patient’s head circumference and comparing it to normative data is an important part of the Pittsburgh Infant Brain Injury Score Clinical Prediction Rule [11]. Often, past head measurements are available on electronic medical records for comparison. An unusual jump in head circumference could be an indicator of intracranial pathology.

Every young patient should be examined for bruises. One study looked at a large number of ED patients who were screened for “high-risk bruises” [53]. A high-risk bruise was described as *any* bruise in a patient less than 6 months of age. In children from 6 to 48 months of age, a high-risk bruise was a bruise on the torso, ears, or neck [54]. 50% of infants with high-risk bruises were found on further workup to be likely or definitely abused. In the older children, 28% of children with high-risk bruises were cases of likely or definite abuse. Head-to-toe body exams for bruises or other injuries should be part of the workup when young children present with non-specific symptoms that could be mild AHI.

A thorough neurological examination (and palpation of the fontanelle when applicable) also should be done. Subtle seizures can be thought to be spontaneous movements [12, 55]. Even if the eyes are open, the absence of crying or grimacing in response to painful stimulation is concerning for head injury.

Abusive head trauma can be caused by impact injury or loading injury from rotational acceleration. If head impact does not occur, no scalp swelling or skull fractures will be present. Even if impact occurs, the scalp and skull might not show any swelling or deformation [56]. The absence of scalp injury does not rule out impact injury as all or part of the mechanism.

Examination of the retina is very important in recognizing mild AHI. Direct funduscopic exams of the retina have a low sensitivity for detecting patterns of retinal hemorrhage frequently found in AHI victims. In one study, non-ophthalmologists were unable or unwilling to do direct funduscopic exams in 55% of AHT victims [57]. Of those who did examine the retina, false-negative exams occurred in 12% of the cases and there were no false-positive exams. This suggests that non-ophthalmologists should attempt more retinal exams, particularly in questionable cases. The study did not comment on the presence or absence of dilated pupils. In mild AHI cases, pupillary changes are not likely to be present. In alert infants, retinal exams can be done in a completely dark room while the child is propped against the caretaker’s shoulder, facing the rear. Another person using a toy that makes sparks and sounds can briefly focus the child’s attention and allow the examiner a quick view of the retina.

Should social factors be considered when undertaking workups for mild AHI?

Risk factors for child abuse have been reported including family and social factors. Some of these include male gender of the child, lower socioeconomic status, caregiver substance abuse, caregiver mental health, and family interpersonal violence [58]. Another study of abusive head injury in children found that the following factors were significant for increased risk [59]: prior contact with Child Protective Services, prior police involvement, and an unknown number of adults in the home. A study of the recent recession (2007–2009) found a marked increase in the rate of cases of abusive head trauma [60]. In a Scottish study, Minns et al. found poverty to be a strong risk factor in AHI cases [61].

When considering social and economic factors in abuse cases, it is important to understand there may be observer bias in the recognition of abuse. Hymel et al. found significant bias in the race and ethnicity of children evaluated and reported for suspected abuse [62]. Lindberg discusses the importance of using objective standards when deciding to evaluate children for abuse, particularly when considering social factors [63].

In fact, studies found that AHI was more likely to be missed if the child is not a minority or if the child comes from an intact family [2, 64]. This suggests that bias in our pre-existing beliefs about race and social factors can impact clinical judgment.

Interventions that could improve our recognition of mild AHI

One hospital developed specific guidelines and order sets to be used in suspected abuse cases. Extensive education of ED providers on the guidelines improved their adherence to those guidelines [65].

Siblings of children who have been identified as abused have been shown also to be at increased risk of abuse [66, 67]. The United Kingdom's Royal College of Radiology recommends that if abuse is diagnosed in a child with multiple-birth sibling(s), the siblings should receive the same imaging studies as the index child [68]. Others recommend any other sibling of an abused child who is under two be evaluated for abuse, as well as other young children in the care of the same caretaker [66].

One paper looked at the quality of radiologists' reading of studies in cases of AHI [69]. Neuroradiologists and non-neuroradiologists blindly evaluated MRIs of known cases of AHI and other cranial abnormalities without being given clinical details or histories. In 16 of 18 cases (89%), neuroradiologists correctly diagnosed AHI. The non-neuroradiologist made the correct diagnosis in 9 out of 18 cases (50%). The authors concluded that neuroradiologists were more likely to recognize AHI on MRI and also were more likely to rely on factors other than the presence of subdural hemorrhage on scans.

Summary

Mild AHI is difficult to diagnose and is dangerous for the infant or toddler. Specific care should be taken by medical care providers to recognize possible mild AHI and to know how to effectively proceed with making a correct diagnosis. Decisions to use imaging studies in infants and toddlers should weigh the risks of radiation and/or anesthesia, and the least dangerous imaging technique which would provide a sufficiently reliable evaluation should be used. Clinicians should be aware of historical, physical examination, and laboratory variables that can be helpful in reaching the right diagnosis. An awareness of the possibility of head injury in mildly symptomatic infants is important. Once a diagnosis of mild AHI is made, cooperation with child protection agencies and law enforcement is necessary to protect the child from further injury.

Recent literature reviews have noted the lack of "gold standard" tests and criteria that differentiate AHI from accidental, non-inflicted head injuries in infants and young children. Critics have pointed out that there are no "controlled clinical trials" defining AHI, so the studies that have proven this medical diagnosis are unreliable and flawed by "circular reasoning" [70–72]. The diagnosis of AHI, however, is supported by thousands of scientific publications in many fields. The science of the evaluation of childhood head injuries has been proven to be reliable by careful scientific clinical and epidemiologic studies [13, 17, 19, 73]. The diagnosis is widely accepted in the relevant medical community [74].

This paper does not intend to specifically identify abuse versus accidents. The awareness of the likelihood of an underlying mild head injury would be helpful in both cases.

Author contribution Sole author is responsible for the manuscript.

Availability of data and materials All material is referenced.

Declarations

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