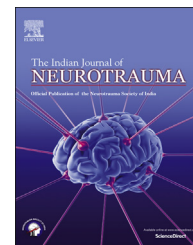


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Review Article

The importance of recognizing abusive head trauma in the neurosurgical setting

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ABSTRACT

Abusive head trauma (AHT) occurs due to an intentional abrupt impact and/or violent shaking leading to an injury to the skull or intracranial contents of a baby or child, usually younger than 2 years of age. Without impact, there may be no external signs of head trauma. It is the leading cause of mortality in children who have suffered intentional physical abuse. It is more likely to occur in very young children with an estimated prevalence of 1 per 3000 in infants under 6 months of age. Studies have highlighted that distressed and exhausted parents can sometimes shake their infant in desperation and parental education has been shown to decrease the incidence of AHT. Clinicians dealing with children who presents with traumatic brain injury (TBI) should always consider the possibility of AHT. AHT is classically characterized by a triad of signs; subdural hematoma, brain edema, and retinal hemorrhage, however, non-specific features may also be seen in clinical practice both acutely or subsequently. Certain neuroradiological findings (subdural hemorrhages, multiple interhemispheric convexity and posterior fossa hemorrhages, hypoxic-ischemic injury and cerebral edema) are suggestive of AHT in young children. Associated spinal injuries can be easily missed and it is important to investigate for this. This review article includes 2 illustrative case studies and gives a comprehensive overview of AHT in children which we hope will be useful for neurosurgeons in their clinical practice. Child protection is everyone's responsibility and is best achieved when different specialties and professionals work together.

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1. Introduction

Injuries are common in children and according to a report from the World Health Organization (2002) trauma is the 6th leading cause of morbidity and mortality in childhood.¹

Although most injuries are sustained accidentally, it is important that clinicians managing children's injuries remain aware of the possibility of a non-accidental cause. Research suggests that nearly 7% of children suffer from some form of physical abuse during their childhood² and abusive head

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trauma (AHT) is the leading cause of mortality amongst the victims of child physical abuse.^{2,3}

The Centers for Disease Control and Prevention of the United States (CDC) has defined AHT 'as an injury to the skull or intracranial contents of a baby or child younger than 5 years due to intentional abrupt impact and/or violent shaking'.⁴

The concept of AHT in children is not new. It was Caffey in 1974 who first used the term whiplash-shaken infant syndrome to describe the association of intracranial injuries, retinal hemorrhage, and certain long bone fractures attributable to child abuse among infants (majority being under 1 year of age).⁵⁻⁷ Over the last 40 years different terminologies has been used and this includes 'shaken baby syndrome', 'shaken impact syndrome', 'infant whiplash-shake injury syndrome', 'intentional head injury', 'non-accidental head injury'.^{8,9}

While pediatricians in the developed world, and to a certain extent in developing countries, are alert to the possibility of inflicted trauma in children, it may not always be the case for other clinicians who infrequently deal with children in their clinical practice.⁸ The electronic media and medical literature in India has recently highlighted reports of a number of serious cases of child physical abuse, some resulting in death, which have gained international attention.^{10,11} This article aims to highlight some of the different presentations of AHT in children, illustrated by two cases, and gives some guidance on working together to keep children safe.

2. Incidence

Recent studies from the USA suggest that more than 120,000 children annually become victims of child physical abuse. This accounted for the deaths of more than 600 children in 2009 in the United States.³ AHT affects ~ 1 in 4000-5000 infants every year. It is estimated that in the UK every year 20-24 per 100,000 infants under the age of a year are diagnosed with AHT.⁸ This figure increases to 36/100,000 in infants aged <6 months¹² with an estimated prevalence of 1 per 3000 in infants under 6 months.¹³ Similar incidence of 29.7 per 100,000 was also reported from the USA.³

In a study in Queensland, Australia over a 4 year period (2005-2008), the average annual incidence of AHT was 6.7 cases per 100,000 and infants under 12 months, and male infants were noted to be more vulnerable.¹⁴ In a study of 3061 children (aged < 5 years) in China with traumatic brain injury studied over 10 years, AHT was suspected in 140 children and 68.6% of AHT occurred in infants aged less than 1 year.¹⁵ In a prospective study of 225 pediatric injuries (aged 2 months-12 years) from the All India Institute of Medical Sciences, New Delhi (March 2006-February 2007), child abuse was identified in 7/225 cases (3.5%).¹ Although accurate figures are not available for the Indian subcontinent, it is presumed not to be too dissimilar.

The financial implications of AHT are immense; estimates showed that initial inpatient hospitalization costs averaged \$18,000 to \$70,000 per child, and long term management costs exceeded \$1 million in 1 case.⁹

Some important and interesting statistics are highlighted in **Box 1**; this show that incidences of AHT are more common than we anticipate and this is also equally relevant to neurosurgical practice.^{13,12,16-19}

Box 1

Important statistics and facts worth considering while dealing with TBI in children.

- A population-based study conducted in south Wales and the southwest of England found that the majority of subdural hemorrhages in children less than 2 years of age were due to child abuse.
- It is estimated that approximately 12 children per 100,000 under the age of 2 years suffer from non-accidental subdural hemorrhage, and at least half of these injuries are related to shaking.
- A survey of 83 mothers in east London found that as many as 1 in 9 mothers had shaken their baby and 2 in 9 had felt like shaking their baby.
- An American study reported that 2.6% of parents admitted to have shaken a child under the age of 2 years and 9% felt like shaking their infant.
- A study of AHT in the Lothian Region of Scotland (1998-2006) found that 64% cases of AHT occurred in the most deprived quintile of the region's population.
- An American study highlighted an increase in the overall rate of AHT noted during 19 months of economic recession from 8.9 per 100,000 (noted in preceding 47 months before recession) to 14.7 per 100,000.
- In a study of 715 autopsies in infants aged <1 year over 50 years in Germany, out of 15 trauma related subdural hemorrhage, 14/15 were related to AHT.

3. Why knowledge of AHT is important for neurosurgeons?

The structure for healthcare delivery differs between countries. The initial presentation of TBI (including cases of AHT) may not always initially present to pediatric services. It is possible that a significant proportion of children with TBI will present directly to neurosurgical teams, sometimes without the involvement of pediatricians. Clinical teams dealing with TBI, some of which may be due to an abusive cause, have a responsibility to undertake a comprehensive assessment of the child, always considering the possibility of a deliberately inflicted injury, and should remain familiar with the scientific evidence that will help enable them to put the pieces of jigsaw together to support their clinical opinion.⁸ It needs to be remembered at all times that the welfare and safety of the child is of paramount importance and in cases where the history is suggestive of deliberately inflicted injury, or where the mechanism of injury remains unclear, it may be relevant that neurosurgical teams seek opinion from pediatricians with expertise in child protection.

4. When to suspect child abuse?

Clinicians working with children need to consider possibility of AHT if the mechanism of reported injury does not correlate

Box 2
Gross motor developmental milestones in a child, knowledge about these is vital when AHT is suspected.

Age of child	Expected motor development
2 months	<ul style="list-style-type: none"> • Can hold head up and begins to push up when lying on tummy • Makes smoother movements with arms and legs
4 months	<ul style="list-style-type: none"> • Holds head steady, unsupported • Pushes down on legs when feet are on a hard surface • May be able to roll over from tummy to back • When lying on stomach, pushes up to elbows
6 months	<ul style="list-style-type: none"> • Rolls over in both directions (front to back, back to front) • Begins to sit without support • If made to stand, supports weight on legs and might bounce • Rocks back and forth, sometimes crawling backward before moving forward
9 months	<ul style="list-style-type: none"> • Stands, holding on to furniture • Can get into sitting position from lying down • Sits without support • Pulls to stand • Crawls
12 months (1 year)	<ul style="list-style-type: none"> • Gets to a sitting position without help • Pulls up to stand, walks holding on to furniture (“cruising”) • May take a few steps with hand being held • May stand alone
18 months (1½ year)	<ul style="list-style-type: none"> • Walks alone • May walk up steps and run • Stoops down to pick up toys • Pulls toys while walking (risk of tripping)
24 months (2 years)	<ul style="list-style-type: none"> • Stands on tiptoe • Kicks a ball • Begins to run • Climbs onto and down from furniture without help • Walks up and down stairs holding on

with the clinical or radiological findings, or is considered to be incompatible with the developmental stage of the child. In the absence of an independent eye-witness account or a self-admission by the perpetrator, a diagnosis of AHT can usually only be made on the balance of probability, based on the clinical findings, features of the history and presentation and

the accepted evidence-base; there is no ‘gold standard diagnostic test’ for the condition.

A working knowledge of child development is essential for every neurosurgeon seeing children. A ‘snap-shot’ view of the gross motor development of a child in the first 2 years of life is given in Box 2. This can help a neurosurgeon to make a quick assessment as to whether a history given regarding the mechanism of injury is likely to be compatible with a child’s developmental stage, though every child is unique and developmental ‘norms’ are a spectrum, so a detailed history from carers and others will always be pivotal.²⁰ The National Institute of Clinical Excellence²¹ in the UK (2009) has published a clinical guideline entitled ‘When to suspect child maltreatment?’; summarized in Box 3.

5. Clinical presentation of AHT

AHT is characterized by a triad of signs: subdural hematoma, brain edema and retinal hemorrhage. Subdural hematoma has been described in up to 90% of diagnosed cases.^{4,8} Retinal hemorrhage is another strong indicator of AHT and a recent literature review indicated its occurrence in 74% of cases of AHT and in 82% of fatal cases.^{4,22} An ophthalmology assessment should always form part of the clinical assessment for AHT in children.

In a retrospective study of 627 infants (aged 0–12 months) in the USA who presented with apparent life threatening event (ALTE), 9/627 (1.4%) were identified to be due to AHT.²³

It is important to remember that not all children with AHT will present with the classical triad of symptoms and clinicians should remain alert to other signs that may indicate the occurrence of AHT. Other signs of AHT may include unexplained respiratory distress, vomiting, poor feeding, irritability, lethargy, apnea, sudden unexplained unresponsiveness, seizures, and the more chronic sequelae of increasing head circumference and macrocephaly, developmental delay, and behavioral changes.^{4,11,24}

Box 3
Recommendations on intracranial injuries²¹ (adapted from NICE (2009) CG89 entitled ‘When to suspect child maltreatment’).

Suspect child maltreatment if a child has an intracranial injury in the absence of major confirmed accidental trauma or known medical cause, in one or more of the following circumstances:

- the explanation is absent or unsuitable
- the child is aged under 3 years
- there are also:
 - retinal hemorrhages or
 - rib or long bone fractures or
 - other associated inflicted injuries
- there are multiple subdural hemorrhages with or without subarachnoid hemorrhage with or without hypoxic-ischemic damage to the brain.

6. Illustrative cases from clinical practice

The article has so far highlighted the reasons why recognizing AHT is important and when to suspect it. We now present 2 cases from our clinical practice to demonstrate typical presentations of head trauma where concerns regarding AHT were raised.

Case#1

A 3-month-old male infant presented having reportedly fallen out of mother's arms when she tripped and fell whilst carrying him down some stairs. The infant was clinically stable and a CT scan confirmed an un-displaced skull fracture. He was transferred to regional neurosurgery center and managed conservatively. AHT was considered and child protection agencies were contacted. The history from his mother remained consistent throughout and the medical evidence indicated an injury consistent with the history given by his mother. Other healthcare professionals working with the family were contacted and no safeguarding concerns were raised. After a thorough investigation by Children's Social Care it was felt that an accidental mechanism was most likely and he was discharged with medical follow-up following an uneventful recovery.

Case#2

An 8-month-old male infant was referred by the health visitor with concerns about an increasing head circumference. His parents reported that they were not concerned about his health and a clinical examination revealed no other problems. An MRI scan confirmed the presence of a subdural hemorrhage with associated hydrocephalus; this was conservatively managed. The possibility of AHT as a cause was raised and child protection procedures were initiated. On further questioning, his parents recalled an event when the infant had fallen backwards while swinging from a cloth line in the garden 6 weeks earlier, hitting the back of his head. This mechanism of injury described was felt to be incompatible with the child's developmental stage.

The case was further complicated by blood test results revealing a borderline von Willebrand's disease which was considered a possible contributory factor to the radiological findings of a subdural hematoma. It is important that medical causes are always considered in the differential diagnosis of any presentation and investigated as appropriate, though it is equally important to appreciate that an underlying diagnosis of a medical condition such as a clotting dyscrasia or bleeding tendency does not preclude a diagnosis of deliberately inflicted injury.

Further investigation by Children's Social Care revealed that there had been previously reported child protection concerns concerning older siblings, and other social concerns that might have impacted upon the carers' parenting ability. A multi-agency case conference was convened and additional concerns were raised. After unsuccessfully working with the family to address the issues of concern, a decision was made to place the children in foster care to ensure their ongoing safety.

7. AHT may be associated with spinal injuries

While signs of head injury may be easily evident in AHT, associated or co-existing spinal may be less easy to detect. Brain injury and/or retinal hemorrhages are often associated with co-existing neck injuries and are more commonly reported in infants aged less than 4 months because of a

relatively large head size. Spinal injury is difficult to assess in the unconscious child and clinicians dealing with a case of AHT should actively seek for these injuries. It is important that all children under 2 years presenting with suspected physical abuse has a full skeletal survey, including a CT scan of the head and plain X-rays of the spine, including lateral views. Performing an MRI of the spine should also be considered.¹³

8. Role of radiology with special neuroradiological considerations

Children who present with AHT are also likely to have inflicted injuries in other areas of the body. The role of imaging in cases of suspected child physical abuse is to identify the extent of inflicted physical injury, as well as to elucidate all imaging findings that may point to alternative diagnoses e.g. osteogenesis imperfecta.²⁵ The radiographic skeletal survey is currently the method of choice for global skeletal imaging in children with suspected physical abuse. Before conducting a skeletal survey, it is important that the case is discussed with the radiologist and pediatricians so that the correct imaging protocol is followed and the images should be interpreted in light of the history available. The suggested scheme from the American College of Radiology for complete skeletal survey is highlighted in [Box 4](#).²⁶

Neuroimaging (either CT or MRI scan of brain) plays a very important role in children with suspected AHT. If the presentation is non-acute and no immediate threat to life is considered, an MRI scan of the brain may be a better modality for imaging as it gives superior anatomical resolution that can localize and characterize subtle extra-axial hemorrhages, particularly in the posterior fossa.² According to the UK-based joint guideline of the Royal College of Radiologists and Royal College of Paediatrics and Child Health, 'The Standards of Radiological Investigations for Suspected Non-Accidental

Box 4 Complete skeletal survey table.²⁶

Adapted from ACR 2006

Appendicular skeleton

- Arms (anteroposterior (AP))
- Forearms (AP)
- Hands (posteroanterior (PA))
- Thighs (AP)
- Legs (AP)
- Feet (PA or AP)

Axial skeleton

- Thorax (AP and lateral), to include thoracic spine and ribs
- AP abdomen, lumbosacral spine, and bony pelvis
- Lumbar spine (lateral)
- Cervical spine (AP and lateral)
- Skull (frontal and lateral)

Injury', every child with suspected AHT should receive a CT scan of the head within 24 h of their admission to hospital, and an MRI of the brain and the spine within 5 days of presentation, with a second follow-up MRI brain examination at 3–4 months.²

A systematic review of literature²⁷ described specific neuroradiological findings which in correlation with clinical findings may indicate AHT:

- Subdural hemorrhages (SDH) were significantly associated with AHT
- Subarachnoid hemorrhages were seen equally in AHT and non-abusive head trauma (nAHT)
- Extradural hemorrhages were significantly associated with nAHT
- Multiple interhemispheric convexity and posterior fossa hemorrhages were associated with AHT.
- Hypoxic-ischemic injury and cerebral edema were significantly associated with AHT
- Focal parenchymal injury was not a discriminatory feature.
- SDH of low attenuation were more common in AHT than in nAHT.

Similar findings were also described in another systematic review which tried to associate clinical and radiological findings to AHT described that subdural hemorrhage, cerebral ischemia, retinal hemorrhages, 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.²⁸

9. Prognosis of AHT

The mortality rate for children with AHT ranges from 13 to 36% according to the available literature.^{3,9} In the UK reports from most recent biennial review of serious case reviews it is estimated that 60% of children who die from physical abuse have been victims of AHT.⁸ Amongst the survivors of AHT, 42–96% suffer long term neurologic morbidity and the outcome is generally worse than with accidental TBI.

Parents or carers will often ask about the prognosis following AHT and it is important that clinicians remain aware of factors that may indicate a poor prognosis. In a retrospective study of 35 children with AHT, a low Glasgow coma score (GCS) at initial presentation, presence of cerebral edema or loss of gray–white matter differentiation on neuroimaging, the need for mechanical ventilation for more than 10 days, a length of intensive care unit stay of more than 10 days, the need for neurosurgical intervention, and seizures in the first week after injury were significantly related to having a poor outcome.²⁹ In a Swedish study only 28.8% of the victims recovered completely following AHT, whereas 53.3% had moderate or severe disability as a consequence.^{4,30}

Long-term consequences of AHT may not be evident immediately but is likely to become apparent at subsequent follow-up. These may include learning difficulties, visual problems (including blindness), hearing and physical disabilities, cerebral palsy, speech problems, seizures, and cognitive impairment.^{24,31} It is also important to note that infants

who appear to be well at discharge can subsequently show evidence of cognitive and learning impairment, possibly at school age as evident from long term follow-up data from Canada.³¹

10. Need for working together to keep children safe

Incidences of child physical abuse are increasingly being reported from around the world. It is important that every clinician working with children is aware of the need to protect the child and to always consider the possibility of deliberately inflicted harm when a child presents with head or spinal injury. It is absolutely essential that professionals working with children and families (neurosurgeons, pediatricians, other healthcare professionals, police, social services etc) work together to safeguard children.²¹ Recognition and Response to Child Abuse and Neglect in the Indian Setting and Child Abuse and Neglect: Asia Pacific Conference and the Delhi Declaration are important guidance documents to be used by clinicians in the Indian setting.^{32,33}

It is equally important that efforts are made to prevent children from being abused. In one regional, hospital-based, parent education program, administered at the time of the child's birth, it was demonstrated that the incidence of AHT decreased by 47%, from 41.5 cases per 100,000 live births during the 6-year control period to 22.2 cases per 100,000 live births during the 5.5-year study period.⁹ In another study undertaken over an 8 year period in the USA, maternity nurses implemented a program to teach parents about the dangers of shaking infants and how to cope safely with an infant's crying and demonstrated a decrease from 2.8 injuries per year (14 cases in 5 years) to 0.7 injuries per year (2 cases in 3 years), representing a 75% reduction.³⁴

11. Conclusion

AHT is the leading cause of death in children who have suffered physical abuse. The initial signs and symptoms may mimic other serious illnesses. The finding of a subdural hemorrhage in children under 2 years of age is most likely to be due to AHT and the possibility of deliberately inflicted head trauma must always be considered, taking into account the history, presentation, and clinical findings in light of the child's developmental stage and the evidence-base available. AHT has long term implications and it is important that prevention strategies through parental education and awareness are encouraged. Child protection is everyone's responsibility and we hope this article will help clinicians in their practice when faced with the challenging scenario of a child with suspected AHT.

Conflicts of interest

All authors have none to declare.

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