Abusive head trauma: recognition and the essential investigation

Alison M Kemp

ABSTRACT
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.

Paediatricians are aware that abusive head trauma (AHT) is high on the list of differential diagnoses in any infant or toddler who has unexplained or inadequately explained intracranial trauma. In the absence of witnessed or admitted child abuse a diagnosis of AHT can only be made on the balance of probability as there is no gold standard diagnostic test for the condition; this presents a diagnostic challenge. The clinical team has a responsibility to undertake a comprehensive assessment of the child and a duty to be familiar with the scientific evidence so that they can piece together information to support their clinical opinion, remembering that it is the welfare of the child that is paramount.

This article discusses the evidence-base behind the clinical signs and symptoms of AHT and sets out the key investigations that are recommended when assessing these children. Much of this work has been conducted by the Welsh Child Protection Systematic Review Group and can be sourced in more detail at www.core-info.cf.ac.uk.

TERMINOLOGY
Over the past 50 years there have been many terms used to describe AHT. Many, such as shaken baby syndrome or shaking impact syndrome, imply causality. In reality the causal mechanism is rarely confirmed and may well include elements of both impact and acceleration-deceleration injury. Other terminology such as intentional head injury assume a knowledge of purpose and the term ‘non-accidental head injury’ has become outmoded as workers in the injury prevention field have dropped the term ‘accident’ in favour of a ‘non-intentional event’. I have therefore adopted the term AHT in line with recent nomenclature proposed by the Committee on Child Abuse and Neglect; American Academy of Pediatrics to include ‘an inflicted injury to the head and its contents’. Although this term may not be perfect it would seem important to maintain a level of international agreement.

EPIDEMIOLOGY
The variation in inclusion criteria adopted by various research groups, together with the relative rarity of the condition make it difficult to define the true incidence. However three UK-based studies give remarkably similar incidence figures. It is estimated that between 20–24 per 100000 infants under the age of a year are diagnosed with AHT every year.1–3 Further analysis of data from the study by Jayawant et al shows that this rises to 36/100000 for infants under 6 months old. In practice this means that paediatricians in the average sized district general hospitals can expect to see a case perhaps once every 1 or 2 years, while paediatric intensive care and paediatric neurology units will do so on a regular basis.

The most recent biennial review of serious case reviews in the UK estimates that 60% of children who die from physical abuse have been victims of AHT,4 highlighting not only the severity of this condition but the need for prevention. One study reports that 2.6% of American parents admit to having shaken a child under the age of 2 years old and 9% felt like shaking their infant.5 It is therefore possible that cases which come to the attention of clinicians are only a proportion of the full spectrum of the condition.5 In a high proportion of cases there is previous evidence of physical abuse, suggesting that AHT is rarely a one-off event. There are recognised trigger factors that include persistent crying and maternal stress or postnatal depression. Recognition of these risk factors should prompt support for carers and preventive interventions.6–8

Recently published population studies confirm that the clinical outcome for children with AHT is poor and considerably worse than those with non-AHT.9–11 Hettler and Greenes10 identified a mortality of 8% (4/49) in the AHT group compared to 1.7% (2/114) in the non–abused; 53% of the AHT cases had persistent neurological impairment at hospital discharge compared to only 7% of the non-abused group.

PRESENTING HISTORY
Very few studies compare the history associated with AHT. Hettler and Greenes10 compared the preceding history of a group of 49 cases of head trauma from ‘definite’ abuse with 114 children with non-definite abuse. Their definition of
abuse was based upon associated abusive injuries together with a social work review. They concluded that there is a high likelihood of abuse in children under the age of 3 years who have traumatic intracranial injury.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Positive predictive values and OR for features associated with AHT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PPV (97.5% CI)</td>
</tr>
<tr>
<td>Apnoea</td>
<td>93% (73% to 98%)</td>
</tr>
<tr>
<td>Rib fractures*</td>
<td>73% (5% to 88%)</td>
</tr>
<tr>
<td>Retinal haemorrhage*</td>
<td>71% (46% to 86%)</td>
</tr>
<tr>
<td>Seizures</td>
<td>66% (45% to 82%)</td>
</tr>
<tr>
<td>Long bone fractures*</td>
<td>59% (48% to 69%)</td>
</tr>
<tr>
<td>Skull fractures</td>
<td>44% (22% to 68%)</td>
</tr>
</tbody>
</table>

* Estimates in this analysis are deemed to be conservative owing to missing data as children who have head trauma from non-abusive causes rarely have complete skeletal surveys or full ophthalmology examinations.

AHT, abusive head trauma; PPV, positive predictive value.

NEUROPAEDIATRIC FEATURES OF AHT

A meta-analysis of 20 comparative studies explored different neuroradiological characteristics.12

The data confirmed that subdural haemorrhage (SDH) is significantly associated with AHT, while subarachnoid haemorrhage is recorded equally in both AHT and non-AHT and is not a discriminatory feature. Extradural haemorrhage however is significantly associated with non-AHT.

Specific characteristics of these extra-axial haemorrhages that are more commonly seen in AHT are inter-hemispheric bleeds, multiple bleeds located over the convexities or in the posterior fossa. Intracerebral changes of AHT include cerebral oedema and hypoxic ischaemic injury, while focal parenchymal lesions were equally prevalent in both conditions.

Studies describe the appearance of the extra-axial bleeds in different ways. Haemorrhages that have a high attenuation (high density or ‘white’ appearance) on a CT are consistent with acute haemorrhages; these are described in the initial scans of both AHT and non-AHT. Low attenuation or hypodense lesions where the appearance is darker are associated with resolving haemorrhages. Low attenuation haemorrhages or multiple SDHs of different attenuations are more commonly seen in AHT than non-AHT. The appearance of a SDH can be affected by a number of factors. However the appearance of a SDH can be affected by a number of factors, such as different rates of resolution, low haemoglobin levels, mixing of cerebrospinal fluid (CSF) with the haemorrhage from rupture of arachnoid mater or villi or coexisting primary or secondary coagulopathy that can impair blood clotting.

SDH can also have a mixed density appearance which has been described in both AHT and
The ease of performing a CT on admission. However, MRI has added benefits and should be performed as soon as possible. MRI is better at identifying small SDHs over the convexities in the posterior fossa or the tentorium. It is more sensitive at identifying lesions within the brain parenchyma itself and when differentiating subarachnoid hemorrhage or low attenuation subarachnoid fluid collections that may be consistent with a benign hygroma of infancy. There is increasing evidence that MRI may offer more support to dating the intracranial trauma utilising signal analysis of resolving SDH on T1 and T2 weighted and FLAIR sequences. In a small child it is relatively easy to extend MRI to include the cranio-cervical junction and spinal cord to exclude coexisting spinal injury. Follow-up MRI can give further information regarding the evolution of the extra-axial haemorrhages that may aid an estimation of the age of the lesions as well as providing prognostic information related to the resolution or persistence of damage to the brain itself.

CLINICAL FEATURES ASSOCIATED WITH AHT

Ever since Tardieu first described this condition in 1860 and Caffey entitled his article ‘Multiple fractures of long bones of children suffering from subdural haematoma’ it has been accepted that a number of features are often associated with AHT. A systematic review of the international literature identified 14 comparative studies that explored these features (table 1).

Retinal haemorrhages (RH) are strongly associated with AHT. Most large studies have identified RH in 70–80% of confirmed AHT. Further systematic review of the characteristics of these haemorrhages revealed that in most cases, the RHs in AHT are widespread throughout the retina, extending to the periphery. They are more often bilateral than unilateral, and they are commonly found throughout all layers of the retina. In contrast, RHs are seen in fewer than 10% of non-AHT. The interpretation of this finding may include the appearance of rapid clot formation together with unclotted blood or serum, benign extra-axial fluid collections of infancy with a superimposed acute SDH, two separate haemorrhagic events or an acute admixture of high density blood and low density CSF.

The number of variables involved in the appearance of SDHs on CT therefore suggests that they should be described in terms of their radiological appearance rather than the terms acute or chronic that were formerly used to describe high and low attenuation collections, respectively.

NEUROIMAGING WHEN AHT IS SUSPECTED

Current guidelines suggest that CT is the first investigation of choice, a recommendation based upon the widespread availability and technical ease of performing a CT on admission. However, MRI has added benefits and should be performed as soon as possible. MRI is better at identifying small SDHs over the convexities in the posterior fossa or the tentorium. It is more sensitive at identifying lesions within the brain parenchyma itself and when differentiating subarachnoid hemorrhage or low attenuation subarachnoid fluid collections that may be consistent with a benign hygroma of infancy. There is increasing evidence that MRI may offer more support to dating the intracranial trauma utilising signal analysis of resolving SDH on T1 and T2 weighted and FLAIR sequences. In a small child it is relatively easy to extend MRI to include the cranio-cervical junction and spinal cord to exclude coexisting spinal injury. Follow-up MRI can give further information regarding the evolution of the extra-axial haemorrhages that may aid an estimation of the age of the lesions as well as providing prognostic information related to the resolution or persistence of damage to the brain itself.

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Table 2  Clinical indicators of abusive head trauma

<table>
<thead>
<tr>
<th>Neuroradiology</th>
<th>AHT</th>
<th>Non-discriminatory</th>
<th>Non-AHT</th>
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<tbody>
<tr>
<td>Extra-axial haemorrhage</td>
<td>SDH</td>
<td>SAH</td>
<td>EDH</td>
</tr>
<tr>
<td>Multiple</td>
<td></td>
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<tr>
<td>Interhemispheric</td>
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<td>Convexity</td>
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<tr>
<td>Posterior fossa</td>
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<tr>
<td>Intracerebral features</td>
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<tr>
<td>Hypoxic ischaemic injury</td>
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<tr>
<td>Cerebral oedema</td>
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Table 3  Essential investigations

<table>
<thead>
<tr>
<th>Child with suspected AHT</th>
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<tbody>
<tr>
<td>History</td>
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<tr>
<td>Examination and observation (and history)</td>
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<td></td>
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<tr>
<td>Neuroimaging</td>
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<td></td>
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<tr>
<td>Axial skeletal imaging</td>
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<td></td>
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<tr>
<td>Ophthalmology</td>
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<td></td>
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<tr>
<td>Additional investigations</td>
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</tbody>
</table>

AHT, abusive head trauma; CPR, cardiopulmonary resuscitation; EDH, extradural haematoma; SAH, subarachnoid haematoma.

Table 2

with suspected AHT has a retinal examination performed by an ophthalmologist using indirect ophthalmoscopy through dilated pupils and findings should be accurately recorded, including the number, distribution, laterality, layers of retina involved together with documentation of any additional ophthalmological findings. A RetCam image may provide a valuable record of the findings. An ophthalmological opinion is of particular value in relation to consideration of differential diagnoses in relation to RH—for example, infectious or congenital causes.

Apnoea

Apnoea is significantly associated with AHT and this appears to coincide with the fact that hypoxic ischaemic injury is more commonly seen on MRI images of these children.23 Multiple factors are proposed to account for the apnoea, such as respiratory insufficiency in an infant who is subjected to delayed medical attention, repeated traumatic events or damage to the respiratory control centres in the brainstem.23 There is also a recognition that seizures are more strongly associated with children with AHT and a suggestion that the seizures may exacerbate further hypoxic ischaemic damage to the brain through excitotoxic mechanisms or by inducing further respiratory insufficiency.23

Fractures

Rib fractures and long bone fractures have been found to be associated with AHT. By comparison, skull fractures were more strongly associated with non-AHT, though this analysis did not reach significance. The explanation for this is likely to be the fact that most cases of non-AHT arise from falls or impact injuries that will predispose to skull fractures, whereas AHT may include a combination of shaking injuries with or without impact.

Meta-analyses of this nature are helpful when looking at single features; however this does not replicate the clinical picture where children often present with different combinations of multiple features. However a study24 combined the individual data from 1053 children (348 cases of AHT and 705 non-AHT) from six population based comparative studies9–11,25,26 and performed an aggregate analysis of data to calculate the OR (figure 1) and predictive probability (figure 2) of abuse in a child under the age of three years old with intracranial injury, given 64 different combinations of influential features. Owing to the level of detail available for individual cases, this study further confirmed the significant association of six features (apnoea, seizures, RHs, long bone and rib fractures and head and neck bruising) with AHT and confirmed that skull fracture was not an influential factor.

Figures 1 and 2 show that the OR and the positive predictive value (PPV) for AHT increased when there are more features present. However for a child under 3 years old with intracranial injury alone the probability of AHT was only 4%. Rib fractures and RH had the greatest effect on the predictive values and once any combination of three features was present the PPV was consistently greater than 85%.

Although this type of probability calculation can never replace a clinical diagnostic process it may be a helpful adjunct to decision-making at various stages along the child protection process—for example, to identify cases that should receive a full child protection risk assessment, or to reassure clinicians when AHT is unlikely, to help the
Crown Prosecution Service decide whether there is supportive evidence to present in court and to support the opinion of expert medical witnesses in court who often need to justify how features combine to support the diagnosis of AHT.

It was not possible to combine the historical, precise neuroradiological features or detail of ophthalmological findings into this analysis owing to the lack of detail in the respective studies; a future prospective study may allow this. In the meantime these additional factors should be considered alongside the clinical findings.

**Spinal injury**

Spinal injury is rare in childhood; the most common causes are motor vehicle crashes and sports injuries. A comprehensive search of the international literature identified 25 case reports of spinal injury secondary to physical abuse. This suggests that the condition is either very rare or one that has received little research. The cases were predominantly younger than 2 years old and fell into two groups; the youngest infants (mean age 5 months) with cervical injury and older toddlers (mean age 13 months) with thoraco-lumbar injury.

Cervical injuries were distributed throughout the cervical spine and the musculoskeletal and spinal cord injuries were varied. Half of the cases were associated with AHT. Symptoms of the spinal injury were often masked by impaired levels of consciousness from AHT or presented as possible respiratory illness with painful neck movement. There were no obvious deformities.

Thoraco-lumbar injuries were most commonly located at T12-L1 and were predominantly fracture dislocations. The injuries were either confined to the musculoskeletal structures with or without spinal cord involvement. The fracture dislocations presented with thoraco-lumbar deformity, kyphosis or thoraco-lumbar swelling, while the cases with spinal cord injury presented with paraplegia with urinary retention.

To identify these cases a skeletal survey must include a lateral x-ray of the whole spine as fracture dislocations is difficult to identify on an AP film. If a spinal lesion is identified an MR scan is indicated to exclude injury to the spinal cord, ligaments or associated soft tissue injury.

### INVESTIGATION PROTOCOL

An understanding of the features that are significantly associated with AHT must be used to inform the diagnostic process (table 2) and an essential investigation strategy (table 3) that should be performed in all children where AHT is suspected.

If the features associated with AHT are to be identified or excluded, there are a series of investigations and assessments that should be performed in every child where it is suspected (table 3). This would include investigating all infants less than 2 years old with injuries suggestive of physical abuse and neurological impairment, all infants with unexplained or inadequately explained intracranial trauma or RH in the absence of a medical cause (eg, coagulopathy). Based on the knowledge that some of these children present without any neurological impairment, UK Standards for radiological investigation recommend that a CT scan is performed in every child aged under 1 year where there are signs/evidence of physical abuse. In addition certain investigations should be included to identify comorbidity (eg, impaired coagulation, low haemoglobin) or other possible causal or contributory factors.

### DIFFERENTIAL DIAGNOSIS

As in all clinical situations differential causes must be considered (table 4). These conditions have their own diagnostic tests that should be performed whenever there are clinical features that suggest an alternative cause.

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**Table 4** Differential diagnosis

<table>
<thead>
<tr>
<th>Condition</th>
<th>Characteristics</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Non-intentional injury</strong></td>
<td>SDHs are more likely to occur in high impact falls or motor vehicle crashes. Low impact falls (&lt;3 feet) rarely cause SDH. RH is rarely associated with non-intentional injury</td>
<td></td>
</tr>
<tr>
<td>Neurosurgical complications</td>
<td>SDH commonly reported as a postoperative complication of neurosurgery</td>
<td></td>
</tr>
<tr>
<td>Perinatal</td>
<td>Asymptomatic neonatal SDH has been reported in any type of delivery. They predominate in the supratentorial region. They are characteristically small and most resolve by 1 month, all by 3 months</td>
<td></td>
</tr>
<tr>
<td>Cranial malformations</td>
<td>Spontaneous bleeding from vascular malformations—for example, aneurysms. Less serious trauma can result in SDH when arachnoid cyst is present</td>
<td></td>
</tr>
<tr>
<td>Cerebral infections</td>
<td>Meningitis: post-infective subdural effusions are reported</td>
<td>Meningococcal septicaemia can be associated RH</td>
</tr>
<tr>
<td>Coagulation and haematological disorders</td>
<td>Leukaemia</td>
<td>These disorders will also predispose to RH and bruising</td>
</tr>
<tr>
<td>Disseminated intravascular coagulation</td>
<td>Sickle cell anaemia</td>
<td></td>
</tr>
<tr>
<td>Haemorrhagic disease of the newborn</td>
<td>von Willibrand's disease</td>
<td></td>
</tr>
<tr>
<td>Haemophilia</td>
<td>Haemorrhagic disease of the newborn</td>
<td></td>
</tr>
<tr>
<td>Metabolic disorders</td>
<td>Glutaric aciduria type 1 is associated with front-temporal atrophy that can predispose to SDH</td>
<td>Case reports describe associated retinal haemorrhages in glutaric aciduria</td>
</tr>
<tr>
<td>Osteogenesis imperfecta</td>
<td>Fractures and RH in osteogenesis and vitreous haemorrhage reported in galactosaemia</td>
<td></td>
</tr>
<tr>
<td>Galactosaemia</td>
<td>Menkes syndrome has associated femoral spurs that can be confused with fractures</td>
<td></td>
</tr>
<tr>
<td>Menkes kinky hair syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Menkes syndrome</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypernatraemia</td>
<td>SDH is described in association with salt poisoning. Hypernatraemic dehydration hypernatraemia may also be a complication of the intracranial trauma</td>
<td></td>
</tr>
<tr>
<td>Enlarged subarachnoid space</td>
<td>Benign extra-axial fluid collections of infancy must be differentiated from low attenuation SDH. If this coexists with SDH the cause must be investigated. There is debate in the literature as to whether benign extra-axial fluid of infancy predisposes an infant to SDH</td>
<td></td>
</tr>
</tbody>
</table>

RH, retinal haemorrhage; SDH, subdural haemorrhage.
As already discussed, AHT is one of the most serious forms of physical abuse with a poor clinical outcome. When there are several of the associated features present the diagnosis can be reasonably straightforward. However in the infant who simply has isolated intracranial features, confirming or excluding AHT as the cause is difficult.

As well as defining the probability of AHT, the clinician is expected to contribute to multiagency decisions regarding the risk of future child abuse and appropriate child protection plans. They may be asked to present evidence as professional or expert medical witnesses in the Family or Criminal Court. In fatal cases a paediatrician will review these processes, which may occur over an extended time period.

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REFERENCES

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