Clinical Radiology (2005) **60**, 22–30

REVIEW

Neuroimaging in non-accidental head injury: if, when, why and how

N. Stoodley*

Department of Neuroradiology, Frenchay Hospital, Bristol, UK

Received 5 January 2004; received in revised form 26 January 2004; accepted 13 May 2004

KEYWORDS
Brain, hemorrhage;
Hypoxia; Infants;
Injuries; Brain, CT

Non-accidental head injury (NAHI) in infants is an important but difficult topic. To miss or misdiagnose NAHI potentially has important consequences. The evidence base upon which to base decisions is limited but growing. This article aims to summarise current literature and thinking in this difficult area.

Introduction

Non-accidental injury in infants is an emotive and difficult topic for any professional to deal with and radiologists are no exception. The stakes are high: not to recognise abuse means that the child may go back into an abusive setting with potentially dire consequences; mistakenly to accuse carers of inflicting injuries can have different but similarly devastating consequences on the family as a whole. Perpetrators rarely admit to what they actually did, and so in most cases conclusions have to be drawn both from personal experience and from various and varied sources within the medical literature. This is reflected in this article, which is a combination of a review of the pertinent literature and of the author's personal experience of acting as an expert witness in over 100 cases of alleged non-accidental head injury. This article attempts to set out the rationale for an imaging approach to the investigation of non-accidental head injury, but there are many other controversial issues surrounding the topic and some of these are addressed in a complementary article.[1]

One of the major difficulties in this area is that certain imaging characteristics have come to be associated with non-accidental head injury (NAHI), and those features inevitably attain a certain prominence in any court proceedings. It is therefore not surprising that these same features show a high incidence when retrospective case series are reviewed using the findings of courts! It could be argued that this potentially circular argument weakens the case for the importance of imaging, but two key questions need to be considered:

(a) How often is this combination of features seen in clinical situations that are patently not abusive, such as infections, coagulopathies, accidental trauma and asphyxial episodes due to other causes?
(b) What combination of features is seen in cases where either there has been an independent, reliable witness to the actual episode of abuse or the perpetrator has described the actual mechanism of injury?

It is unusual to see the combination of features described below in clinical situations other than NAHI, and most of the literature supports this. In my personal experience of cases where there has been a confession or an independent witness, the neuroimaging features have been of multifocal subdural haematomas (SDHs) and usually diffuse hypoxic-ischaemic parenchymal changes. If this combination occurs following witnessed or admitted NAHI and is unusual in other clinical conditions, it is at least reasonable to consider NAHI

* Guarantor and correspondent: N. Stoodley, Department of Neuroradiology, Frenchay Hospital, Frenchay Park Road, BS16 1LE Bristol, UK. Tel.: +44-117-975-3968; fax: +44-117-975-3781.
E-mail address: neil.stoodley@north-bristol.swest.nhs.uk.

as a cause for these appearances where no reasonable history is given and no naturally occurring condition is found on investigation of the infant.

Another valid criticism of workers in this area is that their opinions are not substantiated by good scientific data. This is not surprising given the nature of the problem. In the absence of a randomized controlled trial of shaking infants of various ages with various degrees of force, we must look at the information available from other sources in an attempt to reach reasonable and reasoned conclusions.

Radiologists therefore may be the first to raise the possibility of abuse if an injury on a film is out of keeping with the clinical information given. In order to recognise these situations, the radiologist needs to be aware of what features can reasonably be considered the consequence of accidental trauma and which should raise suspicions about the mechanism of injury. The radiological investigation of non-accidental injury has traditionally relied mainly on the findings of skeletal surveys and radionuclide bone scans. However, the non-accidental injuries that cause most mortality and morbidity are the associated head injuries, and so many centres now routinely use neuroimaging in the investigation of suspected non-accidental injury. The latest edition of *Making the Best Use of a Department of Clinical Radiology* issued by the Royal College of Radiologists describes the use of head CT in the investigation of possible abuse as "mandatory".

The components of a non-accidental head injury (NAHI) may be varied and include skull fracture, subdural and subarachnoid haemorrhage, contusion and intraparenchymal haemorrhage together with other parenchymal injuries including diffuse axonal (shear) injuries and hypoxic-ischaemic damage. All of these features may of course be seen following accidental trauma, but there are differences in incidence and patterns of these various components that aid the differentiation of likely accidental and non-accidental injuries.

There is still some debate about the mechanism of injury in these cases: is it shaking, impact or a combination? The mechanism of injury seems to me to be less important than the differentiation between accidental injury and NAHI. Although it is now firmly embedded in the medical literature, I prefer not to use the term "shaken baby syndrome" and use the terms NAHI or abusive head trauma.

The aim of this article is to summarize the background to the increased emphasis of the importance of neuroimaging in the investigation of this condition, and to explain how evidence from neuroimaging gives clues to the pathology seen following NAHI.

History and epidemiology

Unfortunately child abuse is not uncommon and it takes many forms. It is not a new phenomenon[2] and I suspect that the incidence has not changed significantly over the centuries. The description of the constellation of findings which are now referred to as the "shaken baby syndrome" has been widely ascribed to Caffey,[3] an American paediatric radiologist, but in fact a paper by Guthkelch,[4] a British neurosurgeon, appeared in the BMJ the year before Caffey's article describing the features of this condition. The syndrome is commonly described as comprising skeletal injuries, notably rib and long bone metaphyseal fractures, usually of different ages, SDHs and retinal haemorrhages. There may be other features of physical injury such as bruises or burns, but it is important to emphasize that it is not necessary to have all of the features to suggest child abuse as a reasonable cause for the constellation of injuries present.

SDHs have attained great importance in the literature surrounding non-accidental injury. The incidence of SDH in infants has been reported in two recent papers[5,6] at approximately 24 per 100,000 infants below the age of 1 year. Most of these are due to abuse, and the outcome for these infants is generally poor. In Jayawant's study[5] of 33 children, 9 died and 15 were profoundly disabled following the injury.

Imaging features: accident or abuse?

Skull fractures

The presence of a skull fracture is evidence of a significant impact injury, although such fractures have also been described following delivery, including uncomplicated normal vaginal delivery. If there is associated tender soft tissue swelling the impact is likely to have occurred in the recent past, but injuries such as cephalhaematomas can take some time to become evident and several weeks or more to resolve.

Fractures can obviously be caused by either accidental or non-accidental trauma. The explanations given for injuries in cases subsequently found to be non-accidental often involve falling onto various surfaces from various items of household furniture. How common are fractures