

Non-accidental injury: a radiological perspective

H Carty

Introduction

Non-accidental injury (NAI), though well recognised in Western Society, since Caffey's publications from 1946 onwards, is perhaps less often diagnosed in Asia, with publications on the subject mainly coming from Japan. There are no reliable statistics as to its incidence or the mortality and morbidity from it from Asia. This may be in truth that, compared with their Western counterparts, Asian babies are less frequently injured, but it may too be because of lack of recognition of the early signs and symptoms, these being ascribed to organic pathology. While the diagnosis of NAI is clearcut in the child presenting with bruising, or obvious fractures without an appropriate history, often the clinical presentation initially suggests a medical illness. The diagnosis of abuse then being made by discovering more subtle signs of abuse, e.g. torn frenulum, or neuroimaging that reveals the characteristic fractures of abuse.

Child abuse is a grave diagnosis but one that cannot be shirked if the child in a place of risk is to be protected. Unlike other diseases in children caused by external factors over which there is little or no control, most abused children are normal until they are assaulted by a carer. The victims of a shaking or shaking impact injury are, if they survive, often left severely handicapped for life. Often these children have been seen by health care personnel who failed to appreciate the warning signs of injury.

The radiologist has an important role in the diagnosis of child abuse, and should be part of the multidisciplinary team in any hospital which cares for children.

The role of the radiologist in child abuse may arise as follows:

1. The interpretation of skeletal radiographs, carried out in suspected cases.
2. The assessment of a fracture and its compatibility with a given clinical history.
3. To perform and interpret neuroimaging in children admitted with neurological signs and symptoms.
4. To carry out and interpret cross sectional imaging of the thorax and abdomen in abused children.
5. To alert the paediatricians about the presence and significance of the incidental discovery of skeletal injury on radiographs done for other purposes.
6. To carry out and report on skeletal radiology on children brought in dead prior to post mortem.

To develop the above themes in some detail:

1. Skeletal radiology

When a child presents to the emergency room with suspected abuse, a skeletal survey is an integral part of investigations. Departments of Radiology should have protocols in place as to the images required, the timing of these images, the radiographic technique, parental communication and what they are told so that the technicians do not find themselves faced with angry or bewildered parents who thought their child was coming for a skull X Ray and wants to know why the rest of the radiographs are being done.

The protocols in use in this author's department and the required radiographs for a proper skeletal survey are shown in Appendix. The films must be of high quality, correctly positioned and exposed. A "Baby gram" film is inadequate as a survey in child abuse.

Correspondence to:

Helen Carty, MBBCh, FRCPI, FRCR

Liverpool University and Royal Liverpool Children's Hospital, Professor of Paediatric Radiology, Alder Hey, UK

Skeletal surveys should be done during normal working hours. They do not need to be done at 2.00 a.m. It is important that 2 radiographers are present during the survey so that they are not accused of causing the injuries!

An exception to the above is that if a child presents with a fractured femur, it is important that the whole of that limb is imaged, to include the coned lateral view of the knee and ankle before Gallows traction is applied. The rest of the survey can be completed the following day.

2. Assessment of the injury

The bony lesions of child abuse fall into two categories – those that are highly specific for abuse, such as metaphyseal and rib lesions, (Figures 1-6) and those that are frequent but are similar to those that occur in accidental trauma in an older child, or if in an infant where there is an appropriate history of injury. (Tables 1 and 2) It should be noted, however, that some of the injuries with a high association for abuse such as bilateral skull fractures can on occasion be accidental. A radiologist, as indeed an A&E or orthopaedic consultant must be familiar with the biomechanics of fractures, trauma patterns and a child's developmental status so that an assessment of compatibility of imaging and history may be made. (Figure 7) Fractures of the shafts of the long bones and skull fractures sustained non-accidentally are the two main lesions that may be dismissed as being accidental by lack of careful assessment.

3. Neuroimaging

Many children who sustain a shaking impact injury present as an emergency to hospital with acute neurological presentation without overt soft tissue injury. The initial diagnosis is often meningitis or near miss cot death. Once the child is stable, neuroimaging is required to establish the cause of collapse. In general, CT is the preferred neuroimaging. Ultrasound may be used as an adjunct and is helpful in the detection of shear injuries at the junction of the grey and white matter, lesions rarely seen on CT, but specific to abuse. Ultrasound is not adequate to exclude intracranial injury in abuse as both posterior fossa and cerebral convexity subdural lesions frequently seen in NAI are invisible to ultrasound. Magnetic resonance

(MR) diffusion imaging may prove sensitive in the detection of early traumatic changes, but fresh blood may not be visible at MR imaging and skull fractures will be missed. MR is of course ideal for the long term follow up of abuse.

The main abnormalities seen on neuroimaging are subdural haematomas over the cerebral convexities and the occiput, often extending into the interhemispheric fissure, (Figure 8) and as the severity of the injury increases, evidence of cerebral oedema, hypoxic ischaemic damage, (Figure 9) intracerebral and less frequently intraventricular haemorrhage. Shear injuries at the junction of the grey and white matter may be seen on ultrasound or MRI (Figure 10) but are rarely visible on CT. The most frequent errors of interpretation are a failure to appreciate the presence of blood in the interhemispheric fissure and to dismiss it as the normal falx or to dismiss subdural collections as being of unknown origin and not to appreciate the significance. Sequelae of brain injury include, obstructive and communicating hydrocephalus, multicystic encephalomalacia, infarction and failure of growth.

While neuroimaging will be automatically done in a child with an acute neurological presentation, paediatricians are sometimes reluctant to request neuroimaging in children with "soft" neurological signs or with a skull fracture thought to be abusive, but without neurological signs. It is recommended that those children should have CT, as the demonstration of cerebral injury or a subdural haematoma, both unusual with minor head injury in children, will help to confirm a diagnosis of NAI. The features of NAI on CT are well described in the literature.

4. Thoracic and abdominal injury

Thoracic and abdominal trauma by comparison with skeletal and neuro trauma are relatively rare in NAI. They are associated with a relatively high morbidity and mortality when compared with similar injury sustained accidentally. This is often due to delay in bringing the child to medical attention in the hope that the symptoms will go away. The organs mainly injured nonaccidentally are the stomach and duodenum, the pancreas and liver. The spleen and kidneys are rarely injured in

Table 1. Fractures considered to have a high specificity for abuse

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- Metaphyseal fractures
 - Rib fractures
 - Scapular fractures
 - Fractures of the outer end of the clavicle
 - Fractures of different ages
 - Vertebral fractures or subluxation
 - Digital injuries in non-mobile children
 - Bilateral fractures
 - Complex skull fractures
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Table 2. Fractures frequent but with low specificity

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- Mid clavicular fractures
 - Simple linear skull fractures
 - Single long bone fractures
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(Tables 1 and 2 adapted from J Bone Joint Surg (Br) 1993;75-B: 849-57).



Figure 1. Subtle bucket handle fracture distal tibia.



Figure 2. Healing bucket handle fracture distal tibia.



Figure 3. Healed intracapsular metaphyseal fracture distal tibia. The alteration in contour is typical. This fracture will have healed without periosteal reaction.



Figure 4. Healing metaphyseal fractures both distal femora. This child also had bilateral forearm fractures.



Figure 5. Fresh metaphyseal fracture distal tibia and fibula. Periosteal new bone on both sides of the tibial shaft which is pathological and older than the fracture. This may represent healing of a spiral fracture not radiologically visible or it can reflect rough gripping. Further healing intracapsular fracture medial proximal tibia, age difficult to ascertain but could be the same age as the tibia but by application of a separate force.



Figure 6 (a).



Figure 6 (b).

Figure 6. (a) Chest X Ray - Admission. (b) 10 days' later. On the admission film healing fractures of the necks of the Left 8th, 9th and 10th ribs are visible. The other fractures are only seen when they begin to form callus. Note (b) Fractures. Right rib necks 6-10 and Left 5-9, the 10th now being virtually completely remodelled. The fractures in this location give the typical appearance of a squeezing injury to the chest and has occurred twice. These fractures are frequently found in association with a shaking brain injury.

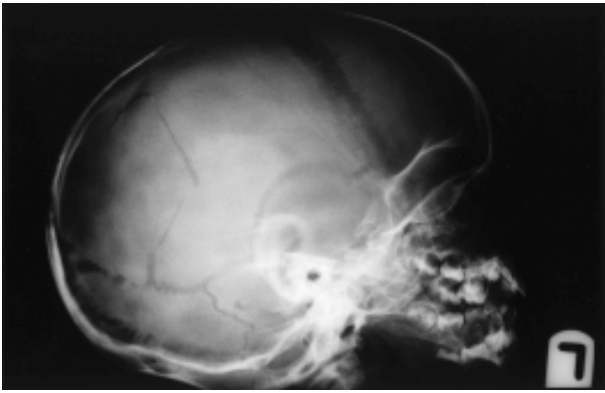


Figure 7. Complex parietal fracture in a child with diastasis of the coronal and squamous temporal sutures due to raised pressure. The clinical history provided on admission was of a fall onto a carpeted floor two hours previously. The child was irritable with fluctuating levels of consciousness. The fracture and the history are incompatible.

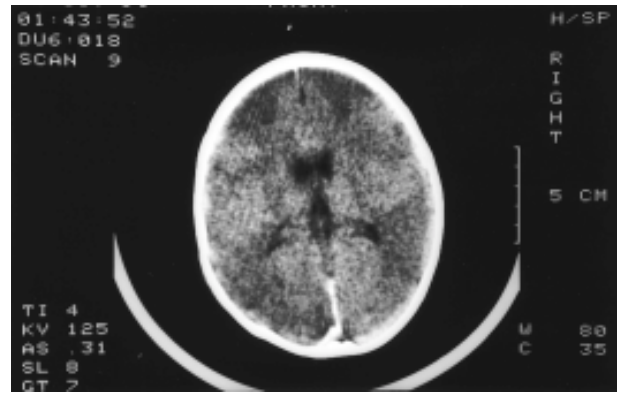


Figure 8. CT head of infant admitted with a history of apnoea at home. There is an interhemispheric fissure subdural extending over the Left occipital cortex and patchy loss of normal density of the grey and white matter, due to hypoxic ischaemic change. The CT appearances are those of a shaken infant.

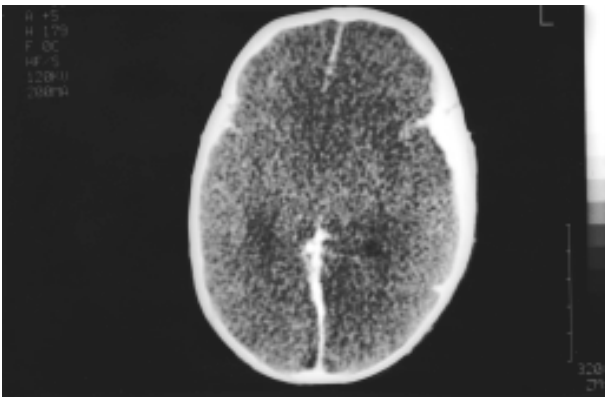


Figure 9. CT of a shaken impact infant. There is gross hypoxic ischaemic change with loss of the normal grey/white matter interface, gross cerebral oedema with obliteration of all fluid filled spaces of the brain, a Left sided subdural haematoma, with mass effect and midline shift and an interhemispheric subdural. This baby died 2 days' later.

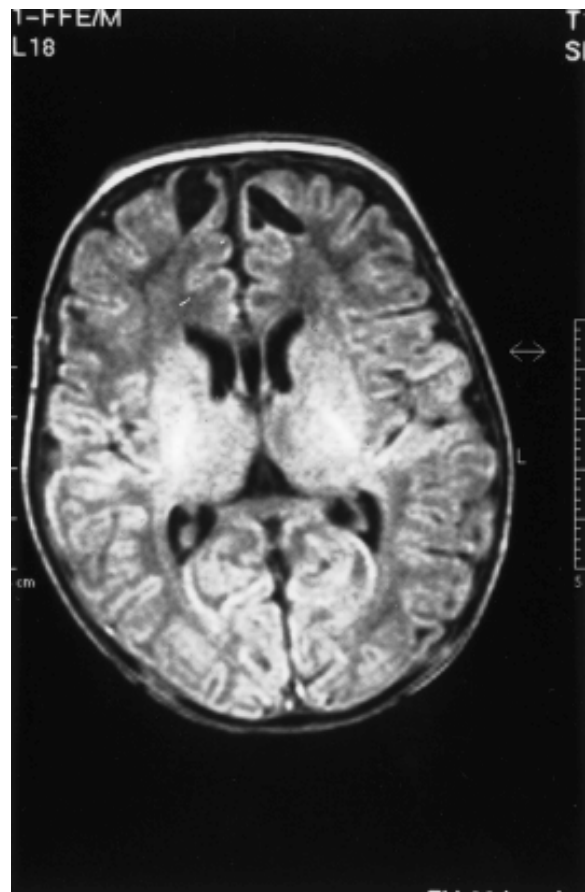


Figure 10. MR scan showing shear injuries in the frontal cortex, a typical location. These also may occur anywhere at grey/white matter junctions.

comparison with accidental trauma. The mechanism of injury is typically a compression of the organs against the spine. Due to the delayed presentation to hospital, bruising may have already faded so one cannot rely on it to help in the diagnosis. By comparison with accidental trauma where there is a clear history, the history is often vague, and inconsistent with the injury. A typically proffered story is of a fall downstairs, a mechanism that is inconsistent with bowel injury. The finding of bruising or occult fractures heightens the certainty of the diagnosis but it is unusual to find fractures, especially in older children.

Rib fractures are frequent in abuse and these may on occasion be associated with pleural haematomas. Overt injury to the lung parenchyma is rare. Pneumothoraces, pulmonary haematomas, rupture of the diaphragm, and even cardiac rupture have all been recorded. Rib fractures are frequent as the level of force required to cause such injury is extreme.

5. Oral and pharyngeal trauma

The common oral injury is tearing of the frenulum, a clinically detectable lesion and one without radiological implications. A penetrating injury to the pharynx caused by insertion of a finger or a sharp object may result in a pneumomediastinum

and subcutaneous emphysema. A complication of the penetrating wound is a retropharyngeal abscess.

It is hoped that this short summary of one radiologist's view of the injuries of abuse, all of which she has encountered in clinical practice, will raise awareness of the problem and show the importance radiology as being pivotal in many cases in making the diagnosis.

The purpose of this article is not to describe all the features of NAI, as these are well described in the literature, but to highlight the role of radiology and its contribution to the diagnosis of child abuse.

Further reading

1. Kleinman PK. Diagnostic Imaging of Child Abuse St. Louis: Mosby, 1998.
2. Carty H. Fractures caused by child abuse. *J Bone Joint Surg (Br)* 1993;75-B:849-57.
3. Carty HML. The radiological features of child abuse. *Current Paediatrics* 1995;5:230-5.
4. Carty H. Non-accidental injury: a review of the radiology. *Eur Radiol* 1997;7:1365-76.
5. Rao P, Carty H. Non-accidental injury: Review of the radiology. *Clin Rad* 1999;54(1):11-24.

Appendix

ROYAL LIVERPOOL CHILDREN'S NHS TRUST RADIOLOGY DIRECTORATE

THE POLICY AND PROCEDURE FOR A SKELETAL SURVEY FOR SUSPECTED NON ACCIDENTAL INJURY

POLICY

It is the policy of the Radiology department of the R.L.C. NHS TRUST to carry out a skeletal survey for suspected non accidental injury using the following procedure.

PROCEDURE

1. The Radiographer carrying out the examination must be accompanied by a nurse or an other Radiographer to act as a witness to the procedure.
2. The patients details must be checked on the radiology order and if the child is over two years old, the Radiographer must check site of injury and refer to a consultant Radiologist. The number of radiographs required may then be reduced depending on site of injury.
3. During the procedure should the Radiographer witness or be told any relevant information by either parent this must be noted on the reverse of the request form and filed with the films. These comments must be signed and dated with the Radiographer's signature and the witnesses signature. The Consultant Radiologist on duty must be made aware immediately of any such observations.
4. All films must be correctly marked with:
Name
D.O.B.
Date of examination
5. The Radiographer will enter all examination details correctly, using <RADIOGRAPHER ENTER/EDIT> in Meditech.
6. All exposure factors must be recorded onto the examination label.

Appendix (con't)

LIVERPOOL CHILDREN'S NHS TRUST
RADIOLOGY DEPARTMENT
STANDING INSTRUCTIONS FOR RADIOGRAPHERS IN RELATION TO
SKELETAL SURVEYS FOR SUSPECTED NON ACCIDENTAL INJURY

1. Radiographers are instructed not to discuss the possible diagnosis with the parents. If they become abusive or question the need for the number of x-rays taken they are told that this is what the doctor has requested and that they should discuss it with him/her.
2. The protocol for "Skeletal Survey – suspected non accidental injury" must be followed. Radiographers have been shown the varying lesions of non-accidental injury and are encouraged to take extra views where required using their own initiative, if a Radiologist is not available. When a Radiologist is present staff have instructions to show the skeletal survey whilst the patient is still in the department, so that further views can be obtained if necessary.
3. Junior Radiologists are not permitted to give a formal report on a skeletal survey for suspected child abuse. They may give a verbal opinion in the temporary absence of a Consultant but a written formal opinion must come from a Consultant Radiologist.
4. If either a Radiographer, a junior trainee or any member of the secretarial staff has occasion to suspect child abuse they are instructed to immediately contact the Consultant Radiologist within the department or referring clinician if out of hours so that necessary contact with other doctors can be established.
5. When a reporting radiologist identifies a suspicious lesion on an x-ray and there has been no question of child abuse before the x-ray was taken the following procedures apply.
 - a) He should contact the referring clinician or GP by telephone and transmit his fears. The report should be issued along the lines that fractures are present and in the presence of this a full skeletal survey is warranted but the words "Non-accidental injury" should not appear on the preliminary report.
 - b) Rarely, sexual abuse may be suspected during the course of a procedure such as a Micturating Cystogram. These are frequently done by junior members of staff. If they see perineal or vaginal bruising they are instructed to immediately cease the examination and to contact one of the Consultant Radiologists who will then advise the necessary authorities and the referring Consultant or GP.
 - c) If the X-rays are sent to the ward unreported it is the requesting clinicians responsibility to seek a formal radiological report at the earliest possible opportunity.
 - d) When a case of NAI is positively identified the X-ray packet is stamped with the statement "Not to be release from the Department without the consent of the Consultant Radiologist". It is hoped that in this way X-rays will not be removed and subsequently lost. It is our practice to copy all films in such a case and retain a copy for further consultation.

VIEWS FOR A SUSPECTED NON ACCIDENTAL INJURY

- a. Skull AP and lateral.
- b. Chest and Abdomen AP only.
- c. Pelvis and legs AP only.
- d. Both arms AP only.
- e. Whole spine Lateral only.
- f. Lateral Tibia and fibula both legs (to include knees and ankles).
- g. Coned views of both knees and ankles, AP and Lateral.

N.B. If there is a suspected fracture a lateral of the affected limb should be performed also

7. After 5 pm or at the weekends if a child is being admitted the skeletal survey should be performed during the next working day. Alternatively the referring Doctor must have authorisation from his/her clinical consultant. If there are any queries related to the skeletal survey being carried out after 5 pm or at the weekend, the clinical Consultant must refer to the Consultant Radiologist on call.
8. No skeletal surveys should be performed on call. i.e. after midnight.
9. The standing instructions for Radiographers in relation to skeletal survey for suspected non accidental injury must be followed.