Occult fractures detected on radiographs in young children with a concern for abusive head trauma

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Aims. To determine the incidence of children < 2 years old with suspected abusive head trauma, to evaluate usage of dedicated skeletal radiographs and the incidence of clinically occult fractures on dedicated skeletal radiographs.
Methods. This is a retrospective single centre study of children < 2 years old with traumatic brain injury, referred to the University Hospital's Social Services Department between December 31, 2012 and December 31, 2020. Clinical and demographic data was retrieved from medical notes and imaging was reviewed by paediatric radiologists.
Results. 26 children (17 males), 2 weeks to 21 months of age (median age 3 months) were included. Eleven children (42%) had traumatic history, fourteen children (54%) had one or more bruises, eighteen children (69%) had abnormal neurological findings. 16 children (62%) had dedicated skeletal radiographs, 7 children (27%) had radiographs of part of the skeleton and 3 children (11%) had no skeletal radiographs. 5 out of 16 children (31%) with dedicated skeletal radiographs had a clinically occult fracture. 15 (83%) of clinically occult fractures had high specificity for abuse.
Conclusion. The incidence of suspected abusive head trauma in children < 2 years old is low. Clinically occult fractures were detected in one third of children with dedicated skeletal radiographs. The majority of these fractures have high specificity for abuse. Dedicated skeletal imaging is not performed in more than one third of the children and hence fractures may be missed. Efforts should be taken to increase awareness of child abuse imaging protocols.

Key words: children, abusive head trauma, non-accidental injury, abuse, imaging, fracture

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INTRODUCTION

Youngest children are at the highest risk of non-accidental injury (NAI) and the majority of child abuse deaths occur in infants and toddlers[1,2]. Common forms of NAI include bruising, burns, fractures, abdominal trauma and abusive head trauma (AHT), formerly known as shaken baby syndrome.

Even though any abuse has negative consequences for the child, AHT is particularly serious, with high morbidity and mortality[3-5]. The estimated incidence of AHT is 25–30 per 100 000 children below one year of age[6-8]. This number is likely to be underestimated given the difficulties with diagnosing AHT which is challenging due to non-specific clinical findings, frequent absence of external signs of head injury, missing or changing traumatic history, as well as lack of NAI-specific intracranial imaging findings[9-11]. Yet, it has been shown, that more than half of serious and fatal head injuries in children younger than two years are caused by NAI (ref.[6]).

There is a high prevalence of skull, extremity and thoracic fractures in infants evaluated for suspected AHT (ref.[1]). Identifying concomitant skeletal injuries in these children is of the utmost importance, since they provide solid evidence of a traumatic event and add crucial information to the challenging diagnostic puzzle of NAI. However, skeletal injuries may be clinically occult and thus impossible to diagnose without radiological investigation[12].

To detect fractures, the so-called skeletal survey is utilised. This is a standardized series of radiographs, covering the entire skeleton of a young child. It is used in the evaluation of all children below two years of age with suspected NAI (ref.[13-15]). The prevalence of occult fractures on skeletal survey is 13–26% for infants and 7–19% for toddlers evaluated for suspected child abuse[15].

At the author's institution, a paediatric University Hospital, the NAI evaluation of infants and toddlers with intracranial haemorrhage traditionally consisted only of detecting skull injuries, external signs of injury, evaluating the social history and observing the parental behaviour towards the child. If no abnormalities were observed, the aetiology of intracranial injury was concluded to be of unknown origin and after treatment, the child was discharged from hospital.

However, over time, growing evidence has challenged the traditional view of AHT. It has been shown that children with AHT may have no scalp swelling or skull fracture, but often have other fractures, many of which are clinically silent[10,16]. As a result, the approach to infants and toddlers with intracranial injury has gradually changed at the institution. Currently, more awareness is paid to careful evaluation of possible abuse. To date, there has been no study evaluating this group of patients at the

national level. There are no national data on the clinical and imaging findings and the use of skeletal imaging to detect possible fractures in these cases as recommended by professional societies[13-15].

The aim of this study was to assess the use and yield of skeletal imaging in detection of occult fractures in children younger than two years of age who were evaluated for suspected abusive head trauma. These children have high risk for occult fractures. The primary objective of this study was to determine the incidence of suspected abusive head trauma treated at the University Hospital and the rate at which NAI-dedicated radiographs was performed in these children. The secondary objective was to determine the prevalence of clinically occult fractures in children with suspected abusive head trauma.

MATERIALS AND METHODS

Ethical standards

This research study was conducted retrospectively using data obtained for clinical purposes and was approved by the Ethics Committee of University Hospital (registration number EK-1255/22).

Subjects

The inclusion criteria were: patients aged 0–2 years with traumatic brain injury with concern for non-accidental mechanism of injury, whose cases were reported to the University Hospital's Social Services Department between December 31, 2012 and December 31, 2020. The sample included patients with traumatic and non-traumatic history. The exclusion criteria were: incomplete medical records, no brain imaging, negative brain imaging and concern for neglect rather than abuse. The need to perform the skeletal survey in these children was assessed according to published recommendations[17]. According to these recommendations, skeletal survey was deemed necessary in each of the 26 children.

Imaging and clinical data

This was a retrospective study. The patients were identified in the University Hospital's Social Services Department database. The patients' radiology images were reviewed in the hospital's Picture Archiving and Communication System (PACS). The initial head Computed Tomography (CT) or Magnetic Resonance Imaging (MRI) of the brain was evaluated for the presence of traumatic brain injury. If present, skeletal radiographs were reviewed for the presence of fractures. In patients with fractures identified on skeletal radiographs, hospital electronic records were reviewed for local clinical signs of injury (bruising, swelling, pain or altered mobility). Detailed patients' clinical data was extracted from the hospital electronic records (age, sex, history provided by patients' caregiver, presence of bruising and neurological status at the time of patient admission).

Data analysis

Head CT or MR imaging was reviewed for the presence of traumatic brain injury by a paediatric radiologist with 11 years of experience in paediatric imaging. The skeletal radiographs were reviewed for the presence of fractures by three paediatric radiologists with 11, 25 and 27 years of experience in paediatric imaging. Disagreements were resolved by consensus.

The radiographs of each patient were characterised as: no skeletal radiograph, skeletal radiographs of incomplete skeleton or dedicated NAI skeletal radiographs (a babygram or a skeletal survey). Only skeletal radiographs performed within the first two weeks after admission were evaluated for the purpose of the study.

Pertinent terms are defined as follows:

a. Babygram: whole skeleton of an infant captured on a series of 1–4 radiographs.
b. Skeletal survey: a standardised series of radiographs that encompasses the entire skeleton.
c. Traumatic brain injury: presence of intracranial haemorrhage (extra-axial, parenchymal or intraventricular), brain contusion or brain laceration. Patients with isolated skull fractures and no evidence of intracranial injury are not included in the study.
d. Clinically occult fracture: fracture identified on a radiograph in a patient without local symptoms. Equivocal fractures are not considered occult fractures. Skull fractures are not considered clinically occult as they are identified on head CT or MRI and often lead the physician to raise suspicion for abusive head trauma in the first place.
e. Bruising: Definite bruising on admission. Equivocal bruising noted in the admission note is considered negative for bruising.
f. Pathological neurological findings: altered mental status, convulsions or focal neurological findings.

Statistical analysis

Demographic data is expressed as total count, percentage or median. History of trauma, external signs of injury and the presence of neurological findings are expressed as binary outcome, total count and percentage. The usage of radiographs is expressed as total count and percentage. The frequency of occult fractures is expressed as total count and percentage.

RESULTS

Study population characteristics

During the period of December, 2012 – December, 2020, 77 children younger than two years of age were referred to the University Hospital's Social Services Department due to possible neglect or NAI. Six patients with incomplete medical records, 25 children with no brain imaging, 14 children with negative brain imaging, and 2 children with traumatic brain imaging changes in

patients with concern for neglect (1 patient with fall from height, 1 patient with brain injury following a dog attack) did not meet inclusion criteria and were excluded from the study. The remaining 26 patients with traumatic brain changes on imaging and concern for abuse were included in the study (Fig. 1).

Demographic and clinical data

In the 26 children with traumatic brain injury, the age ranged from 2 weeks to 21 months, median age was 3 months. Twenty-three children (88%) were younger than 12 months. There were 17 males (65%) and 9 females (35%). Eleven patients (42%) had traumatic history, 15 patients (58%) had non-traumatic history. Fourteen patients (54%) had one or more bruises at the time of admission to hospital. Eighteen patients (69%) had abnormal neurological findings on admission.

Two children died (1 patient had severe brain injury with a history of minor trauma, 1 patient had brain oedema and traumatic brain injury with a history of cardiac arrest).

Usage of skeletal radiographs

Of 26 patients with traumatic brain injury evaluated for possible abusive head trauma, 16 patients (62%) had dedicated NAI skeletal radiographs, 7 patients (27%) had radiographs of part of the skeleton and 3 patients (11%) had no skeletal radiographs.

Traumatic skeletal findings on imaging

Altogether, there were 30 fractures in 12 children (46%), four of which had a non-traumatic history. There were 12 skull fractures, 9 extremity fractures, 8 rib fractures, 1 clavicular fracture.

Clinically occult fractures on skeletal radiographs

Eighteen fractures in 5 out of 26 patients (19%) were clinically occult (Fig. 2). These fractures were only detected in patients with dedicated NAI imaging, resulting in 5 out of 16 (31%) fracture prevalence in this group.

Each patient with a clinically occult fracture had at least one fracture with high specificity for abuse – there were 7 classic metaphyseal lesions (Fig. 3) and 8 rib fractures. Additionally, there was 1 clavicular fracture, 1 metaphyseal and 1 diaphyseal fracture (Table 1).

DISCUSSION

The data collected in the University Hospital demonstrate that in the studied period there were 26 young children with traumatic brain injury evaluated for suspected abusive head trauma and reported to the Social Services Department. This translates to only slightly more than 3 patients annually. In the studied period, more than 100 000 children were born in the country every year[18]. Based on the international data, the expected national incidence of abusive head trauma is above 25 children under one year of age annually[6-8]. Although it is not possible to extrapolate the data from one hospital to a national level, this study was performed in the largest paediatric hospital in the country and the observed incidence was lower than expected. It is possible that cases of abusive head trauma are being missed or not reported to the Social

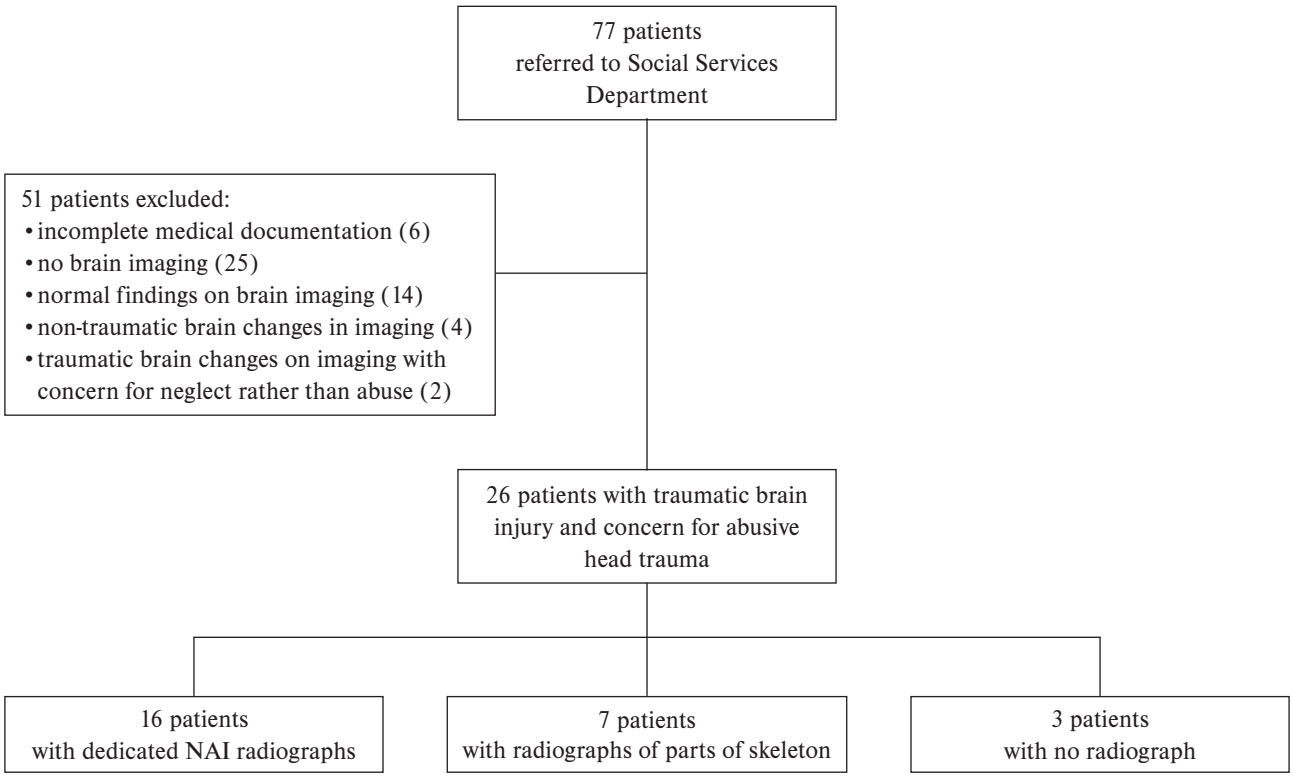

Fig. 1. Flow diagram of patient selection and radiograph evaluation.

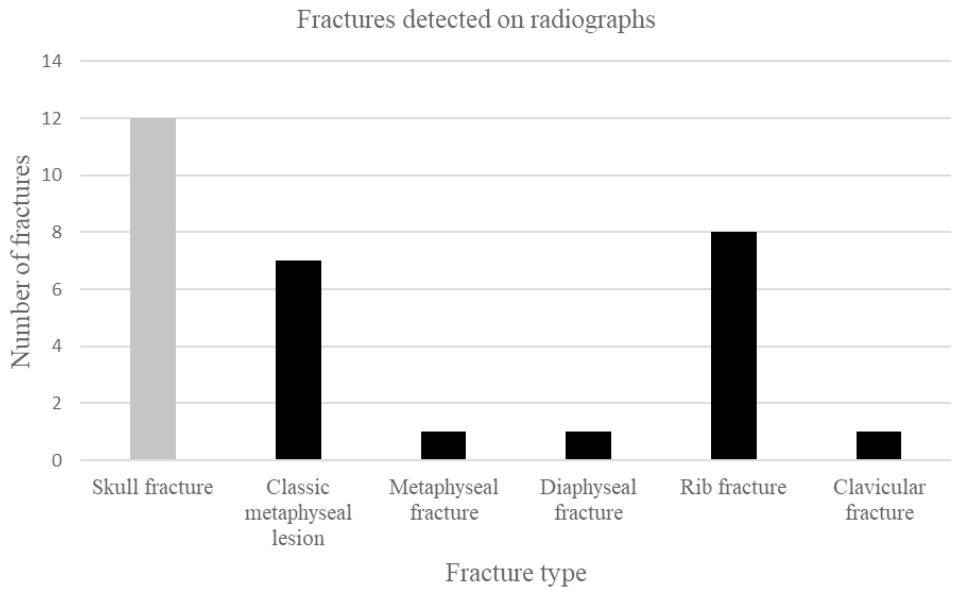

Fig. 2. Fractures detected on radiographs in children evaluated for possible abusive head trauma. Previously known fractures marked grey, clinically occult fractures marked black.

Table 1. Clinical and radiographic details of patients evaluated for possible abusive head trauma with occult fractures detected on radiographic imaging.

	Patients				
Sex	M	F	M	F	M
Age in months	2	4	6	2	1.5
History	Fall into a stroller with glass bottles, in care of an under-age mother	Apathy, convulsions	Altered mental status, convulsions	Excessive crying, decreased appetite, diarrhoea	Fall from mother's arms, convulsions
Traumatic history	Yes	No	No	No	Yes
Neurological status	Normal	Altered mental status, convulsions	Normal	Convulsions	Altered mental status, convulsions
Bruising	Scalp bruise	None	None	None	None
Intracranial imaging findings	Extraaxial haemorrhage	Extraaxial haemorrhage, diffuse brain changes	Extraaxial haemorrhage	Extraaxial haemorrhage, brain contusion, diffuse brain changes	Extraaxial haemorrhage, diffuse brain changes
Occult fractures	Classic metaphyseal lesion	3 classic metaphyseal lesions, 1 metaphyseal fracture, 1 diaphyseal fracture	4 rib fractures	3 classic metaphyseal lesions	4 rib fractures, 1 clavicular fracture
Other fractures	2 skull fractures	2 skull fractures	None	None	None

M, male; F, female.

Services Department. This finding is further supported by a mismatch between the expected number of maltreated children in the lowest age group and the reported number of maltreated children in the national statistics published by the Ministry of Labour and Social Affairs. According to the literature, children younger than one year of age are at the highest risk of maltreatment. Nevertheless, in 2020 only 8% of maltreated children investigated by the Social Services were younger than one year[19,20].

The study has shown that dedicated skeletal radiographs depicted a substantial number of fractures which were clinically occult. In 31% children with dedicated NAI skeletal radiographs, a clinically occult fracture was detected. Without dedicated imaging, these fractures would likely have remained undetected. The incidence of occult fractures in our study is in accordance with similar published studies. In a retrospective study of infants with skeletal survey performed for suspected child abuse, 21% children had an occult fracture. Children with suspected AHT were at highest risk of occult fractures with a 34% incidence[21]. Even though the absence of fractures by no means rules out abuse, detecting a fracture in a child with

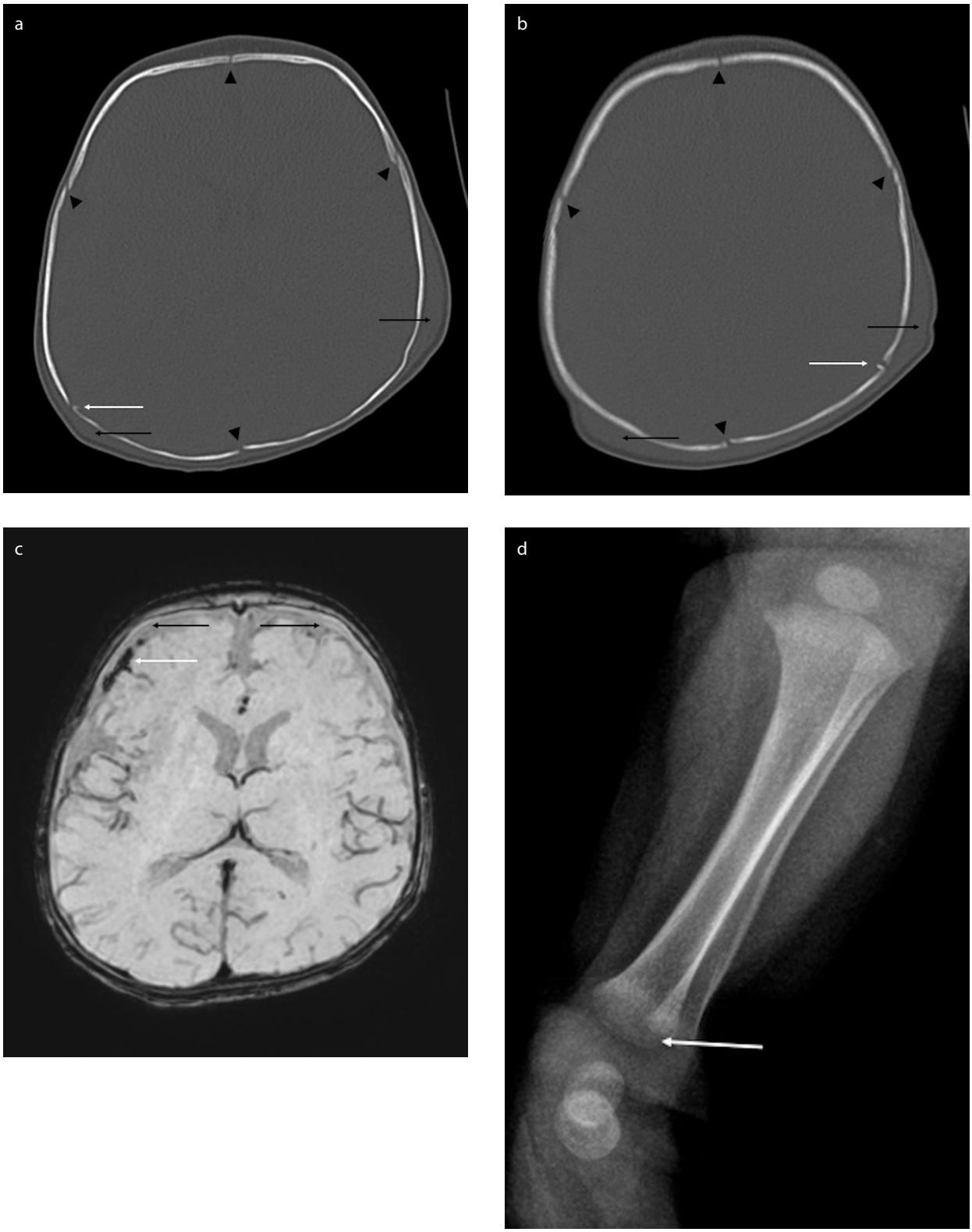

Fig. 3. A 2-month-old boy, reportedly fell into a stroller with glass bottles, brought to the Emergency Department by his grandmother. Physical exam showed a parieto-occipital bruise and no other external signs of trauma.
a. Axial non-contrast CT head bone window shows right parietal fracture (white arrow) and bilateral scalp swelling (black arrows). Cranial sutures marked by arrowheads.
b. Axial non-contrast CT head bone window, slightly more cranially than in a. shows left parietal fracture (white arrow) and bilateral scalp swelling (black arrows). Cranial sutures marked by arrowheads.
c. Axial MR Gradient Echo sequence of the same patient shows right frontal subarachnoideal haemorrhage (white arrow) and bilateral frontotemporal subdural effusions (black arrows).
d. Lateral radiograph of the left tibia shows a classic metaphyseal lesion of the left distal tibia (white arrow).

suspected AHT provides important evidence of a traumatic event. A retrospective study of young children with AHT has shown that 31% of diagnoses were missed at the time of initial presentation and almost 28% of children later suffered further injuries because of delay in the diagnosis[16]. This shows how crucial it is to detect signs pointing to NAI early. As the national healthcare system is not interconnected with the social services databases, it is not possible to evaluate what impact the detection of a clinically occult fracture in a child evaluated by the hospital's Social Services Department has on the child protection process. However, it may be assumed that these findings are regarded as important warning signs of potentially unsafe environment for a young child.

Importantly, 83% of clinically occult fractures in our study were either rib fractures or classic metaphyseal lesions (CML), both with high specificity for abuse. A specific shearing or torsional mechanism of force applied at the metaphysis is required to cause CML. This force is very unlikely to be applied during common handling of a young child[22]. Rib fractures are very uncommon in young children, due to high plasticity of their chest wall and rib fractures in the posterior location or in children younger than 18 months are highly suspicious[23]. In this study, each child with a clinically occult fracture had at least one fracture with high specificity for abuse. This underscores the benefits of skeletal imaging in young children evaluated for possible child abuse.

The study has shown that one third of patients with suspected AHT did not receive dedicated NAI skeletal radiographs, which might have led to occult fractures being missed. This likely reflects the situation, in which the gradual process of improving diagnosis of NAI only started several years ago. Low incidence of children evaluated for possible abusive head trauma means that medical personnel only rarely find themselves in such situations. This makes it difficult to keep up-to-date protocols in mind. To date, there is no structured post-graduate NAI training for physicians. Additionally, dealing with suspected abuse is emotionally difficult and confronting the caregivers about this is challenging for the personnel. This may lead to subconscious avoidance of these situations, regardless of the legal duty to report suspected child abuse. Unfortunately, also in countries with much longer experience with NAI imaging guidelines, problems with adherence exist[24,25]. In a study evaluating the use of skeletal survey in infants and young toddlers with injuries suggestive of NAI, the skeletal survey was performed in 42–82% infants with intracranial haemorrhage[25].

In a 2012 national survey among radiologists, lack of knowledge of NAI was demonstrated[26]. All respondents expressed interest in learning more about the topic. Seventy-eight percent of respondents selected national guidelines as a preferred method of improving their practice. In the last years case reports and review papers on NAI topic have been published in national journals[27-29]. These play an important role in increasing the awareness of NAI in healthcare workers. Other steps that might improve the adherence to recommended NAI protocols at the hospital-level include: an easily accessible, well-organised local NAI plan; distribution of posters and leaflets with the most common warning signs of NAI; setting up a multidisciplinary team with regular meetings; adding NAI into the educational curriculum[30,31]. Last but not least, regular hospital audits need to be performed to evaluate adherence to protocols and to suggest necessary improvements.

This study is subject to several limitations – firstly, given the retrospective nature of this study, it is possible that data regarding the presence of bruising or local signs of injury is underestimated. Secondly, as there is no national NAI registry, this is only a single institution study and therefore the sample is small. Thirdly, only a limited number of skeletal radiographs were performed in some babies with suspected AHT (the so called babygram was performed during the early years of the studied period), which could have led to occult fractures being missed.

The strengths of this study include the fact that this is the first study of patients with suspected abusive head trauma in the country and the detailed review of the imaging findings by experienced paediatric radiologists.

CONCLUSION

The incidence of suspected abusive head trauma at the paediatric University Hospital was low. Clinically occult fractures were detected in one third of infants and young toddlers with suspected abusive head trauma, who received dedicated NAI radiographs. The majority of clinically occult fractures had high specificity for abuse. Dedicated NAI radiographs were not performed in more than a third of the patients, which could have led to fractures being missed. Strategies to increase awareness of NAI imaging protocols need to be employed.

ABBREVIATIONS

NAI, non-accidental injury; CT, computer tomography; MRI, magnetic resonance imaging.

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