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Abusive head trauma: Differentiation between impact and non-impact cases based on neuroimaging findings and skeletal surveys

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ABSTRACT

Objectives: To determine whether imaging findings can be used to differentiate between impact and non-impact head trauma in a group of fatal and non-fatal abusive head trauma (AHT) victims.
Methods: We included all AHT cases in the Netherlands in the period 2005–2012 for which a forensic report was written for a court of law, and for which imaging was available for reassessment. Neuroradiological and musculoskeletal findings were scored by an experienced paediatric radiologist.
Results: We identified 124 AHT cases; data for 104 cases (84%) were available for radiological reassessment. The AHT victims with a skull fracture had fewer hypoxic ischaemic injuries than AHT victims without a skull fracture ($p = 0.03$), but the relative difference was small (33% vs. 57%). There were no significant differences in neuroradiological and musculoskeletal findings between impact and non-impact head trauma cases if the distinction between impact and non-impact head trauma was based on visible head injuries, as determined by clinical examination, as well as on the presence of skull fractures.
Conclusions: Neuroradiological and skeletal findings cannot discriminate between impact and non-impact head trauma in abusive head trauma victims.

1. Introduction

1.1. Background

Abusive head trauma (AHT) is defined by the American Academy of Pediatrics as an inflicted injury to the head and its contents, including those injuries caused by both shaking and blunt impact [1]. Imaging plays an important role in establishing the diagnosis of AHT. In the absence of any other plausible explanation, the diagnosis in most cases is based on clinical and radiological findings associated with abuse [2–4]. The radiological findings are both intracranial findings on CT or MRI and fractures found with conventional radiographs. Furthermore, retinal haemorrhages can be diagnostic of AHT [5] and bruises on the body have been found in 35% of the cases [6].

Neuroradiological findings associated with AHT have recently been described in two systematic reviews that compared AHT and non-AHT patients [4,7]. The study by Kemp et al. analyzed 21 studies, focusing specifically on neuro-imaging. They found subdural haematomas (SDHs) (OR 8.2), multiple SDHs (OR 6), SDHs over the convexity (OR 4.9), interhemispheric SDHs (OR 9.5), posterior fossa SDH (OR 2.5), hypoxic-ischaemic injury (OR 3.7) and cerebral oedema (OR 2.2) to be significantly associated with AHT [4]. The systematic review by Piteau et al. looked for a wider range of radiological findings. They describe 24 studies, of which 17 are

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also described by Kemp et al. They found SDHs (OR 8.9), cerebral ischaemia (OR 4.8) and cerebral oedema (OR 2.2) to be associated with AHT. However, these reviews do not evaluate the difference between impact and non-impact AHT.

Skeletal survey reveals new information in 11% of all children evaluated for possible physical abuse [8]. In the same study, however, children evaluated for possible AHT had positive skeletal surveys in 23% of the cases. In other studies, the number of positive skeletal surveys in AHT victims ranges between 9 and 50%, depending on inclusion criteria, e.g. whether the skeletal surveys are obtained during life or post-mortem [9,10].

1.2. Objectives

Although it is widely recognized that AHT can be caused by either shaking or impact head trauma or a combination of both, in the individual patient the cause of the injury is often unknown without a confessing perpetrator [11]. Unfortunately, there is no tool yet for such differentiation. If we would be able to differentiate between non-impact and impact head trauma, we would overcome the need for confession or a witnessed assault. Knowing what happens exactly at the moment a caregiver severely harms a child can help to both improve the treatment for the perpetrator as the development of prevention projects. Furthermore it can help in formulating a charge against the accused. As imaging findings are the cornerstone for the diagnosis of AHT, we tried to determine whether imaging findings can be used to differentiate between non-impact (shaking) and impact head trauma.

We conducted a retrospective cohort study in which we describe the neuroradiological findings associated with AHT [4,7] and the number and type of fractures in AHT victims in the Netherlands. The aim of this study is to investigate whether there is a difference in imaging findings between children with and without impact head trauma, defined as the presence of skull fractures or visible head injury upon clinical examination.

2. Materials and methods

We performed a retrospective file review of all AHT cases for which the Dutch courts of law requested forensic medical expertise in the period 1-1-2005–31-12-2012. We used 3 inclusion criteria: (1) a diagnosis of AHT confirmed by a forensic physician, (2) children's age under 5 years and (3) imaging available for reappraisal by a paediatric radiologist with experience in child abuse (RR or SR). Forensic paediatric medical expertise in the Netherlands is only available in two centres: the Forensic Medical Child Abuse Centre (FMCAC, Utrecht) and the Netherlands Forensic Institute (NFI, The Hague). Both Institutes provide forensic reports for courts, performed by a physician specialized in forensic paediatrics. A forensic physician evaluates the complete set of medical data (records of the medical evaluation in the clinical setting, past medical care and autopsy reports) and police files, from a forensic point of view. As the verdict of a judge, besides the forensic report, is based on non-scientific information as well, a diagnosis of AHT established by a forensic physician is considered to be the most objective and best reference standard for AHT in the Netherlands. Past medical care consists of contacts with the general practitioner, the primary health care system and hospitals. Police files consist of interrogations of suspects and witnesses, transcripts of wire-taps and all other forensic information collected by the police.

We collected variables describing demographic characteristics, mechanism of injury, outcome and type of imaging performed. The independent variable, mechanism of injury, was defined as evidence for impact head trauma in 2 different ways: (1) a skull fracture was present, and (2) other (non-radiological) signs of blunt force trauma to the head were documented, e.g. bruising or swelling of the soft tissue of the head. The last category also includes children with a skull fracture. This way of classification does not rule out that children who underwent impact trauma but did not sustain a skull fracture or other signs of blunt-impact trauma to the head were classified as no evidence for impact trauma. A detailed list of dependent variables, intracranial injuries, was collected, based on 2 recent systematic reviews describing imaging findings associated with AHT (Table 1). Variables collected for the skeletal survey were whether the skeletal survey was performed according to the American College of Radiology (ACR) or the Royal College of Radiologists (RCR) guidelines, and the number and type of fractures including the number of classic metaphyseal lesions (CMLs).

We included CT and MRI images obtained when the children were alive because several neuroradiological features will change after demise. Post-mortem skeletal surveys were included. A bilateral SDH over the convexity was classified as 1 SDH. Focal parenchymal injury was defined as intraparenchymal haemorrhage or brain contusion. Closed head injury was defined as any intracranial injury without skull fracture. Only fractures of which the radiologist was certain they were present were included. Findings considered to be 'suggestive of' fractures were omitted, unless they were proven to be a real fracture during follow-up skeletal survey or autopsy. All images were reassessed by a paediatric radiologist (either RR or SR) with extensive experience with paediatric forensic cases. All studies were available in an electronic form.

This study was not subject to medical ethical review, as it is a retrospective study and according to Dutch law no Institutional Review Board approval is required for retrospective studies in which patients are described anonymously and do not have to change their behaviour in any way [12].

Data were analyzed using IBM SPSS Statistics 19 for Windows. Continuous data were expressed as means and standard deviations or medians and inter-quartile ranges (IQR) when non-normally distributed, demonstrated with a Kolmogorov–Smirnov test. Differences between groups were tested with Chi square for dichotomous data, Mann–Whitney *U* test for numeric data because of non-normal distribution, Pearson's Chi square for nominal data and Fisher's exact test for nominal data when the expected values in any of the cells of a contingency table was below 5.

3. Results

In the period 2005–2012, 124 reports diagnosing AHT had been written for the law courts. In 104 of these cases (84%) radiological information was available for reassessment. There were 73 boys (70%) and 31 girls (30%), median age at admission was 91 days (range 8 days–3 years 7 months). Ninety-nine of the 104 children (95%) had intracranial injury, 34/104 had one or more skull fractures (33%) and 43/104 (41%) had one or more fractures elsewhere. Twenty-seven of the 104 children (26%) died, 11/104 (11%) had a good outcome, 34/104 (33%) were disabled and for 32/104 (31%) no prognosis could be given based on medical information in the forensic report.

3.1. Neuroimaging

In 99/104 children (95%) neuro-imaging available for reassessment (CT and/or MRI) had been performed while they were alive. In 83/99 children (84%) at least one CT was performed; in 47 children 1 CT was performed, in 19 children 2 CTs, in 10 children 3 CTs, in 5 children 4 CTs, in 1 child 6 CTs and in 1 child 8 CTs. In 53/83 children (64%) the first CT was made on the day of admission. In 2 children, the CT was made 8 and 9 days respectively before admission, and the diagnosis of AHT was established retrospectively. In the other