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High Frequency of Previous Abuse and Missed Diagnoses Prior to Abusive Head Trauma: A Consecutive Case Series of 100 Forensic Examinations

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This study describes the frequency of signs and symptoms of abuse and missed diagnoses prior to the diagnosis of abusive head trauma (AHT) in infants. Data were from a retrospective observational study of 100 consecutive cases of infants diagnosed with AHT over a seven-year period. The most frequent symptom leading to the diagnosis was a loss of consciousness (68%) that always occurred inside a home (parents' or nanny's), never outside. Diagnosis was established using criteria based on the child's lesions and the alleged history. Lesions leading to diagnosis were described: 99 per cent had multifocal subdural haematoma (SDH) located in four areas including lateral space, interhemispheric, tentorium cerebelli and vertex; 60 per cent had a rupture of bridging veins. Previous abuse was found in 79 per cent of cases, of whom 75 per cent underwent medical consultations that did not result in a diagnosis of abuse. The main signs and symptoms of previous abuse were repeated vomiting without fever or diarrhoea (62%), abnormal head circumference increase (49%) and bruises (38%). These results suggest a higher frequency of repeated abuse than previous studies and highlight the great challenges most professionals encounter to evoke and set the diagnosis of abuse. © 2020 John Wiley & Sons, Ltd.

KEY PRACTITIONER MESSAGES:

- Prior signs and symptoms suggestive of abuse are particularly frequent in infants diagnosed with AHT.
- Abuse must be detected as early as possible in order to avoid recurrences.
- Diagnostic criteria, based on clinical history and lesions including multifocal subdural haematoma, rupture of bridging veins, retinal haemorrhages, and spinal cord injury have been defined to enable diagnosis of AHT.

KEY WORDS: child abuse; craniocerebral trauma; diagnosis; prevention

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'This study describes the frequency of signs and symptoms of abuse and missed diagnoses prior to the diagnosis of abusive head trauma (AHT) in infants'

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Introduction

Within the spectrum of child abuse, abusive head trauma (AHT) affects the youngest and most vulnerable children. Because it affects the developing brain, outcomes are severe in terms of mortality and persistent acquired disability (Chevignard and Lind, 2014). Several studies using diverse methods suggest a high frequency of repetition of abuse and missed diagnoses: Jenny *et al*. (1999) reported 31 per cent (54 cases) of undiagnosed cases of AHT at the time of the first medical consultation, with a correct diagnosis only after a mean delay of 2.8 visits and seven days. Sheets *et al*. (2013) in a large retrospective study of 200 children diagnosed as victims of physical abuse compared to 101 reference children, reported previous 'sentinel' injuries in 28 per cent of the first group, as opposed to none in the reference group. These lesions were most often bruising (80%) and intraoral lesions (11%). They had occurred less than three months before in 66 per cent of cases, and less than seven months in 95 per cent of cases. More recently, Letson *et al*. (2016) studied 232 children consecutively admitted with an AHT diagnosis, of whom 31 per cent had a total of 120 'missed diagnosis opportunities', including 98 missed by a physician. Clinically, vomiting without fever and diarrhoea (32%) was the most frequent missed opportunity, followed by bruises (12%). Evidence of prior abuse was reported in 81 per cent of cases in a series of infants diagnosed with AHT, which could have been committed on the child and/or other family members (Sieswerda-Hoogendoorn *et al*., 2013).

'Several studies using diverse methods suggest a high frequency of repetition of abuse and missed diagnoses'

Two opportunities enabled us to study the frequency of abuse prior to the diagnosis of AHT and the frequency of missed diagnoses: the existence of the HAS (Haute Autorité de Santé – French Health Authority) specific diagnostic criteria for AHT and the status of the French forensic experts. The overall goal is to improve early detection of abuse as much as possible in order to prevent further harm and to protect the child.

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The HAS SOFMER (Société Française de Médecine physique et de Réadaptation – French Society of Physical Medicine and Rehabilitation) guidelines on the diagnosis of AHT, established in 2011 and updated in 2017, (Laurent-Vannier *et al*., 2011a, b; Laurent-Vannier, 2014; Haute Autorité de Santé and Société Française de Médecine physique et de Réadaptation, 2017) have defined the diagnostic methodology to be followed by a multidisciplinary team including a paediatric radiologist to eliminate all possible differential diagnoses and make the diagnosis of AHT through shaking, with or without impact. They listed the additional examinations to be carried out, including computed tomography, fundoscopy, a complete blood count and coagulation factors, a full skeletal survey and a MRI scan as soon as permitted by the infant state. Diagnostic criteria have been defined based exclusively on the observed lesions and the alleged medical history, without considering 'risk factors'. Those diagnostic criteria enable, after ruling out all the differential diagnoses (for each of the lesions), a ***confirmed*** or ***likely*** diagnosis of AHT through shaking. The methods used to establish these recommendations and diagnostic criteria are described in Appendix S1 (see the online Supporting Information).

Furthermore, some specific aspects linked to the status of judicial experts in France should be highlighted: judges of criminal proceedings involving minors must request a pre-trial medical assessment by a legal expert (Barbier Sainte

Marie, 2018). This legal expert is a medical practitioner, chosen by a judge within an established list of experts and asked to give an informed opinion about a situation, according to the terms of the judicial instructions strictly defined and monitored by the judge. The expert is independent from both parties and is paid by the state. For each case, the expert receives and analyses the sealed medical files (including health record from birth, hospitalisation records including magnetic resonance imaging and computed tomography scans, file of the attending doctor, of the maternity, etc.), as well as the forensic investigations (e.g., transcript of the initial emergency call, hearings of the various adults likely to be the perpetrator).

The aims of the present study were thus to describe: (1) a series of 100 consecutive cases diagnosed with AHT and the symptoms and lesions at the time of diagnosis; (2) the number and nature of previous manifestations (e.g. signs and symptoms), that could have led to a suspicion of abuse before AHT diagnosis; and (3) the number and nature of contacts with medical care whenever previous manifestations of abuse were present.

Methods

Study Design

This study conducted over a seven-year period (2011–2017) included the first 100 consecutive cases of infants aged under 24 months, diagnosed with AHT using the HAS SOFMER criteria, among cases referred for suspected abuse involving the brain to the first author (ALV) by French courts. As part of the judicial process, all medical data and forensic records were reviewed by the first author, who is a senior consultant specialist in paediatric rehabilitation, specialised in childhood acquired brain injury, including AHT, approved by the Paris Appeal Court (2005) and by the Cassation Court (2015) (national list). In 90 cases, depending on the judicial instructions, the analysis was done in conjunction with a paediatric radiologist forensic expert. All conclusions of the expertise were consensus-based. Four paediatric radiologists were involved in the present study.

‘This study… included… 100 consecutive cases of infants aged under 24 months, diagnosed with AHT using the HAS SOFMER criteria’

Data Collection

Data were anonymised by the first author then prospectively entered into a database. They included: (1) sociodemographic data; (2) symptoms and lesions at the time of diagnosis; (3) previous manifestations suggesting abuse, age at first manifestation and time between its occurrence and diagnosis of AHT; and (4) contacts with a physician prior to AHT diagnosis, when the child was already showing indicators of abuse.

Given that this study was a non-interventional retrospective study consisting of data previously collected by forensic experts, no approval by an ethics committee was necessary (France, Jardé law, 2016).

Statistical Analysis

We described sociodemographic characteristics of the infants, symptoms and lesions leading to diagnosis and history of abuse prior to hospital admission

using means (±standard deviations) and frequencies. When data were missing, we reported descriptive data based on the largest sample size possible. Statistical analyses were conducted using SAS® v9.2 (SAS Institute, Cary, North Carolina, USA).

Results

'The 100 cases were referred from 39 different courts, from all regions of France'

The 100 cases were referred from 39 different courts, from all regions of France.

Sociodemographic Characteristics of the Study Sample

Infants were predominantly males (79%), 16 per cent were born prematurely and 56 per cent were first-born (Table 1). Most parents (97%) were living together and parental education was balanced between low, medium and high levels.

Symptoms and Clinical Findings at Diagnosis

'The main symptom that led to seeking medical care was sudden loss of consciousness (68%)'

Mean (±SD; range) age at diagnosis was 5.4 months (±3.2; 1.1–14.9) (Table 2). The main symptom that led to seeking medical care was sudden loss of consciousness (68%), which invariably (100%) occurred inside a home (parents' or nanny's). Other manifestations included macrocephaly, repeated (>2) vomiting without fever or diarrhoea, poor feeding, irritability/lethargy and seizures. Regarding lesions, all children had subdural haematoma (SDH); 99 per cent of them were multifocal and located in four particular areas: lateral space, interhemispheric, tentorium cerebelli or vertex. SDHs were found in all four locations in 50 cases (see Appendix S2 in the online Supporting Information). The only child with unifocal SDH was a five-week-old infant with cerebral lacerations, bilateral retinal haemorrhages (RH) extended to the periphery, multiple bruises and eleven fractures. SDHs of different ages (different density in two distant SDH) (Adamsbaum *et al*., 2014) were found in 58 per cent of cases. Rupture of bridging veins (60%), RH (80%) and

Table 1. Sociodemographic characteristics of the infants diagnosed with abusive head trauma

	Total N[a]	Mean ± SD or % (n)
Sex	100	
Male		79.0 (79)
Female		21.0 (21)
Preterm birth	98	16.3 (16)
Siblings	100	
None (first born)		56.0 (56)
1		32.0 (32)
2		10.0 (10)
≥3		2.0 (2)
Parents' family status	100	
Living together		97.0 (97)
Separated		1.0 (1)
Single mother		1.0 (1)
Mother in a couple with another partner		1.0 (1)
Parents' education level	100	
Incomplete secondary education		34.0 (34)
Completed secondary education		25.0 (25)
Completed higher education		41.0 (41)

[a]Values lower than 100 indicate missing data for the corresponding variable.

Table 2. Diagnostic criteria and lesions leading to diagnosis of abusive head trauma

	Total N[a]	Mean ± SD or % (n)	Median (min – max)
Age at diagnosis (months)	96	5.4 ± 3.2	4.6 (1.1–14.9)
Initial symptoms leading to seeking medical care	100		
Sudden loss of consciousness		68.0 (68)	
Place where it occurred	68		
In a home		100.0 (68)	
Intracranial lesions	100		
Extradural hematoma		1.0 (1)	
Subdural hematoma		100.0 (100)	
Location			
Unilateral or median		18.0 (18)	
Bilateral		82.0 (82)	
Number of locations			
Single location		1.0 (1)	
Multiple locations		99.0 (99)	
Locations			
Lateral space		98.0 (98)	
Inter-hemispheric		83.0 (83)	
Tentori cerebellum		80.0 (80)	
Vertex		70.0 (70)	
Subdural haematomas of different ages		58.0 (58)	
Rupture of bridging veins		60.0 (60)	
Cerebral lesions		48.0 (48)	
Haemorrhagic cerebro-spinal fluid[b]	63	89.0 (57)	
Ocular lesions			
Time between hospital admission and fundoscopic exam (day)	99	1.8 ± 2.2	1 (0–18)
Retinal haemorrhage	100	80.0 (80)	
Unilateral haemorrhage		11.0 (11)	
Bilateral haemorrhage		69.0 (69)	
Vitreal haemorrhage	99	12.1 (12)	
Spinal lesions	100	10.0 (10)	
Bone lesions	100	22.0 (22)	
Traumatic skin lesions	100	36.0 (36)	
Biomarkers			
Haematocrit level (%)	91	28.6 ± 4.8	28 (16–40)
<30%		60.4 (55)	
Lactate level (mmol/L)	28	5.3 ± 3.0	4.8 (1.5–12.5)
0–2 mmol/L		10.7 (3)	
2–6 mmol/L		60.7 (17)	
6–10 mmol/L		21.4 (6)	
≥10 mmol/L		7.1 (2)	

[a]Values lower than 100 indicate missing data for the corresponding variable.
[b]Among infants who had surgery or autopsy (n = 63).

cerebral lesions (48%) were frequent. Other less frequent lesions observed at the time of diagnosis were bruises (36%), bone fractures (22%, including skull fractures 8%) and spinal lesions (10%).

Almost half (45%) of the cases had a combination of multifocal SDH, rupture of bridging veins and RH; 35 per cent had both multifocal SDH and RH, and 15 per cent had both multifocal SDH and rupture of bridging veins (see Appendix S3 in the online Supporting Information). Five per cent of infants had multifocal SDH but no RH nor rupture of bridging veins. Among them, all had three to five of the following clinical findings used for diagnosing AHT: abnormal increase in head circumference, haemorrhagic cerebrospinal liquid, SDH of different ages, cerebral lesions, bruises, and rib fractures. Mean haematocrit level (n=91) was 28.6 per cent, with 60 per cent of cases less than 30 per cent. Among infants with lactate level data (n=28), 89 per cent (n=25) were above the normal range (<2 mmol/L) and 28.5 per cent >6 mmol/L.

'Almost half (45%) of the cases had a combination of multifocal SDH, rupture of bridging veins and RH'

Table 3. History of symptoms or lesions prior to the hospital admission leading to abusive head trauma diagnosis

	Total N	% (n) or mean ± SD
Number of children with history of symptoms or lesions	100	79.0 (79)
Type of symptoms or lesions suggestive of previous AHT, if any	79	
Repeated vomiting without fever nor diarrhoea		62.0 (49)
Abnormal head circumference increase		49.3 (39)
Sudden loss of consciousness		17.7 (14)
Other type of symptoms or lesions	79	
Bruises		38.0 (30)
Bone fracture		16.5 (13)
Weight growth deceleration		21.5 (17)
Past medical contacts, if history of symptoms or lesions	79	
≥1 general practitioner or paediatrician visit		58.2 (46)
≥1 emergency room visit		26.6 (21)
≥1 hospitalisation		17.7 (14)
≥1 past contact with medical care		74.7 (59)
Age at first symptoms or lesions (months)	73	4.1 ± 3.0
Age at first medical contact (months)	57	4.3 ± 2.8
Delay between first clinical symptoms and first medical contact (days)	57	7.1 ± 10.1
Delay between first clinical symptoms and diagnosis (days)	54	30.9 ± 33.5

Previous Symptoms and Clinical Findings Suggesting Abuse

The first manifestations occurred on average at 4.1 (±3.0) months of age. Past manifestations that could have suggested intra-cranial hypertension or abuse were found in 79 per cent of cases (Table 3). Among them, some were suggestive of previous AHT, including repeated vomiting without fever or diarrhoea (62%), abnormal increase in head circumference (49%), and sudden loss of consciousness (18%). Other manifestations were bruises (38%), bone fractures (16%), and poor weight gain (22%). Among those 79 cases, 75 per cent had been brought to medical attention by their parents when they were already showing those indicators of possible intracranial hypertension or abuse. Medical contacts included medical visits (58%; range: 1–5 visits) (general practitioner or paediatrician), hospital emergency room visits (27%; range: 1–3 visits) and hospitalisations (18%; range: 1–3 times). The delay between the first manifestations of abuse and the first medical contact was 7.1 (±10.1) days with a median [range] of two [0–47] days; the delay between first manifestations of abuse and AHT diagnosis was 30.9 (±33.5) days (median [range]: 11 [0–106]).

Discussion

‘Previous manifestations of abuse were found *a posteriori* in 79 infants diagnosed with AHT’

Previous manifestations of abuse were found *a posteriori* in 79 infants diagnosed with AHT. Among them, 75 per cent had been seen by a medical practitioner when they were already showing indicators of intracranial hypertension and/or abuse, which were not identified as possible abuse.

Symptoms and Lesions at Diagnosis

Interestingly, among this large consecutive series, the most frequent initial symptom leading to the hospitalisation was a sudden loss of consciousness (*N*=68), most often described associated with pallor, absent, decreased or irregular breathing. This sudden loss of consciousness invariably occurred

inside a home (either the infant's, or the nanny's), never outside, in a public place, or in a nursery (Laurent-Vannier *et al*., Forthcoming). This is a strong additional argument against the hypothesis of the spontaneous occurrence of SDH (Vinchon *et al*., 2010b; Melville and Narang, 2011), which otherwise should occur in no preferential place.

Biological results should also be considered. Elevated lactate levels indicate a recent episode of hypoxemia and/or shock and can therefore identify patients who may benefit from more intensive treatment (Levraut *et al*., 2011; Stewart *et al*., 2013).

The lesions found in these 100 children were specific and require the input of a paediatric radiologist as part of the multidisciplinary team. They are plurifocal subdural haematomas of particular localisation (lateral spaces, interhemispheric, tentorium cerebelli or vertex); ruptures of bridging veins; retinal haemorrhages, often bilateral and diffuse; and sometimes spinal or cord lesions. The importance of those lesions had been highlighted by early publications: presence of SDH (Hymel *et al*., 2007; Vinchon *et al*., 2010a; Kemp *et al*., 2011), almost constantly multifocal (Adamsbaum *et al*., 2010; Kemp *et al*., 2011; Hymel *et al*., 2014); rupture of bridging veins (Adamsbaum and Rambaud, 2012; Choudhary *et al*., 2015; Hahnemann *et al*., 2015); RH (Binenbaum *et al*., 2009), frequently multi-layered and extended to the periphery (Levin, 2010; Kemp *et al*., 2011); and spinal cord lesions (Choudhary *et al*., 2014). The diagnostic value of each of these lesions has been confirmed following an international evidence-based comprehensive literature review (Laurent-Vannier *et al*., 2011b; Haute Autorité de Santé and Société Française de Médecine physique et de Réadaptation, 2017). This evidence also suggests that these injuries cannot be due to low falls, resuscitation manoeuvres, lack of oxygen, play, the intervention of another child, haemostasis abnormality without trauma, or vaccines. The HAS diagnostic criteria were established on the basis of these results.

These criteria are in addition to previous diagnostic methods: previously there were relevant clinical prediction rules at different stages of the diagnostic process but no diagnostic criteria (Pfeiffer *et al*., 2018). Hymel *et al*. (2019) developed a clinical prediction rule for AHT based on seven criteria. Their prediction model was developed among children with cranial fracture, extensive RH and extracranial injuries (bruising, skeletal fracture), which makes it inapplicable to the children without those severe lesions. Furthermore, it does not account for the rupture of bridging veins, which has been recently identified as an important criterion (Adamsbaum and Rambaud, 2012).

High Frequency of Previous Manifestations of Abuse and Missed Diagnoses

Previous signs or symptoms that could have led to a suspicion of abuse were found in 79 per cent of cases. Among them, 59 (75%) had previously been seen by a medical practitioner when they were already showing indicators of intracranial hypertension and/or abuse, which were not identified as possible abuse. Twenty-one (27%) had been seen at an emergency room and 14 (18%) been admitted to hospital, which are not the usual modalities of care in France. Overall, the diagnosis was missed in 62 per cent of cases. The most

‘Previous signs or symptoms that could have led to a suspicion of abuse were found in 79 per cent of cases’

frequent manifestations, isolated or associated, were unusual and repeated vomiting without fever or diarrhoea, bruises, abnormal increase of head circumference, poor weight gain, sudden impaired consciousness and fractures, similar to the findings of Letson *et al*. (2016). These results highlight the need for early diagnosis, in order to prevent occurrence of more severe episodes of abuse, leading to death or permanent disability. Obviously, abuse cannot be suspected in all infants who vomit. However, in infants presenting repeatedly with vomiting without fever or diarrhoea, bruises, or a sudden loss of consciousness and hypotonia, systematic actions should be performed by physicians before diagnosing acute gastroenteritis, milk intolerance, breath-holding spell or a loss of consciousness due to gastroesophageal reflux, or accidental bruises. This includes measurement of the head circumference, examination of the child's overall tone and development (e.g. hypotonia, decrease in the infant's abilities), and of the skin with special attention to lesions on torso, ears and neck (Pierce *et al*., 2010) but any bruising in a pre-mobile child should raise concerns (Royal College of Paediatrics and Child Health, 2019). At the slightest suspicion of abuse, hospitalisation and examination by an experienced multidisciplinary team are recommended.

'We found higher frequency of previous abuse than most other studies'

We found higher frequency of previous abuse than most other studies. One explanation may be that we, as judicial experts, have had access to complete medical and forensic data. One could argue that the cases referred for judicial expert opinion are more severe cases. However, the HAS SOFMER guidelines recommend notifying all suspected cases to the justice regardless of their clinical severity. We also found a high frequency of missed diagnoses that can probably be explained in part by the lack of knowledge by professionals of the mechanisms leading to AHT and of the frequent repetition of abuse (Laurent-Vannier and Chevignard, 2019).

Strengths and Limitations

Although this study is retrospective, it reports on a large number of consecutive cases of varying clinical severity diagnosed with AHT using specific diagnostic criteria (described in Appendix S1 in the online Supporting Information). The database was prospectively implemented. The methodology used did not enable a control population. It induced a bias since all cases were referred to a single judicial expert, but this bias was reduced because the cases came from 39 different courts from all over France.

In 90 cases, a paediatric radiologist was involved in the expert process, which allowed precise description of the lesions, especially type and localisation of the SDH, and rupture of the bridging veins. For the other ten children (including two who died immediately and were autopsied) imaging was not reviewed by a paediatric radiologist. Characteristics of RH were not described.

Conclusion

The systematic use of specific injury-based diagnostic criteria for AHT, based exclusively on observed lesions and clinical history, enabled us to exclude or

retain the diagnosis of AHT. Using these criteria, and the large amount of information available to the judicial expert, precise description of previous infant development, medical visits, clinical state over time and at diagnosis was possible. This enabled precise description of previous manifestations of abuse in this large sample. This study highlighted a very high frequency of previous abuse, indicating frequent repetition, and the importance of detecting those manifestations as early as possible, to prevent further harm and implement adequate child protection measures. This is crucial given the poor long-term outcomes of AHT.

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Conflict of interest

The authors have no conflict of interest to disclose. Anne Laurent-Vannier co-chaired the large multi-disciplinary working group that established the diagnostic methodology including diagnostic criteria, under the supervision of the French High Authority of Health in 2011 and 2017.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.