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Abusive Head Trauma through Shaking: Examination of the Perpetrators According to Dating of the Traumatic Event

Effective prevention of abusive head trauma (AHT) requires the identification of potential perpetrators. Current evidence suggests that infant shaking, as a mechanism of AHT, produces immediate symptoms, allowing for the dating of the event based on clinical symptoms. Determining precisely when symptoms occurred may help law enforcement to identify the perpetrator. We retrieved written legal statements and medical records from birth to age at diagnosis of 100 infants consecutively diagnosed with AHT through shaking (2011–17), using forensic expertise files. Timing of abuse allowed for the identification of perpetrators in 91 cases. All abusive events occurred inside a home (parent's or nanny's), never outdoors or in a public place, and always in the presence of only one adult. Approximately one-third ($n = 32$) of the perpetrators were males (31 fathers) and two-thirds ($n = 59$) were females: 49 of them were the infant's nanny and ten were the infant's mother. Infants were not described as crying habitually. Better knowledge of the context of AHT events and risk situations, including recent implementation of a new or unusual modality of childcare, and being the only adult in a home with an infant, should facilitate prevention, including targeted training and avoidance of situations associated with risk. © 2021 The Authors. *Child Abuse Review* published by Association of Child Protection Professionals and John Wiley & Sons Ltd.

KEY PRACTITIONER MESSAGES:

- Abusive events occur in the presence of a single adult, within the privacy of a home.
- First signs of abuse most commonly occur in a recent, therefore unusual, form of childcare.
- With rare exceptions, the perpetrator is either the nanny or one of the parents.
- Identification of the perpetrator and better knowledge of the context of abuse should allow improving targeted prevention.

KEY WORDS: abusive head trauma; child abuse; child maltreatment; baby/infant; perpetrators

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‘Determining precisely when [AHT] symptoms occurred may help law enforcement to identify the perpetrator’

‘Abusive head trauma (AHT) in infancy is the most common type of child abuse, resulting in death and severe morbidity’

‘Determining the timing of AHT is critical for investigators attempting to identify the perpetrator’

Introduction

Abusive head trauma (AHT) in infancy is the most common type of child abuse, resulting in death and severe morbidity (Barlow *et al.*, 2005; Choudhary *et al.*, 2018). Although few long-term follow-up studies have been published, a high percentage of infants with AHT end up with chronic developmental or neurological disabilities (Chevignard and Lind, 2014). The predominant mechanism of AHT is shaking with or without impact (Edwards *et al.*, 2020). Confessions have provided descriptions of shaking as an extremely violent event, repeated in more than half of the cases (Adamsbaum *et al.*, 2010). Therefore, it is crucial to both detect then diagnose abuse as early as possible, and also to identify the perpetrator, in order to prevent recurrence on the same infant or others (Starling *et al.*, 1995).

Guidelines on the diagnosis and legal consequences of AHT through shaking have been published (Laurent-Vannier *et al.*, 2011a, 2011b) and recently, based on an international evidence-based comprehensive literature review, updated by a French task force with the methodological support of the French High Authority for Health (HAS) (Haute autorité de santé et Société française de médecine physique et de réadaptation (French Society of Physical Medicine and Rehabilitation) (SOFMER), 2017). The HAS-SOFMER guidelines 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. Diagnostic criteria have been defined and are based 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).

Prevention also requires the identification of the perpetrator. Perpetrator confessions are moderately frequent (26 to 47%) (Adamsbaum *et al.*, 2010; Edwards *et al.*, 2020; Starling *et al.*, 1995, 2004). Their frequency varies according to the perpetrator's sex and relationship to the child: men (father, stepfather and mother's new partner) typically confess more frequently than women, and fathers more than mothers (Starling *et al.*, 1995, 2004). Among women, babysitters/nannies typically confess much less frequently than mothers (Esernio-Jenssen *et al.*, 2011; Starling *et al.*, 1995, 2004). Finally, reliability of confessions may be challenged (Edwards *et al.*, 2020), and some have argued that perpetrators were coerced in some manner or that mechanisms were suggested to them (Starling *et al.*, 1995). Therefore, it is important to have means other than confessions to identify the perpetrator. Starling *et al.* (2004) have shown that determining the timing of AHT is critical for investigators attempting to identify the perpetrator. Beyond the diagnostic methodology, the HAS-SOFMER guidelines also focus on the means available to date and time the AHT event, and have established that following shaking, the symptoms, when present, occur immediately.

The objective of the present study was to use this clinically based dating procedure in a series of 100 forensic cases of infants diagnosed with AHT

through shaking (Laurent-Vannier *et al.*, 2020), in order to: (1) determine the time/period of behavioural change (i.e. the period between when the child was in a normal state, awake, alert and normally reactive, and when symptoms of varying severity were observed); (2) identify the adult present with the infant at this time/period based on the available evidence; and (3) describe the context of occurrence according to the perpetrator in order to open prevention avenues.

Methods

Study Design

This study conducted over a seven-year period (2011–17) included 108 consecutive cases of suspected abuse involving the brain in children under two years of age that were entrusted to the first author (ALV) by the judicial French courts. Children aged two years and older were not considered as AHT most often occurs in children under 24 months of age. Those with unconfirmed AHT were also not considered, leading to an analysis sample of 100 cases of diagnosed AHT through shaking, according to the HAS-SOFMER diagnostic criteria (Figure 1).

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 and neurology, specialised in childhood acquired brain injury,

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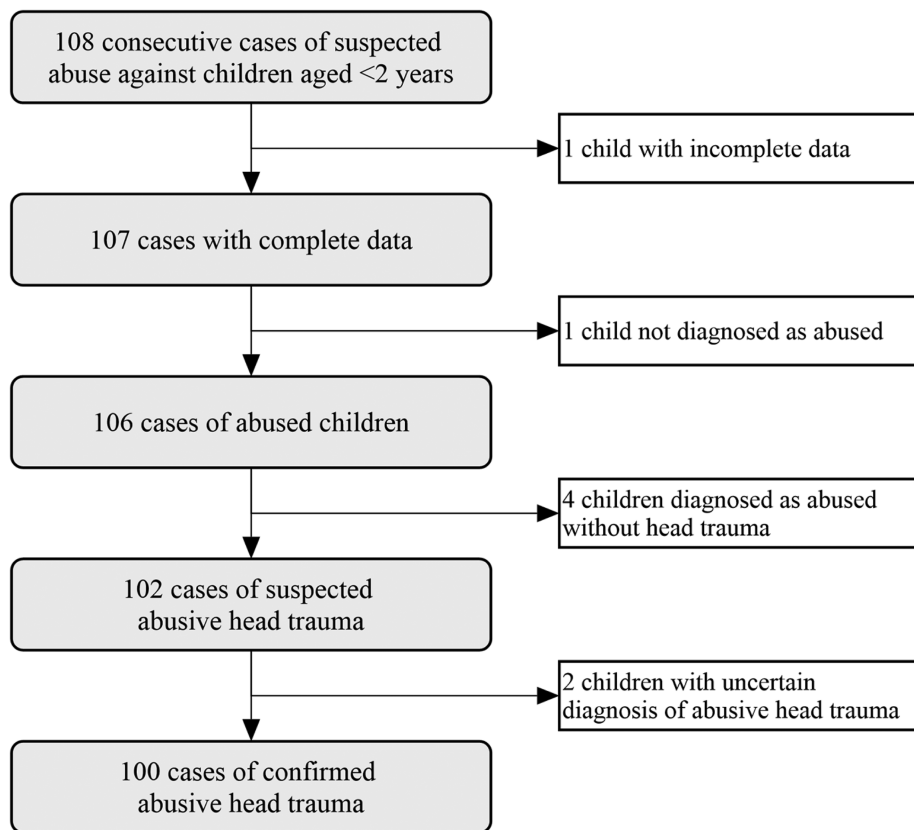


Figure 1. Flow chart of the study sample.

‘All medical and forensic data were thoroughly analysed and confronted to determine precisely when... the symptoms that led to the diagnosis had occurred.’

including AHT, and who is approved by the Paris Appeal Court (2005) and the Cassation Court (2015) (national list). In 90 cases, in accordance with the judicial instructions, the analysis was done in conjunction with a paediatric radiologist forensic expert. Four paediatric radiologists were involved in the present study. All conclusions of the experts were consensus-based (Laurent-Vannier *et al.*, 2020).

Given that this study was a non-interventional study consisting of data previously collected by forensic experts, no ethics approval was necessary. Data were anonymised and only the first author had access to identifying information.

Procedure for Identification of the Perpetrator

For each of the 100 infants, all medical and forensic data were thoroughly analysed and confronted to determine precisely when, or during what period, the symptoms that led to the diagnosis had occurred. In the cases for which it was possible, we then looked at which adult(s) was/were in the presence of the child at this time. For instance, based on medical and forensic data, when an infant in his/her usual clinical state (awake, active and normally responsive) was entrusted to the care of a solitary care provider, the abusive event was determined to have taken place during the custody period in two circumstances: first, the occurrence of a sudden loss of consciousness (LOC) with pallor, absent, decreased or irregular breathing and hypotonia during the custody period; and second, the observation at the end of the custody period of a very unusual clinical state leading to the need to seek medical advice (repeated vomiting without fever or diarrhoea, hypotonia, drowsiness, less reactivity, poor feeding, irritability/lethargy, seizures). Four categories of perpetrators were identified: nannies (a nanny is defined here as most often a female, usually qualified and registered, who is employed for individual childcare, either in her own home or the parents' home); mothers (referring also to fathers' partners); fathers (referring also to mothers' partners); and either parent (when it was not possible to determine whether the father, the mother or both was/were the perpetrator(s)). For statistical testing purposes, mothers, fathers and either parent were grouped into a single category defined as ‘family’.

Data Analysis

The data were prospectively captured into a database for the present study and included:

- 1 socio-demographic data, for example, sex, term of the birth, siblings, parents' family status and education level (if the father and mother did not achieve the same educational level, the highest level was retained); and the main daytime caregiver and, in the event of a nanny, the length of time that this childcare method had been in use;
- 2 historical or physical evidence of prior abuse: 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 age at first abuse; time between occurrence of the first signs/symptoms of abuse and diagnosis of AHT (age of fractures was assessed according to radiological appearance; for other signs and symptoms (e.g. vomiting, bruises), the age of onset has been defined and is based on medical and forensic

data); contacts with a physician prior to AHT diagnosis, when the child was already carrying manifestations of abuse; and clinical manifestations that led to the AHT diagnosis. In the case of an initial LOC data were included on: time of occurrence and context (including the number of children in the care of the adult(s) when LOC occurred); initial alleged history; lesions that allowed a diagnosis of AHT; and history of abuse in older siblings (when available);

- 3 outcome evaluated using the Glasgow Outcome Scale modified for children (GOS-C) of the latest available clinical information. GOS-C ranks children into five categories: good outcome, moderate disability, severe disability, minimally responsive or vegetative state, and death (Barlow *et al.*, 2005).

Statistical Analysis

We described data on sociodemographic characteristics of the infants, AHT diagnostic criteria and lesions leading to diagnosis, history of symptoms or lesions prior to hospital admission and infants' outcomes according to the perpetrator (nanny, mother, father or either parent). We then tested whether there were differences between the 'nanny' and 'family' categories (small sample size did not allow us to analyse 'mothers' and 'either parent' categories separately) using chi-square tests and t-tests for categorical and continuous variables, respectively. When cases had missing variables, they were excluded from analyses that called for those variables. Statistical analyses were conducted using SAS[®] v9.2 (SAS Institute, Cary, NC, USA).

Results

Only two of the 100 selected children were more than 12 months old at the time of the first signs of violence (412 and 440 days, respectively). Forty-seven infants were exclusively cared for by their family, including 45 by both biological parents, one by the father only, and one by the biological mother and her new partner. The other 53 infants were cared for during the day by a nanny; all nannies were female.

Determination of the Time/Period of Behavioural Change

The timing/period when the AHT occurred could be determined in 93 out of 100 cases. In 67 cases, the initial symptom reported was a sudden LOC. It consistently (100%) occurred inside the parents' or nanny's home, never outdoors, in a day care centre or in a public place. A radical and sudden change in the child's condition was reported: major hypotonia. The child was described 'as a rag doll' and experienced respiratory problems (ranging from mild abnormalities to respiratory arrest), severe pallor and eye rolling. The child's condition was so severe that descriptions such as 'I thought he was dead' or 'I have never been so afraid in my life' were frequently offered. In one-third of the cases, resuscitation procedures were performed. In two-thirds of those cases ($n = 45$), a call to an emergency hotline was made. The transcription of this phone call provided an initial, unmodified version of the child's clinical state that could be compared to later versions. This transcription also made it possible to obtain information on the child's condition before the LOC occurred and to know if this condition was usual and normal (feeding, tone, interaction, etc.). In 25 cases, no acute collapse was reported. Symptoms

'The timing/period when the AHT occurred could be determined in 93 out of 100 cases'

'In 91 of the 93 cases where clinical dating was possible, forensic records allowed identification of the adult present with the infant when AHT occurred'

leading to the diagnosis were an obvious change in the child's behaviour and competences, observed at the end of a period of custody by an adult. Depending on the case, the child was described as whining, seeming to be in pain, amorphous, lethargic, unresponsive or much less responsive to interactions, no longer smiling, refusing his/her bottle or eating little, and often showing repeated and unusual projectile vomiting and sometimes with seizure. Similar to the occurrence of a sudden LOC, no change in the child's behaviour and competences was described as occurring outside a home.

In seven cases out of 100, clinical dating was not possible, for example, when the available data were not sufficient or when the alert was belatedly given by an abnormal increase in the head circumference. In five of these cases, the child was in the custody of the parents, but it was not possible to determine the timing of the injury, nor which of the parents was responsible. In the remaining two cases, the perpetrator could not be determined between one of the parents and the nanny because it was not certain that the infant was in his normal state at the time when he was dropped off at the nanny's home.

Determination of the Adult(s) Present with the Infant at the Time of the Behavioural Change Occurrence

In 91 of the 93 cases where clinical dating was possible, forensic records allowed identification of the adult present with the infant when AHT occurred. In two cases, the available forensic data could not determine which parent, the mother or the father, was with the infant at the time of the behavioural change. Forensic expertise identified the 91 perpetrators as follows: 49 were the infant's nanny, 31 the father, one the mother's new partner and ten the mother (Figure 2). Figure 2 and Figure 3 display the flow diagrams of the study sample according to clinical dating and perpetrator, and according to the caretaker and perpetrator, respectively.

Sociodemographic and Contextual Information on AHT According to the Perpetrator

Infants abused by their nanny were more likely to be firstborn (67%) than those abused by their family (43%); they were also more often from a family with a middle or upper sociocultural background (98% of those abused by their nanny vs 33% of those abused by their family). Fifty nine (84%) out of 70 infants for whom the information was available in the medical/forensic files were

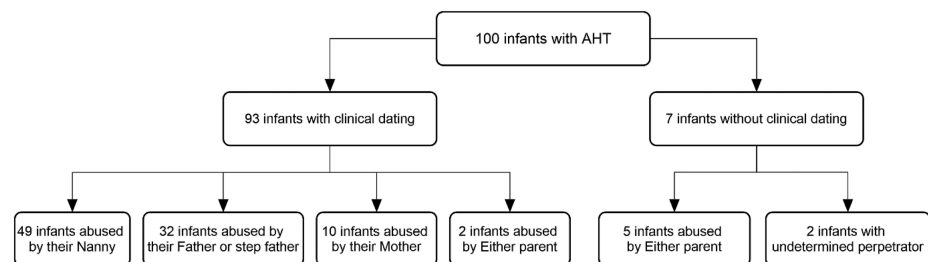


Figure 2. Flow diagram of the study sample by clinical dating (yes/no, first line) and perpetrator (second line). AHT = Abusive head trauma.

described as infants who did not cry habitually, only when they were hungry or tired (Table 1).

Age at diagnosis was higher when the infant was abused by the nanny than by a family member (6.5 ± 2.8 vs 4.3 ± 3.3 months). Further, LOC occurred mainly

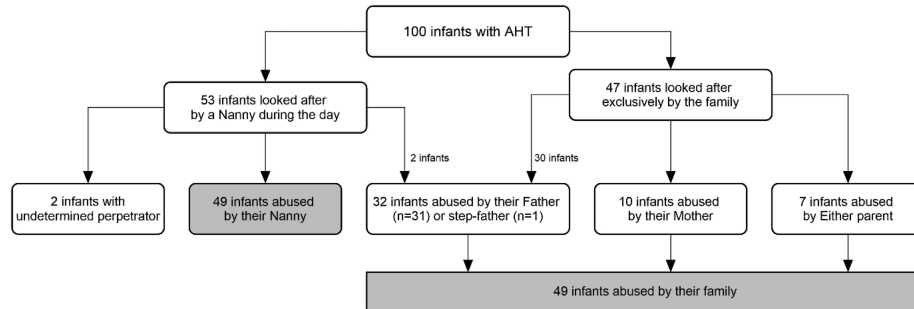


Figure 3. Flow diagram of the study sample by type of usual daytime caretaker (first line) and perpetrator (second line). AHT = Abusive head trauma.

Table 1. Sociodemographic and contextual information on abusive head trauma according to the perpetrator^a

	N ^b (n = 98)	Nanny (n = 49)	Father ^c (n = 32)	Mother (n = 10)	Either parent (n = 7)	'Family' (total) (n = 49)	p-value
Infant sex	98						0.22
Boy		83.7 (41)	75.0 (24)	70.0 (7)	71.4 (5)	73.5 (36)	
Girl		16.3 (8)	25.0 (8)	30.0 (3)	28.6 (2)	26.5 (13)	
Born preterm	96	12.5 (6)	12.9 (4)	30.0 (3)	42.9 (3)	20.8 (10)	0.27
Siblings	98						0.015
None (firstborn)		67.4 (33)	50.0 (16)	40.0 (4)	14.3 (1)	42.9 (21)	
≥1		32.7 (16)	50.0 (16)	60.0 (6)	85.7 (6)	57.1 (28)	
Highest educational level of the parents	98						<0.0001
Incomplete secondary education		2.0 (1)	56.3 (18)	80.0 (8)	100.0 (7)	67.4 (33)	
Completed secondary education		38.8 (19)	15.6 (5)	10.0 (1)	0.0 (0)	12.2 (6)	
Completed higher education		59.2 (29)	28.1 (9)	10.0 (1)	0.0 (0)	20.4 (10)	
Age at diagnosis (months)	98	6.5 ± 2.8	4.1 ± 3.4	4.8 ± 3.8	4.4 ± 2.0	4.3 ± 3.3	0.0006
Place where abusive head trauma happened	98						NA
In a home		100.0 (49)	100.0 (32)	100.0 (10)	100.0 (7)	100.0 (49)	
Loss of consciousness	98	73.5 (36)	71.9 (23)	50.0 (5)	42.9 (3)	63.3 (31)	0.28
Call to emergency hotline	67	80.6 (29)	52.2 (12)	40.0 (2)	66.7 (2)	51.6 (16)	0.01
Resuscitation attempt	66	27.8 (10)	43.5 (10)	40.0 (2)	50.0 (1)	43.3 (13)	0.19
Alleged history/mechanism	97						0.83
Fall or impact		18.4 (9)	12.5 (4)	40.0 (4)	0.0 (0)	16.7 (8)	
No explanation (spontaneous occurrence)		81.6 (40)	87.5 (28)	60.0 (6)	100.0 (6)	83.3 (40)	
Changing history over time	72						0.37
Yes		70.6 (24)	63.0 (17)	37.5 (3)	100.0 (3)	60.5 (23)	
No		29.4 (10)	37.0 (10)	62.5 (5)	0.0 (0)	39.5 (15)	
Confession of guilt	98	6.1 (3)	25.0 (8)	30.0 (3)	0.0 (0)	22.5 (11)	0.02
Presence of other children at the time of acute event	88						<0.0001
None		4.9 (2)	60.0 (18)	50.0 (5)	28.6 (2)	53.2 (25)	
1		26.8 (11)	33.3 (10)	40.0 (4)	71.4 (5)	40.4 (19)	
2		31.7 (13)	6.7 (2)	10.0 (1)	0.0 (0)	6.4 (3)	
≥3		36.6 (15)	0.0 (0)	0.0 (0)	0.0 (0)	0.0 (0)	
Infant described as crying a lot	70						0.46
Yes		13.3 (6)	28.6 (2)	18.8 (3)	0.0 (0)	20.0 (5)	

^aValues are per cent (n) or mean ± SD. p-Values are the difference between nanny vs family (father, mother, either parent) and result from chi-square tests and t-tests for categorical and continuous variables, respectively.

^bThis column indicates the number of cases (out of a maximum of 98) with available data for each variable.

^cThis category includes one mother's new partner categorised as father.

NA = Non-applicable.

around noon (36%) and in the afternoon (33%) for infants abused by their nanny compared with early evening (32%) for infants abused by a family member.

In cases of LOC, the proportion of calls to the emergency hotline was higher when the perpetrator was a nanny (80%) than when it was a family member (51.6% in the family perpetrator group) (Table 1). The number of other children who were present at the time of LOC was higher when nannies were in charge of the child (mean: 2.1 [range: 0–6]) than when it was a family member (mean: 0.5 [range: 0–2]). Overall, 95 per cent of nannies had more than one child to care for and 68 per cent had at least two other children.

The adult present with the child most often reported ‘spontaneous occurrence’ of symptoms without any explanation (80%), followed by ‘short fall’ or ‘shock’ (e.g. an accidental impact against a door or the edge of a bathtub) (17%). In 47 out of 72 cases change of the alleged mechanism over time was observed (table 1-Changing history over time). At the time of the medico-legal expertise, 14 out of 91 identified perpetrators had confessed their abuse and acknowledged having shaken the infant, with immediate symptoms. Only six per cent of nannies confessed, compared to 22.5 per cent of the family perpetrator group.

Diagnostic Criteria, Lesions Leading to Diagnosis and Outcome According to the Perpetrator

The presence of cerebral lesions was significantly more common in children abused by a family member (family perpetrator category) than in those abused by nannies (59.2% vs 38.8%, $p = 0.04$). Traumatic bone lesions were also more

Table 2. Relevant objective findings and outcome according to the perpetrator^a

	N ^b (n = 98)	Nanny (n = 49)	Father ^c (n = 32)	Mother (n = 10)	Either parent (n = 7)	‘Family’ (total) (n = 49)	p-value
Number of subdural haematomas	98						0.27
1–2		22.5 (11)	12.5 (4)	20.0 (2)	0.0 (0)	12.2 (6)	
3		34.7 (17)	25.0 (8)	30.0 (3)	57.1 (4)	30.6 (15)	
4		42.9 (21)	62.5 (20)	50.0 (5)	42.9 (3)	57.1 (28)	
Rupture of bridging veins	98	55.1 (27)	75.0 (24)	50.0 (5)	28.6 (2)	63.3 (31)	0.41
Cerebral injuries	98	38.8 (19)	59.4 (19)	60.0 (6)	57.1 (4)	59.2 (29)	0.04
Retinal haemorrhage	98	85.7 (42)	81.3 (26)	80.0 (8)	28.6 (2)	73.5 (36)	0.13
Spinal injuries	98	8.2 (4)	15.6 (5)	10.0 (1)	0.0 (0)	12.2 (6)	0.50
Traumatic bone lesions	98	10.2 (5)	34.4 (11)	40.0 (4)	28.6 (2)	34.7 (17)	0.004
Traumatic skin lesions	98	30.6 (15)	46.9 (15)	40.0 (4)	28.6 (2)	42.9 (21)	0.21
Haematocrit level (%)	45/30/10/5/45	29.9 ± 3.9	27.8 ± 5.1	24.7 ± 5.3	28.0 ± 6.3	27.1 ± 25.5	0.006
Lactate level (mmol/L)	12/13/1/2/16	4.6 ± 2.6	6.6 ± 3.1	4.2 ± NA	2.2 ± 0.2	5.9 ± 3.2	0.25
Glasgow Outcome Scale category	92						0.001
1. Good outcome		40.0 (18)	3.2 (1)	22.2 (2)	28.6 (2)	10.6 (5)	
2. Moderate disability		24.4 (11)	54.8 (17)	33.3 (3)	28.6 (2)	46.8 (22)	
3. Severe disability		13.3 (6)	12.9 (4)	22.2 (2)	0.0 (0)	12.8 (6)	
4. Minimally responsive state		17.8 (8)	3.2 (1)	11.1 (1)	28.6 (2)	8.5 (4)	
5. Death		4.4 (2)	28.8 (8)	11.1 (1)	14.3 (1)	21.3 (10)	

^aValues are per cent (n) or mean ± SD. p-Values are the difference between nanny vs family (father, mother, either parent) and result from chi-square tests and t-tests for categorical and continuous variables, respectively.

^bFor continuous variables, multiple Ns are the number of samples in each column.

^cThis category includes one mother's new partner categorised as father.

NA = Non-applicable.

common in children abused by a family member than in those abused by nannies (28% to 40% vs 10%, $p = 0.004$). Outcome measured using the GOS-C was worse in the family category ($p = 0.001$). The child death rate was significantly higher for fathers compared to other perpetrators (28.8%, $p < 0.05$) (Table 2).

Historical and Physical Evidence of Prior Abuse Events

There was no significant difference according to the type of perpetrator with regard to the frequency of a history of previous abuse, the number of prior medical contacts, the time between first symptoms and medical consultation, and the time between first symptoms and diagnosis. In case of the presence of previous signs of abuse, repeated vomiting was significantly more common in children abused by nannies than in the family perpetrator group (78.4% vs 45.0%, $p = 0.003$), while bone fractures were more common in children abused by their mothers (33.3%) than in those abused by nannies (5.4%) (Table 3). The age at first symptoms or lesions (5.9 ± 2.2 months old) and first medical consultation (6.0 ± 2.1 months old) was higher in infants abused by nannies than in those abused by the family perpetrator group (2.5 ± 2.7 and 2.7 ± 2.6 months, respectively, both $p < 0.0001$) (Table 3).

Table 3. Historical or physical evidence of prior abuse events and past medical consultations according to the perpetrator^a

	N ^b (n = 98)	Nanny (n = 49)	Father ^c (n = 32)	Mother (n = 10)	Either parent (n = 7)	'Family' (total) (n = 49)	p-value
Infant's historical or physical evidence of prior abuse events	98	75.5 (37)	84.4 (27)	60.0 (6)	100.0 (7)	81.6 (40)	0.46
Type of symptoms or lesions among children with a history of abuse	77						
Repeated vomiting		78.4 (29)	48.2 (13)	33.3 (2)	42.9 (3)	45.0 (18)	0.003
Abnormal increase in head circumference growth		43.2 (16)	48.2 (13)	50.0 (3)	84.7 (6)	55.0 (22)	0.30
Traumatic skin lesions		37.8 (14)	37.0 (10)	50.0 (3)	42.9 (3)	40.0 (16)	0.85
Failure to thrive in weight growth		24.3 (9)	22.2 (6)	33.3 (2)	0.0 (0)	20.0 (8)	0.65
Sudden loss of consciousness		13.5 (5)	22.2 (6)	16.7 (1)	28.6 (2)	22.5 (9)	0.30
Bone fracture		5.4 (2)	25.9 (7)	33.3 (2)	28.6 (2)	27.5 (11)	0.01
Prior contacts with medical care among children with a history of abuse	77						
At least one medical consultation		62.2 (23)	55.6 (15)	16.7 (1)	71.4 (5)	52.5 (21)	0.39
At least one emergency room visit		32.4 (12)	14.8 (4)	50.0 (3)	14.3 (1)	20.0 (8)	0.21
At least one hospitalisation		10.8 (4)	22.2 (6)	33.3 (2)	28.6 (2)	25.0 (10)	0.11
At least one prior contact with medical care		75.7 (28)	70.4 (19)	66.7 (4)	85.7 (6)	72.5 (29)	0.75
Age at first symptoms or lesions (months)	34/24/6/7/37	5.9 ± 2.2	2.7 ± 3.2	2.1 ± 1.4	2.3 ± 1.8	2.5 ± 2.7	<0.0001
Age at first medical consultation (months)	27/18/4/6/28	6.0 ± 2.1	2.7 ± 3.0	2.8 ± 1.3	2.8 ± 1.7	2.7 ± 2.6	<0.0001
Time between first symptoms and medical consultation (months)	27/18/4/6/28	0.1 ± 0.2	0.3 ± 0.3	0.0 ± 0.0	0.5 ± 0.6	0.3 ± 0.4	0.08
Time between first symptoms and diagnosis (months)	24/18/4/6/28	0.8 ± 1.2	0.9 ± 0.9	1.4 ± 1.5	1.9 ± 1.0	1.2 ± 1.0	0.30
History of abuse in older sibling (when applicable)	29						0.006
Yes		8.3 (1)	50.0 (5)	50.0 (2)	100.0 (3)	58.8 (10)	
No		91.7 (11)	50.0 (5)	50.0 (2)	0.0 (0)	41.2 (7)	

^aValues are per cent (n) or mean ± SD. p-Values are the difference between nanny vs family (father, mother, either parent) and result from chi-square tests and t-tests for categorical and continuous variables, respectively.

^bFor continuous variables, multiple Ns are the number of samples in each column.

^cThis column includes one mother's new partner categorised as father.

‘An essential point on which our study is based is the notion of the immediate onset of symptoms following shaking, allowing clinical dating’

Finally, a previous history of abuse in siblings was significantly higher in infants abused by the family than in those abused by nannies (50.0 to 100% vs 8.3%, $p = 0.006$) (Table 3).

Discussion

Our findings indicate that abuse consistently occurred within a home in the presence of only one adult. About half the perpetrators were nannies, one-third were the fathers, while only ten per cent were the mothers.

Clinical Dating

An essential point on which our study is based is the notion of the immediate onset of symptoms following shaking, allowing clinical dating. This notion emanates from complete and detailed clinical descriptions of an infant's behaviour and clinical status after the abusive event, some of them based on confessed cases, which have shown that symptoms of varying severity appear immediately after the abusive event, with no lucid interval (Adamsbaum *et al.*, 2014; Bell *et al.*, 2011; Biron and Shelton, 2005; De Leeuw *et al.*, 2013a, 2013b; Esernio-Jenssen *et al.*, 2011; Gilliland, 1998; Starling *et al.*, 2004). It is moreover this immediacy of symptoms and the child being ‘calmed’, with a cessation of crying, that lead to the frequent repetition of the gesture:

‘When I can't calm my son, I take him under the arms and, holding him firmly, I moved him forward and back, I shook him several times without realizing my own strength. His head snapped back and forth from time to time. After I shake him like that, he's tired and goes to sleep.’ (Adamsbaum *et al.*, 2010, p. 551)

Apart from the confessions, the notion of immediate modification of the child's state has also been reported by persons, different from the perpetrator, who had to take care of the child immediately after the facts: ‘It should be noted that in all of the cases where information was supplied by someone other than the perpetrator, the child was not normal during the interval’ (Gilliland, 1998, p. 724). This notion was also confirmed by the transcription of all calls to the emergency services that were analysed in our study. Transcriptions were very similar in terms of the wording and the clinical features described: all of them reported the extreme suddenness of the symptoms' onset and the very severe clinical state (child was described ‘as a rag doll’, ‘I thought he was dead’). In one-third of cases, the adult started resuscitation procedures. None of these transcriptions reported that the infant had symptoms before this sudden occurrence of the LOC. This contrasts with further versions that these adults gave to police officers, where in some cases they mentioned symptoms prior to the LOC, reinforcing the frequent ‘changing history’ observed in cases of AHT (Edwards *et al.*, 2020).

Other arguments are based on the lesions retained by the HAS-SOFMER diagnostic criteria (HAS and SOFMER, 2017). These lesions have been highlighted in several studies as very specific: multifocal subdural haematoma (SDH) and bridging veins rupture (Adamsbaum *et al.*, 2010; Adamsbaum and Rambaud, 2012; Case, 2008; Kemp *et al.*, 2011). These lesions have otherwise

been reported following some high-velocity road traffic accidents or major falls (Nahmani, 2018; Ronning *et al.*, 2018). Actually, there is no argument in the literature suggesting that, after such a violent mechanism, a delay in symptom onset could be observed (Arbogast *et al.*, 2005; Willman *et al.*, 1997).

Interest in Clinical Dating

In France, this analysis falls within the framework of medico-legal expertise conducted by experts who are independent of both parties, according to the terms of a judicial mission defined and monitored by a judge of criminal proceedings. This clinical dating is not part of the responsibility of the doctors who take care of the child in the initial phase. They are only required to identify the medical problem and possible abuse. The legal experts, provided with a combination of comprehensive medical records from birth and legal documents including the transcript of the call to the emergency service, are able to perform clinical dating of the acute signs of abuse in most cases.

Identification of the Perpetrator

The timing of the abusive event is critical for investigators attempting to identify the perpetrator (Starling *et al.*, 2004). In 91 out of the 93 cases where clinical dating was possible, we were able to determine the adult present with the infant at the time of symptom occurrence and therefore to deduce the identity of the perpetrator. Moreover, these results were probably enabled by the fact that our study did not cover all AHTs but specifically AHT through shaking, a particularly violent mechanism resulting in initial severe symptoms. In fact, analysis of the procedural documents indicated that, at the time of the LOC or infant's behavioural change, other children could be present inside the home, but consistently only one adult. Except for one mother's new partner, all perpetrators were the nanny, the father or the mother. Overall, half of the identified perpetrators were parents and the other half the infant's nanny. The implication of infant's close relatives was emphasised in a prospective study of child alleged falls, some of them from less than five feet (Williams, 1991).

The order of frequency of confessed perpetrators in our study, and in some other studies (Adamsbaum *et al.*, 2010; Starling *et al.*, 1995, 2004), was different from the one of identified perpetrators (49 nannies, 31 fathers, 10 mothers), particularly for the nannies (Esernio-Jenssen *et al.*, 2011; Starling *et al.*, 1995, 2004).

This distribution of identified perpetrators with a clear female predominance was also different from the male predominance reported in most previous studies (Fingarson *et al.*, 2019; Schnitzer and Ewigman, 2005; Scribano *et al.*, 2013; Starling *et al.*, 1995, 2004). This predominance was the result of an overrepresentation of nannies, which could be explained by cultural specificities. In France, many women return to work early at the end of their maternity leave (10 weeks postpartum). Similarly, unlike previous reports (Fingarson *et al.*, 2019; Schnitzer and Ewigman, 2005; Scribano *et al.*, 2013), in our study, at the time of abuse, nearly all parents were living together and there was only one mother's new partner among the male perpetrators (the abused child in this case was one of the two over 1 year of age). The implication of perpetrators other than biological parents has,

‘This clinical dating is not part of the responsibility of the doctors who take care of the child in the initial phase’

‘In 91 out of the 93 cases where clinical dating was possible, we were able to... deduce the identity of the perpetrator’

‘In this large consecutive series, abuse never occurred outside a home nor in a day care centre’

‘The constant occurrence of AHT inside a home is a strong argument... against the hypothesis of a spontaneous occurrence of SDHs’

however, also been highlighted in several publications (Fingarson *et al.*, 2019; Schnitzer and Ewigman, 2005; Scribano *et al.*, 2013). Therefore, it is likely that the distribution of perpetrators between genders and between family versus other caregivers is country- or community-specific.

Findings Regardless of the Type of Perpetrator

In this large consecutive series, abuse never occurred outside a home nor in a day care centre. This finding had been previously highlighted by Chadwick *et al.* (1991): in a population of children consecutively hospitalised in a trauma centre after an alleged fall, the only children who died were those who suffered an alleged indoor fall of less than one metre (7 out of 100), as opposed to only one child who died following a fall of more than three metres (1 out of 118 fell 9 m). The incongruity of this result strongly suggested that abuse was concealed. The authors of this study concluded that ‘research on children’s injuribility should utilise the longer falls rather than indoor falls witnessed by just one person’ (Chadwick *et al.*, 1991, p. 1355). Further, regardless of the perpetrator, the most frequently alleged mechanism giving rise to the sudden LOC was spontaneous occurrence, followed by a fall from a low height or a shock. A change in alleged mechanism was very common, similar to that in previous reports (Hettler and Greenes, 2003). The constant occurrence of AHT inside a home is a strong argument, however, against the hypothesis of a spontaneous occurrence of SDHs, or of weakening factors predisposing to the spontaneous occurrence of SDHs (Vinchon *et al.*, 2010), which tend to occur randomly inside or outside in public places.

Several arguments are in favour of the perpetrator’s knowledge of the inappropriateness of the act: the fact that abuse occurred in a face-to-face relationship and never in the presence of a neutral (independent) witness, and the delay in seeking care. Indeed, following LOC, despite the infant’s very worrying clinical condition, only two-thirds of the perpetrators called the emergency hotline.

Findings According to the Type of Perpetrator

Nannies

Historical or physical evidence of prior abuse events was found in more than three-quarters of cases, with first signs of abuse or LOC occurring very early: during the first day of custody in nine per cent of cases, during the first week in more than a quarter of cases, during the first month in more than half of cases and during the first three months in 91 per cent of cases (Table 4). Repeated vomiting was the most frequently reported symptom. Infants who were abused by nannies displayed fewer cerebral lesions and had fewer poor neurological outcomes than those abused by biological parents.

Fathers

Nearly one-third of fathers who were perpetrators had a high education level. Father perpetrators were associated with a very severe initial clinical presentation, as evidenced by elevated lactate rates (indicating previous major respiratory disorders) and a higher mortality rate (similarly to Esernio-Jenssen *et al.*, 2011).

Table 4. Timing of previous signs of abuse and occurrence of abusive head trauma for cases of infants abused by nannies ($n = 49$)

	N	Median (min – max) or % (n)
Age at the start of nanny custody (months)	49	4.1 (1.5–16.8)
Time between start of custody and first signs of abuse (days)	34	26 (0–212)
Time between start of custody and first medical contact (days)	27	27 (4–212)
Time between start of custody and AHT diagnosis (days)	45	42 (0–318)
Number of abuses that occurred	34	
Within the first day of custody		8.8 (3)
Within the first week of custody		26.5 (9)
Within the first month of custody		61.8 (21)
Within the first three months of custody		91.2 (31)

AHT = Abusive head trauma.

Mothers

Similar to other studies (Schnitzer and Ewigman, 2005; Scribano *et al.*, 2013; Starling *et al.*, 1995, 2004), mothers represented the smallest group of perpetrators (10%). They were associated with more bone lesions than the other perpetrators.

Parents (Undetermined)

All of these parents who were perpetrators had a low education level. In three cases for which data were available (out of 7), there was a history of previous violence in siblings, who were already in foster care (see Table 3 for history of abuse in older siblings).

Reflection on Crying

Crying is often reported to be the trigger event of abuse. In our study, most infants were described as not crying habitually. Several hypotheses could be made. One could argue that infants cry more in the presence of the perpetrator because this person does not meet his/her needs. The importance of recent changes in caregiving modalities and caregiver relationships was highlighted by Fingarson *et al.* (2019). This adaptation of care to the infant's needs probably explains why mothers, in most studies, are the least frequent perpetrators, although they are usually the ones who spend the most time with the infant. Another factor to be considered is the tolerance and availability of the adult faced with infant crying. Finally, a possibility that cannot be excluded is that shaking the infant could also be an expression of an abuse of power by an adult. This possibility was described by Adamsbaum *et al.* (2019) in a study on abusive metaphyseal fractures which were inflicted when dressing/undressing the infant or changing the infant's diapers:

'Perpetrators admitted inflicting violent indirect forces (torsion, traction, compression and forced movements). The baby's crying was cited as the trigger for abuse in less than a quarter of cases. The violence was habitual in 67% of cases.' (p. 154)

In the End, Prevention is Crucial

Although infants were described as not crying habitually in this study, one cannot rule out that crying increases in the presence of an abusive adult, and

'Infants cry more in the presence of the perpetrator because this person does not meet his/her needs'

‘Recognising symptoms or lesions compatible with abuse among children should be emphasised as a strategy to prevent further injury’

crying remains a trigger that is often mentioned in AHT occurrence (Edwards *et al.*, 2020). In any case, it is important to give a universal simple message about the fact that a child can cry for prolonged periods without being ill, and that a baby may be abused by an exasperated adult. Simple advice should be given to calm the child down and on what to do in case of exasperation: ‘lie the child on his back and leave the room, then ask for help’ (Simonnet *et al.*, 2014, p. 1917). Another method is the ‘Take Five Safety Plan’ proposed by Bechtel *et al.* (2020) to manage caregiver frustration with infant crying which can help reduce the likelihood of AHT.

It is also important to be aware that situations where several children are in the care of a single adult, particularly in the case of a new or unusual childcare arrangement, may increase the risk of abuse. Recognising symptoms or lesions compatible with abuse among children should be emphasised as a strategy to prevent further injury (Laurent-Vannier *et al.*, 2020).

Beyond this, prevention programmes should also be targeted differently as efforts directed towards mothers might not reach those who are most at risk of perpetrating abuse (i.e. fathers, mothers' new partners and nannies). These programmes have also failed to demonstrate successful replication (Keenan and Leventhal, 2010). Fathers and mothers' new partners should be informed not only about the possibility of being exasperated by infant crying, but also of infant needs and how to meet them. Regarding nannies in our study, almost all of them were certified and had therefore probably received training on crying and AHT, but this did not prevent abuse. Several recommendations could be proposed: an adaptation period should be systematically organised before starting whole day care, and the number of children simultaneously in the care of a nanny should be limited. Nannies should be encouraged to report any difficulty in order to get help. Lastly, their training should be improved.

Finally, although this concerns only a few cases, special attention should be focused on families of newborns when there is a history of siblings being placed in foster care because of abuse.

Strengths and Limitations of the Study

Although this study is retrospective, it reports on a large number of cases that were consecutively referred to one single independent judicial expert by 39 judges from all regions of France, and the database was prospectively implemented. Diagnosis was performed, based exclusively on objective elements, following scientific recommendations established by a committee of experts under the supervision of the French HAS (described in Appendix S1 in the online Supporting Information). The methodology used did not enable the inclusion of a control population. All cases were referred to a single judicial expert and this may have introduced a bias, however this bias was reduced because the cases came from 39 different courts from all over France. In 90 cases, depending on the judicial instructions, a paediatric radiologist was involved in the expertise process. For the other ten children (including two who died immediately and were autopsied), imaging was not reviewed by a paediatric radiologist.

Conclusion

By relying on symptom onset to identify the timing of abusive events, we were able to identify the perpetrators and circumstances in the majority of cases of AHT by shaking. Regardless of the perpetrator, abuse consistently occurs within a home in the presence of only one adult. The results of this study can be used to improve abuse prevention, which should be adapted and targeted towards the main categories of perpetrators: nannies, fathers and mothers.

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Conflict of Interest

We have no conflict of interest to disclose. ALV co-chaired the large multidisciplinary working group that established the diagnostic methodology including diagnostic criteria, under the supervision of the French HAS 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.