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ORIGINAL ARTICLE

Age determination of subdural hematomas: survey among radiologists

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Abstract Abusive head trauma is a severe form of child abuse. One important diagnostic finding is the presence of a subdural hematoma. Age determination of subdural hematomas is important to relate radiological findings to the clinical history presented by the caregivers. In court this topic is relevant as dating subdural hematomas can lead to identification of a suspect. The aim of our study is to describe the current practice among radiologists in the Netherlands regarding the age determination of subdural hematomas in children. This is a cross-sectional study, describing the results of an online questionnaire regarding dating subdural hematomas among pediatric and neuro-radiologists in the Netherlands. The questionnaire consisted of sociodemographic questions, theoretical questions and eight pediatric cases in which the participants were asked to date subdural hematomas based on imaging findings. Fifty-one out of 172 radiologists (30 %) filled out the questionnaire. The percentage of participants that reported it was possible to date the subdural hematoma varied between 58 and 90 % for the eight different cases. In four of eight cases (50 %), the age of the subdural hematoma as known from clinical history fell within the range reported by the participants. None of the participants was "very certain" of their age determination. The results demonstrate that there is a considerable practice variation among Dutch radiologists regarding the age determination of subdural hematomas. This implicates that dating of subdural hematomas is not suitable to use in court, as no uniformity among experts exists.

Keywords Hematoma, subdural · Magnetic resonance imaging · Tomography, X-ray computed · Age determination · Child abuse

Introduction

Abusive head trauma (AHT) is one of the most severe forms of physical child abuse. It is the most important cause of traumatic brain injury in young children, with a reported incidence of 14–40 per 100,000 children under the age of 1 per year, leading to significant mortality and morbidity [1]. Radiological imaging plays a pivotal role in the diagnosis of AHT [2]. An important diagnostic finding is the presence of a subdural hematoma (SDH). A systematic review by Kemp et al. showed a clear association of SDH with AHT, expressed by an OR of 8.2 [3]

One important issue, especially in legal proceedings, is the issue of timing of the injury. Age determination of SDHs is important in order to relate radiological findings to the clinical history presented by the parents/caregivers. It is not uncommon for expert witness radiologists to be requested by court to date SDHs based on imaging findings. In court this topic is relevant, as it will be of great value to relate the injuries to possible suspects that might have had contact with the child. Incorrect age determination of a SDH, conflicting with available clinical history, can lead to an incorrect suspicion of child abuse or an incorrect identification of a potential perpetrator.

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Obviously, a false-positive diagnosis of child abuse or indicating a wrong potential perpetrator can cause severe social and emotional problems for the involved child and parents/caregivers.

To our knowledge, no definite time line for dating SDHs has been published, although some authors proposed a method to develop an evidence-based time line [4]. Publications on the age determination of SDHs are mainly based on intracerebral, i.e., parenchymatous, hematomas [5, 6], or studies in adults or in which patients characteristics are not reported [7–9]. Recently, Bradford et al. reported that the validity of previously accepted concepts regarding dating SDHs have elapsed, as the studies of these concepts were based on had been performed in specific settings and are not applicable to a general population [10]. In our tertiary referral center we noticed, both in a clinical as well as in a pediatric forensic setting, a practice variation among radiologists regarding dating of SDHs. Where some radiologists do not date at all, others date up to days or even hours specific. As it can have legal implications if different conclusions are drawn, it is of interest to assess the potential variation between radiologists.

If the variation in practice between radiologists would be known, this would give insight in the value of radiological reports dealing with dating SDHs in a forensic setting. Also, knowledge of the variation in practice can help to provide recommendations for adequate radiological reporting in case of suspected AHT. We therefore conducted a survey among pediatric and neuroradiologists in the Netherlands. The aim of our study is to describe the current practice among radiologists in the Netherlands regarding the age determination of SDHs in children, using an anonymous on-line questionnaire. Based on clinical experience, we hypothesized that a significant practice variation among radiologists regarding the age determination of SDHs exists.

Methods

This study is a cross-sectional study, describing the outcomes of an anonymous online questionnaire on dating SDHs among pediatric radiologists and neuroradiologists practicing in the Netherlands.

Participants

In the Netherlands, neuroimaging of children is performed by pediatric radiologists as well as neuroradiologists. Therefore the questionnaire was distributed per email among all pediatric radiologists and neuroradiologists that are registered in the Netherlands as member of their subspecialty section within the Dutch Radiological Society (*n*-total=183). In order to be registered for a subspecialty section, the radiologists need to be clinically involved in the specific radiological subspecialism. Although membership is not a prerequisite to work in a subspecialty field of radiology, the majority of radiologists active in a subspecialty are member of their sections. Approval for the use of the email addresses was obtained from the chair of the sections of pediatric radiology and neuroradiology of the Dutch Radiological Society. The radiologists were invited to participate anonymously in this study, with a link to the online questionnaire. The questionnaire has been online for 4 weeks in the beginning of 2013. In this period, the eligible participants received two reminders to fill out the questionnaire. We specifically asked eligible participants not willing to participate in the study to open the questionnaire and opt out after filling in their sociodemographic data, in order to be able to compare the participants and radiologists who did want to participate. No compensation was offered to the radiologists to participate in the study.

Questionnaire

We developed a questionnaire using SurveyMonkey® (www.surveymonkey.net), an online survey software and questionnaire tool. Questions were based on clinical experience. The questionnaire consisted of three parts (see Electronic supplementary material). In the first part, we collected sociodemographic data on type of hospital where the radiologists practiced, number of years of clinical experience, and sub specialization. The second part of the questionnaire consisted of theoretical questions regarding SDHs with mixed densities. The third part consisted of eight pediatric cases (four CT and four MRI images), in which the participants were asked to date SDHs based on imaging findings (Figs. 1, 2, 3, 4, 5, 6, 7, and 8). We added arrows in the images for this publication; the arrows were not visible in the questionnaire. Age, gender, and (concise) reason for hospital visit were provided in all cases. Participants were asked to give an approximate age of the SDH, and a minimum and maximum age for this SDH. Furthermore they were asked how certain they were about this age estimation, scored on a five-point Likert scale, subdivided in "very uncertain", "uncertain", "neutral", "certain", and "very certain". CT and MRI images were selected by an experienced pediatric radiologist (RRvR) and neuroradiologist (CBLMM), from the PACS database (Impax 6.5.0, Afga, Mortsel, Belgium) from the Academic Medical Center Amsterdam, the Netherlands. The timing of the incident leading to the SDH was derived from the forensic analysis. It is not certain for all cases if this is correct, but for the purpose of this research, describing *the variation* among radiologists, this was not of influence. The questionnaire was piloted among two radiologists in order to enhance intelligibility; subsequently these radiologists were excluded from the eligible study participants.

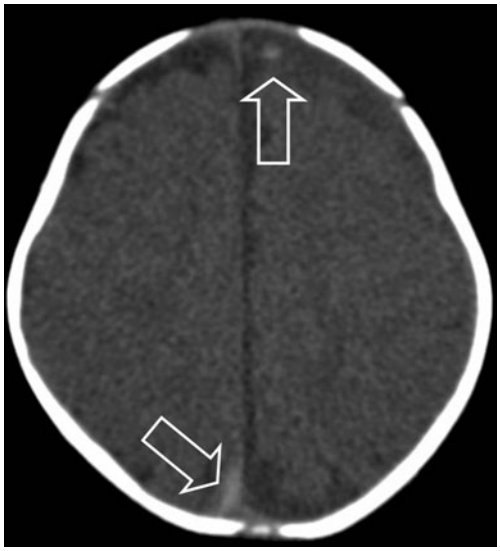

Fig. 1 Case 1. Axial CT image of a 5-month-old boy who fell from a carrycot. *Information not available to the participating radiologists*: the boy was brought to the emergency department after a trauma with immediate neurological signs. The clinical history later changed into an abusive incident. The CT scan was performed 1 day after the incident. CT scan shows a left frontal and right posterior SDH (*open arrows*)

Statistical analysis

Data obtained by SurveyMonkey® were collected in excel and analyzed with the use of IBM SPSS Statistics 20 (Statistical Product and Service Solutions, IBM Software Group's Business Analytics Portfolio). Continuous data were expressed as means and standard deviations or medians and minimum–maximum when appropriate. Differences between groups were tested using a *t* test (normally distributed data) or Mann–Whitney *U* test (non-normally distributed data) for numerical data and by using a Chi square test for categorical data. Not all participants filled out all questions; the number of participants for each question is listed in Tables 2, 3, and 4. We did not impute any data to replace missing values.

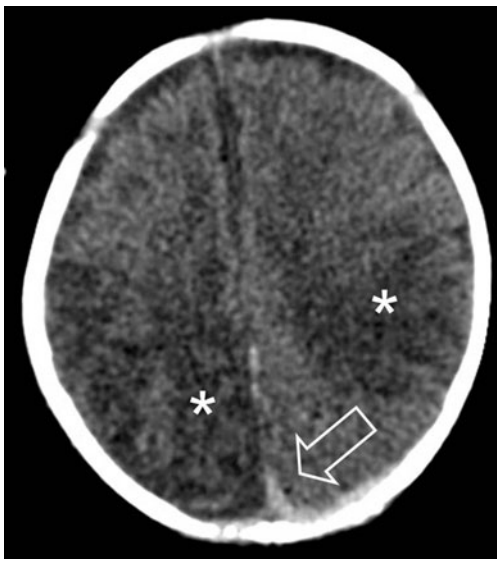

Fig. 2 Case 2. Axial CT image of a 3-week-old boy who presented with pallor, weakness, and convulsions. *Information not available to the participating radiologists*: the boy was admitted because of the persisting convulsions. This CT scan was performed on day 9 after admission. Police investigations ruled this to be an abusive head trauma case. Based on the police investigations the time of the accident was dated as 9 days old. CT shows a SDH along the left posterior convexity (*open arrow*). Note the bilateral hypodens areas indicating oedema of the brain (*asterisks*)

Fig. 3 Case 3. Axial CT image of a 7-month-old girl who according to parents choked during feeding. *Information not available to the participating radiologists*: according to the clinical history the girl choked during feeding and became comatose. Before to this she had been healthy. Her father took her to the hospital and reportedly accidentally bumped her head against the car when getting her out of the car. She was admitted to the hospital in comatose state and discharged severely handicapped. This CT scan was made immediately after arrival at the hospital. Police interrogations revealed this was an abusive head trauma case. CT shows a SDH with hypo and hyperdense components (*open arrow*). The SDH extends to the right posterior convexity (*arrow*)

Results

Response rate

We sent the questionnaire to the 183 email addresses of the members list from the sections of pediatric radiology (n=48) and neuroradiology (n=135) of the Dutch Radiological Society. The flow scheme of excluded persons, participants, those who opted out and non-responders is provided in Fig. 9. Nine email addresses were incorrect, one radiologist was in the list with two different email addresses and another radiologist appeared to be retired. These 11 email addresses were excluded. A total of 172 radiologists (39 pediatric radiologists and 133 neuroradiologists) received the email, of which 51 (30 %)

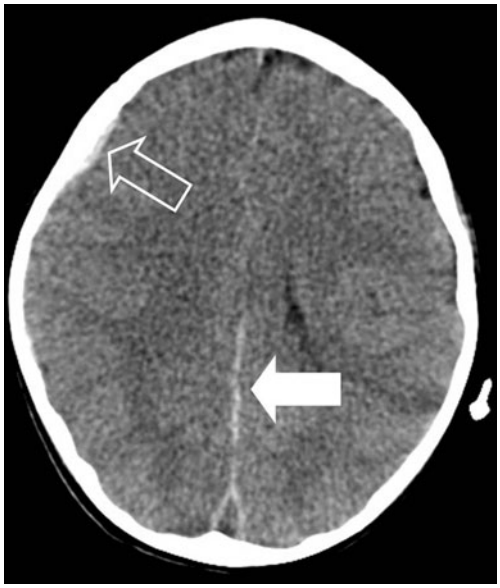

Fig. 4 Case 4. Axial CT image of a 3-year-old boy who fell from the stairs. *Information not available to the participating radiologists*: the boy was brought to the hospital comatose, according to parents he had fallen from the stairs that night. Signs of physical abuse (bruises and burning wounds) were found all over his body. He was admitted for several weeks, this CT scan was made 12 h after the incident. Police investigations revealed that the day before admission he had been seen in good condition by several people. In the night before admission, the neighbors had heard him crying for several hours. CT shows a thin hyperdense SDH along the right convexity (*open arrow*) and a SDH along the falx cerebri (*arrow*)

participated and completed the questionnaire. Twenty-seven radiologists (16 %) rejected the questionnaire through either the "opt out option" or by emailing the research group. In case of ending the questionnaire after filling out sociodemographic data only, the radiologists were classified as opting out as well. Sociodemographic data of 21 radiologists who opted out were available. There were 94 non-responders (55 %).

Sociodemographic characteristics

The characteristics of participants and radiologists who opted out are listed in Table 1. Twenty-three of 51 participants were working in a university hospital (45 %). Ten participants reported to be a subspecialist in pediatric radiology (20 %), and 37 in neuroradiology (73 %). Median number of years of clinical experience was 8 (range 0–35 years). The participants did not significantly differ in working situation and working experience from the radiologists who opted out, but there were significantly more radiologists in the participants group with a subspecialism compared with the radiologists who opted out (p=0.02). The participants spent a median of 16 h a week on neuroradiology (range 1–70 h); 63 % dated SDHs in clinical practice. Knowledge regarding dating SDHs was mainly obtained from supervisors during radiology training (Table 2).

Theoretical questions

Answers to the theoretical questions are listed in Table 3. Nearly half of the participants responded that in theory, it was possible to date a SDH of mixed density on CT or MRI. The reported causes for mixed density SDHs are listed in Table 3.

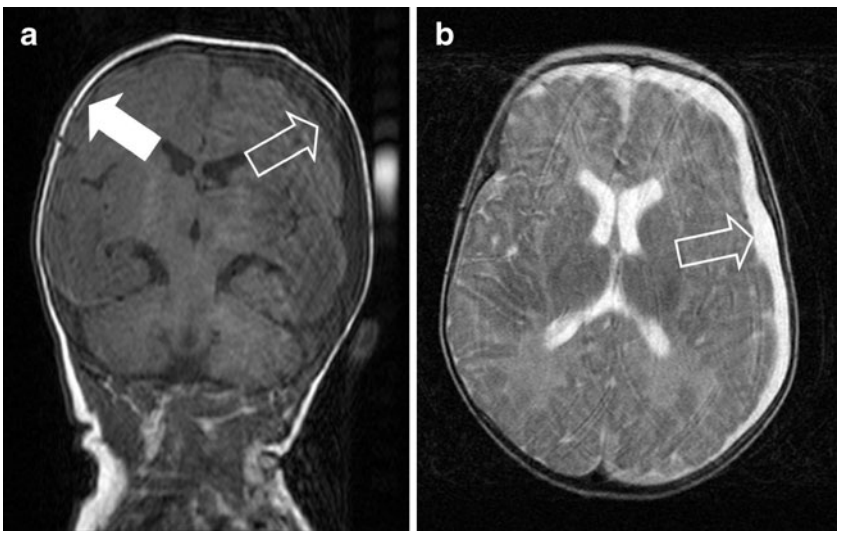

Fig. 5 **a** Case 5. Coronal T1-weighted MR image of a 5-month-old boy who fell from a carry cot. *Information not available to the participating radiologists*: the boy was brought to the emergency department after a trauma with immediate clinical signs. He was pale, weak, and unresponsive and was admitted to the pediatric ward. The clinical history later changed into an abusive incident. The MR scan was performed after 2 days. MRI, hampered by motion artefacts, shows a left-sided hypointense SDH (*open arrow*). A thin right-sided hyper-intense SDH is seen on the right side (*arrow*). **b** Axial T2-weighted MR image of the same boy shows a hyper-intense SDH along the left convexity (*open arrow*). The thin right-sided SDH is not visible on this image

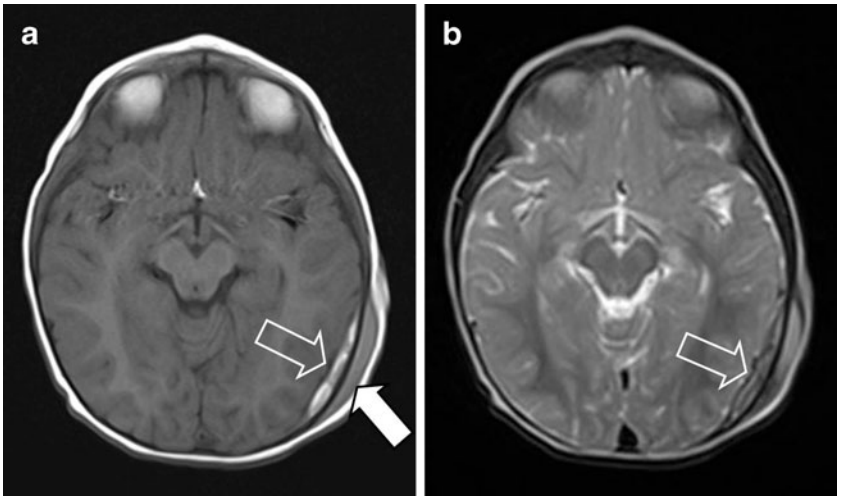

Fig. 6 **a** Case 6. Axial T1-weighted MR image of a 1-year-and-3-month-old boy who fell from a bunk bed. *Information not available to the participating radiologists*: the history revealed that the boy was put on a bed (1.60 m high) by a sibling. He fell off and cried immediately; parents took him to the GP but were referred to the ED because of swelling on the head. The child was admitted to the pediatric ward for one night for observation. Parents noticed a new swelling of the head after some days, and therefore a MRI was performed on day 9. No other trauma was described. MR shows a mixed intensity SDH along the left convexity (*open arrow*). There is a significant subcutaneous haematoma present (*arrow*). **b** Axial T2-weighted MR image of the same boy also shows a mixed intensity SDH (*open arrow*)

Practice of dating SDHs

The medians of the reported estimated ages and the medians of reported minimum and maximum estimates as reported by the participants for the different cases are provided in Tables 4 and 5.

For the four CT cases, the percentage of the participants that reported it was possible to date the SDH was 63, 58, 64, and 83 % for cases 1, 2, 3, and 4, respectively. This resulted in 40, 40, 40, and 53 % of the participants actually reporting an estimated age and 40, 40, 45, and 47 % reporting a range only for CT case 1, 2, 3, and 4, respectively. In two of four CT cases (50 %, cases 1 and 4) the age of the SDH as known from clinical history fell within the range reported by the radiologists. In the CT case with the highest consensus (case 4, Fig. 4), age of the SDH was estimated 12 h (range 5 h–3 days). According to clinical information this SDH was indeed 12 h old. In the CT case with the lowest consensus (case 2, Fig. 2), age of the SDH was estimated 2 days (range 1.5–8 days). According to clinical history the SDH was 9 days old.

For the four MRI cases, the percentage of the participants that reported it was possible to date the SDH varied was 63,

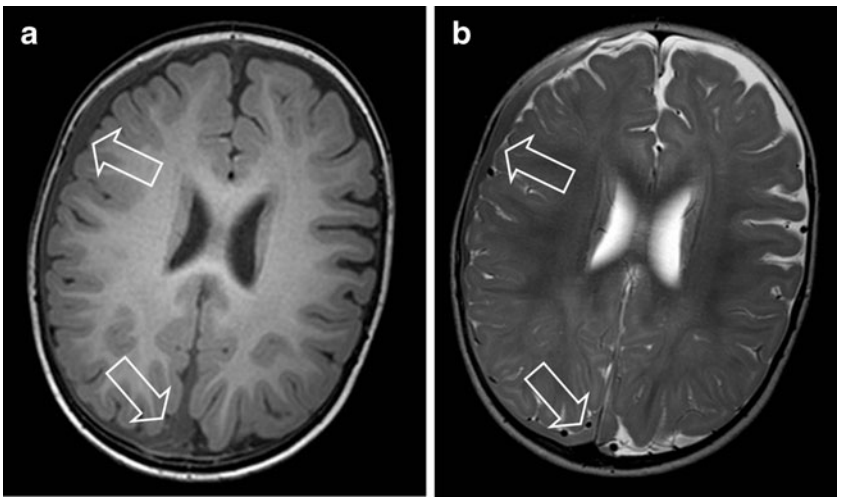

Fig. 7 **a** Case 7. Axial T1-weighted MR image of a 10-month-old boy who fell from a high chair. *Information not available to the participating radiologists*: the boy sat on a high chair and tipped himself backwards by pushing the table with his feet. He landed with his head on a concrete floor. Mother took him to the GP, but was sent home because there were no clinical signs of head trauma. The mother thought he was not comfortable and went back to the GP the next day. On the third day she went to the hospital because she was worried about her son. At that time an MRI was performed. MR image shows a hypo-intense SDH along the complete length of the right convexity (*open arrows*). **b** Axial T2-weighted MR image of the same boy shows a hypo-intense SDH (*open arrows*)

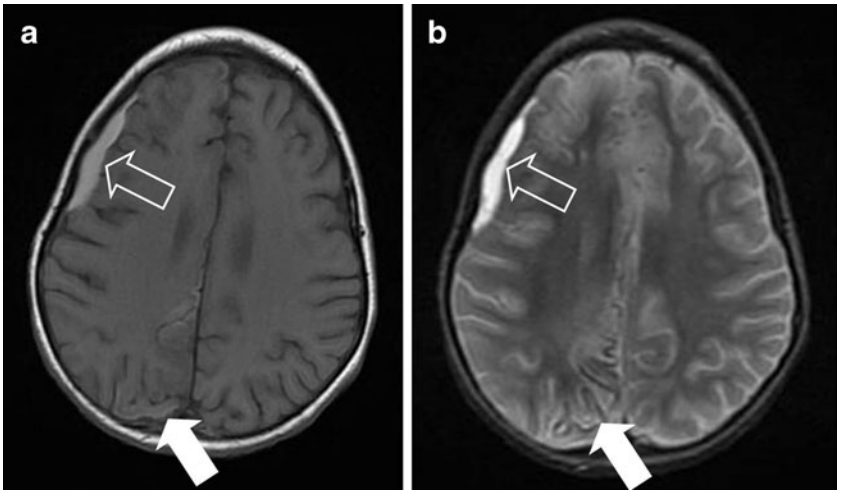

Fig. 8 **a** Case 8. Axial T1-weighted MR image of a 3-year-old boy who fell from the stairs. *Information not available to the participating radiologists*: the boy was brought to the hospital comatose, according to parents he had fallen from the stairs that night. Signs of physical abuse were found all over his body. He was admitted for several weeks, this MR scan was made 2.5 weeks after the incident. Police investigations revealed that the day before admission he had been seen in good condition by several people. In the night before admission the neighbors had heard him crying for several hours. MR image shows a hyper intense right sided SDH (*open arrow*). Subcortical laminar necrosis is visible (*arrow*). **b** Axial T2-weighted MR image of the same boy shows a hyper intense SDH (*open arrow*) and hemosiderin depositions in the subcortical laminar necrosis (*arrow*)

90, 69, and 88 % for cases 5, 6, 7, and 8, respectively. This resulted in 35, 62, 50, and 67 % of the participants actually reporting an estimated age and 33, 70, 52, and 73 % reporting a range only for MRI case 5, 6, 7, and 8, respectively. In two of four MRI cases (50 %, cases 6 and 8) the age of the SDH as known from clinical history fell within the range reported by the radiologists. In the MRI case with the highest consensus (case 6, Fig. 6), age of the SDH was estimated 6 days old (range 6–17 days). According to clinical information this SDH was 9 days old. In the MRI case with the lowest consensus (case 5), age of the SDH was estimated 4 weeks old (range 1–10 weeks). According to the clinical information, this SDH was 2 days old.

The radiologists did not report to be very certain on their age determination. The most reported value for all cases was "neutral"; none of the radiologists considered themselves to be 'very certain' in one of the cases. There was no difference in certainty between pediatric and neuroradiologists (p=0.3 for CT and p=0.8 for MRI). There was no correlation between number of years of working experience and certainty (p=0.61 for CT and p=0.42 for MRI). There was no difference in certainty between university hospital and non-university hospital radiologists (p=0.30 for CT and 0.89 for MRI).

Discussion

We investigated the variation in both theory and knowledge among pediatric and neuroradiologists regarding age determination of SDHs. The results of our study demonstrate that there is a considerable practice variation among radiologists, and therefore suggest that dating of SDHs is not a topic about which radiologists currently agree.

This is supported by several aspects of the questionnaire. First, 63 % of the participants reported to date SDHs in clinical practice. This means that 37 % of the participants are either not confronted with the request to determine the age of a SDH, or they do not think they can reliably do this. Second, for the cases presented in the questionnaire, 58–83 % of the participants reported they could date the four different CT cases and 63–90 % of the participants reported they could date the four different MRI cases. However, not all participants who reported they could date the SDH, subsequently did so. Eventually

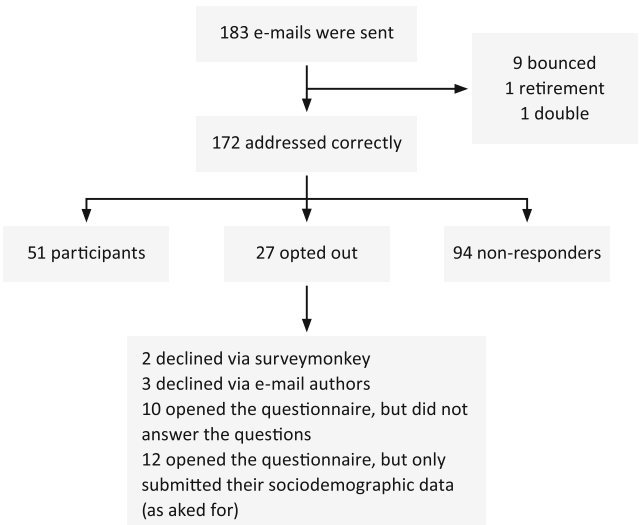

Fig. 9 Flow diagram depicting in- and excluded questionnaires with reasons for exclusion

Table 1 Sociodemographic characteristics of participants and radiologists who opted out

	Participants	Radiologists who opted out	*p*
N	51	21	–
Working in an university hospital, *n* (%)	23 (45)	9 (43)	0.86
Years of working experience, median (min-max)	8 (0–35)	15 (0–45)	0.2
Sub specialism, *n* (%)[a]			
Pediatric radiology	10 (20)	3 (14)	0.02
Neuroradiology	37 (73)	11 (52)	
None of these	4 (8)	7 (33)	

[a] Because of rounding of the decimals, the total adds to more than 100 %

only 40–53 % of the participants actually reported an estimated age and 40–47 % reported a range for the CT cases. For the four MRI cases, 35–67 % of the participants reported an estimated age and 33–73 % reported a range only. This could be either due to indifference in completing the whole questionnaire, or it could be due to uncertainty about the dating. We assume that the participants, who did fill out both age estimation and a range, are in general the radiologists who are most certain about their dating. Thirdly, the estimates and corresponding ranges that were reported did not overlap very well and did not include the age of the SDH as deduced from clinical history in four out of eight cases. The uncertainty of participants about their age determination is furthermore confirmed by the fact that the most reported level of certainty for all cases was "neutral" and that none of the participants reported to be "very certain" about any of their reported ages. It is furthermore remarkable that the reported age ranges based on MRI data were broader than those based on CT data, although MRI is generally considered to be more useful for age estimation.

To our knowledge, no evidence-based guideline or decision tree for the age determination of SDHs has been published. Estimates are based on intracranial hematomas [5, 6, 11]. Conflicting information can be found as well. Although most studies report a progression from hyperdense, via isodense to hypodense on CT images [7, 9] in a large study by Lee et al. the majority of hypodense SDHs appeared before isodense SDHs [12]. Other studies describing the relationship between age of the SDH and CT/MRI appearance are often small [13, 14], or the moment of origin of SDH is not reliably determined [15, 16]. In a small but well-designed study by Vinchon et al., 20 pediatric SDH cases in which time of trauma was known, CT and MRI data were studied in order to describe time-related modifications that could be used to date the trauma [4]. They found that hyperdensity was found in all cases studied less then 7 days after the trauma and was absent after day 11. For MRI, they also report a specific temporal evolution on T1, T2, and flair. However, hypo- and hyperdensities/intensities were overlapping for all modalities and sequences. They propose a method to develop an evidence-based time scale to date SDHs. To our knowledge, no follow-up study on their research has been published yet.

The lack of well-designed studies regarding age determination of SDHs might be an explanation for the practice variation

Table 2 Experience with dating SDHs for participants

Question	Result *n* (%)[a]	Sample *n*
Time spend on neuroradiology		
Hours, median (range)	16 (1–70)	50
Source of knowledge (various options possible)		
During training, supervisors	39 (77)	51
During training, literature	31 (61)	
After training, continuing medical education	28 (55)	
During clinical practice, discussions with colleagues	23 (45)	
Other	0(0)	
Dates in practice		
Yes	32 (63)	51
In what setting?		
Clinical	30 (91)	33
Forensic	0 (0)	
Both	3 (9)	

[a] Unless otherwise specified

Table 3 Results theoretical questions

Question	Result *n* (%)[a]	Sample *n*
Is it possible to date a mixed density on a CT scan		
Yes	20 (43)	46
Is it possible to date a mixed intensity on a MRI scan		
Yes	21 (46)	46
Number of intervals when dating mixed density		
1	5 (11)	46
>1	20 (44)	
Cause of mixed density (various options possible)		
Bleed-rebleed	41 (94)	44
Repeated trauma	38 (87)	
Sedimentation	33 (75)	
Natural resorption	21 (48)	
Admixture CSF	20 (46)	
Other	3 (7)	

among radiologists. On the other hand, lack of evidence in the current medical literature for dating of SDHs could have also lead to more people reporting not being able to date, instead of dating without certainty. It might be possible that the participants applied knowledge of dating intraparenchymal hematomas on SDHs, as an analogy between these two has been described [11].

Table 4 Results practical questions CT

Case	It is possible to date this SDH Yes: *n* (%)	Median of the reported estimated age (range)	Median of the reported minimal age (range)	Median of the reported maximal age (range)	Self-confidence Scale: *n* (%)	Age SDH according to history/forensic evaluation
Case 1	*n*=48	*n*=19	*n*=21	*n*=19	*n*=31	–
A 5-month-old boy; Alleged history: fell from a carry cot	30 (63)	2 days (1 h – 1 week)	16 h (0 h – 5 days)	8 days (2 h – 10 weeks)	−2: 4 (13) −1: 9 (29) 0: 13 (42) 1: 5 (16) 2: 0 (0)	1 day
Case 2	*n*=48	*n*=19	*n*=20	*n*=19	*n*=28	–
A 3-week- old girl; Alleged history: suddenly pallor, weakness, convulsions	28 (58)	2 days (1 h – 2 weeks)	1.5 days (1 h- 1 week)	8 days (1 day – 6 weeks)	−2: 2 (7) −1: 5 (18) 0: 19 (68) 1: 2 (7) 2: 0 (0)	9 days
Case 3	*n*=47	*n*=19	*n*=21	*n*=21	*n*=26	–
A 7-month-old girl; Alleged history: choking during feeding	30 (64)	3 days (1 h – 5 weeks)	2 days (0 h – 4 weeks)	2 weeks (1 day – 20 weeks)	−2: 1 (4) −1: 8 (31) 0: 15 (58) 1: 2 (8) 2: 0 (0)	Several hours
Case 4	*n*=47	*n*=25	*n*=22	*n*=26	*n*=36	–
A 3-year-old boy; Alleged history: fell from the stairs	39 (83)	12 h (0 h – 2 days)	5 h (1 h – 1 day)	3 days 6 h – 1 week)	−2: 0 (0) −1: 10 (28) 0: 18 (50) 1: 8 (22) 2: 0 (0)	12 h

Table 5 Results practical questions MRI

Case	It is possible to date this SDH Yes: *n* (%)	Median of the reported *estimated* age (range)	Median of the reported *minimal* age (range)	Median of the reported *maximal* age (range)	Self-confidence Scale: *n* (%)	Age SDH according to history/forensic evaluation
Case 5	*n*=51	*n*=18	*n*=17	*n*=17	*n*=30	–
A 5-month-old boy; Alleged history: fell from a carry cot	32 (63)	4 weeks (2 h – 24 weeks)	1 week (0 h- 4 weeks)	10 weeks (6 h – 100 weeks)	−2: 0 (0) −1: 9 (30) 0: 12 (40) 1: 9 (30) 2: 0 (0)	2 days
Case 6	*n*=50	*n*=31	*n*=35	*n*=36	*n*=45	–
A 1-year-and-3-month old boy; Alleged history: fell from a bunk bed	45 (90)	6 days (5 h – 6 weeks)	3 days (0 h – 3 weeks)	17 days (2 h – 24 weeks)	−2: 1(2) −1: 10 (20) 0: 19 (42) 1: 15 (33) 2: 0 (0)	9 days
Case 7	*n*=48	*n*=24	*n*=27	*n*=25	*n*=35	–
A 10-month-old boy; Alleged history: fell from high chair	33 (69)	17 days (1 h – 24 weeks)	6 days (0 h – 4 weeks)	3 weeks (12 h – 36 weeks)	−2: 0 (0) −1: 6 (17 0: 20 (57) 1: 9 (26) 2: 0 (0)	3 days
Case 8	*n*=48	*n*=32	*n*=36	*n*=35	*n*=41	–
A 3-year-old boy; Alleged history: fell from the stairs	42 (88)	10 days (3 h – 4 weeks)	5 days (0 h – 3 weeks)	4 weeks (4 h – 34 weeks)	−2: 2 (5) −1: 8 (20) 0: 20 (49) 1: 11 (27) 2: 0 (0)	2.5 weeks

Unfortunately, we did not include detailed questions about the origin of the knowledge of the participants. Part of the practice variation in this study might be explained by the fact that in two cases multiple SDHs were visible, so that the different radiologists might have referred to different SDHs in the same case.

Limitations

A possible limitation of this study is that, despite two reminders sent by email, we had a 30 % response rate. Although radiologists not willing to participate were asked to opt out through the questionnaire and to leave their sociodemographic data, only 16 % of the eligible participants rejected the questionnaire this way. The majority of the radiologists did not respond at all. Another limitation is that out of the 51 participants, not all of them filled out the complete questionnaire. Some did report an estimated date for the SDH but did not report a range or vice versa. Not all participants filled out all cases, resulting in different numbers suitable for analysis per case. The first question for each image was whether the participant was able to date this SDH. Not everyone answered this question and even if they did, not all participants subsequently filled out an answer to the next question. We hypothesize that this is partly due to "survey weariness" and partly due to uncertainty about the right answer. Another limitation is the fact that per case only two images could be displayed in the questionnaire. Under normal circumstances more images (and for MRI more sequences) would be available. We did try to overcome this problem by selecting the most relevant images/sequences. This could have resulted in less reliable answers compared to a clinical situation with all images available. Due to the lack of consensus about which range of answers is acceptable, this is a descriptive study of the variance among radiologists and not a study in which the accuracy of the individuals is tested.

Generalizability

The participants did not differ significantly from the radiologists who opted out on the items working situation or working experience, but there were more neuroradiologists among the participants compared to the radiologists who opted out. As the subspecialty sections of the Dutch Radiological Society represent the majority of the active radiologists in this field, the results are likely to be representative for Dutch

radiological practice. It seems reasonable to assume, that radiologists with interest in and therefore knowledge about this topic would be most willing to participate. This would cause more uniform results than in clinical practice. However, people with less experience in the field might not be asked as expert witnesses in court, so we cannot predict exactly how our results relate to the practice variation among all Dutch or all European pediatric and neuroradiologists dating SDHs for court. There is no reason to assume that radiological practice and interpretation in the Netherlands differs significantly from the rest of Europe. This is especially true for neuroradiology, which has a very active European Society of Neuroradiology with a charter for education and training in clinical neuroradiology and a European subspecialty diploma[17]

New steps

We did not investigate why participants do date SDHs, although no guideline exists. A survey is a difficult way to answer this question, as one is always trying to gain as much information as possible on one side, and is keeping the questionnaire as short as possible on the other side, to raise the number of complete forms. In-depth interviews with radiologists might give the answer to this question. A systematic literature search for the evidence of dating SDHs might provide insight in the possibility of dating SDHs on imaging findings and might clarify the level of certainty that can be applied to statements regarding this topic. If no literature on this topic exists, a prospective study in which patients with a known head trauma are scanned repeatedly could provide insight in the development of SDHs over time. If there is evidence for dating SDHs, this knowledge should be made generally known to radiologists (either during initial training or with CME), in order to enhance uniform reporting concerning this controversial topic.

Conclusion

We conclude that there is lack of consensus on the possibility of dating SDHs on imaging findings only among Dutch radiologists and that their answers regarding dating SDHs in pediatric cases vary widely. The large practice variation reported here makes the radiological statement with respect to dating SDH less valuable in court, as only evidence that is considered to be beyond reasonable doubt according to professionals is accepted. Besides the large practice variation, the broad time ranges reported makes dating SDHs less valuable in court as well, as the judicial system needs information that can pinpoint a trauma to a certain moment in time. This underlines the current opinion that a diagnosis of child abuse cannot be made based on radiological findings only, but should always be made in multidisciplinary team approach taking into account all of the available medical data.

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Conflict of interest The authors declare that they have no conflict of interest.

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