

Retinal haemorrhages and related findings in abusive and non-abusive head trauma: a systematic review

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Abstract

Aim To report the retinal signs that distinguish abusive head trauma (AHT) from non-abusive head trauma (nAHT). **Methods** A systematic review of literature, 1950–2009, was conducted with standardised critical appraisal. Inclusion criteria were a strict confirmation of the aetiology, children aged <11 years and details of an examination conducted by an ophthalmologist. Post mortem data, organic disease of eye, and inadequate examinations were excluded. A multivariate logistic regression analysis was conducted to determine odds ratios (OR) and probabilities for AHT.

Results Of the 62 included studies, 13 provided prevalence data (998 children, 504 AHT). Overall, retinal haemorrhages (RH) were found in 78% of AHT vs 5% of nAHT. In a child with head trauma and RH, the OR that this is AHT is 14.7 (95% confidence intervals 6.39, 33.62) and the probability of abuse is 91%. Where recorded, RH were bilateral in 83% of AHT compared with 8.3% in nAHT. RH were numerous in AHT, and few in nAHT located in the posterior pole, with only 10% extending to periphery. True prevalence of additional features, for example, retinal folds, could not be determined.

Conclusions Our systematic review confirms that although certain patterns of RH were far commoner in AHT, namely large numbers of RH in both the eyes, present in all layers of the retina, and extension into the periphery, there was no retinal sign that was unique to abusive injury. RH are rare in accidental trauma and, when present, are predominantly

unilateral, few in number and in the posterior pole.

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Introduction

The correct diagnosis of abusive head trauma (AHT) in children is both challenging and crucially important. AHT remains the commonest cause of fatal abuse in young children, and retinal haemorrhages (RH) are recognised as a key feature of this condition.^{1,2} It has previously been proposed that retinal folds and haemorrhagic retinoschisis in an infant with brain injury may be *diagnostic* of a shaking injury.^{1,3,4} Recently, however, extensive RH, retinal folds, and schisis cavities have been reported in witnessed accidental head injuries,^{5–7} calling into question the validity of ‘classic’ descriptions of retinal findings in AHT.

The ophthalmological opinion is pivotal in these cases and, given the increasing expectations of clinicians to offer a ‘scientific basis’ for any estimate of probability of abuse in a child with RH, we have conducted a systematic review to address the question ‘What pattern of RH and associated retinal features distinguish between AHT and non-abusive head trauma (nAHT)?’

Materials and methods

Our systematic review included an all-language literature search across 12 bibliographic

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databases, supplemented by a hand search of selected websites and non-indexed journals, and the references of all full-text articles, to identify original articles published from 1950 to January 2009 (Figure 1). We combined three sets of keywords, one relating to all terms encompassing child abuse (eg, shaken baby syndrome, battered baby), one relating to child terms (neonate, baby and so on), and 75 words or phrases relating to specific retinal findings or relevant coexistent conditions (eg, RH, subhyaloid haemorrhage, and so on) (Supplementary Appendix 1). Identified articles were transferred to a database to coordinate the review and collate critical appraisal data. Relevant studies with an English language version available were reviewed. Authors were contacted for the primary data and additional information where necessary.

Quality standards

A key standard for included studies was confirmation of an abusive aetiology in AHT. Thus, we have adopted our previously published² 'rank of abuse' where ranks 1 or 2 minimise 'circularity' in diagnosis, by *not relying solely on clinical features* (Table 1). Thus, any studies that relied solely on the physical findings alone to determine abusive injury, without a full multidisciplinary assessment, or those where abuse was simply 'suspected', were excluded. This avoids the risk that the diagnosis of abuse may have been made solely on the basis of the injuries under analysis. An abusive aetiology was only accepted where there had been an admission,

witnessed abuse or at the least a full multidisciplinary assessment. The comparative cases (nAHT) for this review were exclusively confirmed accidental trauma, that is, where the study had explicit criteria for determination of accidental origins/described the mechanism of injury. The second quality standard relates to the ophthalmological examination. Our highest rank was an examination conducted by an ophthalmologist, using indirect ophthalmoscopy and pupillary dilatation (+ / - additional retinal imaging), with detailed recording of the retinal findings relating to RH (laterality, layers of retina involved, number and extent (from optic disc to peripheral retina) of haemorrhages) and additional features (eg, retinoschisis). Our minimum accepted standard was an examination by an ophthalmologist, as it is well-recognised that non-ophthalmologists may miss RH⁸ and additional findings are unlikely to have been documented in detail. We also wished to determine any correlation between specific intracranial findings and retinal findings.

Statistical analysis: probability of AHT when RH present/absent

A multilevel logistic regression analysis was carried out using R (version 2.10.1, The Foundation for Statistical Computing, <http://cran.r-project.org/bin/windows/base/old/2.10.1/>) on five comparative studies suitable for analysis. R is a widely used cross platform programming language and software environment for statistical computing, and graphics and data analysis.⁹

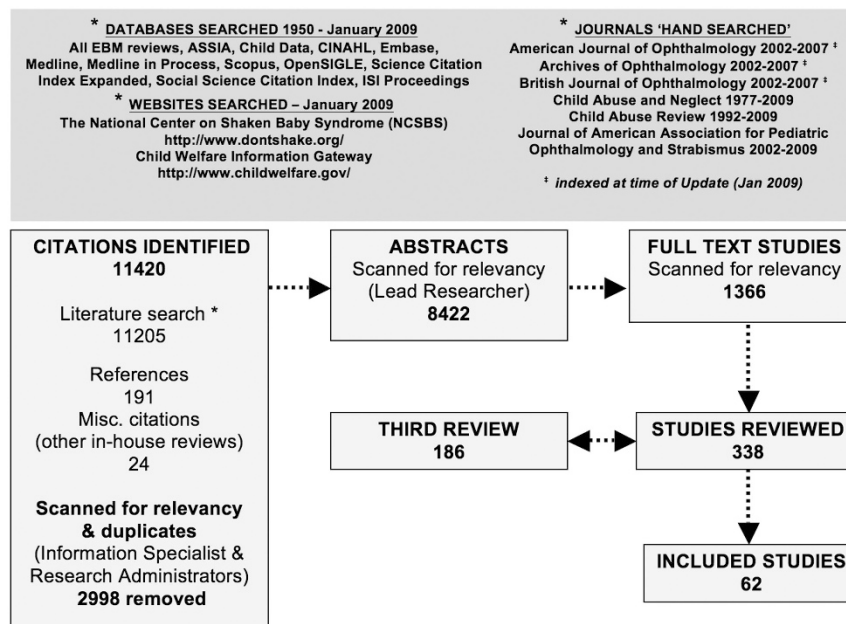


Figure 1 Systematic review search strategy and review process.

Table 1 Inclusion and exclusion criteria*Inclusion criteria*

- Studies of children aged 0 to <11 years
- AHT—ranking of abuse of 1–2
- nAHT—non-abusive aetiology confirmed (abuse excluded/accident confirmed)
- Ophthalmic examination performed by an ophthalmologist
- Ophthalmic findings described with reference to severity, location, and laterality

Exclusion criteria

- Consensus statements or personal practice studies
- Study exclusively addresses retinal findings in association with:
 - Prior ophthalmic surgery
 - Solid mass lesions of the eye (eg, retinoblastoma) or brain
 - Post mortem examination alone (ie, where eyes not examined in life)
- Medical causes of RH
- RH found in the immediate postnatal period
- Blunt trauma to the eye
- AHT—ranking of abuse within study of 3–5 or mixed ranking where cases ranked 1–2 could not be extracted
- Ophthalmic examination performed by non-ophthalmologist

Ranking Criteria used to define abuse

- | | |
|---|--|
| 1 | Abuse confirmed at case conference or admitted by perpetrator, or independently witnessed (with or without subsequent legal proceedings) |
| 2 | Abuse confirmed by stated criteria including multidisciplinary assessment (social services/law enforcement/medical) |
| 3 | Abuse defined by stated criteria |
| 4 | Abuse stated but no supporting detail given |
| 5 | Suspected abuse |

This multilevel approach allows for the possibility that data may be more strongly correlated within the studies than between the studies.¹⁰ The estimated odds ratios (ORs are shown for the overall analysis, as well as for the individual studies, along with their 95% confidence intervals (CI).

Results

Of the 338 studies reviewed, 62 met the inclusion criteria. 8 studies were comparative, including three cross-sectional,^{11–13} two comparative case series,^{14,15} one prospective cohort study,¹⁶ one case–control¹⁷ and one retrospective cohort study.¹⁸ The remainder were case reports^{5,6,19–38} or case series,^{3,7,39–68} concerning AHT alone,^{3,19–23,25–31,33–43,45,49–51,53–56,58–63,65,68} and nAHT alone,^{5,6,24,32,44,46–48,52,57,64,66,67} and one with both.⁷ Where details were lacking, the authors provided further information relating to ophthalmological examination details, findings, and confirmation of aetiology by personal correspondence.³² Although Haviland *et al*¹⁷ was a case–control study, only AHT cases had ophthalmological examinations, and thus were analysed with the non-comparative data. One study group (Vinchon *et al*) provided us with access to their raw data set, incorporating data used in the three studies,^{13,16,67} including two comparative studies^{13,16} and one non-comparative study regarding motor vehicle

collisions.⁶⁷ The data set for each of these three studies was ascertained simultaneously utilising the same criteria and we have, therefore, interpreted the data as one continuous set for the purposes of our analysis.

The commonest reasons for exclusion of studies were inadequate confirmation of abuse or an inadequate standard of ophthalmological examination recorded in the study. Data were interpreted in three data sets:

Data set 1: Larger studies with consecutive cases presented—suitable for prevalence analysis and homogenous comparative studies entered into a meta-analysis.^{11,12,14,15,17,18,47,56,61,64,66} (Vinchon raw data set)^{13, 16, 67}

Data set 2: Highly selected case series/studies with <10 subjects each.^{3,5–7,19–46,48–55,57–60,62,63,65,68}

Data set 3: Both of the above data sets combined.

The total data set 3 includes 998 children, 504 with AHT. All AHT cases in the comparative studies were <3 years (mean age could not be determined), however, the non-comparative studies recorded five older abused children,^{31,51(Case 5),63(Cases 1,2,4)} (Supplementary Appendix 2), all of whom were severely injured, four fatally. Among nAHT cases, 11/13 of the large studies addressed children <3 years, and the oldest child with RH in the

remaining studies was 10 years⁵² (aetiology of nAHT—Supplementary Appendix 3).

The multilevel logistic regression analysis (Table 2 and Figure 2) details the probability of abuse when a child with head trauma is found to have RH, with an OR of 14.66 and an estimated probability of 91% (95% CIs 48%, 99%).

Retinal findings

The features of the RH in relation to laterality, number and extent of haemorrhages and the layers of retina involved, are summarised for data set 1 (Table 3). Of the 363 children with AHT, 78% (283) had RH *vs* 5% (25/465) of children with nAHT. Six studies recorded the laterality

of RH in AHT^{11,12,17,18,56,61} and four in nAHT.^{11,14,18,66} Of these, 83% (141/170) of AHT cases had bilateral RH *vs* 8% (1/12) case of nAHT,¹¹ this latter case was an 8-month old who had 10 RH per eye following a fall from a bed onto a linoleum floor.

Four studies mentioned the number of RH in AHT^{11,12,18,61} and three in nAHT.^{11,14,66} As terminology varied, we took the following terms to indicate ‘larger’ numbers of RH present: multiple, diffuse, extensive, numerous, ‘too numerous to count’, marked, massive, extended, scattered, many, and severe. Terms taken to represent ‘smaller’ numbers were: ‘single haemorrhage’, few and small. The majority of AHT cases, 83%, (60/72) had larger numbers of RH, while none of the eight cases of nAHT with this information had extensive RH.

The distribution of RH (eg, did they extend to the periphery), was only recorded in seven AHT^{11,18,56,61} (Vinchon raw data set)^{13,16,67} and seven nAHT^{11,14,18,66} (Vinchon raw data set)^{13,16,67} studies. The majority of AHT cases, 63%, (101/160) had peripheral extension of RH, while only 9% (2/22) of nAHT cases had.^{(Vinchon raw data set)^{13,16,67}} The recording of the layer (intraretinal, preretinal, or subretinal haemorrhage) in which the RH was present is varied across the 13 studies and no consistent terminology was used (Table 3). Only three studies report the prevalence of RH in multiple layers for AHT cases.^{18,56,61} Pooled data from these three studies reported RH in 81% (146/180)^{18,56,61} of infants with AHT with 84% (122/146) being bilateral. Prevalence of multilayered RH which could be extracted from two studies^{18,61} was 77% (54/70). RH in all the three layers were described in a single study, recorded as present in 73% (47/64) of infants.⁶¹

Table 2 Studies included in multilevel logistic regression analysis

Study ID	Year	RH present/ total AHT	RH present/ total nAHT	OR (with 95% CI)
		cases	cases	
Bechtel <i>et al</i> ¹¹	2004	9/15	7/67	33.07 (24.55, 44.57)
Feldman <i>et al</i> ¹⁴	2001	28/39	1/3	7.64 (4.89, 11.93)
Pierre-Kahn <i>et al</i> ¹⁵	2003	13/16	0/7	15.44 (10.15, 23.51)
Trenchs <i>et al</i> ¹⁸	2007	6/10	1/1	7.81 (4.02, 15.20)
Vinchon <i>et al</i> ^{13,a}	2005	72/95	13/141	23.88 (20.63, 27.64)
Overall		128/175	22/219	14.66 (6.39, 33.62)

Abbreviations: AHT, abusive head trauma; CI, confidence interval; nAHT, non-abusive head trauma; OR, odds ratio; RH, retinal haemorrhage.

^aIndicates data drawn from all three studies.

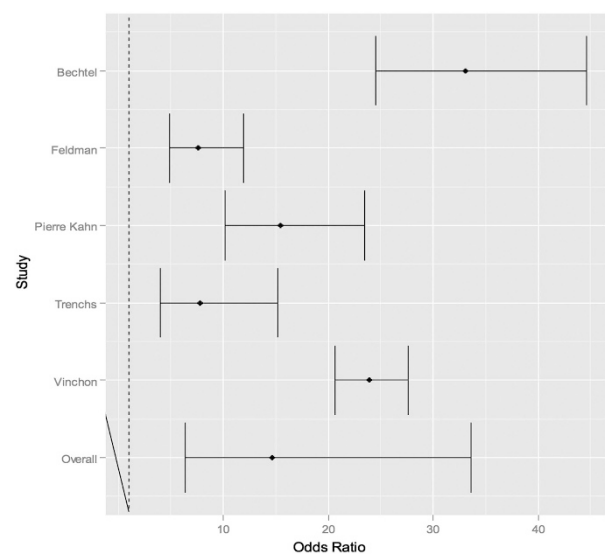


Figure 2 Odds of AHT in a child with RH: multilevel logistic regression analysis.

Retinal findings: additional features (data set 3)

There were a wide range of additional retinal features described for both AHT and nAHT cases (Table 4). The true prevalence of traumatic retinoschisis or retinal folds in AHT could not be determined as only one study⁵⁶ in data set 1 described perimacular retinal folds (7/76 AHT cases) and none recorded the presence or absence of retinoschisis. Among the case reports, three cases of accidental (nAHT) retinoschisis were noted following an 11 m fall³² and two crush injuries to the head, one by an adult⁷ and the second by a 63-kg child.⁶ Perimacular retinal folds were also found in two of these cases^{6,7} and in a third child who was crushed by a 19.5 kg television.⁵ Posterior vitreous detachment (PVD) was mentioned in two cases of AHT, one of which noted bilateral PVDs²² but unilateral RH, with vitreous detachment in the presence of a large preretinal haemorrhage in the other eye.⁴³ Of note, no cases of nAHT recorded retinal tears, epiretinal membrane, macular hole, neovascularisation,

Table 3 Layer of retina involved in cases of AHT and nAHT (data set 1), where sufficient detail given

Study	No. of intraretinal haemorrhage/ total cases with RH		No. of preretinal haemorrhage/ total cases with RH		No. of subretinal haemorrhage/ total cases with RH	
	AHT	nAHT	AHT	nAHT	AHT	nAHT
Bechtel <i>et al</i> ¹¹	9/9	7/7	5/9	0/7	N/A	N/A
Buys <i>et al</i> ¹²	3/3	No RH	2/3	No RH	N/A	No RH
Elder <i>et al</i> ⁴⁷	N/A	No RH	N/A	No RH	N/A	No RH
Feldman <i>et al</i> ¹⁴	28/28	1/1	0/28	1/1	N/A	N/A
Haviland and Ross Russell ¹⁷	N/A	N/A	N/A	N/A	N/A	N/A
Kivlin <i>et al</i> ⁵⁶	76/76	N/A	36/76	N/A	10/76	N/A
Morad <i>et al</i> ⁶¹	58/64	N/A	58/64	N/A	47/64	N/A
Pierre-Kahn <i>et al</i> ¹⁵	13/13	No RH	N/A	No RH	N/A	No RH
Trenchs <i>et al</i> ¹⁸	2/6	1/1	4/6	N/A	1/6	N/A
Trenchs <i>et al</i> ⁶⁶	N/A	2/3	N/A	1/3	N/A	N/A
Vinchon <i>et al</i> ^{a,13,16,67}	72/72	13/13	N/A	N/A	N/A	N/A
Total	261/271 (96%)	24/25 (96%)	105/186 (56%)	2/11 (18%)	58/146 (40%)	—

Abbreviations: AHT, abusive head trauma; nAHT, non-abusive head trauma; N/A, not assessed/not mentioned; RH, retinal haemorrhage.

^a Indicates data drawn from all three studies.

vitreous detachment, and choroidal rupture; however, exudates were found in nAHT cases, but not in AHT cases (Table 4 and Supplementary Figure 1).

Coexistent intracranial features in children with RH

Few studies recorded detailed associated findings, precluding analysis. Among the comparative studies (131 AHT, 22 nAHT) with details of neuro-imaging,^{11,12,14,15,18} (Vinchon raw data set)^{13,16,67} all cases (AHT and nAHT) with RH showed intracranial abnormalities (one nAHT case with a depressed skull fracture alone¹³). These included any combination of extra-axial haemorrhage, cerebral contusion, intra-cerebral abnormality, and cerebral oedema. Coexistent extradural haemorrhages (EDH) and RH were noted in five cases of nAHT, although the RH was only noted following drainage of the EDH.⁴⁸

Of note, among the non-comparative studies (data set 2) there are nine cases (aged 2–24 months) of AHT with RH, presenting with neurological symptoms, but no neuro-radiological abnormalities on presentation^{25,35,50,69} (six from a single study⁶⁹ are same cases as Morad *et al*,⁶¹ confirmed by authors). While 6/9 had computed tomography (CT) and magnetic resonance imaging (MRI), three had CT only.^{35,50,69}(Case 4) However, repeated CT showed a focal area of encephalomalacia 1 month later in one case³⁵ and bilateral subdural haemorrhages (SDH) 2 weeks later in a second.⁵⁰ In a third case, 7 days after an initial negative CT and MRI, repeated MRI showed SDH.⁶⁹(Case 7) No repeat CT or MRI was performed in 5/9^{25, 69}(Cases 1,5,6,8) but in one case three MRI scans (performed for 24 h, 7 days, 6 months) were normal,⁶⁹(Case 3) despite presenting with seizures, lethargy, and irregular breathing.

Discussion

This comprehensive systematic review, reflecting data on almost a thousand children, including a meta-analysis of five studies, has confirmed that RH have a strong association with AHT (OR 14.7, probability 91%) and are rarely present following accidental trauma. This review is unique in applying strict standards of ophthalmological examination, and security of diagnosis of abuse and non-abusive trauma, thus meeting the stringent standards that are now expected both in a clinical and legal setting.

RH were rarely described in nAHT, and those described were predominantly few in number, unilateral and located at the posterior pole, with extension into the periphery occurring infrequently. However, although certain patterns of RH were far commoner in AHT, namely large numbers of RH in both the eyes present in all layers of the retina and extension into the periphery, there was no pattern of RH that was unique to abusive injury. Although the majority of nAHT cases had unilateral RH, these were reported in 17% of AHT. Given the association between bilateral RH and AHT, it is disappointing that this level of detail is often missing in the literature. Similarly, the presence of subretinal blood seems to be extremely rare in nAHT, recorded in only one child.³² Owing to the inconsistent recording of additional retinal findings (other than RH) in the large scale studies, it was impossible to determine their true prevalence. These included features previously described as 'pathognomonic' of AHT, namely 'extensive RH accompanied by perimacular folds and schisis cavities found in association with intracranial haemorrhage or other evidence of trauma to the brain in an infant without another clear explanation'.^{1,3,4,70} In particular, it is

Table 4 Detailed retinal findings (data set 3)

Retinal features (where present)	AHT (423/504 cases with retinal findings/total)		nAHT (44/494 cases with retinal findings/total)	
	References	References	References	References
Intraretinal haemorrhages	390	3,7,11–18,23,25–27,29,31,33–35,38–43,45, 49–51,53,55,56,58–63,65	39	5–7,11,14,18,24,32,44,46,48,52,57,64,66 (Vinchon raw data set)13,16,67
Preretinal haemorrhages	178	3,19,25–27,29,33,38,40,43,45,49,51,53,56, 59–61,65	10	5,14,24,32,44,48,52,66
Subretinal haemorrhages	69	3,18,21,27,31,40,42,49,50,56,61,62,65	1	32
Vitreous haemorrhages	41	3,11,12,22,28,29,31,36,39,42,43,45,49,50,56, 58–60	2	6,46
Schisis cavities (peripheral retinoschisis, retinoschisis, macular schisis)	30	7,38,60,61,63	3	6,7,32
Retinal folds	21	7,38,39,42,45,49,53,56,60,65	3	5–7
Dome like RH under ILM	7	56	0	
Exudates	0		4	57
Dot/blot RH	12	11,12,25,45,55	4	5,24,46,64
Flame RH or NFL RH	11	11,12,25,29,55,65	3	24,46,64
White centred RH	15	7,11,18,43,45,55	2	24,48
Disc swelling/papilledema	10	49,50,56,61	1	57
Optic nerve haemorrhage	10	22,33,49,60,62	0	
Retinal detachment	8	12,27,28,30,37,42,54,62	0	
Retinal tears/peripheral retinal holes	6	28,30,37,58a	0	
Epiretinal membrane	1	23	0	
Macular hole	2	20,58b	0	
Retinal neovascularisation	3	42,65	0	
Choroidal rupture	1	56	0	
Retinal oedema	1	49	3	44,46,57
Vitreous detachment	2	22,43		

Abbreviations: HT, abusive head trauma; ILM, inner limiting membrane; nAHT, non-abusive head trauma; NFL, nerve fibre layer; RH, retinal haemorrhage.

^a Found during vitrectomy.

^b Macular hole found at vitrectomy.

unclear if the absence of features, such as retinoschisis or perimacular retinal folds, in the nAHT literature reflects the absence of data or the absence of recording. However, these features were not recorded in any nAHT cases within the consecutive data sets, appearing only in isolated case reports.^{6,7,32}

The included studies ascertained children presenting with head trauma or SDH and, while it is clear that 97% of those with RH had coexistent intracranial abnormalities, there were nine AHT cases described as having normal imaging at the outset. These cases had abnormal neurological signs, three with evidence of intracranial injury on follow-up imaging, one without and five had no follow-up MRI, which would be the optimal imaging strategy.

The mechanism of injury for those children with RH and nAHT varied from motor vehicle collision to falls. The falls concerned included only one from >20 feet, two between 4 and 20 feet and eight below four feet, thus it was not possible to define precise patterns of injury by fall height. Although crush injury is a rare cause of accidental childhood trauma, it was described in 15

children, six of whom had RH. Three of these had extensive, multilayered RH, more commonly seen in AHT.^{5–7} Thus, while only a fifth of the described crush injuries resulted in severe RH, it is an important mechanism to be aware of, as in common with a high fall, they may result in the ‘classical’ retinal features of AHT.

Unfortunately, many studies could not be included in the review due either to inadequate multidisciplinary confirmation of abuse,⁷¹ lack of ophthalmological detail, or details of the standard of ophthalmological examination.⁷² Clearly an optimal examination, in particular ensuring an adequate view of the periphery, is essential, even though this may be technically challenging in an awake infant. Two studies have documented peripheral haemorrhages in the absence of posterior pole findings in AHT.^{18,51} As with all systematic reviews, analysis of potential confounding factors in relation to RH, for example, severe raised intracranial pressure,^{15,61} coagulopathy, and so on, was hindered by a lack of detail in the primary studies.

Unfortunately, primary authors used a wide variety of nomenclature and reported detailed findings variably,

thus hampering a meta-analysis of specific retinal features. We would, therefore, strongly recommend that ophthalmologists adopt a standardised examination record of all children with suspected AHT. This should define the extent, layer (eg, preretinal, intraretinal, and subretinal) and location within the retina of any RH, and the presence/absence of any additional findings.⁷³ This will require consensus as to precisely what they are seeing, and in which layer of the retina they determine the RH to be in.⁷³ It is particularly important to record all relevant negative findings for example, the absence of perimacular fold, vitreous detachment, and so on, in order to determine their true sensitivity and specificity. The use of imaging techniques such as RetCam^{65,74} may enhance accurate documentation, although, as a two-dimensional image, descriptions will still be needed, and it is advised that the findings from indirect examination are recorded before the use of the RetCam. The use of the RetCam may cause some discomfort, with one suggestion that it contributed to RH in a neonate.⁷⁵ There have been reports of the value of optical coherence tomography (OCT)⁷⁶ in defining the layer of RH and possible role of the vitreous attachments in their causation. However, the universal use of the RetCam or OCT in all cases may be limited by practicalities and cost.⁶⁵

Summary

In addressing the question 'What pattern of RH and associated retinal features distinguish between AHT and nAHT?' this rigorous systematic review, with explicit standards for confirmation/exclusion of abuse and ophthalmological examination, has confirmed RH are common in AHT, most frequently being bilateral, extensive, multilayered, and extending to the periphery. In contrast, such findings of bilateral, multilayered, confluent RH are an extremely rare finding in nAHT, where when RH are present, they are usually unilateral, posterior, and few in number. Current literature precludes a logistic regression analysis of key additional features such as schisis cavities, epiretinal membranes, or retinal folds, as their presence or absence in nAHT was not routinely recorded. These findings have a clear association with AHT, although a small number of severe crush injuries or high fall (11 m)³² have produced a similar spectrum of findings as AHT, thus no pattern of RH is 'unique' to AHT. There is an urgent need for an international standard of examination and explicit recording of findings, including the precise site, location, extent, and level of RH, and the presence or absence of associated retinal features. This would enhance clinical practice, including second opinions, facilitate child protection reports, and contribute to future research.

Summary

What was known before

- RH and associated findings are an important element in the diagnosis of AHT. Uncertainty exists as to the likelihood of RHs among children with accidental head trauma. Increasing demand for an 'evidence based' approach to the diagnosis of AHT.

What this study adds

- A systematic review confirms that the OR that a child with RH has suffered AHT is 14.7 (CI 6.39, 33.62) and the probability of abuse is 91%. RH in AHT are predominantly bilateral, numerous, and extend to the periphery. RH are rare in non-AHT and are usually few in number, in the posterior pole, and only 10% extend to the periphery. No one retinal finding is unique to AHT.

Conflict of interest

The authors declare no conflict of interest.

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Supplementary Information accompanies the paper on Eye website (<http://www.nature.com/eye>)