

Child Protection Evidence

Systematic review on

Retinal Findings

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While the format of each review has been revised to fit the style of the College and amalgamated into a comprehensive document, the content remains unchanged until reviewed and new evidence is identified and added to the evidence-base. Updated content will be indicated on individual review pages.

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Glossary

Ophthalmological terms used in review:

Zone 1 is defined as the circle, the radius of which is twice the distance between the center of optic disc and center of macula.

Zone 2 is defined as the area from the edge of the **zone 1** peripherally to a point tangential to the nasal ora serrata.

Zone 3 is the residual temporal crescent of retina anterior to **zone 2**.

(from ICROP)

Macular Hole: a break in the retina involving the fovea.

Retinal detachment: separation of the neuro-sensory retina from retinal pigment epithelium.

Retinoschisis: abnormal splitting of the retina's neurosensory layer, usually in the outer plexiform layer resulting in loss of visual function in the affected area.

Schisis cavity refers to the space created as a result of the split.

Summary

This systematic review evaluates the scientific literature on vitreo-retinal findings in abusive and non-abusive head trauma in children, non vitreoretinal ocular findings in abusive head trauma, vitreoretinal findings in the newborn and whether retinal findings in abusive head trauma could be dated. The findings from eligible studies published up until **February 2020** were included in this review.

The review aims to answer the following clinical questions:

1. What differences are found between abusive head trauma retinal findings versus non-abusive head trauma retinal findings?
2. What are the differential diagnoses of retinal haemorrhages in children with clinical features associated with child abuse?
3. Retinal haemorrhages in newborn infants:
 - a) What are the retinal findings in newborn infants?
 - b) What are the obstetric correlates to retinal haemorrhages in the newborn?
 - c) What is the evolution of newborn retinal haemorrhages?
4. Can you date retinal findings in children?
5. Which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness?

Questions 1,2 4 and 5 only include children <11 years or where the median age falls within this age range.

The 2020 update included 19 new studies¹⁻¹⁹ relating to retinal findings in children with a head injury across each of the clinical questions, including the first paper to address the dating of retinal findings.¹⁶

Key findings:

- Increasing emphasis has been placed on the detailed pattern of retinal findings and whether these characteristics may aid in distinguishing abusive head trauma from other aetiologies. Ophthalmologists may also encounter children with direct trauma to the eye as a direct consequence of abuse and a recent review highlights the characteristics that may assist in identifying these injuries. To date however there are no large scale comparison studies involving eye injuries due to abuse versus those due to accidental injury.
- There have been no new studies in 2020 to add to the meta-analysis of studies detailing retinal findings in children less than three years with a head injury. The current meta-analysis highlights the association between retinal haemorrhage and abusive head trauma (odds ratio of 15.31, 95% CI 18.78-25.74).

- Resolution patterns and duration of retinal haemorrhages measured from sequential retinal imaging has been reported in one new study, adding evidence in a previously unanswered area.

Background

Retinal haemorrhages (RH) are commonly seen in children who have sustained abusive head trauma with intracranial injury evident on neuro-imaging. Retinal haemorrhages have also been reported in accidental trauma, newborn infants and other medical conditions with overlapping signs of abuse. Non vitreoretinal ocular injury is reported in the setting of child maltreatment and fabricated induced injuries. During child protection proceedings, legal representation for defence teams often request ophthalmologists to date the occurrence of retinal findings.

This systematic review, including the current update, evaluates the scientific literature on abusive and non-abusive retinal injuries in children with a head injury, retinal findings in the newborn, non vitreoretinal injury and whether retinal findings can be dated. Eligible studies published up until February 2020 were included in this review which aims to answer the following clinical questions:

1. What differences are found between abusive head trauma retinal findings versus non-abusive head trauma retinal findings?
2. What are the differential diagnoses of retinal haemorrhages in children with clinical features associated with child abuse?
3. Retinal haemorrhages in newborn infants:
 - a) What are the retinal findings in newborn infants?
 - b) What are the obstetric correlates to retinal haemorrhages in the newborn?
 - c) What is the evolution of newborn retinal haemorrhages?
4. Can you date retinal findings in children?
5. Which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness?

Questions 1,2 4 and 5 only include children <11 years or where the median age falls within this age range.

Methodology

A comprehensive literature search was performed using all OVID Medline databases for all original articles published since 1950. Supplementary search techniques were used to identify further relevant references. See [Appendix 1](#) for full methodology including search strategy and inclusion criteria.

Potentially relevant studies underwent full text screening and critical appraisal. To ensure consistency, ranking was used to indicate the level of confidence that abuse had taken place and also for study types. [Appendix 2](#) shows a flow chart of references assessed throughout the stages of this update.

Findings of clinical question 1

What differences are found between abusive head trauma retinal findings versus non-abusive head trauma retinal findings?

Summary of new studies

- The 2020 update of this review included three new studies^{3,8,9}
- Retinal haemorrhage in infants with head injury have a high positive likelihood ratio for abusive head trauma (AHT)³
- Some studies have shown statistically significant differences in retinal and vitreous haemorrhage between AHT and nAHT groups
- Children in the AHT group exhibited retinal haemorrhage (RH) more frequently (79% versus 10%; $P < 0.001$; $\chi^2 1/4 72.5$), with bilateral and diffuse haemorrhage in 77% of cases, whereas RH was only focal in nAHT⁸
- Ocular findings in AHT patients were significant for retinal haemorrhages (63%) and vitreous haemorrhages (37%), while nAHT patients had no ocular findings ($p < 0.001$)⁹
- A case controlled study of 20 AHT patients and 149 healthy neonates born via spontaneous vaginal delivery with RH found that RH size was significantly larger in AHT patients compared to the NVD group (3.1 ± 0.512 vs 0.96 ± 0.046 disk diameters, resp.). The AHT group also demonstrated a higher RH incidence involving all three retinal layers compared to the NVD group (60% vs 0.6%, resp. [$P < 0.001$]). Vitreous hemorrhages were more common in the AHT group compared to the NVD group (54.3% vs 1.5% [$P < 0.001$]).²

Children included in the majority of comparative studies were aged less than three years old,^{2,3,8,9,20-30} however two studies included children up to the age of 17 years.^{31,32} Non comparative AHT cases included older abused children aged three to eight years old.³³⁻³⁵ Non-comparative nAHT cases included children up to the age of 14 years.³⁶

When considering gender distribution, one comparative study showed no significant difference in gender distribution between AHT and nAHT cases.²⁸ In another study, there was a greater preponderance of males among the accidental group than among the inflicted injury group.³¹ Two further retrospective cohort studies showed male predominance in both AHT and nAHT groups ranging from 53.3% to 78% Male.^{8,9}

A multilevel logistic regression analysis showed the probability of abuse when a child aged less than three years is found to have retinal haemorrhages: odds ratio (OR) 15.31 (confidence interval (CI) 7.84, 29.89).^{20,24,27,29,30,37,38}

Influence of ethnicity and socio-economic group

Not addressed by the included studies.

1.1 Retinal findings

Retinal findings were recorded in relation to laterality, number and extent of haemorrhages and layers of the retina involved, as follows:

Laterality of retinal haemorrhages

Comparative data showed that the majority of AHT cases were bilateral^{8,20,23,25,27,31} in contrast to nAHT, where 0-8% of cases were bilateral.^{8,20,24,31,39}

A retrospective cohort study of 145 AHT children and 50 nAHT showed that 0% of nAHT children had bilateral haemorrhage while 77% of AHT had bilateral haemorrhage.⁸

Studies detailing accidental trauma include isolated case reports of bilateral retinal haemorrhages following severe crush injury or high fall.^{31,32,36,40}

One study detailing RH in AHT compared to normal vaginal delivery found no significant difference in laterality for either group (P=0.618).²

Another comparative study found RH were bilateral in 92% of AHT and 75% of indeterminate and unilateral in 5% of accidental cases.³

Number of retinal haemorrhages

Comparative data identified that the majority of AHT cases had larger numbers of retinal haemorrhages in comparison to the accidental cases.^{2,20,23,24,27,28,31}

In isolated non-comparative single case reports⁴¹⁻⁴⁵ of non-abusive injury, multiple bilateral retinal haemorrhages are seen,^{41-43,45} three of these reports were crush injuries.^{42,43,45}

Extent of retinal haemorrhages

Few comparative studies recorded the extent of retinal haemorrhages; of those that did^{20,27,29-31,39} the majority of AHT extended to the ora serrata, while very few nAHT cases did.²⁹⁻³² A retrospective cohort study found optic nerve oedema in two AHT patients and none in nAHT patients.⁸

Amongst the non-comparative nAHT studies, the majority found that retinal haemorrhages were limited to the posterior pole.^{41,42,44,46}

Retinal layer

Devising a summary of the retinal layer most involved was hampered by authors' varying terminology.

Among comparative studies, intraretinal haemorrhages predominated in both AHT and nAHT; except in one study which showed intraretinal haemorrhages to be more common in AHT;³¹ subretinal haemorrhages were only (or more commonly)³¹ recorded in AHT and preretinal haemorrhages were more common among AHT.^{20,23-27,29-31} A recent study of witnessed accidents versus confessed abuse noted more flame-shaped haemorrhages amongst nAHT.²⁸

In one comparative study, only the abuse cases exhibited retinal haemorrhages, all of which were multi-layered including preretinal and intraretinal and subhyaloid.³² In one non-comparative nAHT study detailing the layer, 4/7 cases were multi-layered with the precise layer not defined.³⁶ From non-comparative nAHT literature, intraretinal haemorrhage remained the most common location but with preretinal haemorrhages also noted.^{37,40,42,43,45-47}

Additional retinal features

Numerous additional retinal features were recorded.^{20,23-27,29-31,33-35,37-86} Of note, schisis cavities were recorded in up to ten-times as many AHT cases^{28,31,35,45,77,78} as nAHT cases.^{31,37,43,45}

Retinal folds are more common amongst AHT cases^{31,39,45,49,55,58,61,65,70,77,86} than nAHT cases,^{40,43,45} as are vitreous haemorrhages.^{20,23,31,34,43,49,54-56,58,59,61,62,64,70,72,73,75-77,84}

Two cases of subhyaloid haemorrhage were recorded in AHT cases, one required surgery, the other had cleared by two months.⁶³ Few cases of epiretinal membrane,⁶⁰ retinal tears^{72,74,75,85} and macular hole^{50,75} were recorded and these were exclusively amongst AHT cases.

The presence of RH increased the odds of a coexistent intracranial haemorrhage by a factor of 23.4 (P<0.0001). There were no cases with RH in the absence of intracranial abnormalities. RH were inversely associated with the presence of a skull fracture (P<0.0001).³

A retrospective cohort study found a statistical difference in vitreous haemorrhage between AHT and nAHT cases.²

Retinal findings amongst perpetrator admitted AHT cases

One comparative study addressed retinal findings amongst perpetrator admitted AHT and independently witnessed nAHT,²⁸ two other studies were non-comparative AHT cases.^{87,88}

In the comparative study 84% of AHT cases had retinal haemorrhages versus 17% of nAHT. Amongst those, 56.8% of AHT had severe retinal haemorrhages versus 2.27% of nAHT.²⁸ The majority of cases included bilateral, multiple retinal haemorrhages.^{87,88} It was notable however that despite perpetrator admitted injury, 3/17 cases were unilateral while 2/17 had less than five retinal haemorrhages per eye.⁸⁸

Neuroradiological features amongst children with retinal haemorrhages

Amongst comparative studies, where the detail is available, all cases had abnormalities on neuroimaging^{20,23,24,26,27,29-32,83} apart from in one study²¹ where all AHT had abnormalities but 2/16 nAHT did not.

Amongst nAHT cases, two studies^{46,47} noted retinal haemorrhages in conjunction with extradural haemorrhages; although in one case these were only noted post-surgery.⁴⁷ The remaining cases underwent surgery, but it is unclear as to whether the retinal examination was conducted pre or post-operatively.⁴⁶

Nine cases (included in four studies)^{62,66,83,89} had neurological symptoms but no identifiable abnormalities on initial imaging. However, subsequent imaging in 3/9 cases became abnormal, five did not undergo repeat imaging, and one with severe neurological symptoms had normal imaging repeated on three occasions.

There appears to be a correlation between severity of retinal haemorrhage and encephalopathy.^{21,31}

It is noted that the six cases from Morad et al⁸⁹ are the same as those in the included study by the same author⁷⁸ (as confirmed by author correspondence) but described in more detail.

1.2 Coexistent features

Statement	Related evidence			
	nAHT		AHT	
	Comparative	Non Comparative	Comparative	Non Comparative
Skull fractures occurred predominantly amongst non-abusive head trauma (nAHT)	20,24,29,30,32	36,37,40,42-47,57	20,29,30,32	25,33,39,45,49,53,56,64,67,76,81
Rib fractures were recorded exclusively in AHT			20,21,23,29,30	21,49,56,58,66,69,78-81,84,86
Long bone fractures were also far more frequent amongst AHT than nAHT cases	21,28-30		20,21,23,29,30	28,49,50,54,56,58,64,67,69,76,78-81,83,84
Multiple fractures were more frequent amongst AHT than nAHT cases	29,30		20,29,30	25,49,56,58,67,69,78-81,84

One case of a three year old with perpetrator admitted shaking had interhemispheric subdural haemorrhage and cerebral oedema with no co-existent fractures.⁸⁷ Other clinical features included clavicle fracture,⁷⁸ corneal abrasion,⁸³ bruising^{21,52,66} bites and perineal injuries,⁷⁸ and visceral injuries.²¹

1.3 Key Evidence statements

- Fundal examination must be conducted by an ophthalmologist with pupillary dilatation and use of indirect ophthalmoscopy in order to ensure that haemorrhages to the periphery are accurately noted
- Retinal haemorrhages are a rare finding in accidental trauma and are predominantly associated with high impact head injury or crush injury
- It is recommended that children undergoing ophthalmological examination for suspected abuse have standardised recordings of all retinal findings.

1.4 Research implications

- Future studies should incorporate standardised recording of all retinal features, noting their presence or absence in all cases
- Further studies of the putative association between extradural haemorrhage and retinal haemorrhage would be of value.

Variable standards of ophthalmological examination led to many studies being excluded

- Amongst included studies, a wide range of terminology and classification systems regarding extent and severity of retinal haemorrhages hampered meta-analysis
- A lack of standardised neuroimaging and timing to retinal examination contributed to heterogeneity between studies.

Findings of clinical question 2

What are the differential diagnoses of retinal haemorrhages in children with clinical features associated with child abuse?

Summary of new studies:

- The 2020 update of this review included seven new studies^{4,6,7,10,17-19}
- There was no association between retinal haemorrhage and vaccination⁷
- There was no retinal haemorrhage found in children with raised intracranial pressures from non-traumatic causes¹⁸
- 4/29 patients with Cerebral venous sinus thrombosis had retinal haemorrhage⁴
- Retinal haemorrhage was seen in the presence of organic disease in optic neuritis and disseminated encephalomyelitis¹⁷ and following traditional village treatment in CRB-1 related retinopathy¹⁰
- Diffuse Retinal and optic nerve sheath haemorrhages were found in a child who underwent prolonged CPR and was noted to have a coagulopathy on admission. An autopsy determined the cause of death to be a myocardial infarct in the distribution of an anomalous coronary artery.⁶

Within this review, we were interested in retinal findings in children who were not subjected to physical trauma but where either they had a condition whose features may mimic child abuse, or a condition which has been proposed to cause retinal haemorrhages (only children less than 11 years or where the median age falls within this age range were included).

There have been 37 articles that addressed this issue.^{4,6,7,10,17-19,36,81,90-117} The children's ages ranged from birth to 15.8 years. The majority of children were aged less than 18 months but older children were reported in three studies.^{17,36,94}

Influence of ethnicity and socio-economic group

Not addressed by the included studies.

Clinical overlap with abuse

Studies were only included if the children had one or more of the features considered to be associated with child abuse as follows: fractures, bruising or intracranial bleeding. Please note that pre-existing known bleeding disorders were excluded from this review – see [inclusion/exclusion criteria](#).

RH were found in the following conditions:

Metabolic conditions, including: Glutaric aciduria,^{100,104} Methylmalonic aciduria with homocysteinuria (Cobalamin C deficiency),^{99,115} Congenital disorder of glycosylation Type 1A¹⁰⁹ and Osteogenesis imperfecta.¹⁰¹

Haematological conditions, including: Platelet function defect (Hermansky-Pudlak syndrome),¹¹³ Protein C deficiency,^{93,103} Low fibrinogen levels¹⁰⁶ and Haemorrhagic disease of the newborn (cardiopulmonary resuscitation also performed).¹¹⁷

Vascular abnormalities, including: Fibromuscular dysplasia,⁹⁸ Spinal cord arteriovenous malformation,⁹⁴ Cerebral aneurysm (two cases)^{36,90} and arteriovenous malformation (two cases).^{36,111}

Intracranial abnormalities included a case of external hydrocephalous in the presence of witnessed head trauma. Abuse was excluded following police and social service investigation.¹¹⁰ Correspondence with the author confirmed the standard of ophthalmological examination met the inclusion criteria.

Other intracranial abnormalities associated with RH include optic neuritis and acute disseminated encephalomyelitis¹⁷ and cerebral sinovenous thrombosis (CSVT). A retrospective cross sectional study found RH in four of 28 with cerebral sinovenous thrombosis only and one with CSVT and meningitis.⁴ Apart from the latter the RH were mainly peripapillary and associated with papilloedema, the RH with CSVT and meningitis was between 30-35 intraretinal haemorrhages in the posterior poles of each eye. No children less than three years of age (age group of interest for AHT) with CSVT alone had RH.⁴

Features of abuse

All of the children in the included studies had an intracranial haemorrhage^{36,81,92-94,98-101,103,104,106,109-111,113,115,117} and nine had co-existent bruising where recorded.^{93,101,103,106,109,117} The three cases with osteogenesis imperfecta also had fractures present.¹⁰¹

Retinal haemorrhage findings

Retinal haemorrhages found were bilateral in 13/21 cases^{36,92-94,98-101,106,109-111,113,115,117} and they were located in the posterior pole in 8/12 (where location recorded).^{92,100,101,104,109-111,113,115}

They were predominantly intraretinal (13/14 – where recorded)^{94,98-101,104,106,113,115,117} or subhyaloid.^{109,111} Only seven cases had multiple or extensive retinal haemorrhages^{98,100,101,109-111,117} and in only three studies^{36,98,110} were they in more than one layer.

In one case of cerebral artery aneurysm with intracranial haemorrhage, an examination nine days after admission postoperatively demonstrated extensive pre-retinal and intra-retinal haemorrhages in one eye.⁹² Subhyaloid haemorrhages in the child suffering from external hydrocephalous cleared within six months.¹¹⁰

Conditions in which retinal haemorrhages are proposed to occur

Five studies examined children with seizures, including 397 children.^{95,107,112,114,116} Of these, 235 cases had febrile seizures; the remaining cases included epilepsy, metabolic disease, infection or CVA.^{95,107,112,114,116}

Retinal haemorrhages were only recorded in two cases.^{107,112} The first case¹⁰⁷ describes an infant with generalised seizure and no other risk factors, who had flame-shaped haemorrhages in the posterior pole unilaterally.

A single case report¹¹² detailed an infant with hyponatremia and prolonged seizure, who had multiple retinal haemorrhages in the posterior poles bilaterally.

Apparent life-threatening events

In 292 cases of children aged less than two years old who were examined,^{81,91,96} no retinal haemorrhages were found.

Prolonged coughing

In 135 cases of children aged less than two years old who were examined,^{97,102} no retinal haemorrhages were found.

Cardiopulmonary resuscitation

A single study¹⁰⁸ met our inclusion criteria in which 43 children were examined following resuscitation.

One infant was noted to have bilateral, numerous, punctuate haemorrhages. However, this child also had one hour of open chest cardiac massage with deranged clotting and platelet counts.¹⁰⁸

One eight week old infant was found to have diffuse bilateral retinal and optic nerve sheath hemorrhages. The child was found unconscious, underwent prolonged cardiopulmonary resuscitation, and was noted on admission to have a coagulopathy. An autopsy determined the cause of death to be a myocardial infarct in the distribution of an anomalous coronary artery.⁶

Retinal haemorrhages of children in the intensive care unit

Two studies have examined children admitted to the intensive care unit for the prevalence of retinal haemorrhages.^{90,105}

One study included children aged six weeks to six years, excluding penetrating eye trauma and abusive head trauma.⁹⁰ In this study, 24/159 children (15.1%) had retinal haemorrhages and 12/24 had unilateral retinal haemorrhages, with 11 having the haemorrhages restricted to Zone 1. Severity of bleeding was mild to moderate in 75% of children. There were seven cases of

trauma, of which two were road traffic accidents and one was a crush injury. The remaining cases had leukaemia, sepsis, or intra-cerebral abnormalities.

The second study¹⁰⁵ examined all children who were intubated in the intensive care unit, from birth to four years. Those with retinopathy of prematurity, retinoblastoma, retinal trauma, or previous retinal haemorrhages were excluded. Excluding four cases with abusive head trauma, 2/81 children had retinal haemorrhages, one of whom had sustained a crush injury and one cardiac arrest and CPR. Both of these cases had bi-lateral mild to moderate retinal haemorrhages. The child with a crush injury had multi-layered retinal haemorrhages. The infant undergoing cardiopulmonary resuscitation, who died of hypoxic ischemic encephalopathy, had mild intraretinal haemorrhages, exclusively in the posterior pole. Correspondence with the author confirmed that abuse had been excluded by the child abuse team in this case.

Raised Intracranial pressure

A prospective cohort study of 56 children found no RH in children with raised intracranial pressure (ICP) from non traumatic causes.¹⁸

Vaccinations

A retrospective cohort study found no association between receiving a vaccination injection and the presence of RH in the subsequent seven, 14 or 21 days.⁴ Of 2210 children with vaccination records, 163 were examined within seven days of vaccination, 323 within 14 days and 494 within 21 days. Only one child with retinal haemorrhage attributed to AHT had vaccination within 14 days of examination.

2.1 Key Evidence statements

- While bleeding disorders are recognised causes of retinal haemorrhages in children, this review has identified a small number of conditions which may also need to be considered when assessing such children
- No evidence has been found for the putative association between apparent life-threatening events, prolonged cough and retinal haemorrhages
- There is no evidence, to date, to substantiate cardiopulmonary resuscitation as a cause of retinal haemorrhages, although further large-scale studies are warranted
- Retinal haemorrhages have been noted in a very small number of cases with seizures, although one of these cases had co-existent risk factors
- Recent studies of critically ill children have identified very rare associations with retinal haemorrhage in this population

- To date there is no evidence for raised intracranial pressure from non-traumatic causes or vaccination causing retinal haemorrhage in children.

2.2 Research implications

- None of the conditions in which retinal haemorrhages were noted have been examined in a large-scale epidemiological study, thus the true prevalence of retinal haemorrhages in these cases cannot be determined. It would be particularly beneficial for such studies to be conducted on children with osteogenesis imperfecta and the metabolic disorders identified
- Further studies of children undergoing cardiopulmonary resuscitation, preferably with ophthalmological exam pre- and post-cardiopulmonary resuscitation, are warranted.
- Retinal hemorrhages have been described in association with minor trauma in the setting of external hydrocephalus and enlargement of subarachnoid space. The mechanism is unclear and it is unknown whether these conditions increase susceptibility to ocular haemorrhage. Further studies looking at the presence of retinal haemorrhage in external hydrocephalus with and without trauma will help to define this relationship.

2.3 Limitations of review findings

- The most significant limitation is that the cases reported are all isolated case reports and thus the true prevalence of retinal haemorrhages in these conditions cannot be determined
- Given that retinal haemorrhages were likely to be a rare association with cough and cardiopulmonary resuscitation, larger scale studies would have been preferable to explore these potential associations.

Findings of clinical question 3

Retinal haemorrhages in newborn infants

Given the significance of retinal haemorrhages when they are identified in young infants, an important differential diagnosis are retinal findings as a consequence of birth trauma. Thus, this review aimed to answer the following questions:

- a) What are the retinal findings in newborn infants?
- b) What are the obstetric correlates to retinal haemorrhages in the newborn?
- c) What is the evolution of newborn retinal haemorrhages?

We undertook a separate newborn-specific literature search of international literature. Of these, 20 articles addressed this issue.^{1,2,5,12,15,118-132} Including five from the 2020 update.^{1,2,5,12,15}

Summary of 2020 Update

- Two case studies were included: one infant with foveal haemorrhage following normal vaginal delivery at term¹² and the second with Tersons syndrome following vaginal delivery¹
- One prospective cohort study found the prevalence of retinal haemorrhage in high risk newborns was 18% and bilateral in 63% of cases. Factors increasing the risk were: instrumental delivery and neonatal asphyxia. Haemorrhages resolved within 28 days of first examination except where vitreous haemorrhage was present⁵
- One retrospective cohort study investigating infants treated with hypothermia for hypoxic ischaemic encephalopathy (HIE) found that RHs are frequent in neonates with HIE. RH frequency was found to be statistically more frequent in stage II or III HIE ($P < 0.01$), 76% of infants in that group had RH. RHs involving the macula were resorbed later than haemorrhages in other locations¹⁵
- One retrospective cohort study of 730 healthy neonates born via vaginal delivery found RH in 27.4%. When compared to AHT they were found to have smaller RH size (0.96 ± 0.046 disk diameters vs 3.1 ± 0.512 resp.), lower percentage of vitreous haemorrhage (0.6% vs 60%, resp. [$P < 0.001$]), and a lower percentage involving all three layers (54.3% vs 1.5% [$P < 0.001$]). 95% of NVD retinal haemorrhage resolved within four weeks of birth.²

Influence of ethnicity and socio-economic group

Not addressed by the included studies.

Retinal haemorrhages recorded following different modes of delivery

Retinal haemorrhages were recorded in 26% (range 21.4% – 40%) of infants following spontaneous vaginal delivery^{2,118-121,123-125,132} and were found to be more common in instrumental deliveries.^{118-120,123-127,130-132}

The strongest association was found with vacuum delivery^{119,120,123,125,126,130-132} or a failed vacuum delivery followed by a forceps delivery (double instrumental delivery).^{119,120,125,132} Infants delivered by caesarean section were less likely to develop retinal haemorrhages than those delivered by spontaneous vaginal delivery,^{118-121,123-125,127-129,132} apart from those undergoing an emergency second-stage caesarean section after failed instrumental delivery.^{119,120,131} Only four infants underwent elective caesarean section¹²⁵ (no retinal haemorrhages recorded) and eight Hispanic infants born via Caesarean delivery (no detail re: elective or otherwise) were examined and none had retinal haemorrhages.¹²²

Factors increasing risk were instrumental delivery and neonatal asphyxia (doubled the risk).

Other obstetric correlates

Data relating to the duration of the second stage of labour, or the expulsive phase, were conflicting as to its association with retinal haemorrhages.^{123,124,128}

Retinal features

There was a lack of standardisation in the recording of retinal features among included studies.

Severity

Where the severity of retinal haemorrhages was noted, the findings varied, with mild, moderate and severe retinal haemorrhages all being recorded.^{119,121,123,125-132}

One comparative study between AHT and NVD found the number of RHs and involved zones did not differ significantly between groups ($P=0.495$ [AHT], $P=0.034$ [NVD]).² However they also found that the AHT group presented with significantly more severe retinal findings; they were more likely to involve the macula, optic nerve, and all three layers of the retina, and were more likely to be accompanied by vitreous haemorrhage.²

Size of retinal haemorrhages

Size of retinal haemorrhages was recorded in eight studies and the majority were found to be small.^{121,125,127-131} The average size of RH in healthy neonates born via spontaneous vaginal delivery was reported to be 0.96 ± 0.046 disk diameters on average and larger than two disc diameter in 11.7% of cases.²

Layer

Six studies recorded the layer in which haemorrhages occurred^{118,121,123,125,127,132} which were intraretinal for all cases apart from a single subretinal haemorrhage.¹²³ One study found that in RH associated with SVD group, 307 eyes (92.2%) had intraretinal haemorrhage only with 6.3% pre-retinal and 1.5% involving all layers.

Laterality

Eight studies reported the laterality of the haemorrhages,^{1,2,5,118,123-125,127} which were more commonly bilateral but with 22-48% occurring unilaterally.

Location

Haemorrhages were predominantly found in the posterior pole^{120,121,123-127,132} with two studies recording haemorrhages to the periphery.^{123,127} A prospective cohort study of 3123 children found bilateral haemorrhages in 63%.⁵

Outcome

Three studies conducted follow-up examinations and noted that the majority resolved within two weeks, with 97% resolved by 42 days.^{123,125,127} In two subjects haemorrhages were still present at 31 and 58 days, respectively.¹²⁵

A routine ophthalmologic examination of a 38-day old female infant using indirect ophthalmoscopy revealed a dense haemorrhage on the fovea and a couple of superficial haemorrhages in the nasal retina of the left eye.¹² The haemorrhage at the nasal retina resolved in the first week of follow-up, and the foveal haemorrhage resolved 12 weeks after birth.

An infant was described as having unilateral multi-layer retinal haemorrhage with occipital infract and subarachnoid haemorrhage on MRI following vaginal delivery.¹ The fundus haemorrhage resolved without sequelae. Terson syndrome has been postulated as a mechanism for birth related haemorrhage.

A prospective cohort study of 3123 children found haemorrhages resolved within 28 days of first examination except where vitreous haemorrhage was present.⁵

A retrospective cohort study of 149 healthy neonates born via spontaneous vaginal delivery with RH in the first seven days of life found 94.6% of patients and 96.2% of eyes had completely resolved RH at four weeks. In only one severe case with vitreous haemorrhage did RHs require 12 weeks to resolve.²

Additional findings

One study examined the role of handheld spectral-domain optical coherence tomography (SD-OCT). They noted the presence of bilateral subfoveal fluid in six infants. Follow up SD-OCT at one month of age showed resolution in 2/3 infants, and resolution in the remaining case by two months.¹²¹

A further study of 20 Hispanic infants utilising OCT noted 10% had sub-retinal fluid and 10% had cystoid macular oedema.¹²²

3.1 Key Evidence statements

- When examining an infant less than 42 days of age with suspected abuse in whom retinal haemorrhages are found, consideration should be given to whether these are a consequence of delivery
- The vast majority of retinal haemorrhages occurring as a consequence of birth resolve by two weeks of age
- The mode of delivery most commonly associated with retinal haemorrhages is a vacuum delivery, either on its own or following failed forceps
- Infants delivered by caesarean section rarely develop retinal haemorrhages.

3.2 Research implications

- The included studies are of a high quality and address this subject comprehensively. However, further studies documenting the rate of resolution of haemorrhages would be of benefit
- While there is a clear association between a vacuum or double instrumental delivery and retinal haemorrhages, it is impossible to discern how much of this relationship relies on the pressures applied to the infant skull, and how much is a consequence of the obstructed labour requiring instrumental intervention
- While subdural haemorrhages have been recorded as a consequence of delivery, it is unfortunate that no study has been conducted examining the coexistence of subdural haemorrhages and retinal haemorrhages in the newborn
- There is a need for an internationally agreed recording of retinal haemorrhages in children.

3.3 Limitations of review findings

- Few authors recorded the layer, extent and severity of retinal haemorrhages in sufficient detail to determine if the pattern recorded in abusive head trauma is ever found in the newborn.

Findings of clinical question 4 Can you date retinal findings in children?

One study included in the 2020 update looked at resolution patterns and duration of retinal haemorrhages measured from sequential retinal imaging in childhood encephalopathies and found 60% of intra-retinal haemorrhage (IRH) showed pattern A change (decrease in size) and 35% showed pattern B (increase in size).¹⁶ In pattern A the median survival time was 10 days for IRH and 38 days for pre-retinal haemorrhage (PRH). The percentage reduction per day was 14.5% for IRH and 6.3% for PRH. In pattern B the temporary increase in size was up to four days. Importantly no new retinal haemorrhages were reported during longitudinal follow up of these infants. Dating of RH is difficult but this study adds to the evidence base in this area.

4.1 Key Evidence statements

- The study population has retinal haemorrhage related to encephalopathies from heterogenous causes
- In childhood encephalopathies, retinal haemorrhage can increase or decrease in size, but there is no increase in the number of retinal haemorrhages. The median survival time is 10 days for intraretinal haemorrhages and 38 days for pre-retinal haemorrhage.

4.2 Research implications

- There is a need for further studies looking at whether there is a relationship between the rate of resolution of retinal findings and cause. An important part of this report is that a temporary increase in size measured with the number of pixels on a two dimensional photograph does not imply new bleeding.¹⁶ In addition, there was no increase in the number of haemorrhages. Hence, if there was an increase in the number of retinal haemorrhages this could have implications for the possibility of a new injury in non-hospitalised children.¹⁶ However further research would be required in children with AHT.

4.3 Limitations of review findings

- To date there are no studies looking at the temporal resolution of retinal haemorrhage in AHT.

Findings of clinical question 5 Which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness?

The 2020 update of this clinical question included two new studies.^{11,14}

A case series of two children (aged six months and four months) presented with strabismus who on investigation had confirmed physical abuse with RH on ophthalmology examination and SDH with multiple skeletal fractures.¹⁴

A prospective cohort study of ocular features in child abuse in the African population found a range of presentations in children age 2-16 years (mean age 8.25 years). Inflicted eye injuries included corneal abrasions present in 25.4%, hyphaema and uveitis in 42.9%, retinal detachment in 7.1%, scleral rupture in 7.1% and globe rupture in 21.4%. Complications of the injuries included

cataracts seen in 25%, corneal opacities in 39.3% and retinal detachment in 7.1%. Visual impairment after treatment was 10.7%, severe visual impairment in 21.4% and blindness in 25%. The most common implements of abuse were sticks or canes and the alleged perpetrators were parents and relatives in 35.7%.¹¹

As part of our retinal findings review, we sought to establish which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness. Seven articles addressed this issue.^{11,14,133-137}

Globe rupture

Two infants aged nine and 14 months are reported with unilateral traumatic globe rupture. Each infant had coexistent injuries including bruising and/or fractures.¹³⁶ Each had subconjunctival haemorrhages in association with the globe rupture, 100% hyphema and chemosis. One of the two infants had presented one week earlier, with her eye examined, and discharged without a child abuse evaluation.

In a study of child abuse and the eye within an African population of 56 children aged 0-16 years visiting an outpatient eye clinic, patients presented with retinal detachment (7.1%), sclera rupture (7.1%), and globe perforation (21.4%).¹¹

Subconjunctival haemorrhages

Two studies reported 16 children presenting with subconjunctival haemorrhages.^{135,137} The children were aged one to 68 months. 12 of the 16 presented due to the subconjunctival haemorrhages and eight of the 16 were bilateral. Co-existent injuries were identified in 14 out of 16 children. These injuries included fractures, burns, bruises and abusive head trauma. It is notable that in two of three cases of infants less than five months of age who presented with subconjunctival haemorrhages, abuse was not recognised during these assessments and the infants re-presented some weeks later.¹³⁷

A systematic review aiming to identify the spectrum of non-vitreoretinal ocular injury due to child maltreatment found that all the children that had suffered physical abuse with ocular injury had subconjunctival haemorrhages.¹³⁴ The subconjunctival haemorrhages in 10 cases were unilateral and in eight cases bilateral.

Traumatic hyphema

A series of seven children aged between four and 14 years presented with hyphema ranging from 5-14% as a consequence of being struck in the eye with a belt.¹³³ Coexistent facial and trunk bruising was also reported in one case, but no details were given relating to further assessment for fractures or other injuries.

Anterior segment – Eyelid pathology, Cornea abrasion, anterior uveitis and cataract

In a study of child abuse and the eye within an African population of 56 children aged 0-16 years visiting an outpatient eye clinic.¹¹ The proportion of affected eyes (39.3%) included 36 right eyes (64.3%) and 20 left eyes (35.7%). The distribution of common ocular disorders was conjunctiva hyperemia (46.4%), corneal abrasion/ulcers (25.4%), anterior uveitis (42.9%), and cataracts (25.0%). 10.7% of patient presented with lid oedema. The most common implements of abuse were sticks/canes and the alleged perpetrators were parents and relatives in 35.7%.

Strabismus

A case series of two children aged four and a half months and six months presenting with squints were found to have intraocular bleeding.¹⁴ The first child presented with an esotropia and bilateral 6th nerve palsy. The second presented with an exotropia due to pre-retinal haemorrhage.

Influence of ethnicity and socio-economic group

There is a suggestion that children in low socio-economic groups are more affected than the children in higher socio-economic groups, due to child labour related injuries (e.g. chemical injuries in an apprentice mechanic) and child neglect related injuries from inadequate supervision.¹¹ There is a dynamic of corporal punishment being acceptable in certain communities and cultures. This is born out both in the previous SR above and the new African study, where there is a trend for perpetrators being relatives of the victim. The people who inflicted the injuries were parents/relatives (uncles) in 35.7% of cases and the children themselves (accidents) in 21.4% of cases. Circumstances predisposing participants to eye injuries were child labour in 39.3% and beatings in 25.0%.

5.1 Key Evidence statements

- This small series of cases highlights the significance of subconjunctival haemorrhages in infants as a potential presenting sign for physical abuse
- Ophthalmologists examining children with trauma to the eye should consider physical abuse within the differential, even in older children where hyphema was reported as a consequence of being struck by a belt
- Ophthalmologists should be aware that child maltreatment can present with anterior segment pathologies and strabismus and should consider performing fundus examination on this population.

5.2 Research implications

- There is clearly a need for comparative studies describing features of eye injuries as a consequence of physical abuse in comparison to those resulting from accidental injury
- A prospective study of infants presenting with subconjunctival haemorrhages to determine the likelihood of coexisting injuries would be of value
- When eye injuries as a consequence of abuse are being reported, full details of coexistent investigations and injuries will make an important contribution.

5.3 Limitations of review findings

- This review was limited by small case series/studies
- No comparative literature is available at present
- Authors did not consistently report what investigations were undertaken to identify other injuries
- A number of larger studies were excluded due to a lack of clear confirmation of abuse among the children reported
- When eye injuries as a consequence of abuse are being reported, full details of coexistent investigations and injuries will make an important contribution.

Other useful references

The review identified a number of interesting findings that were outside of the inclusion criteria. These are as follows:

Clinical question 1

Retinal Imaging

The use of RetCam imaging to record retinal findings facilitates accurate quantification of the retinal features present and the opportunity for further opinions.^{39,138,139} There is a recorded instance of RetCam potentially contributing to retinal haemorrhage in the newborn,¹⁴⁰ however, in a recent prospective study of 50 eyes in 25 children, 60 minutes after a RetCam examination for retinopathy of prematurity, none had developed retinal haemorrhage.¹⁴¹

MRI scanning of the brain may include images of the eye. If this involves GREY2 sequences,¹⁴² or the use of susceptibility weighted imaging¹⁴³ it may reveal retinal haemorrhages. Hand-held spectral domain optical coherence tomography, with¹⁴⁴ or without¹⁴⁵ electroretinography may be of value in defining retinal features.

Subconjunctival haemorrhages

These are thought to occur in infants with prolonged coughing or haematological disorders. Two studies report their presence in child abuse.^{135,137} There have been no large-scale studies of this association.

Examination and recording of retinal findings

Recent studies have evaluated tools to improve the standardised recording of retinal findings in suspected abusive head trauma.¹⁴⁶⁻¹⁵⁰ In a study of 72 children undergoing examination by ophthalmologists and non-ophthalmologists, non-ophthalmologists were correct in their findings in 44% of cases; they had no false-positives but retinal haemorrhages were present in the 13% of cases they missed.¹⁵¹ This highlights the importance of an appropriate examination technique.

Indications for ophthalmological examination in suspected abuse

An assessment of the value of retinal examination in children (aged 0-58 months) with suspected abuse but no intracranial injury reports that those infants with no intracranial injury, normal mental status, no facial bruising and a single linear fracture of the skull not involving the occipital bone do not have any retinal findings and there is no added value of performing a retinal examination in these children.¹⁵²

Updated UK national guidance

This relates to the ophthalmological examination and assessment of children with suspected physical abuse, including a standardised examination pro forma based on our validated reporting tool.^{153,154}

Pathophysiology of Retinal Haemorrhages

A finite element infant eye model indicates that shaking could generate sufficient force to cause retinal haemorrhage.¹⁵⁴

Clinical question 2

Retinal haemorrhages have been described in adults in association with extreme hypoxia^{155,156} and in children with profound anaemia.¹⁵⁷ A fatal case of a child aged almost two years with a subarachnoid haemorrhage secondary to vertebral artery dissection and co-existent retinal haemorrhages is described. The mechanism was attributed to a fall, witnessed by the father.¹⁵⁸

There is now updated UK national guidance relating to the ophthalmological examination and assessment of children with suspected physical abuse, including a standardised examination pro forma based on our validated reporting tool.^{153,154}

A further study exploring the relationship between CPR and retinal haemorrhages unfortunately could not be included as pre-CPR examinations were not conducted in the majority, and there was no mention of exclusion of AHT in the case with retinal haemorrhage.¹⁵⁹

Clinical question 3

None

Clinical question 4

A Cochrane review has been published which addresses the neonatal outcomes of instrumental delivery.¹⁶⁰ Additionally, a retrospective study examining the prevalence of intracranial haemorrhage in newborn infants was conducted. No child underwent ophthalmological examination.¹⁶¹ A further study which did not meet the quality standards for inclusion due to a lack of detail identified that of 123 infants, one infant had a retinal haemorrhage persisting to two months.¹⁶²

Clinical question 5

Recurrent conjunctivitis in a five month old infant with multiple hospital attendances was ultimately found to be caused by Fabricated Induced Illness.¹⁶³

Related publications

Publications arising from the retinal findings review

Maguire SA, Watts PO, Shaw AD, Holden S, Taylor RH, Watkins WJ, Mann MK, Tempest V, Kemp AM. Retinal haemorrhages and related findings in abusive and non-abusive head trauma: A systematic review. *Eye*. 2013; 27:28-36.

Maguire SA, Lumb RC, Kemp AM, Moynihan S, Bunting HJ, Watts PO, Adams GG. A systematic review of the differential diagnosis of retinal haemorrhages in children with clinical features associated with child abuse. *Child Abuse Review*. 2013;22(1):29-43.

Watts P, Maguire S, Kwok T, Talabani B, Mann M, Wiener J, Lawson Z, Kemp A. Newborn retinal hemorrhages: A systematic review. *Journal of AAPOS*. 2013;17(1):70-78

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Appendix 1 - Methodology

We performed an all-language literature search of original articles, their references and conference abstracts published since 1950. The initial search strategy was developed across OVID Medline databases using keywords and Medical Subject Headings (MeSH headings) and was modified appropriately to search the remaining bibliographic databases. The search sensitivity was augmented by the use of a range of supplementary ‘snowballing’ techniques including consultation with subject experts and relevant organisations, and hand searching selected websites, non-indexed journals and the references of all full-text articles.

Standardised data extraction and critical appraisal forms were based on criteria defined by the National Health Service’s Centre for Reviews and Dissemination.¹⁶⁴ We also used a selection of systematic review advisory articles to develop our critical appraisal forms.¹⁶⁵⁻¹⁶⁹ Articles were independently reviewed by two reviewers. A third review was undertaken to resolve disagreement between the initial reviewers when determining either the evidence type of the article or whether the study met the inclusion criteria. Decisions related to inclusion and exclusion criteria were guided by Cardiff Child Protection Systematic Reviews, who laid out the basic parameters for selecting the studies.

Our panel of reviewers included paediatricians, ophthalmologists, pathologists, neonatologists and designated and named doctors in child protection. All reviewers underwent standardised critical appraisal training, based on the CRD critical appraisal standards 3, and this was supported by a dedicated electronic critical appraisal module.

Inclusion criteria

Clinical question 1: ‘What differences are found between abusive head trauma retina findings versus non-abusive head trauma retinal findings?’

Inclusion	Exclusion
Studies of children aged 0 to <11 years	Consensus statements or personal practice studies
Abusive head trauma (AHT) - ranking of abuse of 1-2	AHT - ranking of abuse within study of 3-5 or mixed ranking where cases ranked 1-2 could not be extracted
Non-abusive head trauma - non-abusive aetiology confirmed (abuse excluded/accident confirmed)	Study exclusively addresses retinal findings in association with:

	<ul style="list-style-type: none"> • prior ophthalmic surgery • solid mass lesions of the eye (e.g. retinoblastoma) or brain • post mortem examination alone (i.e. where eyes not examined in life) • medical causes of retinal haemorrhage (RH) • RH found in the immediate postnatal period • blunt trauma to the eye
Ophthalmic examination performed by an ophthalmologist	Ophthalmic examination performed by non-ophthalmologist
Comparative studies	Non-comparative studies
Ophthalmic findings described with reference to severity, location and laterality	

Clinical question 2: ‘What are the differential diagnoses of retinal haemorrhages in children with clinical features associated with child abuse?’

Inclusion	Exclusion
Children <15 years old examined while alive	Adult data or mixed child and adult data where child data could not be extrapolated
Medical diagnosis confirmed	Organic disease stated but not explicitly confirmed by clinical test or by characteristic clinical profile
Ophthalmic examination performed by an ophthalmologist	Major trauma
Details of retinal haemorrhages (RH) found, to include at least one of: layer, location or severity recorded	Solid mass lesion of the eye, retinopathy of prematurity or diabetes mellitus, newborn RH
RH as the primary ophthalmological finding	Ophthalmic surgery prior to RH detection
Children with proposed confounding condition (seizures, acute life threatening event, cough, cardiopulmonary resuscitation, hypoxia, osteogenesis imperfecta,	Known coagulopathy or severe anaemia diagnosed prior to presentation with RH
	Post-mortem studies
	Vitreous haemorrhage precluding visualisation of the retina
	RH as a consequence of birth

immunisations, Vitamin D deficiency)
examined for presence of RH

Criteria used to address ‘retinal haemorrhages in newborn infants’

Inclusion	Exclusion
Ophthalmic examination performed by an ophthalmologist within 120 hours (5 days) of birth, and prior to discharge from obstetric unit	Infants not examined prior to discharge from hospital
Ophthalmic examination with the pupils dilated using the indirect ophthalmoscope	Cases with confirmed or suspected child abuse
Ophthalmic examination conducted using a ‘RetCam’ where the images were reviewed by an ophthalmologist	Preterm infants born prior to 32 weeks gestation
Studies conducted within Organisation for Economic Co-operation and Development (OECD) countries to attain greatest consistency in obstetric practices	Birth weight of less than 1500g of any gestation
	Infants who have undergone ophthalmic surgery
	Post-mortem studies
	Infants with congenital eye conditions and/or established organic eye disease including Retinopathy of Prematurity (ROP)
	Studies in which the presence of vitreous hemorrhages obscures the fundal view
	Studies in which the ophthalmologic examination has been carried out by anyone other than an ophthalmologist, regardless of their training
	Infants who have sustained blunt trauma to the eye(s)
	Animal studies

Ranking of abuse

Ranking	Criteria used to define abuse
1	Abuse confirmed at case conference or civil or criminal court proceedings or admitted by perpetrator or independently witnessed
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

Ranking Confirmation of active exclusion of abuse from non-abused group	
A	By multi-disciplinary assessment and child protection clinical investigation or forensic recreation of the scene
B1	By checking either the child abuse register or records of previous abuse
B2	By confirmation of organic disease or witnessed accidental causes
C1	Stated but no detail given
C2	No attempt made

Ranking Confirmation of accidental/unintentional traumatic causes of retinal findings	
A	Witnessed trauma
B	Consistent account of accident by either two (or more) individuals or the same individual over time
C	Accidental cause stated
D	No detail given

Ranking Confirmation of medical causes of retinal findings	
A	Diagnostic test confirmed organic cause
B	Diagnosis confirmed from clinical profile
C	Stated diagnosis but no detail given
D	No detail of aetiology

Quality standards for ophthalmological examination

Ranking used for clinical questions 1 and 2:

- The optimal standard was studies in which all children had been examined by an ophthalmologist, using indirect ophthalmoscopy and pupillary dilatation (+/- additional retinal imaging) with detailed recording of the retinal findings relating to retinal haemorrhage (laterality, layers of retina involved, number and extent – from optic disc to peripheral retina – of haemorrhages) and additional features (e.g. retinoschisis).
- However, this detailed description was not always available, and the minimum accepted standard was examination undertaken by an ophthalmologist since it is well recognised that non-ophthalmologists may miss retinal haemorrhages and additional findings are unlikely to have been documented in detail.

Ranking used for clinical question 3:

Ranking Quality standards for retinal examination

1	Examined by ophthalmologist, dilated pupil examination AND indirect ophthalmoscopy clearly documented
2	Examined by ophthalmologist, with use of 'RetCam' (making the assumption that the baby's pupils were dilated)
3	Examined by ophthalmologist, EITHER dilated pupil examination documented without mention of examination method, OR indirect ophthalmoscopy documented without mention of pupil status
4	Examined by ophthalmologist, no details regarding pupil dilatation or use of indirect ophthalmoscopy, and only if detailed documentation of retinal hemorrhages is included
5	Mixed Ranking

Ranking of evidence by study type	
T ₁	Randomised control trial (RCT)
T ₂	Controlled trial (CT)
T ₃	Controlled before-and-after intervention study (CBA)
O ₁	Cohort study / longitudinal study
O ₂	Case-control study
O ₃	Cross-sectional
O ₄	Study using qualitative methods only
O ₅	Case series
O ₆	Case study
X	Formal consensus or other professional (expert) opinion (automatic exclusion)

Search strategy

The below tables present the search terms used in the 2015 Medline database search for retinal findings. Truncation and wildcard characters were adapted to the different databases where necessary.

What differences are found between abusive head trauma retinal findings versus non-abusive head trauma retinal findings?

1. Infant/ or Infant, Newborn/ 2. (child\$ or toddler\$ or neonate\$ or baby or infant\$).mp. 3. Child, Preschool/ 4. babies.mp. 5. child/	40. ha?morrhagic retinoschisis.mp. 41. (Intraocular ha?morrhage\$ or Intraretinal ha?morrhage\$).mp. 42. epiretinal membrane.mp. 43. (Multiple small punctate haemorrhage\$ or Multiple small punctate hemorrhage\$).mp.
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6. or/1-5	44. multilayer retinal h?emorrhage*.mp.
7. ((non-abusive or nonabusive) adj3 (injur: or trauma)).mp.	45. pale-centered hemorrhage\$.mp.
8. ((non-accidental or nonaccidental) adj3 (trauma or injur\$)).mp.	46. Pale-centered retinal hemorrhage\$.mp.
9. (non-accidental\$ and injur\$).mp.	47. (Preretinal haemorrhage\$ or Preretinal hemorrhage\$).mp.
10. physical abuse.mp.	48. (Residual foveal haemorrhage\$ or Residual foveal hemorrhage\$).mp.
11. abusive head trauma.mp.	49. (foveal haemorrhage\$ or foveal hemorrhage\$).mp.
12. inflicted brain injur\$.mp.	50. *Retina/
13. (or/7-13) and 6	51. Retinal capillary network\$.mp.
14. (child abuse or child maltreatment or child protection).mp.	52. (Retinal detachment adj5 (haemorrhag\$ or hemorrhag\$)).mp.
15. (battered child\$ or shaken baby or battered baby).mp.	53. Retinal exudates.mp.
16. (battered infant\$ or shaken infant\$).mp.	54. Retinal fold\$.mp.
17. (Shak\$ Baby Syndrome or shak\$ impact syndrome).mp.	55. Retinal hemorrhage/
18. (intracranial injur* adj3 abuse).tw.	56. (retinal haemorrhage\$ or retinal hemorrhage\$).mp.
19. non-accidental head injur*.tw.	57. retinal injur\$.mp.
20. non?accidental head injur*.tw.	58. ruptured retinal capillar\$.mp.
21. NAHI.tw.	59. (Splinter haemorrhage\$ or Splinter hemorrhage\$).mp.
22. exp Child Abuse/	60. (Subhyaloid haemorrhage\$ or Subhyaloid hemorrhage\$).mp.
23. or/14-22	61. (Subhyaloid macular hemorrhage\$ or Subhyaloid macular haemorrhage\$).mp.
24. 13 or 23	62. (Subretinal hemorrhage\$ or Subretinal haemorrhage\$).mp.
25. (Bilateral retinal haemorrhag\$ or Bilateral retinal hemorrhage\$).mp.	63. (Unilateral retinal haemorrhage\$ or Unilateral retinal hemorrhage\$).mp.
26. (Blot retinal haemorrhage\$ or Blot retinal hemorrhage\$).mp.	64. (Vitreous haemorrhage\$ adj5 retina\$).mp.
27. Disc oedema.mp.	65. (Vitreous hemorrhage\$ adj5 retina\$).mp.
28. (Dot retinal hemorrhage\$ or Dot retinal haemorrhage\$).mp.	66. punctate hemorrhage.mp.
29. (Extramacular dot hemorrhage\$ or Extramacular dot haemorrhage\$).mp.	67. foveal hemorrhage.mp.
30. (eye hemorrhag\$ or eye haemorrhag\$).mp.	68. retinal capillar\$.mp.
31. (Flame shaped hemorrhage\$ or Flame shaped haemorrhage\$).mp.	69. intraretinal h?emorrhage\$.mp.
32. (Flame hemorrhage\$ or Flame haemorrhage\$).mp.	70. (Preretinal h?emorrhage\$ or pre-retinal h?emorrhage\$).mp.
33. Posterior pole.mp.	71. Vitreoretinal traction.mp.
34. (fundal adj 5 Posterior pole finding).mp.	72. or/25-71
35. (Haemorrhagic retinopathy or Hemorrhagic retinopathy).mp.	73. 24 and 72

36. ((Haemorrhag\$ or Hemorrhag\$) adj5 retin\$).mp.	74. (rat: or mouse or mice or hamster: or animal: or dog: or cat: or rabbit: or bovine or sheep).mp.
37. Ha?morrhagic retinopathy.mp.	75. (lamb or woodpecker or pig or porcine).mp.
38. Retinoschisis/	76. Animals/
39. retinoschisis.mp.	77. animal stud\$.mp.
	78. "Review"/
	79. or/74-78
	80. 73 not 79
	81. limit 80 to yr="2014 -Current"

What are the differential diagnoses of retinal haemorrhages in children with clinical features associated with child abuse?

1. Infant/ or Infant, Newborn/	43. (Subretinal hemorrhage\$ or Subretinal haemorrhage\$).mp.
2. (child\$ or toddler\$ or neonate\$ or baby or infant\$).mp.	44. (Unilateral retinal haemorrhage\$ or Unilateral retinal hemorrhage\$).mp.
3. Child, Preschool/	45. (Vitreous haemorrhage\$ adj5 retina\$).mp.
4. babies.mp.	46. (Vitreous hemorrhage\$ adj5 retina\$).mp.
5. child/	47. punctate hemorrhage.mp.
6. or/1-5	48. foveal hemorrhage.mp.
7. (Bilateral retinal haemorrhag\$ or Bilateral retinal hemorrhage\$).mp.	49. retinal capillar\$.mp.
8. (Blot retinal haemorrhage\$ or Blot retinal hemorrhage\$).mp.	50. intraretinal h?emorrhage\$.mp.
9. Disc oedema.mp.	51. (Preretinal h?emorrhage\$ or pre-retinal h?emorrhage\$).mp.
10. (Dot retinal hemorrhage\$ or Dot retinal haemorrhage\$).mp.	52. or/7-51
11. (Extramacular dot hemorrhage\$ or Extramacular dot haemorrhage\$).mp.	53. Purtscher retinopathy.mp.
12. (Flame shaped hemorrhage\$ or Flame shaped haemorrhage\$).mp.	54. Terson Syndrome.mp.
13. (Flame hemorrhage\$ or Flame haemorrhage\$).mp.	55. Immunization/
14. Posterior pole.mp.	56. Vaccination/
15. (fundal adj 5 Posterior pole finding).mp.	57. Vaccines/
16. (Haemorrhagic retinopathy or Hemorrhagic retinopathy).mp.	58. (immuni?ation or vaccin\$).mp.
17. ((Haemorrhag\$ or Hemorrhag\$) adj5 retin\$).mp.	59. exp Cardiopulmonary Resuscitation/
18. Ha?morrhagic retinopathy.mp.	60. (cardio-pulmonary resuscitation or cardiopulmonary resuscitation).mp.
19. (optic nerve haemorrhage* or optic nerve hemorrhage*).mp.	61. CPR.mp.
20. Retinoschisis/	62. heart massage.mp.
	63. cardiac massage.mp.
	64. Resuscitat\$.mp.
	65. exp Vitamin D/
	66. vitamin d.mp.
	67. Apparent Life-Threatening Events.mp.

<p>21. retinoschisis.mp.</p> <p>22. ha?morrhagic retinoschisis.mp.</p> <p>23. (Intraocular ha?morrhage\$ or Intraretinal ha?morrhage\$).mp.</p> <p>24. epiretinal membrane.mp.</p> <p>25. (Multiple small punctate haemorrhage\$ or Multiple small punctate hemorrhage\$).mp.</p> <p>26. pale-centered hemorrhage\$.mp.</p> <p>27. Pale-centered retinal hemorrhage\$.mp.</p> <p>28. (Papilledema or papilloedema).mp.</p> <p>29. (Preretinal haemorrhage\$ or Preretinal hemorrhage\$).mp.</p> <p>30. (Residual foveal haemorrhage\$ or Residual foveal hemorrhage\$).mp.</p> <p>31. (foveal haemorrhage\$ or foveal hemorrhage\$).mp.</p> <p>32. *Retina/</p> <p>33. (Retinal detachment adj5 (haemorrhag\$ or hemorrhag\$)).mp.</p> <p>34. Retinal exudates.mp.</p> <p>35. Retinal fold\$.mp.</p> <p>36. Retinal hemorrhage/</p> <p>37. (retinal haemorrhage\$ or retinal hemorrhage\$).mp.</p> <p>38. retinal injur\$.mp.</p> <p>39. ruptured retinal capillar\$.mp.</p> <p>40. (Splinter haemorrhage\$ or Splinter hemorrhage\$).mp.</p> <p>41. (Subhyaloid haemorrhage\$ or Subhyaloid hemorrhage\$).mp.</p> <p>42. (Subhyaloid macular hemorrhage\$ or Subhyaloid macular haemorrhage\$).mp.</p>	<p>68. ALTE.mp.</p> <p>69. exp Seizures/</p> <p>70. seizure\$.mp.</p> <p>71. exp Cough/</p> <p>72. cough*.mp.</p> <p>73. Hypoxia.mp.</p> <p>74. Apnoea.mp.</p> <p>75. Apnea/</p> <p>76. Anoxia/</p> <p>77. exp Valsalva Maneuver/</p> <p>78. valsalva retinopathy.mp.</p> <p>79. Valsalva Maneuv\$.mp.</p> <p>80. or/53-79</p> <p>81. 6 and 52 and 80</p> <p>82. Animals/</p> <p>83. animal stud\$.mp.</p> <p>84. (rat:or mouse or mice or hamster: or animal: or dog: or cat: or rabbit: or bovine or sheep).mp.</p> <p>85. (lamb or woodpecker or pig or porcine).mp. [mp=title, abstract, original title, name of substance word, subject heading word, keyword heading word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier]</p> <p>86. "Review"/</p> <p>87. (adult or adults).tw.</p> <p>88. or/82-87</p> <p>89. 81 not 88</p> <p>90. limit 89 to yr="2014 -Current"</p>
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Retinal haemorrhages in newborn infants

<p>1. exp Infant, Newborn/</p> <p>2. exp Infant/</p> <p>3. (infant* or newborn* or baby or babies or neonate*).mp.</p> <p>4. or/1-3</p> <p>5. exp Choroid Hemorrhage/</p> <p>6. exp Retinal Hemorrhage/</p>	<p>39. "assisted vaginal deliver*".mp.</p> <p>40. "mechanical vaginal deliver*".mp.</p> <p>41. "spontaneous vertex deliver*".mp.</p> <p>42. ((induction or extraction or suction or ventouse or prolonged or forcep* or cesarean) adj3 (deliver* or birth)).mp.</p> <p>43. normal vaginal delivery.mp.</p>
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<p>7. exp Vitreous Hemorrhage/ 8. exp Retinal Detachment/ 9. exp Retina/ 10. (h?emorrhage* adj3 retin*).ti,ab. 11. ((retina* or eye) adj3 detachment).mp. 12. multilayer retinal h?emorrhage.mp. 13. Eye Hemorrhage/ 14. macular h?emorrhage*.mp. 15. "h?emorrhagic retinopathy".mp. 16. Intraretinal h?emorrhage*.mp. 17. (retina* adj3 (trauma or injur*)).mp. 18. "Dot retinal h?emorrhage*".ti,ab. 19. ("choroid h?emorrhage*" or "vitreous h?emorrhage*" or "macular h?emorrhage*").mp. 20. ("disc diameters" or "disc oedema" or "posterior pole").mp. 21. "Preretinal h?emorrhage*".mp. 22. "ocular manifestation*".mp. 23. ((Intraocular or Intraretinal or intracranial or macular) adj (trauma* or injur*)).mp. 24. or/5-23 25. exp Delivery, Obstetric/ 26. exp Vacuum Extraction, Obstetrical/ 27. exp Extraction, Obstetrical/ 28. exp Obstetrical Forceps/ 29. exp Obstetric Labor Complications/ 30. exp Parturition/ 31. exp Cesarean Section/ 32. exp Labor, Induced/ 33. Breech Presentation/ 34. exp Extraction, Obstetrical/ 35. exp Vaginal Birth after Cesarean/ 36. exp Labor Presentation/ 37. "spontaneous vaginal deliver*".mp. 38. "operative vaginal deliver*".mp.</p>	<p>44. ("midcavity forceps" or "obstetric forceps" or "wrigleys forceps" or "outlet forceps").mp. 45. ("low cavity forceps" or "neville barnes forceps" or "kielland forceps" or "ferguson forceps").mp. 46. (prolonged labo?r or second stage of labo?r).mp. 47. ("delayed delivery" or "delayed second stage" or "failed forceps").mp. 48. failed ventouse.mp. 49. "Kiwi Omnicup".mp. 50. "polyethylene vacuum cup".mp. 51. "after coming head".mp. 52. ((vacuum or vaginal) adj3 (birth or deliver*)).mp. 53. (instrumental deliver* or instrumental birth).mp. 54. ((breech or instrumental) adj3 (birth or deliver*)).mp. 55. "secondary to birth".ti,ab. 56. exp Birth Injuries/ 57. (complicat* adj3 (birth or deliver* or labo?r)).mp. 58. birth related injur*.mp. 59. ((trauma or injur*) adj3 (deliver* or labo?r or birth)).mp. 60. Caesarean delivery.mp. 61. (C-section or Caesarian section).ti,ab. 62. or/25-61 63. 4 and 24 and 62 64. exp Retinopathy of prematurity/ 65. Retinopathy of prematurity.ti,ab. 66. (rat:or mouse or mice or hamster: or animal: or dog: or cat: or rabbit: or bovine or sheep).mp. 67. animal stud\$.mp. 68. "Review"/ 69. or/64-68 70. 63 not 69 71. limit 70 to yr="2014 -Current"</p>
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Which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness?

<p>1. Infant/ or Infant, Newborn/ 2. Child, Preschool/ or preschool child.mp.</p>	<p>24. Orbit/ 25. (Ophthalmoplegia or Ophthalmoplegia).mp.</p>
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3. child/ 4. (child* or toddler* or neonate* or baby or infant* or toddler* or babies).mp. 5. or/1-4 6. physical abuse.mp. 7. non accidental.mp. 8. nonaccidental.mp. 9. non-accidental.mp. 10. soft tissue injur*.mp. 11. (or/6-10) and 5 12. exp child abuse/ 13. (child adj3 maltreat*).mp. 14. child protection.mp. 15. exp Battered Child Syndrome/ 16. exp Shaken Baby Syndrome/ 17. (battered child or shaken baby or battered baby).mp. 18. (battered infant or shaken infant).mp. 19. shak* baby syndrome.mp. 20. shak* impact syndrome.mp. 21. or/12-20 22. 11 or 21 23. exp Eye/	26. Nerve pals*.mp. 27. Lid injur*.mp. 28. (Conjunctival haemorrhage\$ or Conjunctival hemorrhage\$).mp. 29. (Subconjunctival haemorrhage\$ or Subconjunctival hemorrhage\$).mp. 30. Corneal laceration\$.mp. 31. palpebral fissure.mp. 32. (Echymosis eyelid or Ecchymosis eyelid).mp. 33. Lacerat\$ eyelid.mp. 34. Eye Injur\$.mp. 35. Orbital injur\$.mp. 36. (Conjunctival haemorrhage\$ or Conjunctival hemorrhage\$).mp. 37. (Ocular finding\$ or Ocular trauma\$).mp. 38. Ophthalmology/ 39. Ophthalmological finding\$.mp. 40. Eye Injuries, Penetrating/ 41. Eye Injuries/ 42. or/23-41 43. 22 and 42 44. limit 43 to yr="2014 -Current"
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Fifteen databases were searched together with hand searching of particular journals and websites. A complete list of the resources searched can be found below.

Databases	Time period searched
All EBM Reviews – Cochrane DSR, ACP Journal Club, DARE, and CCTR	1996 – 2010*
ASSIA (Applied Social Sciences Index and Abstracts)	1987 – 2012†
Child Data	1958 – 2009†
Cochrane Central Register of Controlled Trials (CENTRAL)	2010 – 2014
CINAHL (<i>Cumulative Index to Nursing and Allied Health Literature</i>)	1982 – 2020
EMBASE	1980 – 2020
MEDLINE	1950 – 2020
MEDLINE In-Process and Other Non-Indexed Citations	1951 – 2020
Open Grey	2010 – 2012
Open SIGLE (System for Information on Grey Literature in Europe)	1980 – 2005†
Pubmed (Epub ahead of print)	2014
Scopus	1960 – 2020

Web of Knowledge – ISI Proceedings	1990 – 2020
Web of Knowledge – ISI Science Citation Index	1981 – 2020
Web of Knowledge – ISI Social Science Citation Index	1981 – 2020
* ceased indexing	
† institutional access terminated	
‡ no yield so ceased searching	
Journals 'hand searched'	Time period searched
American Journal of Ophthalmology	2002 – 2014
Archives of Ophthalmology	2002 – 2014
British Journal of Ophthalmology	2002 – 2014
Child Abuse and Neglect	1977 – 2014
Child Abuse Review	1992 – 2014
Journal of American Association for Pediatric Ophthalmology and Strabismus	1992 – 2014
Websites searched	Date accessed
Child Welfare Information Gateway (formerly National Clearinghouse on Child Abuse and Neglect)	9 January 2015
The National Center on Shaken Baby Syndrome (NCSBS)	9 January 2015

Retinal haemorrhages in newborn infants

Databases	Time period searched
CINAHL (<i>Cumulative Index to Nursing and Allied Health Literature</i>)	1970 – 2020
Cochrane Library	1970 – 2014
EMBASE	1970 – 2020
MEDLINE	1970 – 2020
MEDLINE In-Process and Other Non-Indexed Citations	1970 – 2020
Pubmed (Epub ahead of print)	2014
Scopus	1970 – 2020
Web of Knowledge – ISI Proceedings	1970 – 2020
Web of Knowledge – Conference Proceedings Citation Index- Social Science & Humanities	1970 – 2020
Web of Knowledge- ISI Science Citation Index	1970 – 2020
Web of Knowledge -ISI Social Science Citation Index	1970 – 2020
Journals 'hand searched'	Time period searched
British Journal of Obstetrics and Gynaecology	2009 – 2014
<i>British Journal of Ophthalmology</i>	2009 – 2014
Child Abuse and Neglect	1977 – 2014
Child Abuse Review	1992 – 2014
Journal of the American Association for Pediatric Ophthalmology and strabismus	2009 – 2014

Which features or characteristics of eye injury are present in child maltreatment, neglect and fabricated or induced illness?

Databases	Time period searched
CINAHL (<i>Cumulative Index to Nursing and Allied Health Literature</i>)	1982 – 2020
<i>Cochrane Central Register of Controlled Trials (CENTRAL)</i>	2010 – 2014
EMBASE	1980 – 2020
MEDLINE	1946 – 2020
MEDLINE In-Process and Other Non-Indexed Citations	1970 – 2020
Open Grey	2010 – 2014
Pubmed (Epub ahead of print)	2015
Scopus	1960 – 2020
Web of Knowledge – ISI Proceedings	1990 – 2020
Web of Knowledge – ISI Science Citation Index	1981 – 2020

Web of Knowledge – ISI Social Science Citation Index	1981 – 2020
Journals 'hand searched'	Time period searched
American Journal of Ophthalmology	2002 – 2015
British Journal of Ophthalmology	2002 – 2015
Child Abuse and Neglect	1977 – 2015
Child Abuse Review	1992 – 2015
JAMA Ophthalmology formally known as <i>Archives of Ophthalmology</i>	2002 – 2015
Journal of American Association for Pediatric Ophthalmology and Strabismus	1992 – 2015
Websites searched	Date accessed
Child Welfare Information Gateway (formerly National Clearinghouse on Child Abuse and Neglect)	21 January 2015
The National Center on Shaken Baby Syndrome (NCSBS)	21 January 2015

Pre-review screening and critical appraisal

Papers found in the database and hand searches underwent three rounds of screening before they were included in this update. The first round was a title screen where papers that obviously did not meet the inclusion criteria were excluded. The second was an abstract screen where papers that did not meet the inclusion criteria based on the information provided in the abstract were excluded. In this round the pre-review screening form was completed for each paper. These first two stages were carried out by a systematic reviewer at the RCPCH and a clinical expert. Finally, a full text screen with a critical appraisal was carried out by members of the clinical expert sub-committee. Critical appraisal forms were completed for each of the papers reviewed at this stage. Examples of the pre-review screening and critical appraisal forms used in previous reviews are available on request (evidence@rcpch.ac.uk).

Appendix 2 - Flow of studies

2020 update

