

# Rare retinal haemorrhages in translational accidental head trauma in children

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## Abstract

**Purpose** The characteristic findings in accidental head injury consist of linear skull fracture, epidural haematoma, localized subdural haematoma, or cortical contusion because of a linear or translational impact force. Retinal haemorrhages have been found, although uncommon, in accidental head trauma.

**Methods** We performed a retrospective study of 24 consecutive cases of children with severe head injuries caused by falls. Inclusion criteria were skull fractures and/or intracranial haemorrhages documented by computerized tomography. All patients underwent a careful ophthalmic examination including dilated indirect funduscopy within the first 48 h following admission.

**Results** No retinal haemorrhages could be found in patients whose accidents were plausible and physical and imaging findings were compatible with reported histories. Excessive bilateral retinal haemorrhages were found in only three children with the typical signs of shaken baby syndrome. In eight children, trauma had led to orbital roof fractures.

**Conclusions** Retinal haemorrhages were not found in any of the patients with accidental trauma despite the severity of their head injuries. Hence, we add more evidence that there are strong differences between the ocular involvement in accidental translational trauma and those in victims of non-accidental trauma. Fall-related injuries carry a very low risk of retinal haemorrhages.

*Eye* (2009) 23, 1535–1541; doi:10.1038/eye.2008.317; published online 17 October 2008

**Keywords:** accidental head injury; retinal haemorrhages; shaken baby syndrome; skull fracture

## Introduction

Trauma is the most common cause of death in childhood. The characteristic findings in accidental head injury consist of linear skull fracture and epidural haematoma, localized subdural haematoma, or cortical contusion because of a linear or translational impact force. Even higher impact forces occur in falls from heights leading to depressed or comminuted skull fracture, subarachnoid haemorrhage, or cortical contusion.<sup>1</sup> In a situation in which the head impacts a small surface area, a depressed skull fracture can also result from short falls.<sup>2</sup>

Intraocular involvement, that is, retinal haemorrhages, can rarely occur in accidental head trauma. However, there is copious evidence that severe intracranial injury and/or retinal haemorrhages because of minor head trauma are exceedingly rare. Retinal haemorrhages almost always require severe life-threatening impact injury.<sup>3–13</sup> They are often relatively mild, isolated to the posterior pole and unilateral.

In contrast to the low incidence of retinal haemorrhages in accidental head trauma, they are present in approximately 83% of shaken baby syndrome.<sup>14</sup> Retinal haemorrhages seen in non-accidental trauma are more severe. The extensive multilayered haemorrhages extending to the ora serrata are highly specific for shaken baby syndrome, even if unilateral.<sup>10,14,15</sup> Childbirth can also cause retinal haemorrhages because of mechanical stress.<sup>16</sup>

The differential diagnosis of retinal haemorrhages in children also include coagulopathies (including haemophilia and hypoprothrombinaemia caused by vitamin K deficiency), leukaemia, persistent hyperplastic primary vitreous, retinal infections, Coat's disease, retinopathy of prematurity, and hypertension.<sup>17</sup> Retinal haemorrhages can occur after minor trauma if there is an underlying

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Received: 9 July 2008  
Accepted in revised form: 16 September 2008  
Published online: 17 October 2008

Proprietary interest: None

medical condition, such as osteogenesis imperfecta type I.<sup>18</sup> Extensive retinal haemorrhages are not caused by cardiopulmonary resuscitation, vomiting, coughing, or apnoea.<sup>19</sup>

The aim of this retrospective study was to determine the frequency and the severity of retinal haemorrhages in paediatric patients with accidental translational head trauma caused by falls.

### Materials and methods

A retrospective chart review was performed of all consecutive cases of children with severe head injuries caused by falls seen in the Paediatric Intensive Care Unit of the University Children's Hospital, Zurich between January 2003 and May 2008. Criteria for entry into the study regarding severity of falls were skull fractures and/or intracranial haemorrhages documented by computerized tomography (CT).

In all, 24 children met these criteria. The mean age was 31 months (range: 1–124 months). This age group of children and the range differs from that of younger children typically suffering non-accidental injury. The boys outnumbered the girls by 17 (71%) to 7 (29%). Falls had been witnessed by a non-caretaker in 16 cases (67%).

All patients underwent an ophthalmic examination, including dilated indirect ophthalmoscopy within the first 48 h following admission. Eye examination was performed by an ophthalmologist in each case. Laboratory studies, such as complete blood count and coagulation studies (prothrombin and partial thromboplastin time) were obtained from all children. Data were collected and analysed using the data analysis module from Microsoft Excel 7.0 (Redmond, WA, USA).

### Results

The clinical data for each patient are summarized in Table 1.

The fall height of the patients reported here ranged from 0.4 to 4.0 m (mean fall height was 1.5 m).

Fundoscopy revealed retinal haemorrhages in three children. All of them were reported by their caretakers to have fallen to the floor. None of these accidents had been witnessed by a second person other than the caretaker. After careful consideration in each case, the strong suspicion of shaken baby syndrome was raised because of the typical constellation of findings. The multidisciplinary child protection team had been activated and a diagnosis of non-accidental trauma was made. When confronted with this accusation, the perpetrators confessed in two cases. All the three patients with retinal haemorrhages are reported in detail below.

### Patient 6

A 5-month-old boy was reported by the partner of the mother to have fallen down from a changing table. After 1 h, he has suffered a seizure with consecutive brief loss of consciousness. Upon admission to the Paediatric Intensive Care Unit, a bulging fontanel and hypothermia were noted. On closer examination, the boy had multiple pattern bruises on his body. CT and magnetic resonance imaging (MRI) showed multiple skull fractures of different ages and bilateral frontal hygromas.

A cerebrospinal fluid drainage was performed. The patient suffered recurrent seizures.

Fundus examination showed extensive bilateral retinal and preretinal haemorrhages of different ages. The haemorrhages were located predominantly in the posterior pole, but extended also to the ora serrata. In addition, bilateral papilloedema, tortuous vessels, and venous engorgement were also found. The right fundus was more affected by a subretinal haemorrhage and macular oedema (Figure 1).

The diagnosis of shaken baby syndrome was established based on the combination of fundoscopic and imaging findings, and physical injuries (hypothermia and multiple pattern bruises).

### Patient 14

A previously healthy 3-month-old boy with epileptic seizures was transferred to the Paediatric Intensive Care Unit. The father had found his son in front of the changing table. The patient was intubated and conventionally ventilated for 3 days. Clinical and CT/MRI examination revealed subdural haemorrhages of the falx cerebri and the tentorium cerebri, bilateral frontal hygromas, occipital haemorrhagic cortical infarction, and a haematoma of the neck.

Fundus examination revealed bilateral multilayered flame-shaped retinal haemorrhages. The diffuse prae-/intraretinal and subhyaloidal haemorrhages were located predominantly in the posterior pole, but extended also to the ora serrata.

The father's confession was obtained.

### Patient 15

A two-month-old girl was brought to the Paediatric Intensive Care Unit because of irregular breathing. On admission, she was not rousable and did not react to any painful stimulation. The mother reported that her daughter had fallen down from her arms. Cardiopulmonary resuscitation had to be performed. The child was intubated and conventionally ventilated for 4

**Table 1** Clinical characteristics of patients with major head trauma

<i>Case number/sex/ age (months)/ witnessed<sup>a</sup></i>	<i>Ocular signs on presentation</i>	<i>Ocular findings</i>	<i>Diagnostic imaging</i>	<i>Treatment</i>	<i>Accident cause</i>
1/M/38/yes	R monole haematoma, periorbital swelling, and SCH	R orbital roof fx and normal retinas	R orbital roof fx and small frontal epidural haematoma (CT)	Observation	Staircase fall (height: 1.2 m)
2/F/6/yes	None	Normal	R epidural haematoma with midline shift and partially collapsed ventricular system (CT)	Intubation, conventional ventilation, mannitol infusion, craniotomy, and repair of dural laceration	Fall from a chair (height: 0.7 m)
3/M/43/yes	R monole haematoma	R orbital roof fx and normal retinas	R small frontal epidural haematoma and orbital roof fx (CT)	Observation	Fall from a window (height: 1.8 m)
4/M/10/yes	None	Normal	L parietal skull fx (CT)	Observation	Fall from a chair (height of 0.5 m)
5/M/124/yes	R monole haematoma, periorbital swelling, SCH, and chemosis	R orbital roof fx, orbito-naso-ethmoidal fx, limitation of upward gaze, vertical diplopia, and normal retinas	R frontal bone and orbital roof fx, orbito-naso-ethmoidal fx, and small frontal epidural haematoma (CT)	Orbital roof reconstruction	Fall from a tree (height: 2.5 m)
6/M/5/no	None	Bil. multilayered haemorrhages (of different ages)	Multiple skull fxs (of different ages) Bil. frontal hygromas (CT)	Cerebrospinal fluid drainage	Shaken baby syndrome; pretended fall from a changing table
7/M/9/yes	None	Normal	L parietal skull fx and parietal, epidural, and subgaleal haematoma (CT)	Observation	Fall from a changing table (height: 0.8 m)
8/F/1/no	None	Normal	R parietal skull fx and small parietal hyperdense subdural haematoma (CT)	Observation	Fall from a windowsill (height: 1.0 m)
9/M/46/yes	R monole haematoma, periorbital swelling, and SCH	R orbital roof fx, diplopia, and past pointing because of decompensated exophoria and normal retinas	R frontal skull fx, orbital roof fx, and frontal contusional haematoma (CT)	Intubation, conventional ventilation	Fall from a hayroof (height: 3.5 m)
10/M/41/yes	L monole haematoma	L orbital roof fx and normal retinas	L fx of frontal, temporal, and occipital basilar skull, orbital roof fx, subgaleal haematoma, cerebral oedema, and a slight midline shift (CT)	Intubation, conventional ventilation, and red blood cell transfusion because of anaemia	Fall off a bicycle after being hit by a car (height: 1.0 m)
11/F/10/yes	None	Normal	L frontal skull fx and small frontal epidural haematoma (CT)	Observation	Fall from a couch (height: 1.0 m)
12/M/29/yes	None	Normal	R parietal skull fx (CT)	Observation	Fall from a chair (height: 0.5 m)
13/ F/40/yes	L monole haematoma	L orbital roof fx and normal retinas	L parietal skull fx, orbital roof fx, and small parietal epidural haematoma, (CT)	Observation	Fall from a swing (height: 1.5 m)
14/M/3/no	None	Bil. diffuse prae-/intraretinal and subhyaloidal haemorrhages, extending to the ora serrata	Subdural haematomas of the falx cerebri and the tentorium cerebri, Bil. occipital haemorrhagic cortical infarction, and frontal hygromas (CT/MRI)	Intubation, conventional ventilation, and antiepileptic therapy	Shaken baby syndrome; pretended fall from a changing

**Table 1** (Continued)

<i>Case number/sex/ age (months)/ witnessed<sup>a</sup></i>	<i>Ocular signs on presentation</i>	<i>Ocular findings</i>	<i>Diagnostic imaging</i>	<i>Treatment</i>	<i>Accident cause</i>
15/F/2/no	None	Bil. prae-/intra-retinal and subhyaloidal haemorrhages extending to the ora serrata	Subdural haematomas of the falx cerebri and the tentorium cerebri of different ages and cerebral oedema (CT/MRI)	Cardiopulmonary resuscitation, intubation, and conventional ventilation	Shaken baby syndrome; pretended fall from her mother's arms
16/F/81/no	None	Normal	R temporal skull fx and small temporal hyperdense subdural haematoma (CT)	Observation	Fall from a tree (height: 1.5 m)
17/ F/36/no	L monocular haematoma	L orbital roof fx and normal retinas	L orbital roof fx and small frontal epidural haematoma (CT)	Observation	Fall from a window (height: 2.0 m)
18/M/52/yes	None	Normal	R parietal skull fx and small parietal hyperdense subdural haematoma (CT)	Observation	Fall from a monkey bars (height: 1.2 m)
19/ M/45/yes	None	Normal	L parietal skull fx (CT)	Observation	Fall from a monkey bars (height: 1.0 m)
20/M/1/no	None	Normal	R parietal skull fx (CT)	Observation	Fall from a bed (height: 0.4 m)
21/M/13/yes	None	Normal	Generalized cerebral atrophy, enlarged inner and outer liquor spaces, and hyperdense subdural haematoma (CT/MRI) <sup>b</sup>	Craniotomy, cerebrospinal fluid drainage, and antiepileptic therapy	Fall from a changing table (height: 0.8 m)
22/F/5/yes	None	Normal	L frontal and parietal, and skull fx (CT)	Observation	Fall from her mother's arms (height: 1.3 m)
23/F/70/yes	L SCH	Normal	Bil. frontobasal skull fxs (CT)	Observation	Fall from a window (height: 4.0 m)
24/M/33/No	R monocular haematoma and periorbital swelling	R orbital roof fx and normal retinas	R frontobasal skull and pyramid fx, orbital roof, and medial orbital wall fx (CT)	Observation	Fall from a window (height: 2.5 m)

Bil. = bilateral; CT = computed tomography; F = female; Fx = fracture; L = left; M = male; MRI = magnetic resonance imaging; R = right; SCH = subconjunctival haemorrhage.

<sup>a</sup>Witnessed by a non-caretaker.

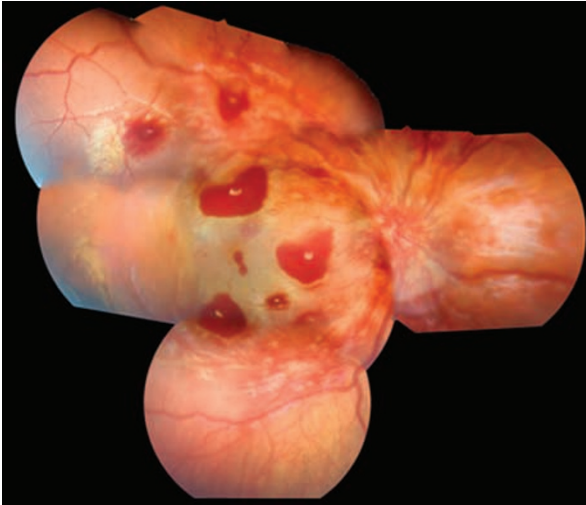
<sup>b</sup>Thrombocytopenia because of high-dose valproate antiepileptic therapy and known hydrocephalus.

days. CT and MRI showed subdural haematomas of the falx cerebri and the tentorium cerebri of different ages and a cerebral oedema. The girl suffered recurrent seizures.

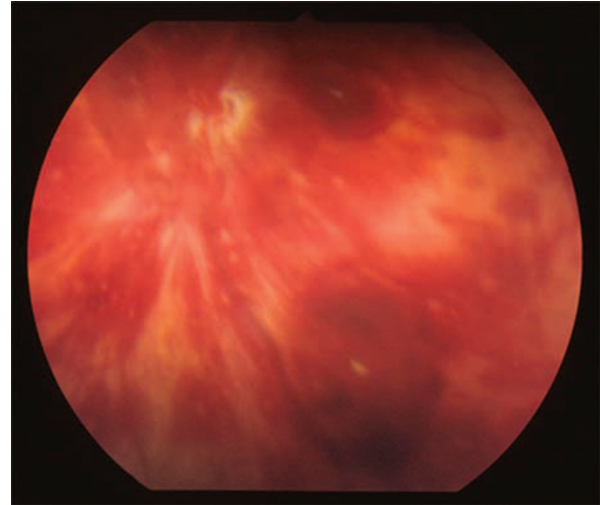
Furthermore, fundus examination showed posterior pole flame-shaped retinal haemorrhages as well as numerous isolated and confluent dot haemorrhages in the midperipheral retina extending to the ora serrata (Figure 2). The suspected diagnosis of shaken baby syndrome was established based on the combination of fundoscopic and CT findings. When confronted with this suspicion, the mother's confession was obtained.

All other accidents were plausible and findings compatible with histories. In 16 of the remaining 21 children, the accidents were witnessed by a second person other than the caretaker. None of the other five children had any physical injuries consistent with non-accidental injury. In addition, the multidisciplinary child protection team did not find any indications that the head trauma had been inflicted.

In eight children, trauma had led to orbital roof fractures. Only one of the patients noticed vertical diplopia because of an elevation deficit. Orbital reconstruction was performed.



**Figure 1** Fundus image of the right eye of the patient 6 with shaken baby syndrome. Severe haemorrhagic retinopathy showing large intra- and praeretinal haemorrhages as well as a subretinal haemorrhage and macular oedema. Furthermore, papilloedema and venous engorgement are seen.



**Figure 2** Fundus image of the left eye of patient 15 with shaken baby syndrome. Extensive posterior pole flame-shaped intraretinal haemorrhages as well as confluent praeretinal dot haemorrhages.

Red blood cell transfusion had to be performed in patient 10, because blood test revealed anaemia. Patient 21 had a known history of hydrocephalus and epileptic seizures. Blood test revealed thrombocytopenia because of high-dose valproat antiepileptic therapy. All remaining patients had normal blood tests.

## Discussion

Traumatic brain injury originates from forces producing strain (deformation/unit length) or stress (force/original cross-sectional area) of the scalp, skull, and brain.<sup>8,20</sup> The factors determining the severity of injuries in falls are the height of the fall, the landing surface, and the position on falling. Falls are considered to cause predominantly translational acceleration, which produces mainly focal brain damage.<sup>8,15,20</sup> In contrast, forces resulting in angular acceleration produce primarily diffuse brain damage. However, sudden impact deceleration in falls is mostly associated with an angular vector and deformation of the skull is accompanied by subdural cavitation tangential to the applied force.

There is broad agreement in the literature that minor head trauma only very rarely causes severe intracranial injury or retinal haemorrhages. However, two Japanese reports of subdural and retinal haemorrhages after minor trauma are opposed to abundant evidence in the literature.<sup>21,22</sup> Regarding this dilemma, it has been noted that child abuse could not have been adequately ruled out at a time where shaken baby syndrome had neither even been described nor widely recognized in the world's literature.<sup>23</sup>

Orbital roof fractures occurred in eight children. When excluding the children with shaken baby syndrome, these injuries occurred in 38% of the patients. Orbital roof fractures as a type of skull fracture primarily occur in younger children as a consequence of the proportionally larger cranium and the non-pneumatized frontal sinuses.<sup>24</sup> Most isolated fractures are caused by a height of only a few feet or down a single flight of stairs.

Retinal haemorrhages have not been found in any of the patients with accidental trauma despite the severity of their head injuries. This finding provides more evidence for the rare occurrence of retinal haemorrhages in accidental head trauma in children. In a multicentre, cooperative study of 823 head-injured children, retinal haemorrhages occurred in five patients because of accidental cause.<sup>3</sup> In four children, haemorrhages were associated with falls and in one they occurred after a motor vehicle accident. Duhaime *et al*<sup>4</sup> who studied 100 patients with head injuries found retinal haemorrhages because of accidental trauma in only one victim of a fatal motor vehicle accident. Johnson *et al*<sup>6</sup> reported two children with retinal haemorrhages because of side impact car accidents. One of the children died. The authors postulated a special injury mechanism in lateral impact crashes related to the constellation of injuries in the 'tin ear syndrome' of child abuse. The blunt impact force to the ear creates rotational acceleration of the head, which can lead to severe brain injury, retinal haemorrhage, and ear bruising. Three children with retinal haemorrhages caused by accidental 'household trauma' were reported by Christian *et al*.<sup>7</sup> Relatively mild unilateral retinal haemorrhages were ipsilateral to the

intracranial haemorrhage and isolated to the posterior pole. In fact, they reported falls in a household environment resulting in severe head trauma. Plunkett<sup>8</sup> found 18 fall-related head injury fatalities (falls were from 0.6 to 3.0 m) searching a United States Consumer Product Safety Commission database for head injury associated with the use of playground equipment. In four of the patients, bilateral retinal haemorrhages had been shown; in three cases, haemorrhages had been described as multilayered (three of the falls leading to death were witnessed by a non-caretaker). Bechtel *et al*<sup>10</sup> reported retinal haemorrhages in 7 of 67 children with accidental head trauma. Haemorrhages were generally mild (unilateral in six of seven patients, one single haemorrhage in three patients). Severe, extensive, multilayered bilateral haemorrhages and perimacular retinal folds in a victim of an alleged fatal television tip-over were described in a single case report by Lantz *et al*.<sup>11</sup> Recently, Gnanaraj *et al*<sup>12</sup> have examined the ocular manifestations of both a clinical series and a pathological series. In the clinical series, only 1 child out of 11 had retinal haemorrhages from a crush head injury because of television tip-over. In four out of nine children, who all had multiple skull fractures, retinal haemorrhages were found in the autopsy series of crush head injuries because of road traffic accidents. A possible explanation of the higher incidence in the latter group might be delivered by the maximal severity of their injuries leading to death. These severe high-impact head trauma scenarios go along with a major static load applied to the head for more than 200 ms (such as a heavy object falling on to the victim or a car driving over the victim's head). The same holds true for the eight deceased patients with extensive retinal haemorrhages reported by Kivlin *et al*<sup>13</sup> very recently. Haemorrhages were bilateral in seven patients and extended into the periphery in all patients. They noted themselves that victims were injured by extremely severe forces that far exceed those in household accidents.

Intraocular involvement in accidental paediatric head trauma is not limited to retinal haemorrhages. Fatal scenarios can include vitreous haemorrhage, retinal detachment, optic nerve avulsion, and enucleation. In fact, manifest and occult traumas (shaken baby syndrome and birth trauma) have shown to be the most common aetiology of paediatric vitreous haemorrhage.<sup>25</sup> Traumatic causes, such as non-penetrating trauma, penetrating trauma, shaken baby syndrome, postocular surgery, and birth trauma accounted for almost three quarters of all paediatric patients with vitreous haemorrhages.

All three children reported in detail had non-accidental head injuries and all were found to have profound degrees of bilateral retinal haemorrhages.

Retinal haemorrhages are common in shaken infants.<sup>10,14,15</sup> Particularly, extensive multilayered haemorrhages extending to the ora serrata (as seen in our patients), perimacular folds, and haemorrhagic macular retinoschisis strongly support this diagnosis.<sup>14,15,26</sup>

Differences in incidence and severity of retinal haemorrhages are not the only characteristics deserving consideration when distinguishing accidental from abusive injury. In cases of doubtful traumatic head injury, interpretation of the CT helps distinguish between accidental and non-accidental causes. Homogeneous hyperdense subdural haematoma seems to occur more frequently in accidental head trauma, whereas mixed-density subdural haematoma is more frequent in cases of non-accidental head injury. However, mixed-density subdural haematoma may be observed within 48 h of accidental head trauma.<sup>27</sup> No statistically significant difference could be demonstrated in the prevalence of calvarial fracture, epidural haematoma, subarachnoid haemorrhage, brain contusion, or interhemispheric subdural haematoma between children with accidental and non-accidental trauma.<sup>27</sup> However, interhemispheric subdural haematoma has been suggested as a particular characteristic of the shaking or shaking impact itself.<sup>15,28</sup> Two of the children with shaken baby syndrome had interhemispheric subdural haematoma. In comparison, none of the patients with accidental trauma developed interhemispheric subdural haematoma. In contrast, four of them were found to have typical hyperdense subdural haematomas.

In conclusion, retinal haemorrhages were not found in any of the patients with accidental head trauma. Hence, we could add more evidence that there are strong differences between the retinal findings in accidental translational trauma and those in victims of non-accidental trauma. Fall-related injuries carry a very low risk of retinal haemorrhages, unless acceleration-deceleration shearing forces, rotational (whiplash-like) vector forces, or a major static load are involved. These mechanisms are rather associated with traffic accidents and crush injuries. And even then, retinal haemorrhages, or even retinoschisis or retinal folds occur only rarely after accidental head trauma as part of a very severe or fatal scenario.

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