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Systemic and ocular findings in 169 prospectively studied child deaths: retinal hemorrhages usually mean child abuse

M.G.F. Gilliland*[a], Martha W. Luckenbach[b], Thomas C. Chenier[c]

[a]*East Carolina University School of Medicine, Department of Pathology, Brody Building 1 South 08, Greenville, NC 27858-4354, USA*
[b]*3235 Academy Avenue, Portsmouth, VA 23703, USA*
[c]*East Carolina University School of Allied Health Sciences, Department of Biostatistics/Epidemiology, Greenville, NC 27858, USA*

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Abstract

The presence and location of ocular hemorrhages were prospectively studied in 169 randomly selected child deaths referred to a medical examiner. Causes of death in the study group included natural diseases and various injuries involving the head, trunk, and asphyxia. Retinal hemorrhages were identified in 70 cases: 62 head injuries, four central nervous system diseases (but not other natural diseases), and four deaths of undetermined cause. The presence of retinal, peripheral retinal, optic nerve sheath, and intrascleral hemorrhages were strongly associated with head injury as compared to other injuries and natural diseases (Yates corrected P-values <0.001). Among the head-injured with retinal hemorrhages, nine had a history of severe traumatic event (e.g., an unrestrained rear-seat passenger in high-speed collision) and 53 were victims of inflicted injury (e.g. violent shaking). In the absence of a verifiable history of a severe head injury or life-threatening central nervous system disease, retinal and ocular hemorrhages were diagnostic of child abuse.

Keywords: Child abuse; Shaken baby syndrome; Retinal hemorrhages; Ocular hemorrhages

1. Introduction

Physical abuse of children involves inflicting injury which results (or may potentially result) in bodily harm including death. Deliberate injuries to children have

* Corresponding author.

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been acknowledged for over a century [1] but were not fully described as a recognizable constellation of injuries until the early 1960s by Adelson [2] and Kempe [3], and later on by Caffey [4].

Various studies [4–8] have identified retinal hemorrhages (Fig. 1) as indicators of child abuse which must be thoroughly investigated whenever found. Since retinal hemorrhages are recognized as potential markers of abuse, increased effort must be made to rule out accidental trauma or natural disease as their cause.

Diagnosis of child abuse continues to be elusive at times despite a host of literature on this subject, and increased awareness of the problem in the medical community and society at large. Moreover, in the situation of the unexplained infant or child death, a pathologist is often confronted with incomplete or inconclusive information. Although retinal hemorrhages have long been associated with head injuries received during periods of abuse, their presence has not always been convincing enough for the diagnosis of abuse to be made [1]. This study was undertaken to examine the nature and extent of ocular hemorrhages (Fig. 2) and associated systemic injuries to determine the reliability of ocular hemorrhage as a marker for lethal child abuse.

2. Materials and methods

2.1 Sample selection

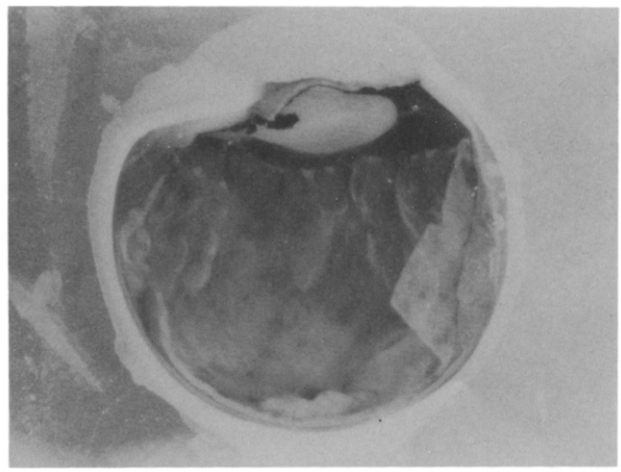
A prospective study was made of 175 of ~400 child deaths investigated at the Dallas County Medical Examiner's Office in the years 1982–1989. Selection depended on the prosector's willingness to participate in the study. Nineteen current or former pathologists contributed one or more cases each by the end of case collection. All deaths were equally likely to be included in the study because assignment of the various prosectors was random. The deaths included diagnoses of child abuse, suspected child abuse, apparent accidental trauma, and apparent natural death. History, autopsy findings, and ocular findings were gathered and reviewed for this study.

2.2. Extent of evaluation

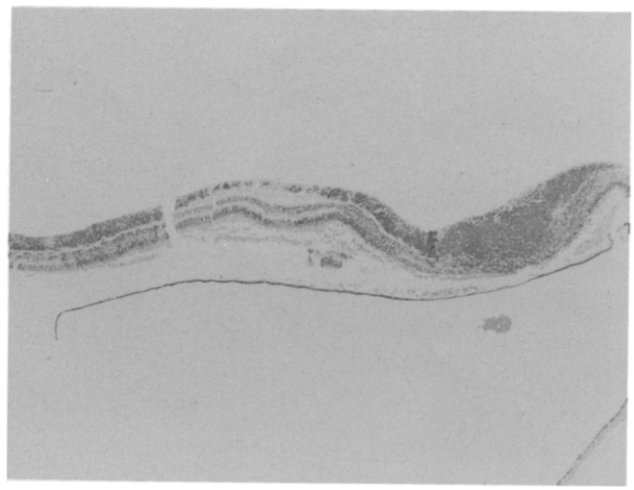
History included: demographic information (name, age, race, sex), the initial information available at the time of the death report, the report of scene investigation, initial caregiver statements, medical records, follow-up scene investigation by police and/or social service, and subsequent caregiver statements. Complete autopsies were performed. Actual and suspected child abuse cases were radiographed.

2.3. Ocular examinations

Both eyes of each victim were completely examined whenever appropriate. Posterior removal was preferred because this approach facilitated obtaining an optic nerve section free of crush artifact. The orbit was unroofed, exposing both the globe and the optic nerve to the point at which it had been transected when the brain was removed. After removal, the eyes were examined externally. They were then fixed in 10% buffered formalin for ≥ 3 days before examination; they were commonly pro-



A

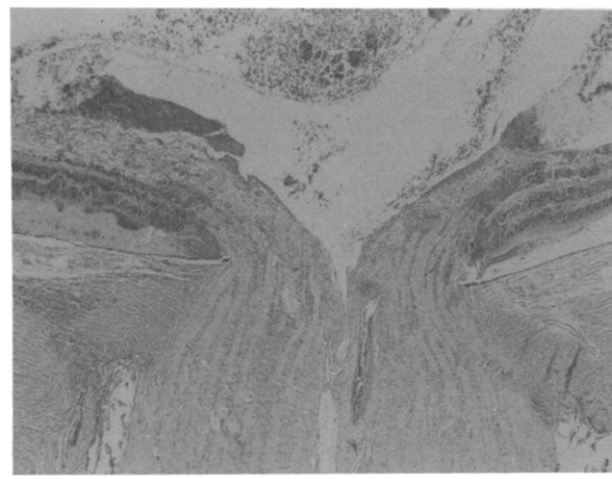


B

Fig. 1. (A) Gross photograph of the retina with hemorrhages at the periphery extending out to the ora serrata; (B) Photomicrograph depicting hemorrhages at the ora serrata (original magnification 10 ×).

cessed in batches at the eye pathology laboratory. After fixation the eyes were again examined externally for direct ocular trauma and hemorrhage at the optic nerve sheath. The eyes were then opened in the standard horizontal, pupil-optic nerve plane and photographs were made of selected cases. Microscopic sections were made of the cross section of the optic nerve and of the horizontal, pupil-optic nerve section, with special emphasis on the macula. All sections were stained with hematoxylin and eosin as well as with Periodic Acid Schiff reagent and iron stain methods.

A



B

Fig. 2. (A) Gross photograph of hemorrhage surrounding the optic nerve; (B) Photomicrograph depicting hemorrhage from the optic nerve sheath extending into the posterior sclera (original magnification 16 ×).

2.4. Definitions

Immediate cause of death. In order to compare similar cases, the population was grouped by the immediate cause of death. In cases of injury, the mechanism of death was used: asphyxia, blunt force injuries of trunk, and craniocerebral trauma (CCT) defined the groups. In cases of natural processes, broad groupings of disease were used to define the immediate cause of death: central nervous system (CNS) diseases, Sudden Infant Death Syndrome (SIDS), and 'Other' (cardiac, infectious and respiratory illnesses). Respiratory deaths had microscopic evidence of sufficient inflamma-

tion in the airways to exclude a diagnosis of Sudden Infant Death Syndrome (SIDS). SIDS was determined by: history, complete autopsy examination, scene investigation, and social service information. Deaths were classified as 'Undetermined' if no anatomic cause of death was established although mild to moderate injury was present, and history or scene circumstances were inconsistent with a 'Natural' death. These were suspected abuse deaths with inadequate evidence (see Appendix for brief case histories).

Child abuse deaths. The diagnosis of child abuse was generally made by the constellation of findings of severe injuries with confessions, witnesses, or circumstances which indicated that the child's death was caused by the intentional act of another person.

Acceleration-deceleration injury. Shaking injury has been described as acceleration-deceleration injury in which the relatively heavier head of the infant supported by relatively weaker cervical musculature can be set into violent motion by jerking the infant back and forth or from side to side while holding the trunk, shoulders, or extremities. Subdural hemorrhage is attributed to tearing of the bridging veins but the amount of hemorrhage is usually scant [9]. The question of whether or not impact is a part of shaking injuries [10–12] is not addressed in this report.

Statistical analyses. Statistical analyses were performed to test for associations between deliberate injury and the presence of the various hemorrhages after the deaths were classified by immediate cause of death (see above). The statistical method was a single table analysis using Greenland, Robins 95% confidence limits for relative risk and chi-square with Yates correction.

3. Results

3.1. Sample population

Prosectors were approached in 175 cases. Entry into the study was declined in one case. In two cases adequate history could not be obtained and in three additional cases the eyes could not be examined grossly or microscopically because of marked autolytic changes. A total of 169 cases were included in the study. All but three of the children had complete autopsies. The three head-only examinations involved two traffic accidents and a 5-year-old child with a subarachnoid hemorrhage. Both eyes received complete ocular examinations in all but three cases: in an accidental gunshot victim only the obviously injured eye was examined; in two other cases damage to one eye during removal prevented the preparation of microscopic sections.

The sample population was similar in age, race and gender distribution to the total population of children examined at the Dallas County Medical Examiner's Office during the period. The ages of the 169 children ranged from 26 weeks gestational age to 9 years 11 months. Fifty-four percent were <1 year old, 24% were in the age range 1–2 years, and 22% were >2 years of age. Ninety-eight were white. 51 were black, 16 were of Hispanic origin, and four were of other ancestry; 101 of the children were male.

3.2. Immediate causes of death

The cases were classified by immediate cause of death. Brief summaries of surface

and internal injuries involving the head, trunk, and extremities included for comparison purposes are shown in Table 1. In 77 cases a diagnosis of fatal child abuse was made and 15 of these had no external injuries. Injuries were infrequent in the asphyxias and natural deaths and were usually limited to superficial contusions or abrasions of the forehead or knees and shins described in the table as 'trivial childhood injuries'.

Table 1
External and internal injuries by cause of death

Site	No. of cases
Asphyxia: 19 deaths	
Face	11: 3 fatal injury, 2 neglect, 6 trivial childhood injuries
Ear	0
Scalp	2: both neglect
Subscalpular	4: 2 fatal injury, 2 neglect
Skull fracture	0
SDH[a]	0
SAH[b]	0
Brain edema	9: all cases resuscitated
CNS[c] contusion	0
Fingermark	0
Trunk contusion	0
Rib fracture	1: old rib fracture, not directly related
Extremity contusion	5: all trivial childhood injuries
Extremity fracture	3: prior abuse; 2 not cause, related in third
CCT[d]: 80 deaths	
Face	54: only 8 trivial childhood injuries
Ear	12: all abuse or part of the fatal injury
Scalp	59: all abuse or part of the fatal injury
Subscalpular	70: single area usually corresponded to history of single fall or blow; >2 injuries involved of ≥2 sq. in. surface
Skull fracture	31: all abuse or part of the fatal injury
SDH	67: all abuse or part of the fatal injury
SAH	52: all abuse or part of the fatal injury
Brain edema	78: not found in 2 MVA[c] cases, large skull fracture
CNS contusion	19: all abuse or part of the fatal injury
Fingermark	21: all abuse or part of the fatal injury
Trunk contusion	18: all abuse or part of the fatal injury
Rib fracture	12: 7 older, 5 part of fatal injury
Extremity contusion	35: all abuse or part of fatal injuries
Extremity fracture	4: acute injury or prior abuse
CNS: 13 deaths	
Face	1: forehead — trivial childhood injuries
Ear	0
Scalp	0

Table 1 (*continued*)

Site	No. of cases
Subscalpular	0
Skull fracture	1: old abuse
SDH	0
SAH	2: 1 spontaneous hemorrhage
Brain edema	8: 7 resuscitated, 1 brain tumor
CNS contusion	0
Fingermark	0
Trunk contusion	0
Rib fracture	2: 1 old abuse, other unrelated to death
Extremity contusion	2: 1 trivial childhood injuries, 1 discipline
Extremity fracture	0
Other: 21 deaths	
Face	1: forehead — trivial childhood injuries
Ear	0
Scalp	3: 2 small, 1 other old abuse
Subscalpular	1: probably abuse, unrelated to cause of death
Skull fracture	1: old abuse
SDH	0
SAH	0
Brain edema	3: all resuscitated
CNS contusion	0
Fingermark	0
Trunk contusion	0
Rib fracture	1: unrelated to cause of death
Extremity contusion	0
Extremity fracture	0
SIDS[f] = 13 deaths	
Face	0
Ear	0
Scalp	1: one case, much discussed
Subscalpular	1: same case
Skull fracture	1: birth trauma apparently unrelated to death
SDH	0
SAH	0
Brain edema	1: resuscitated
CNS contusion	0
Fingermark	0
Trunk contusion	0
Rib fracture	0
Extremity contusion	0
Extremity fracture	0
Trunk injury = 13 deaths	
Face	10: only 1 trivial childhood injuries
Ear	1: abuse
Scalp	6: all abuse
Subscalpular	9: all abuse, only 2 single ≤ 1 sq. in.

Table 1 (*continued*)

Site	No. of cases
Skull fracture	2: all abuse, trunk injury significantly worse
SDH	3: all abuse, trunk injury significantly worse
SAH	4: all abuse, trunk injury significantly worse
Brain edema	3: 2 resuscitated
CNS contusion	0
Fingermark	3: abuse
Trunk contusion	9: abuse
Rib fracture	5: 3 healing, 2 fresh part of fatal injury
Extremity contusion	9: abuse
Extremity fracture	1: healing prior abuse
Undetermined = 10 deaths	
Face	3: only 1 same as trivial childhood injuries
Ear	0
Scalp	3: small injuries
Subscalpular	2: 1 of 1 sq. in., other 8 totalling 3 sq.in.
Skull fracture	0
SDH	1: 'not enough injury'
SAH	3: 'not enough injury'
Brain edema	4: 2 resuscitated
CNS contusion	0
Fingermark	1: abuse but cause of death not obvious
Trunk contusion	0
Rib fracture	2: both healing, not obviously part of death
Extremity contusion	2: trivial childhood injuries
Extremity fracture	1: healing diaphyseal fracture

[a]SDH, Subdural hemorrhage.
[b]SAH, Subarachnoid hemorrhage.
[c]CNS, Central nervous system (brain).
[d]CCT, Craniocerebral trauma.
[e]MVA, Motor vehicle accident.
[f]SIDS, Sudden Infant Death Syndrome.

The asphyxial death group (n = 19) includes: aspiration of foreign object (n = 2), drowning and near-drowning (n = 8), overlay (n = 3), position/wedging (n = 4), and suffocation (n = 2). Most of this group had no external evidence of injuries other than petechiae. CCT caused the most deaths (n = 80). Mechanisms of CCT included: shaking, blunt force, combined blunt trauma and shaking, crush injury, and a gunshot wound. External injury varied in this group; most had some contusions and some were obviously severely injured. Trunk injury deaths (n = 13) were all blunt force injuries. They included contusions and lacerations of internal chest and/or abdominal organs, usually with blood in one or more of the body cavities. External injury and fractures varied in this group but were much more extensive than in natural or asphyxial deaths.

CNS deaths (n = 13) were caused by: brain tumor (n = 1), intraventricular hemorrhage (n = 1), subarachnoid hemorrhage (n = 1), meningitis (n = 4), and seizure disorder (n = 6). 'Other' deaths from natural causes totalled 21 deaths: respiratory deaths (n = 11), volvulus (n = 1), dehydration (n = 1), cardiac disease (n = 3), and sepsis (n = 5). Few of these children had external or internal injuries and those present were superficial. Thirteen deaths were attributed to SIDS. External injuries other than trivial childhood injuries were not found in these groups.

Ten cases were classified as 'Undetermined'. A re-examination of these cases is included in the discussion.

3.3. *Ocular hemorrhages in various causes of death*

Table 2 records the presence of: retinal, peripheral retinal (at the ora serrata), optic nerve sheath, and intrascleral hemorrhages in the various causes of death. Head injury (CCT) accounts for most of the observed hemorrhages. Central nervous system (CNS) disease accounted for all but one of the other cases of hemorrhage. One of the children who died of trunk injury also had a mild degree of head injury reflected in the optic nerve sheath hemorrhage. Retinal and other ocular hemorrhages were among the injuries identified in the cases classified as undetermined.

The prevalence of these four types of hemorrhage (retinal, peripheral retinal, optic nerve sheath, and intrascleral) for the head-injured children (n = 80) was compared with the other children (n = 89). There was a significantly greater prevalence of all four types of hemorrhage among the head-injured group. The relative risks for these four hemorrhage types was in the range 8.6–52, indicating that the head-injured child in our population was >8–52 times more likely to have these types of hemorrhage present at autopsy than any non-head-injured child. The P value was <0.001 for all four types of hemorrhage (shown in Table 3).

Table 2
Hemorrhages grouped by immediate cause of death

Immediate cause of death	Retinal	Peripheral	Optic nerve	Intrascleral	Total
Asphyxia	0	0	0	0	19
CCT[a]	62	50	57	47	80
CNS[b]	4	3	2	1	13
Other	0	0	0	0	21
SIDS[c]	0	0	0	0	13
Trunk injury	0	0	1	0	13
Undetermined	4	3	2	0	10
Total	70	56	62	48	169

[a]CCT, Craniocerebral trauma.
[b]CNS, Central nervous system (brain).
[c]SIDS, Sudden Infant Death Syndrome.

Table 3
Relative Risk (RR); Greenland, Robins 95% Confidence Limits for (RR); and Yates corrected chi-squares and *P*-values for comparison of head-injured children vs. all other children

	Relative Risk (RR)	Greenland, Robins 95% Confidence Limits	Yates corrected	
			Chi-squares	*P*-values
Retinal	8.62	4.41 < RR < 16.8	78.7	<0.001
Peripheral	9.27	4.20 < RR < 20.4	56.6	<0.001
Optic nerve	12.4	5.25 < RR < 29.3	75.1	<0.001
Scleral	52.2	7.38 < RR < 370.	40.7	<0.001

4. Discussion

4.1. Differential diagnoses

Retinal hemorrhages are a well-recognized sign of the 'shaken baby syndrome' in the pediatric clinical literature. Other, non-traumatic, causes of retinal hemorrhages are recognized in the pediatric age-group as well. Retinal hemorrhages found in newborns are often mentioned in the differential diagnosis of the shaken baby syndrome but do not have associated sequelae, and even deep hemorrhages are healed by 6 weeks of age [13]. The differential diagnoses of retinal hemorrhages described by Annable [13] include vascular obstruction, inflammatory conditions including vasculitis, toxic states including acute febrile and infectious illnesses; vascular diseases; anemia; and some drugs [13]. Vascular malformations have also been associated with retinal hemorrhages [14]. Lethargy, coma, and brain injury can be found in some of these conditions.

If a child dies suddenly and unexpectedly and the death is referred to a medical examiner, most of the conditions in the differential diagnosis can be excluded. Some are not usually lethal conditions, others are identified during a complete autopsy. A complete autopsy is necessary to determine accurately that a death is non-traumatic [2,15–17]. Furthermore, a complete postmortem ocular examination is a necessary procedure in the autopsy of a child whose death is unexplained [10,11,18,19]. This is true even if no retinal hemorrhages were identified prior to death, since direct ophthalmoscopy, the most common clinical eye examination, visualizes only the posterior retina. Only indirect ophthalmic examination reveals the retinal periphery. Therefore, in order to detect peripheral retinal hemorrhages, the eyes of children must be examined either by indirect ophthalmoscopy or by postmortem ocular technics [19]. Indeed, the optic nerve and posterior scleral hemorrhages are only identified by postmortem technics [20–21].

4.2. Age

Retinal hemorrhages were identified most often in children < 1 year of age, a finding similar to the observations of Riffenburgh and Sathyavagiswaran [18]. Other ocular hemorrhages were also more common in children < 1 year of age.

4.3. Ocular hemorrhage occurrence

As was expected [4–8,11–13,22], head injury accounts for most of the observed hemorrhage — retinal, peripheral retinal, optic nerve sheath, and intrascleral hemorrhage. We found such hemorrhages in some cases with CNS diseases, but far less often than in the head-injured.

4.4. Mechanisms

Mechanisms proposed to produce retinal hemorrhage include: venous congestion or retinopathy from chest compression; Terson's Syndrome (retinal and vitreous hemorrhages associated with subarachnoid hemorrhage and brain edema); vascular congestion; increased intracranial pressure; and acceleration-deceleration (shaking with or without impact) injury of the retina or its vessels. Review of these mechanisms accounts for retinal hemorrhages in 66 of the 70 cases, all but the retinal hemorrhages found in the four undetermined deaths.

Mechanisms — chest compression: no cases. Although isolated cases of retinal hemorrhage continue to be attributed to resuscitation (in particular to the chest compression component of resuscitation), 70 children in this population received cardiopulmonary resuscitation (CPR) for ≥ 30 min. and yet had no retinal hemorrhages [22]. This is in agreement with a recent report by Fackler, Berkowitz, and Green, in which retinal hemorrhage was absent in newborn piglets after CPR [23].

Both Purtscher's and Valsalva retinopathy have been mentioned in discussions proposing CPR as a mechanism of producing retinal hemorrhages. The cotton-wool spots of Purtscher's are not part of most descriptions of retinal hemorrhages. The hemorrhages found in Purtscher's and Valsalva retinopathy tend to be superficial [20]. Lambert et al. [20], Munger et al. [11], and Budenz et al. [12] found the distribution of retinal hemorrhages through all layers of the retina inconsistent with the description of either Purtscher's or Valsalva retinopathy. Both Lambert et al. and Munger et al. concluded that the chest compression mechanism did not account for the hemorrhages found in their studies [11,20]. Chest compression is not an adequate explanation for retinal hemorrhages.

Mechanisms — subarachnoid hemorrhage: two cases. Terson's syndrome (retinal and vitreous hemorrhage associated with significant spontaneous subarachnoid hemorrhage), discussed by Shaw et al. [24], is another proposed mechanism. Significant subarachnoid hemorrhage is uncommon in children. Only three children in this population had significant subarachnoid hemorrhage. Of these three, only two had retinal hemorrhages: a 5-year-old with no history suggestive of abuse had an apparent spontaneous subarachnoid hemorrhage, as did a 3-week-old with meningitis and necrotizing encephalitis. The hemorrhages in both of these children were few and more prominent in the posterior retina; microscopic hemorrhage was also observed at the retinal periphery in both. The child with the spontaneous subarachnoid hemorrhage had optic nerve and intrascleral hemorrhage, the child with meningitis did not. Terson's Syndrome would account for two of the 70 cases with retinal hemorrhages.

Mechanisms — retinal vascular congestion: two cases. Retinal vascular congestion secondary to retinal vein thromboses was identified in two cases of the 70. It may have caused the hemorrhages in one of the CCT cases. However, another mechanism is necessary to account for the hemorrhages found in the other eye. Retinal vein thrombosis caused unilateral retinal hemorrhages in one case of meningitis. Capillary congestion without retinal vein thrombosis appeared to have produced the retinal hemorrhages in the child with the brain tumor. Retinal vascular congestion probably caused retinal hemorrhages in at least two of the 70 cases having retinal hemorrhages.

Mechanisms — increased intracranial pressure: no cases. Munger et al. note the concurrent incidence of intracranial hemorrhages with cerebral edema and retinal hemorrhages [11]. Brain edema was identified in all of the head injury cases reported by Budenz et al. [12]. In this population, brain edema was identified in 68 of 70 cases with retinal hemorrhages. Brain edema was found in all 56 of the cases with peripheral retinal hemorrhages and all 47 of the cases with intrascleral hemorrhage, and in all but one of the 62 cases of optic nerve hemorrhage. However, brain edema was found in 38 cases without retinal hemorrhages, 50 cases without peripheral retinal hemorrhages, 42 cases without optic nerve sheath hemorrhages, and 58 cases without intrascleral hemorrhages.

Brain edema in this population (n = 106) is a marker of head injury (n = 79); unsuccessful resuscitation in asphyxia, trunk injury, and natural disease (n = 24); and brain tumor (n = 1). It was also found in two children with undetermined causes of death. Brain edema alone is not sufficient to cause retinal hemorrhages or other ocular hemorrhages.

Mechanisms — shaking and impact injury: 62 cases. This mechanism proposes motion of the vitreous body with respect to the retina causing vitreoretinal traction at points of attachment. The infant retina is firmly attached to the vitreous base anteriorly extending to the periphery (ora serrata) and at the macula. The vitreoretinal traction mechanism explains hemorrhage at the points of attachment — the retinal periphery, the macula, and at blood vessels. Shearing forces involving other vessels may account for other ocular hemorrhages as the subdural hemorrhages found in the shaken baby syndrome are attributed to shearing of the bridging veins.

Massicotte, Folberg et al. demonstrated a strand of vitreous matter connecting the hemorrhage at the periphery (ora serrata) back to the apex of a macular fold [25]. They concluded that vitreoretinal traction was the probable injury mechanism. Acceleration-deceleration injury to the retina accounts for both peripheral retinal hemorrhages and the folds identified by Massicotte, Folberg et al. [25] and others [11,26].

The ora serrata (peripheral retinal) hemorrhages found in 50 of our head-injured children are most consistent with an acceleration-deceleration mechanism of injury. Two of the three head-injured children with peripheral retinal hemorrhage were unrestrained rear seat passengers involved in high speed collisions. The mechanism of injury in both these children probably included acceleration-deceleration and was similar to a brief violent shaking as described in confessions. An other child may

have had acceleration-deceleration mechanics with head impact after a fall despite incomplete slowing by impacts on forearms. Fifty of the 70 retinal hemorrhages could be accounted for by acceleration-deceleration injury with or without impact.

Peripheral retinal hemorrhages were not found in 12 other head-injured children. Circumstances indicated impact was the primary mechanism of injury rather than acceleration-deceleration. Even a child thrown from a motorcycle (single deceleration impact injury) was without peripheral retinal hemorrhage. Lesser degrees of acceleration-deceleration injuries could be transmitted to the retina and its vessels and account for 12 of the 70 cases of retinal hemorrhages which do not include the periphery.

4.5. Significance of ocular hemorrhages

This study demonstrates the statistically significant association of head injury with retinal and peripheral retinal hemorrhage as well as optic nerve and intrascleral hemorrhages. When considered in the context of systemic injury and history, retinal, peripheral retinal, ocular, and intrascleral hemorrhage mark abnormal child deaths — deaths due to serious disease, frank trauma, or child abuse.

These hemorrhages also mark living children who have been abused (in the absence of serious disease or frank trauma to explain their presence). The peripheral hemorrhages can only be seen during life with indirect ophthalmoscopy [19] and may be a marker of shaking which is deliberate injury to a child.

Optic nerve sheath hemorrhage and intrascleral hemorrhage were found more commonly in head-injured than in other children. These injuries can only be found at postmortem examination and must be sought if the child dies.

4.6. Significance of clinical history.

Discrepancy between the systemic and ocular injury and the caregiver's history remains the best indicator of child abuse. The absence of a history of trauma has been recognized to be false or self-serving in cases of fracture of bone, subdural hematoma, failure to thrive, and other manifestations of injury. Falls from beds, for example, have not produced significant injury [6,27–30].

The head-injured children in this series include 18 who had a history that, for the most part, adequately explained the injury identified clinically and at autopsy. It was rare that the history explained the identified injury adequately in the other head-injured children. One late-coming history was a confession: 'I shook the baby real hard and he went limp'.

In the 'Natural' deaths, significant disease processes were identified at autopsy and the clinical histories corresponded to the diseases. Additional history was needed in one of these cases where the initial complaint was: 'The child rolled off the couch and became unresponsive'. Additional history indicated loss of the ability to walk during the preceding week as well as some degree of lethargy, corresponding to the brain tumor found at autopsy.

4.7. A second look at the undetermined cases in Appendix 1

These cases were reviewed in the context of our observations of most of the population. None of the children's deaths was natural. All of the children had been

abused. Our historic predilection as forensic pathologists has been to call these deaths undetermined. More emphasis placed on the fact of abuse, rather than on the uncertainty of the cause or mechanism of death, would identify abusive caretakers and possibly help reduce the carnage.

In summary, retinal, peripheral retinal, optic nerve sheath and intrascleral hemorrhages were found far more frequently in head-injured children than with any other kind of injury, natural disease, or suspicious (undetermined) death. A strong statistical association was identified between head injury and all ocular hemorrhages. The combination of ocular and systemic injury wholly out of proportion to historical and investigative information distinguishes child abuse head injury from natural disease and from other injury. In the absence of natural disease or adequate history of severe head injury, the presence of retinal and ocular hemorrhage is pathognomonic of child abuse.

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Appendix 1: Undetermined cause and manner

Case 1

A 2-month-old being cared for by a variety of non-relatives while the mother was incarcerated presented in arrest with history of 'acting weird'; resuscitation was briefly successful. Pneumonia and retinal and optic nerve hemorrhages found at autopsy but no other natural disease.

Case 2

A 7-month-old born prematurely became unresponsive and was shaken. The child had cheek, nose and scalp injuries, and healing rib fractures. No explanation was offered for the fractures. No natural disease found.

Case 3

A 2-month-old presented as a crib death and was found to have healing subarachnoid hemorrhage and 12 healing rib fractures. No explanation was offered for the fractures. No natural disease found.

Case 4

A 2-month-old was found dead. External ocular and retinal hemorrhages were found at autopsy but no natural disease. The father was known to be violent. A minor motor vehicle accident 2 days prior was offered to explain the acute injuries.

Case 5

A 3-month-old was said to have aspirated milk and become unresponsive. The parents appeared indifferent to its death. A recent, healing subdural hemorrhage, no evidence of significant aspiration, and no natural disease found.

Case 6

A 1-month-old presented as a crib death and was found to have retinal and optic nerve hemorrhages with intraventricular hemorrhage as well. No natural disease found. The family was being investigated for injury to a sibling.

Case 7

A 20-month-old was found dead. A 6-week-old sibling had died 2 weeks prior to this. The parents acted indifferent — one was thought to be psychotic. No natural disease found.

Case 8

A 7-month-old was found dead. Fresh abrasions of the hands and feet and a healing arm fracture were found at autopsy. No explanation was offered for the fracture. No natural disease found.

Case 9

An 18-month-old was found dead. Bruising injuries of cheek and forehead were attributed to cat scratches. Only scant subarachnoid hemorrhage and no natural disease found. The family was well known to police for involvement with drugs.

Case 10

A 3-month-old was found dead. One retinal hemorrhage was found. Three other children had died — two of abuse, the other a suspicious death. No natural disease found.

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