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Are Retinal Hemorrhages Found After Resuscitation Attempts?

A Study of the Eyes of 169 Children

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Resuscitation attempts have been hypothecated to explain retinal hemorrhages in infants who are suspected victims of child abuse. This study was undertaken to test that hypothesis by postmortem ocular examinations following unsuccessful resuscitation attempts on a sample of 169 children selected by 19 prosectors willing to contribute to the study. Cardiopulmonary resuscitation had been attempted for a minimum of 30 min in 131 of the children, whereas 38 controls did not have such protracted attempts; 70 children with prolonged resuscitation attempts had no retinal hemorrhages, including eight children whose fatal blunt force injuries of the trunk represented extremes of the forces used in resuscitation attempts. Children who died of asphyxia, respiratory illnesses, sudden infant death syndrome, and various other causes had no hemorrhages; neither did 21 children who died of head injury or central nervous system (CNS) diseases, nor did 29 controls. Retinal hemorrhages were present in 70 children, 61 with prolonged resuscitation attempts and nine controls. Among those with attempted resuscitation, 56 had head injuries, and four had CNS diseases and sepsis, all recognized causes of retinal hemorrhages. The other death that involved a resuscitation attempt and retinal hemorrhages was an officially "undetermined" death. The child had come from a household with two prior child deaths and documented abuse. No case is found in this study to support the hypothesis that retinal hemorrhages are caused by resuscitation attempts.

Key Words: Resuscitation—Retinal hemorrhages—Child abuse—Shaken baby.

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Nonaccidental injuries to children have been recognized for some years, since the initial reports by Caffey (1), Adelson (2), and Kempe et al. (3). They have been described in the radiologic, pediatric, neurologic/neurosurgical, ophthalmologic, and forensic literature as various aspects of the phenomenon have come to be recognized (4–9). Retinal hemorrhages were first recognized as a marker of intentional head injury in infants and young children, a part of the "shaken baby syndrome" (4,5). Their presence has been regarded as strongly indicative of child abuse (4,5,9–11) and as requiring thorough evaluation.

A few authors have cited single cases and asserted that blows to the back, intended to revive from apnea, caused retinal hemorrhages (12,13). Because these assertions were at variance with the earliest literature, two prospective clinical studies of resuscitated children were undertaken to determine the frequency of retinal hemorrhages following resuscitation attempts. In the first study by Kanter in 1986 (11), of 54 children examined, only one was found to have retinal hemorrhages in the absence of other injuries. The hemorrhages were attributed to hypertension and seizures (11). Goetting and Sowa (14) studied 20 children and found two with retinal hemorrhages in the absence of other recognized injuries. In this latter study, the hemorrhages were attributed to resuscitation (14). In neither of the prospective studies were the eyes examined after death. Weedn et al., who report a single case of a scalded infant with head and neck burns with autopsy and postmortem ocular examination, associate retinal hemorrhages with resuscitation (15).

It is generally accepted that a complete autopsy is necessary to determine accurately that a death is nontraumatic. Complete postmortem ocular exam-

ination is as necessary as a complete autopsy (16). The most common clinical eye examination, direct ophthalmoscopy, visualizes only the posterior retina. The retinal periphery, however, can be seen only by indirect ophthalmic examination. Such an examination usually requires an ophthalmologist with special instrumentation, the indirect ophthalmoscope. Peripheral retinal hemorrhages are described in an article examining deliberately traumatized children (17). Such hemorrhages will always go undiscovered unless the eyes are examined either by indirect ophthalmoscopy or postmortem ocular examination. Neither of the prospective clinical studies describe use of the indirect ophthalmoscope in the fundoscopic examination.

The present study correlates ocular and systemic findings in selected child deaths from 1982 to 1989 and investigates the nature and extent of injuries and natural disease. This report examines the hypothesis that resuscitation or blows to the back cause retinal hemorrhages. It assesses the frequency with which retinal hemorrhages are found following unsuccessful resuscitation attempts in children who die of a variety of causes.

MATERIALS AND METHODS

A sample, selected by 19 prosectors willing to contribute to the study, of 169 of the ~400 child deaths investigated at the Dallas County Medical Examiner's Office from 1982 to 1989 was studied. These deaths included intentional injuries, suspected child abuse, apparent accidental injuries (nonintentional trauma), and apparent natural deaths. History, including circumstances and medical information, autopsy examination, and ocular examination were to be correlated for this study.

History included the usual demographic information (name, age, race, and gender); the initial information available at the time that the death was reported; a report of the scene investigation; medical records; and follow-up scene, police, and/or social service investigations. Complete autopsies were performed on all but three of the children who had head-only examinations—a traffic accident victim, a child who died of an accidental gunshot wound, and an older child with a subarachnoid hemorrhage. Radiographic examination was performed in child-abuse and suspected child-abuse cases.

Complete ocular examination was performed on both eyes in all but three cases—only the obviously injured eye was taken in the accidental gunshot case. In two cases, one eye was damaged during removal such that microscopic sections could be made from only one eye.

Posterior removal of infant eyes avoided cutting the optic nerves too short. The orbit was unroofed, exposing both the globe and the optic nerve to the point where it had been transected at the time the brain was removed. The eyes were fixed in formalin and examined after a delay varying from a few days to several months and were commonly batch processed. They were examined externally for evidence of direct ocular trauma and hemorrhage at the optic nerve sheath. They were opened horizontally in the standard pupillary–optic nerve plane. Photographs were made in selected cases. Microscopic sections were made of the cross sections of the optic nerves and of the horizontal pupil–optic nerve sections, with special emphasis upon the macula. Hematoxylin–eosin-stained sections were examined, as were sections stained with periodic acid–Schiff reagent and an iron stain.

RESULTS OF STUDY

Resuscitation attempts lasting a minimum of 30 min had been made on 131 of the 169 children, either by cardiopulmonary resuscitation (CPR) by an emergency medical services team or rescue squad or emergency department personnel trained in Advanced Cardiac Life Support or Basic Life Support, or had been initiated by bystanders or caretakers. A control population of 38 children had not received such vigorous resuscitation attempts. Six of these children had brief nonprofessional CPR, but these efforts were discontinued after professional assessment recognized the fact of death.

Of the 131 resuscitation attempts, 40 had been terminated unsuccessfully. Attempts in the remaining 91 cases were initially successful with variable survival intervals—usually on a ventilator. In 36 of the cases, the survival was brief—<24 h—and 52 of the children survived >24 h but <30 days. Three children survived >30 days. The 38 control children who did not have prolonged resuscitation attempts included 20 who were pronounced dead when found and had no survival interval. In 18 other control cases, the children were ill or injured but had no cardiac or respiratory arrest that would require vigorous resuscitation: 12 of them survived briefly (<24 h), four survived between 24 h and 30 days (usually on ventilators), and two survived >30 days.

The ages of the 169 children ranged from 26 weeks' gestational age to 9 years, 11 months; 90% were newborn to 36 months; and the mean age was 17 months. A total of 98 were white, 51 were black, 16 were of Hispanic origin, and four were of other ancestry. Most (101) of the children were male. The children who were resuscitated had age, race,

TABLE 1. *Children (n = 99) without retinal hemorrhages, grouped by causes of death and by the presence or absence of a resuscitation attempt*

Cause of death	Resuscitation attempt		Total
	Present	Absent	
Asphyxia	14	5	19
CCT	13	5	18
CNS	8	1	9
Other natural	7	3	10
Respiratory	9	2	11
SIDS	8	5	13
Trunk injury	8	5	13
Undetermined	3	3	6
Total	70	29	99

CCT, craniocerebral trauma; CNS, central nervous system; and SIDS, sudden infant death syndrome.

and gender distributions similar to those of the total group and were not different from other children examined at the Dallas County Medical Examiner's Office and reported in the literature. Similarly, the demographics of the children with retinal hemorrhages were not different from those of the total group.

Causes of the 169 deaths fell into several groups. Most of the deaths were caused by craniocerebral trauma (CCT) and included intentional and unintentional injuries. The 80 head injury (CCT) causes included blunt force, shaking, combined blunt force and shaking, and crush injuries. The 19 asphyxial deaths included aspiration of a foreign object, drowning and near-drowning, overlay, position/wedging, and suffocation. The 13 trunk injury deaths included contusions and lacerations of chest and/or abdominal organs, usually with blood in one or more of the body cavities. External injury and fractures were variable in the group. The 13 sudden infant death syndrome (SIDS) deaths were determined by history, complete autopsy examination, scene investigation, and social service information. The 13 central nervous system (CNS) causes of death included brain tumor, meningitis, seizure disorder, and spontaneous subarachnoid hemorrhage. Respiratory causes of death reflected those cases with microscopic evidence of sufficient inflammation in the airways to exclude a diagnosis of SIDS, a total of 11. Other causes of death were found in 11 cases, including cardiac diseases, dehydration, and sepsis. Undetermined cause of death was reserved for nine deaths with no anatomic cause, in which injury was mild to moderate, and in which history or scene circumstances were inconsistent with a natural death.

Table 1 shows 99 cases in which retinal hemorrhages were not found. These cases are grouped by cause of death and whether or not the child had a prolonged ($\geq$30 min) resuscitation attempt. None of 70 children with resuscitation attempts had retinal hemorrhages. These include 46 children with causes of death grouped as trunk injury, asphyxia, SIDS, respiratory, or other causes (cardiac or metabolic). The 20 children with similar causes of death who had no resuscitation attempts served as controls in this group.

No retinal hemorrhages were identified in 21 children with resuscitation attempts and conditions that have been associated with retinal hemorrhages. These include 13 with head injury and eight with CNS diseases. Three others who had resuscitation attempts were grouped with undetermined causes although trauma was present, because it was not sufficient to explain death. No retinal hemorrhages were identified in this group. An additional nine children had similar causes of death (head injury, CNS diseases, or undetermined causes) but no resuscitation attempt. None of these children had retinal hemorrhages.

Table 2 shows 70 cases in which retinal hemorrhages were present. These cases are grouped by cause of death and whether or not the child had a prolonged ($\geq$30 min) resuscitation attempt. Of the 61 who were resuscitated, 56 had head injuries, three had CNS causes of death, and one had sepsis—all conditions known to be associated with retinal hemorrhages. One died of undetermined cause. Nine other children had head injuries, CNS diseases, or undetermined causes of death, but had no attempted resuscitation.

The histologic appearance of the retinal hemorrhages is similar to the range of appearances depicted by Riffenburgh and Sathyavagiswaran (16) and by Massicotte et al. (17). Figure 1 is an example of an extensive peripheral retinal hemorrhage from this series. The nature and extent of the hem-

TABLE 2. *Children (n = 70) with retinal hemorrhages, grouped by causes of death and by the presence or absence of a resuscitation attempt*

Cause of death	Resuscitation attempt		Total
	Present	Absent	
Asphyxia	0	0	0
CCT	56	6	62
CNS	3	1	4
Other natural	1	0	1
Respiratory	0	0	0
SIDS	0	0	0
Trunk injury	0	0	0
Undetermined	1	2	3
Total	61	9	70

CCT, craniocerebral trauma; CNS, central nervous system; and SIDS, sudden infant death syndrome.

orrhages in this series are the subjects of a separate study.

Two technical observations were made in the course of the study. The first was that use of the Stryker saw to unroof the orbit did not appear to introduce any artifactual hemorrhage. All but a very few eyes were removed posteriorly by using the saw. If the Stryker saw caused hemorrhages, most of the cases would have hemorrhages and the few that were removed anteriorly might be free of hemorrhage. This was not observed.

The other observation was that mechanical aspiration of the globe did not introduce any hemorrhagic artifacts in the retina in the few cases in which it was performed. Vitreous humor was removed for chemical or toxicologic examination in only six cases. Formalin was used to reinflate these globes. The procedures were variably disruptive to the globe. Most often the retina was loose in the globe in sections but had no hemorrhages, except in two cases with head injury.

DISCUSSION

Review of anatomy and of the physiology of resuscitation has led to assertions that resuscitation causes retinal hemorrhages (14,15). Elevated intrathoracic pressure is said to increase jugular venous pressure and intracranial pressure (14). The elevated intrathoracic pressure is also described as being transmitted to the intracranial space by way of the paravertebral venous plexus and cerebrospinal fluid (14). It is further asserted that during intracranial hypertension the venous drainage through the central retinal vein is impeded and the retinochoroidal anastomosis is obstructed by increased cerebrospinal fluid pressure (14).

In the series reported by Goetting and Sowa (14), two of the 20 cases were found to have hemorrhages by using fundoscopic examination. On the basis of their observations, one would expect to find retinal hemorrhages in perhaps 10% of children with similar causes of arrest who died after resuscitation attempts.

Retinal hemorrhages were not found in the absence of injuries or natural disease known to cause hemorrhages in our series. A total of 49 children in our series received prolonged vigorous resuscitative attempts and died of comparable causes to those in Goetting and Sowa's series. These include 14 asphyxial causes, eight CNS diseases, seven other illnesses, nine respiratory diseases, eight SIDS, and three undetermined causes. None of these children had retinal hemorrhages, although all had chest compression with increased intrathoracic pressure.

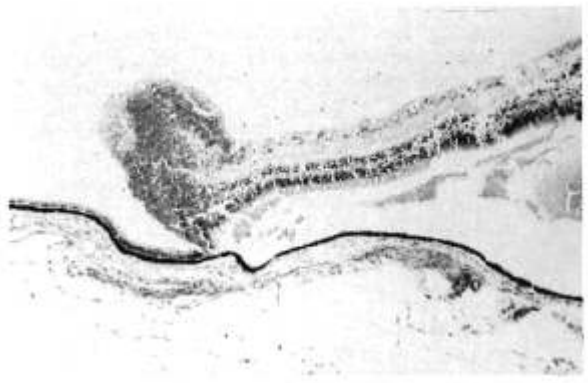

FIG. 1. Extensive hemorrhage at the ora serrata that would not be observed by routine ophthalmic examination. Original magnification, ×25.

It may be that increased pressure is not transmitted to the retina as directly as described (14). Increased venous pressure from chest compression was only transmitted to the cephalic veins when the jugular venous valves were incompetent, as in the case of long-standing right heart failure, or when they were absent in long-standing tricuspid insufficiency in a study of 32 adults by Fisher et al. (18). A study of vascular pressures in adults during resuscitation showed jugular venous pressures of 14 and 29 mm Hg during relaxation and compression (14,19). The contribution of the paravertebral venous plexus and cerebrospinal fluid to increased intracranial pressure is described as modest "except with abdominal binding or under conditions of increased intracranial pressure" by the original authors (20).

Increased intracranial pressure has been recognized as a cause of preretinal and retinal hemorrhages in a study of a monkey by Smith et al., but the hemorrhages were not found until after the third increase in pressure by saline infusion at the cisterna magna (21). Separate subdural hemorrhage was observed at the optic nerve sheath as well (21). The case that Goetting and Sowa included as an addendum had a few hemorrhages found after the third resuscitation attempt on the day of admission, and postresuscitation cardiomyopathy is also described. This asthmatic child's two isolated retinal hemorrhages may well have occurred in one eye following resuscitation attempts while he had increased intracranial pressure from his partial asphyxial state that was caused by myocardial depression. This clinical scenario was not found in any of the children in this study.

Goetting and Sowa (14) and Weedn et al. (15) refer to Purtscher retinopathy in discussing the etiology of the retinal hemorrhages observed in their cases. Purtscher retinopathy is a term used clini-

cally to describe exudates, white cotton-wool spots, a small number of posterior retinal hemorrhages, decreased visual acuity, and a relatively benign clinical course with only a few reports of significant visual loss. Recently Behrens-Baumann et al. have reproduced Purtscher lesions in a pig by embolization of the ophthalmic artery (22). Purtscher retinopathy is probably of diverse pathophysiologic origin and should not be used as a simple explanation of retinal hemorrhages. Goetting and Sowa (14) do not describe exudates or white spots, nor do Weedn et al. (15).

The infant described by Weedn et al. (15) had scald burns primarily of the head and neck that were not found in any of the burned children in our series. Three children with scald burns on other parts of their bodies were resuscitated and ultimately died of infectious complications of their burns but did not have retinal hemorrhages.

Eight children in our series died as the result of significant trunk injuries caused by extreme use of the forces applied in resuscitation. These were similar to the cases of unskilled resuscitation described by Bacon et al. (12) and by Kirschner and Stein (13). None of the children in our series had retinal hemorrhages. An additional five children had similar injuries and had no resuscitation attempts. In these, too, retinal hemorrhages were absent.

Although retinal hemorrhages have been described in 25% of traumatic asphyxia cases, the external marks of traumatic asphyxia were also described and were quite pronounced (23). Petechiae of the skin and conjunctiva have been associated with resuscitation (more often in adults) as well as asphyxial mechanisms of death (24,25). The proposed mechanism of production of petechiae is increased cephalic venous pressure and hypoxia. Nine children in the series had facial petechiae. One had trunk trauma, three had head injuries, one had *Neisseria meningitidis* sepsis. In the whole group, the only child with retinal hemorrhages had significant head injury. Four other children in this group with asphyxial deaths had a few facial petechiae but no retinal hemorrhages. One child nearly drowned and was resuscitated, but died later. Three had prolonged chest compression as a part of the mechanism of injury. Two of these had a resuscitation attempt in addition: a child who had been smothered and a child who had died of positional asphyxia under a bench-type automobile seat. A child who was wedged between the mattress and the rail of his crib had no resuscitation attempt. None of the 14 asphyxiated children with attempted resuscitation had retinal hemorrhages, nor did five controls who had no resuscitation attempt.

Only children with craniocerebral trauma, CNS diseases, sepsis, or undetermined cause of death had retinal hemorrhages. This was true whether resuscitation was attempted or not. Most of the children with resuscitation attempts and with retinal hemorrhages had head injury. The injuries were considered sufficient to cause death in the 56 cases grouped as head injury. The case that was classified as undetermined had no external or internal injuries except an isolated peripheral retinal hemorrhage; this death occurred in a setting of two prior child deaths and a charge of child abuse against the caretaker. These kinds of head injury—blunt force, shaking, combined blunt force and shaking, and crush injuries—are well known to be associated with retinal hemorrhages. This is similar to the observation of Kanter that the risk of retinal hemorrhage was much higher in their trauma victims (five among nine traumatized children) than in their control population (one of 45) (11). The four cases with CNS diseases and sepsis had illnesses with which retinal hemorrhages have been associated in the literature even before CPR came into wide use.

Most resuscitation attempts in this series did not lead to injuries of any description, whether performed by skilled or unskilled persons. In this series, retinal hemorrhages were found after injury and a few natural diseases—not after resuscitation.

Retinal hemorrhages are important markers of child abuse in the post-neonatal period. Although they can occur in the absence of child abuse, their presence well warrants as extensive an investigation into the child's history and circumstances as can be mounted to account for them. If the child dies, a thorough autopsy including ocular examination is necessary, as is careful radiography, if it has not been done during life.

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