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Prevalence of Retinal Hemorrhages in Pediatric Patients After In-hospital Cardiopulmonary Resuscitation: A Prospective Study

Amy Odom, MD*; Elizabeth Christ, MD*; Natalie Kerr, MD||; Kathryn Byrd, MD||; Joel Cochran, DO¶; Fredrick Barr, MD*; Mark Bugnitz, MD*; John C. Ring, MD*‡; Stephanie Storgion, MD*; Robert Walling, MDS; Gregory Stidham, MD*; and Michael W. Quasney, MD, PhD*#

ABSTRACT. *Objective.* Child abuse occurs in 1% of children in the United States every year; 10% of the traumatic injuries suffered by children under 5 years old are nonaccidental, and 5% to 20% of these nonaccidental injuries are lethal. Rapid characterization of the injury as nonaccidental is of considerable benefit to child protection workers and police investigators seeking to safeguard the child care environment and apprehend and prosecute those who have committed the crime of child abuse. Physically abused children present with a variety of well-described injuries that are usually easily identifiable. In some cases, however, particularly those involving children with the shaken baby syndrome, obvious signs of physical injury may not exist. Although external signs of such an injury are infrequent, the rapid acceleration-deceleration forces involved often cause subdural hematomas and retinal hemorrhages, hallmarks of the syndrome. Frequently, retinal hemorrhages may be the only presenting sign that child abuse has occurred. Complicating the interpretation of the finding of retinal hemorrhages is the belief by some physicians that retinal hemorrhages may be the result of chest compressions given during resuscitative efforts. The objective of this study is to determine the prevalence of retinal hemorrhages after inpatient cardiopulmonary resuscitation (CPR) in pediatric patients hospitalized for nontraumatic illnesses in an intensive care unit.

Design. Prospective clinical study.

Setting. Pediatric intensive care unit.

Patients. Forty-three pediatric patients receiving at least 1 minute of chest compressions as inpatients and surviving long enough for a retinal examination. Patients were excluded if they were admitted with evidence of trauma, documented retinal hemorrhages before the arrest, suspicion of child abuse, or diagnosis of near-drowning or seizures. All of the precipitating events leading to cardiopulmonary arrest occurred in our intensive care unit, eliminating the possibility of physical abuse as an etiology.

Interventions. None.

Measurements. Examination of the retina was performed by one of two pediatric ophthalmologists within 96 hours of CPR. The chart was reviewed for pertinent

demographic information; the platelet count, prothrombin time, and partial thromboplastin time proximate to the CPR were recorded if they had been determined.

Results. A total of 43 pediatric patients hospitalized with nontraumatic illnesses survived 45 episodes of inpatient CPR. The mean age was 23 months (range, 1 month to 15.8 years), and 84% of the patients were under 2 years old. The majority of the patients (44%) were admitted to the intensive care unit after surgery for congenital heart disease, and another 21% were admitted for respiratory failure. The mean duration of chest compressions was 16.4 minutes \pm 17 minutes with 58% lasting between 1 and 10 minutes. Five patients had chest compressions lasting >40 minutes, and two patients had open chest cardiac massage. All patients survived their resuscitative efforts. Ninety-three percent of patients had an elevated prothrombin time and/or partial thromboplastin time while 49% were thrombocytopenic. Sixty-two percent of the patients had low platelet counts and an elevated prothrombin time and/or partial thromboplastin time. Small punctate retinal hemorrhages were found in only one patient.

Conclusions. Retinal hemorrhages are rarely found after chest compressions in pediatric patients with nontraumatic illnesses, and those retinal hemorrhages that are found appear to be different from the hemorrhages found in the shaken baby syndrome. Despite the small number of patients in this prospective study, we believe that these data support the idea that chest compressions do not result in retinal hemorrhages in children with a normal coagulation profile and platelet count. A larger number of patients should be evaluated in a prospective multi-institutional study to achieve statistical significance in a nondescriptive study. *Pediatrics* 1997;99(6). URL: <http://www.pediatrics.org/cgi/content/full/99/6/e3>; retinal hemorrhages, CPR, shaken baby syndrome, child abuse, coagulopathy.

ABBREVIATIONS. CPR, cardiopulmonary resuscitation; PT, prothrombin time; PTT, partial thromboplastin time.

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Child abuse occurs in 1% of children in the United States every year; 10% of the traumatic injuries suffered by children younger than 5 years are nonaccidental, and 5% to 20% of these nonaccidental injuries are lethal.^{1,2} Rapid characterization of the injury as nonaccidental is of considerable benefit to child protection workers and police investigators seeking to safeguard the child care environment and apprehend and prosecute those who have committed the crime of child abuse. Physically abused children present with a variety of well-described injuries that are

usually easily identifiable.² However, in some cases, particularly those involving children with the shaken baby syndrome, obvious signs of physical injury may not exist.³⁻⁷ Although external signs of such an injury are infrequent, the rapid acceleration-deceleration forces involved often cause subdural hematomas and retinal hemorrhages, hallmarks of the syndrome. Frequently, retinal hemorrhages may be the only presenting sign that child abuse has occurred.

Several studies have documented that retinal hemorrhages occur in a large percentage of child abuse cases, especially those resulting from shaken baby syndrome.⁵⁻¹⁰ Some physicians believe these lesions are pathognomonic for nonaccidental injury.^{5,11,12} Other physicians, however, have suggested that chest compressions performed during cardiopulmonary resuscitation (CPR) may cause retinal hemorrhages.^{13,14} This is supported by one prospective study¹⁴ and several anecdotal case reports. However, in nearly all cases the cardiopulmonary arrest was unwitnessed, and therefore, the etiology of the arrest is not accurately known. Furthermore, coagulation studies and platelet counts have not always been documented in these reports, and thus, the possible propensity for bleeding in these patients was not completely evaluated.

The still unanswered questions about the relationship between retinal hemorrhages and CPR have obvious medical, legal, and social implications. The physician caring for the child presenting with retinal hemorrhages must decide whether these lesions were caused by physical abuse or resulted from chest compressions given by care givers or emergency personnel. This study was undertaken to help elucidate a possible association between chest compressions performed during in-hospital CPR and retinal hemorrhages in pediatric patients admitted to the hospital for nontraumatic illnesses.

METHODS AND MATERIALS

The Pediatric Intensive Care Unit at Le Bonheur Children's Medical Center is a 20-bed medical/surgical unit and a separate 12-bed transitional care unit for technology-dependent children. There are approximately 1500 children with a wide variety of illnesses admitted to the two units per year. Approval of the study was obtained from the Institutional Review Board. Children between 0 to 16 years admitted between November 1994 and September 1996 to the pediatric intensive care unit or transitional care unit who subsequently required 1 minute or more of chest compressions after cardiopulmonary arrest were enrolled in the study. Patients were excluded from the evaluation if admission diagnosis included evidence of trauma, suspected child abuse, near-drowning, or seizures. Patients with documented retinal hemorrhages before CPR or who had CPR performed out-of-hospital were also excluded from the study. No postmortem fundoscopic examinations were performed.

Dilated fundus examinations were performed at the bedside by one of two pediatric ophthalmologists within 96 hours of the arrest and chest compressions. The posterior pole and midperipheral retina to the equator were visualized. The number, size, and type of retinal hemorrhages were recorded.

Coagulation studies, including a prothrombin time (PT) and partial thromboplastin time (PTT), and platelet counts were performed near the time of the CPR for many patients at the discretion of the attending physician. The patient's age, admission diagnosis, history of retinopathy of prematurity, etiology of arrest, length of chest compressions, coagulation studies results, platelet counts, and ophthalmological examination findings were recorded. A descriptive analysis was performed on the data.

RESULTS

Forty-three patients survived chest compressions lasting >1 minute between November 1994 and September 1996. Their ages ranged from 1 month to 15.8 years (mean = 23.2 months) (Table 1). The majority of the patients were between 1 month and 2 years (36/43). Admission diagnoses of the eligible patients are shown in Table 1, and included congenital heart defects (19/43), respiratory failure due to pneumonia, asthma, apnea, or bronchiolitis (9/43), sepsis (4/43), cardiomyopathy (4/43), congenital diaphragmatic hernia (3/43), necrotizing enterocolitis (1/43), bronchopulmonary dysplasia admitted after placement of an intraventricular shunt for hydrocephalus secondary to an intraventricular hemorrhage (1/43), arteriovenous malformation (1/43), and vein of Galen aneurysm with congestive heart failure (1/43). Two patients, one with a diaphragmatic hernia and one with a cardiomyopathy each had two episodes of chest compressions and were evaluated by the ophthalmologists after each episode. Thus, the total number of cardiopulmonary arrests after which retinal examinations were performed was 45.

The precipitating events for each of the 45 cardiopulmonary arrests are shown in Table 2. A plugged or dislodged endotracheal or tracheostomy tube was determined to be the cause in 11 of 45 arrests requiring chest compressions. Other precipitating events included respiratory failure secondary to apnea, bronchospasm, or aspiration (8/45), arrhythmias (5/45), hyperkalemia (5/45), tension pneumothorax or hydrothorax (3/45), cardiac tamponade (2/45), sepsis (2/45), and primary myocardial ischemia (1/45). In 7 of 45 episodes of cardiopulmonary arrest, the precipitating event was indeterminate.

Mean CPR interval was 16.4 ± 17 minutes and ranged from 1 minute to 60 minutes (Table 3). The majority of the episodes of chest compressions lasted for 1 to 10 minutes (26/45), although 6 of 45 lasted 11 to 20 minutes, 8 lasted 21 to 40 minutes, and 5 lasted for >40 minutes (Table 3). Two patients in our study had open chest cardiac massage during their resus-

TABLE 1. Characteristics of Patients Evaluated for Retinal Hemorrhages After Chest Compressions

No. of patients	43
Age (mean)	23.2 mo
	(range 1 mo–15.8 y)
Age ranges	
1–12 mo	33
1–2 y	3
2–5 y	2
5–10 y	1
10–16 y	4
Sex (M/F)	20/23
Diagnosis	
Congenital heart disease	19
Respiratory failure	9
Sepsis	4
Cardiomyopathy	4
Congenital diaphragmatic hernia	3
Bronchopulmonary dysplasia	1
status postintraventricular shunt	
Necrotizing enterocolitis	1
Arteriovenous malformation	1
Vein of Galen aneurysm	1

TABLE 2. Precipitating Events for 45 Cardiopulmonary Arrests Requiring Chest Compressions of Patients Evaluated for Retinal Hemorrhages

Precipitating Event	n
Plugged or dislodged endotracheal tube/ tracheostomy tube	11
Respiratory failure	8
Arrhythmia	5
Hyperkalemia	5
Tension pneumothorax/hydrothorax	3
Sepsis	2
Cardiac tamponade	2
Right heart failure	1
Primary myocardial ischemia	1
Indeterminate	7
Total no. of cardiopulmonary arrests	45

TABLE 3. Chest Compressions in Pediatric Intensive Care Unit Patients and the Prevalence of Retinal Hemorrhages

Mean duration of chest compressions (min \pm SD)	16.4 \pm 17 (range 1–60 min)
Number of patients with chest compressions lasting	
1–10 min	26
11–20 min	6
21–40 min	8
>40 min	5
No. of patients with open chest cardiac massage	2
No. of patients with retinal hemorrhages	1

citation. Ophthalmologic examinations performed by pediatric ophthalmologists within 96 hours of the chest compressions revealed multiple small punctate retinal hemorrhages bilaterally after 1 of the 45 episodes of chest compressions (Table 3). These hemorrhages were different than those observed in the shaken baby syndrome.

Coagulation studies were performed near the time of the arrest in 29 of the 45 episodes of chest compressions (Table 4). Either the PT or PTT was elevated in 27 of these 29 episodes (93%). Platelet counts were evaluated in 41 of the 45 episodes. Fewer than 2×10^5 platelets/ μ L were found in 20 of these 41 episodes (49%). Both platelet count and PT or PTT were abnormal in 29 episodes of chest compressions with 18 (62%) of these patients having abnormal values for both measurements.

DISCUSSION

Chest compressions during CPR elevates intrathoracic pressure, and the mechanism by which elevated intrathoracic pressure results in retinal hemorrhages was postulated by Gilkes and Mann.¹⁵ Blunt trauma to the thorax leads to a rise in intrathoracic pressure and an increased central venous pressure. This increased central venous pressure can result in retinal hemorrhages in two possible ways. First, the increased central venous pressure may be directly transmitted to the retinal venous system. Second, the increased central venous pressure can result in an elevated intracranial pressure that has been suggested to cause retinal hemorrhages.^{16,17} However, there is little direct evidence that the increased in-

TABLE 4. Coagulation Profiles and Platelet Counts Near the Time of Chest Compressions of Patients Evaluated for Retinal Hemorrhages

	No. Abnormal/ No. Evaluated	Percent Abnormal
Elevated PT and/or PTT	27/29	93%
Thrombocytopenia	20/41	49%
Elevated PT and/or PTT and thrombocytopenia	18/29	62%

Abbreviations: PT, prothrombin time; PTT, partial thromboplastin time.

trathoracic pressures with chest compressions during CPR result in retinal hemorrhages. Furthermore, no large scale prospective studies have been done to evaluate the association of retinal hemorrhages after chest compressions when the etiology of the arrest is definitively nontraumatic.

Whether or not retinal hemorrhages can be caused by chest compressions obviously has important medical, legal, and social implications. The consequences of misdiagnosing child abuse and attributing retinal hemorrhages to CPR can have devastating consequences for the child and other children in the care of the abuser. However, wrongly accusing a care giver of child abuse can be equally disastrous. The physician caring for the child presenting with retinal hemorrhages must decide if these ocular lesions were caused by physical abuse or the result of chest compressions that care givers or emergency personnel may have given the child. Thus, it is important to determine if retinal hemorrhages are found after chest compressions given during resuscitative efforts.

In our study, one 1-month-old patient was found to have retinal hemorrhages after chest compressions. This patient had 60 minutes of chest compressions that were done via open chest cardiac massage. Her PT was 22.9 seconds, PTT was 78 seconds, and her platelet count was 91 000 platelets/ μ L. These retinal hemorrhages were also morphologically different from the retinal hemorrhages observed in the shaken baby syndrome in that they were numerous, small punctate hemorrhages. Retinal hemorrhages were not found after any other of the 44 episodes of chest compressions, despite a majority of these patients also having a coagulopathy and/or thrombocytopenia. A second patient of the same age also had prolonged open chest cardiac massage, elevated PT and PTT and decreased platelets. This patient had no retinal hemorrhages on examination by the pediatric ophthalmologists. Thus, we find no patients with normal coagulation studies and platelet counts who have retinal hemorrhages after chest compressions. Furthermore, retinal hemorrhages are a rare finding after chest compressions in patients with a coagulopathy or a low platelet count and are atypical of retinal hemorrhages seen in shaken baby syndrome.

Although the numbers are limited, other studies also support this conclusion. Kanter¹⁸ performed a prospective study on 54 children who underwent chest compressions. Six of the 54 children had retinal hemorrhages. In five of these patients, trauma or child abuse was the precipitating event of the cardiac

arrest, although the sixth patient had seizures and severe arterial hypertension. Both of these conditions are known risk factors for the development of retinal hemorrhages.^{19,20} Kanter¹⁸ concluded that trauma should be assumed when retinal hemorrhages are found and that retinal hemorrhages should not be attributed to CPR alone. Our study differs in that all arrests occurred in the intensive care unit whereas the patients in Kanter's study occurred outside of the hospital. In addition, the events leading up to the arrest were witnessed, and all patients survived their resuscitations.

Gilliland and Luckenbach²¹ microscopically examined at autopsy the retina of 169 children who underwent prolonged resuscitative efforts. Seventy children had retinal hemorrhages, and the etiology of all but one were attributed to illnesses with which retinal hemorrhages have been associated. The cause of the cardiac arrest for the one patient with retinal hemorrhages who died despite chest compressions was listed officially as undetermined. This child came from a home in which two other pediatric deaths had occurred and episodes of abuse had been documented. Thus, these authors concluded that their data did not support the idea that retinal hemorrhages are caused by CPR.

However, some reports have suggested that chest compressions given during resuscitative attempts can result in retinal hemorrhages.^{13,14,22–25} Although one of these reports is a prospective evaluation of children who received CPR, most reports are anecdotes in which the arrests were not witnessed by anyone but the care giver. In fact, in the prospective study, one of the two arrests occurred out-of-hospital although the cause of the in-hospital arrest was unwitnessed and the diagnosis of sudden infant death was made.¹⁴ In most of these cases, intentional injury cannot be entirely ruled out. In most cases coagulation studies were not done. One case report describes an 17-month-old female infant who was evaluated for probable adenoviral gastroenteritis who had no retinal hemorrhages on her initial examination by an attending pediatrician.¹³ This patient experienced a respiratory arrest and required approximately 60 minutes of chest compressions. She was transported to another hospital and on evaluation had multiple scattered intraretinal and subhyloid hemorrhages. Her PT and PTT were normal, but her platelet count was low at 167 000/ μ L. This patient is similar to our one patient who had retinal hemorrhages in that both received chest compressions for about 60 minutes and both were thrombocytopenic. Of the other four patients in our study who had chest compressions for >40 minutes, two were thrombocytopenic, and all had elevated coagulation studies, but none of them had retinal hemorrhages. Thus, in cases with prolonged chest compressions, thrombocytopenia may be a risk factor for the development of retinal hemorrhages.

This study has the following limitations. First, the number of patients reported in this study is small. An adequate number of patients would require a multiinstitutional study. Second, a direct causal effect of chest compressions on retinal hemorrhages

cannot be practically assessed using this approach. Prearrest fundoscopic examinations would need to be performed on every patient admitted to our unit, but this would be impractical because of the large volume of patients admitted to our unit. However, we believe that the approach used in this study will determine if there is an association of retinal hemorrhages with chest compressions and perhaps identify risk factors for developing retinal hemorrhages after chest compressions. Third, we did not examine the retina of children who did not survive their CPR. The frequency of retinal hemorrhages in this population of children may differ from the frequency seen in children who survive their resuscitation and may warrant further study.

In summary, we evaluated the fundi of 43 children after 45 episodes of chest compressions. All of the precipitating events leading to cardiopulmonary arrest occurred in our intensive care unit, eliminating the possibility of physical abuse as an etiology. Despite coagulopathies in the majority of the cases, retinal hemorrhages were found in only one patient who underwent an open chest cardiac massage and had an extensive coagulopathy. No retinal hemorrhages were found in the patients who had normal coagulation studies or only abnormal PT/PTT or an abnormal platelet count. Despite the small numbers of patients in this prospective study, we believe that these data support the idea that chest compressions do not result in retinal hemorrhages in children with a normal coagulation profile and platelet count. Furthermore, retinal hemorrhages are an infrequent finding in children with abnormal coagulation studies and low platelet counts. A larger number of patients should be evaluated in a prospective multiinstitutional study to achieve statistical significance in a nondescriptive study.

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