

Shaken Babies—Some Have No Impact Injuries

REFERENCE: Gilliland, M. G. F. and Folberg, R, "Shaken Babies—Some Have No Impact Injuries," *Journal of Forensic Sciences*, Vol. 41, No. 1, January 1996, pp. 114–116.

ABSTRACT: One study has questioned the validity of shaking as a mechanism of head injury in children. A prospective, postmortem study investigated 80 deaths from head trauma to identify the roles of shaking and direct impacts. Evidence of shaking was defined as two or more of the following criteria: 1) finger marks and/or rib fractures, 2) subdural and/or subarachnoid hemorrhage, or 3) a history of vigorous shaking. Shaking to the exclusion of other head trauma was defined as the presence of two or more of the above criteria together with the complete absence of scalp or skull injuries. Nine (11.3%) of the 80 study deaths qualified as exclusively shaking injuries by this definition. Thirty (37.5%) of the deaths had direct injuries as well as two of the criteria of shaking; these deaths were classified as combined shaking and blunt trauma. Forty-one (51.3%) of the deaths had impact injuries without having two of the criteria of shaking. We reviewed the extent of ocular injuries in all the cases. We found ocular hemorrhages with increased frequency in cases with two or more of the criteria of shaking compared to cases with only impact mechanism of injury. Retinal hemorrhages continue to show themselves to be a good marker of infants injured by vigorous, intentional shaking. This study likewise confirms the observations of others that most, but not all, shaken babies have impact injuries as well.

KEYWORDS: forensic science, pathology and biology, shaken baby syndrome, retinal hemorrhage, ocular hemorrhage, child abuse

The early descriptions of whiplash shaken infant syndrome suggested that many abused children were shaken (1). Many cases were reported using clinical signs and symptoms to identify shaken baby syndrome. Ludwig and Warman excluded other evidence of abuse (external head trauma, skull fracture, multiple skeletal fractures, burns, or patterned or severe bruising) in their description of twenty shaken babies (2). They acknowledged that some of the excluded babies may have had shake injuries as well but were trying to focus on shaking as a mechanism of injury.

As more reports of systemic and ocular findings at death have been described it has become evident that many of the babies believed to have been shaken have suffered impact injuries (3–10).

In 1987 Duhaime, et al. (3) reported that all 13 fatally injured children and nearly half (17 cases) of the 35 nonfatal cases of shaken baby syndrome had evidence of blunt head trauma in their study. This group constructed a mechanical model and measured acceleration by shaking and by impact. They concluded that shaking alone did not generate adequate force to produce injuries but

that impact did result in sufficient force to cause intracerebral trauma (3). Elnor's group found impact injuries in all ten of their suspected child abuse deaths (7).

In order to investigate whether shaking without direct head trauma is sufficient to inflict a lethal injury on an infant, we reviewed findings from a large series of child deaths.

Materials and Methods

A prospective, postmortem study investigated 169 child deaths examined at the Southwestern Institute of Forensic Sciences in Dallas, TX between 1982 and 1989. Detailed descriptions of the population and methods have been previously published (11,12).

A subpopulation of 80 deaths due to head trauma was examined in this study. Deaths were classified as shaking mechanism by the presence of two or more of the following criteria: 1) finger marks and/or rib fractures, 2) subdural and/or subarachnoid hemorrhage, or 3) a history of vigorous shaking. Rib fractures were selected as part of the criteria because a postmortem radiologic-pathologic study by Spevak, et al. (13) has shown that cardiopulmonary resuscitation is unlikely to cause rib fractures in infants (13). Shaking to the exclusion of other head trauma was defined as the presence of two or more of the above criteria together with the complete absence of scalp or skull injuries. Those infants with two or more of the criteria but having scalp or skull injuries were classified as having combined shaking and impact injuries. Infants which did not have two or more of the criteria and had scalp and/or skull injuries were classified as having impact injuries.

Results

Nine (11.3%) of the 80 head-injury deaths met the definition of death by the exclusive shaking mechanism of injury. Thirty (37.50%) of the deaths had at least two of the criteria of shaking as well as direct injuries; these deaths were classified as caused by combined shaking and impact trauma. Forty-one (51.3%) of the deaths had impact injuries without having two or more of the criteria of shaking. Only one of these children had a history of being shaken vigorously without any of the other criteria (fingermarks and/or rib fractures, subdural and/or subarachnoid hemorrhage) and had facial, scalp, and subscalpular contusions.

Table 1 shows the frequency of various ocular injuries in the three groups. We compared the deaths with shaking mechanism with those with only impact injuries. We found increased frequency of ocular hemorrhages (optic nerve sheath and posterior scleral) other than retinal hemorrhages in cases with two or more of the criteria of shaking, Table 2.

Discussion

Child abuse deaths with no scalp contusions or skull injuries have been described in the literature (4–6,8–10). Table 3 shows

¹Associate Professor, East Carolina University School of Medicine, Department of Pathology, Greenville, NC.

²The F. J. Blodi Professor of Ophthalmology and Pathology, The University of Iowa School of Medicine, Iowa City, IA.

Received for publication 1 May 1995; accepted for publication 27 June 1995.

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TABLE 1—Ocular hemorrhages found in three mechanisms of head injury.

Mechanism	Total	Retinal	Peripheral	Optic Nerve	Posterior Scleral
Blunt	41	26	19	25	18
Combined	30	29	24	27	23
Shake	9	7	7	5	6
Total	80	62	50	57	47

TABLE 2—Relative Risk (RR); Greenland, Robins 95% Confidence Limits for (RR); and Yates corrected chi-squares and P-values for comparison of shaking and impacts as mechanisms of injury.

	Greenfield, Robins		Yates-corrected	
	Relative Risk (RR)	95% Confidence Lts	Chi-squares	P-value
Retinal	1.46	1.13 < RR < 1.87	7.98	0.005
Peripheral	1.72	1.19 < RR < 2.47	8.01	0.005
Optic Nerve	1.35	1.02 < RR < 1.78	3.63	0.057
Scleral	1.69	1.14 < RR < 2.51	6.45	0.011

eight autopsy studies of up to 14 deaths which specify whether impact injuries were identified. In all of these studies retinal hemorrhages were frequently identified.

This study confirmed earlier observations that some shaken babies do not have evidence of blunt head injuries (4–6,8–10). Duhaime, et al.'s model of child injury only explains the fatal injuries in their series and others in which children have scalp or skull injuries (3). Their model does not explain the nonlethal head injuries in their own series except to say that impact injuries were probably present or the impact occurred against such a soft surface that no contusions or fractures were observed.

The Duhaime model is inadequate to explain death in children with no scalp and skull injuries after complete autopsy examination. A photograph of the model is included in another article from the same work published in 1988 and shows significantly less flexure of the neck than is regularly observed in infants (14). The model is held with its head and much of its trunk above and in front of the experimenter. The head is minimally flexed compared to observations of the more extreme positions attainable in even a deceased child of that size.

Hadley, et al. responding to the conclusion derived from the Duhaime model reported five autopsied cases of whiplash-shake injury with no scalp injuries or skull fractures (5). Five of the six children also had spinal cord hemorrhages and four had spinal cord contusions consistent with a shaking mechanism of injury. The authors concluded that direct impact is not an essential element of the injury mechanism in young patients who sustain severe whiplash-shake injuries (5). Their artist's representation of the mechanism of injury corresponds to two of the confessions in our series in which the child was shaken by the shoulders.

Alexander et al. also responded to the challenge that shaking was not sufficient to cause severe brain injury observed in infants. They found that 12 of 24 infants diagnosed as having shaken baby syndrome had no evidence of direct impact (five of nine fatally injured infants and seven of 15 surviving infants) (6).

In an earlier study Jacobi reviewed injury patterns in 22 shaken babies and 19 other babies with skull impact injuries. He found

TABLE 3—Frequency of impact injuries and retinal hemorrhages in autopsy studies of child abuse.

Study	Year	Impact Injuries	Retinal Hemorrhages	Autopsied Children
Duhaime et al.	1987	13	10	13
Rao et al.	1988	11	8	14
Hadley et al.	1989	1	6	6
Alexander et al.	1990	5	ns	9
Elner et al.	1990	10	7	10
Massicotte et al.	1991	2	3	3
Munger et al.	1993	4	12	12
Budenz et al.	1994	9	11	13

ns = not stated.

that shaking (defined clinically) was fatal in 3 children while direct impacts were immediately fatal in 10. He also observed that the mean age of the shaken babies was 6 months while that of the other children was 13 months. Shaking alone was not as often fatal as direct impacts but it was a lethal mechanism of injury in the child abuse deaths in children in Jacobi's study (15).

Riffenburgh and Sathyavagiswaran studied the eyes of 77 victims of child abuse. They observed that 23 of the 47 children with retinal hemorrhages had external evidence of injury while 25 of the 30 without retinal hemorrhages had external injuries. They concluded that retinal hemorrhages were more likely to occur if the infant were shaken or swung than with severe direct head trauma (16). They did not specifically address the question of whether impact was necessarily a part of shaking-type of abuse. In this study three of the nine children classified as shaking without impact had histories of shaking. Autopsy findings were consistent with a shaking mechanism without direct impacts. Another of the seven had a history of being slammed against a bed and no evidence of impact injuries. Two perpetrators pled guilty to injury to a child; these children had no impact injuries. The last three did not have histories of trauma but had intracranial injuries and no impact injuries, similar to those with histories of shaking.

Shaking alone is a lethal mechanism of injury in some infants in this study. In this study as well as others, most infants believed to have been shaken have some evidence of impact injury. If there is a benign or trivial explanation for the impact component of the injury found in a deceased child, it does not explain severe intracranial injuries. All of children in the studies described in Table 3 had lethal intracranial injuries attributed to child abuse. Shaking injuries are part of child abuse—non-accidental, intentional injury to children (4–6,8–10). Identification of a shaking mechanism of injury with or without impact identifies child abuse.

Examination of the extent of ocular hemorrhages show that shaking and combined shaking and blunt injuries produce more ocular injuries than blunt impact alone, Table 2. The comparison of cases of shaking mechanism (both with and without impact injuries) with cases of blunt impact mechanism alone shows an increased frequency of ocular injuries in shaking mechanism of injury. Our findings agree with the conclusion of Riffenburgh and Sathyavagiswaran that retinal hemorrhages are more likely to occur in a shaking or swinging mechanism of injury (16).

The relative risk is significantly greater for retinal and peripheral retinal hemorrhages ($P = 0.005$). The relative risk is also significant ($P = 0.011$) for posterior scleral hemorrhages but is not quite significant for optic nerve hemorrhages ($P = 0.057$).

In a previous analysis of injury patterns in these children the presence of retinal, peripheral retinal, optic nerve sheath, and

intrasceral hemorrhages were strongly associated with head injury as compared with other injuries and natural diseases (Relative Risks of 8.62–52.2 and Yates-corrected *P*-values <0.001). Among the head injured (the same 80 children discussed in this study), sixty-two had retinal hemorrhages. Nine had a history of severe traumatic event (for example, an unrestrained rear-seat passenger in high-speed collision); 53 were victims of inflicted injury (for example, violent shaking). In that analysis 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 (12).

Ocular hemorrhages, especially retinal hemorrhages which can be detected with routine ophthalmoscopic examination during life, continue to be good markers of abusive shaking injuries in children.

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Address requests for reprints or additional information to
M. G. F. Gilliland, MD
East Carolina University School of Medicine
Dept. of Pathology
Brody Building 1 South 08
Greenville, NC 27858-4354