

Inflicted Head Injuries in Infants and Children *An Important Cause of Developmental Disabilities*

by Elizabeth Gilles, M.D.

Introduction

Unfortunately, child abuse remains common in the United States. According to the U.S. Department of Health and Human Services, child-protection agencies received nearly 2 million reports of child abuse in 2002.

Child abuse is rarely premeditated. It occurs when caregivers lose control — often while trying to stop behavior (such as crying) or when punishing perceived transgressions (such as toileting accidents). Caregivers cause injuries by shaking, throwing, hitting, slapping, gagging, strangling and smothering children. Children with physical, cognitive, emotional and developmental disabilities, and those with physical health problems, are more vulnerable to maltreatment.

Inflicted head injuries occur predominantly in children younger than 3 years. Although inflicted head injuries are less common than accidental head injuries, they're more likely to cause morbidity and mortality. Survivors of inflicted head injuries commonly experience behavioral, cognitive and motor disabilities, as well as visual impairments and seizures.

Mandated reporting laws require physicians and other health-care professionals to report patterns of injuries and behavior that raise concerns of abuse or neglect. Studies show that — especially when injuries are not severe — health-care providers misdiagnose about a third of inflicted head injuries in infants and children during initial examinations. When such injuries are incorrectly attributed to unintentional trauma or disease, children remain at risk. In fact, before a correct diagnosis is made, approximately 25 percent of such children sustain additional injuries or die from subsequent head trauma.

Terminology

John Caffey, a radiologist, coined the terms “battered child syndrome” and “shaken baby syndrome” in 1962 and 1972, respectively. By labeling injury patterns, Caffey heightened

the awareness of abuse and, therefore, inspired more research into accidental and inflicted head injuries. Conversely, labeling has had deleterious consequences. Terms such as “shaken baby syndrome” underestimate the ages of those injured, the complexity of injury-event sequences and the mechanisms of injury. In addition, popularizing such terms has led to at least two types of errors.

The first is that overly simplistic analyses of clinical and imaging data can result in abuse being over- or under-diagnosed. The second is that, in court cases, defense experts have increasingly relied on symptoms common to accidental injuries — such as the presence of impact evidence and the absence of retinal hemorrhages — to “prove” a child wasn't shaken, when in fact there is clear and convincing evidence that abuse occurred. For these reasons, this article uses the term *inflicted* to describe childhood neurotrauma from assault.

Case Example

A.J., a 4-month-old boy in excellent health, was left with his mother's boyfriend. Five hours later, the boyfriend called the mother and said that A.J. wasn't breathing. The mother called 911. When paramedics arrived, A.J. was unresponsive, with gasping respirations and a rectal temperature of 92 degrees. A.J. was intubated and transported to the hospital. Shortly thereafter, he experienced seizures. He was given a loaded dose of phenobarbital and placed on a ventilator.

A.J. was unresponsive to sensory stimuli, and his anterior fontanelle was full. He had two finger-shaped purplish bruises on the right side of his face, a bruised right pinna, and a fingertip bruise at the angle of the left mandible. He also had a 2-centimeter purplish bruise on his left thorax and petechiae on the inner right ear and posterior palate. The frenulum of A.J.'s upper lip was torn and the occiput was boggy. He had extensive bilateral subhyaloid and inner-retinal hemorrhages without papilledema. Capillary refill was four seconds. A.J.'s

Questions to Consider

When examining a child with head injuries, a physical examination alone shouldn't rule in — or out — inflicted neurotrauma as the cause of the injuries. Consider the following questions:

- Are the injuries confined to the head?
- Are the brain injuries focal or diffuse, or both?
- Are there injuries that suggest a specific injury mechanism (slap mark, strangulation bruising, etc.)?
- What is the clinical timing of the injury?
- Is there evidence of injuries of varying ages (e.g., old bites)?
- Are there other suspicious patterns of injury (e.g., rib fractures)?
- What forces were required to cause such injuries?
- Does the history account for the physical findings?
- Was there a delay in seeking medical attention?
- Are there changing histories?
- Was the injury witnessed?
- Is there an accidental mechanism that might result in the injuries?

pupils were small and nonreactive. He had an oculoccephalic (doll's eye) response, but no corneal reflexes. A.J. had no gag reflexes, cough or spontaneous movements; he was areflexic.

A non-contrast computed tomography (CT) scan showed diffuse cerebral hypodensity, bilateral thin convexity and an interhemispheric acute subdural hematoma. There was an occipital subgaleal hematoma, right parietal soft-tissue swelling, and an 8-centimeter left parietal skull fracture. A skeletal survey showed the skull fracture and three acute, left thorax rib fractures (T6-T8).

The mother described A.J. as a fussy baby who had "bad colic," but was otherwise healthy. She said that A.J.'s behavior was normal on the day of the injury and said he had eaten well that morning. He was developing appropriately. The attending physician filed mandated reports of suspected physical abuse to county social-services and law-enforcement officials that day.

In a police interview, the boyfriend stated that he fed A.J. about two hours after the child's mother left for work. He said A.J. "choked" and he "hit the baby on the back to get him breathing." He said A.J. became limp and apneic (stopped breathing). When told that his history didn't account for the physical findings, he stated that he "shook" the baby "a couple times" to get him to breathe.

Two days after being hospitalized, A.J. was declared brain-dead and life support was withdrawn. Autopsy results revealed that A.J. had four cranial-impact sites, a previously undiagnosed basilar fracture, bilateral retinal and optic-nerve sheath hematomas, and extensive brain necrosis. The forensic pathologist ruled A.J.'s death a homicide by blunt-force trauma.

When law-enforcement officials presented the autopsy findings to the boyfriend, he broke down and admitted to getting angry with A.J. because he wouldn't stop crying. He said that, after force-feeding him, he grabbed him with his right hand and slapped him hard across the left side of his face. He said that A.J. went limp and stopped breathing. About two minutes later, the boyfriend said, A.J. started to "whine" and make "funny noises." He said he punched the baby, then picked him up by the shoulders and threw him against the wall. A.J. stopped moving and his breathing became irregular. The boyfriend panicked and called the infant's mother. He eventually pleaded guilty to felonious child abuse and manslaughter and was sentenced to five years in prison.

This case exemplifies many of the issues involved in evaluating and documenting suspected child abuse, determining injury mechanisms, and unraveling the sequence of events that led to the injuries. A physical exam was essential to establishing an inconsistency between the boyfriend's explanation and the child's injuries. An autopsy supplemented the exam findings.

Mechanisms of Injury

Brain and other injuries occur when applied forces strain brain and other tissues beyond their structural tolerance. Primary mechanisms of injury include forces developed when the head accelerates about the neck (angular acceleration) and from impact (translational forces). Rotational acceleration results from any action that moves the head from side to side or front to back. Impact plus rotation increases the applied force substantially. Primary injuries are typically focal or diffuse. Significant forces are required to cause severe inflicted injuries.

Secondary mechanisms involve the brain's reaction to primary injuries. They include hypoperfusion of brain tissue (from hypotension/shock) and hypoxia.

Symptoms

In general, greater applied forces result in more severe injuries. That's true whether the injuries are accidental or inflicted. Acute symptoms after head injuries are non-specific, including altered mental status, seizures, decreased feeding, listlessness, lethargy, vomiting, fever and altered breathing. More severely injured infants and children are comatose, flaccid and apneic. Less severely injured infants might exhibit irritability, altered behavior, vomiting and a decreased appetite.

Injury Patterns

Although there are no pathognomonic injuries that prove a child has been abused, some findings and constellations of injury make abuse a more likely cause. Inflicted head injuries are characterized by a variety of findings that reflect the primary-injury dynamics and secondary-injury insults. The following discussion focuses on extra- and intracranial injuries. Other injuries (such as fractures and abdominal trauma), particularly in the absence of a major trauma history, help confirm a diagnosis of inflicted injuries.

Ocular and Optic-Nerve Sheath Hemorrhages

Retinal hemorrhages are exceedingly common in inflicted head injuries. These hemorrhages are found in 47 to 100 percent of cases (depending on study design), but aren't pathognomonic. A pattern of extensive retinal hemorrhages, vitreal hemorrhages and retinal detachment is more likely to have been caused by abuse than by accident.

In children with asymmetric intracranial pathology, retinal hemorrhages tend to be ipsilateral to the side of greatest brain injury and subdural hematoma. They are not pathognomonic, being found in a number of disorders, including subarachnoid hemorrhage and meningitis. Retinal hemorrhages in children with papilledema have no diagnostic significance. Optic-nerve sheath hemorrhages, found in autopsies, are much more common to inflicted head injuries than to other conditions.

Extracranial Injury Patterns

The most common impact injuries are scalp bruising, soft-tissue swelling, cephalohematomas, subgaleal hematomas and fractures. Scalp bruising is visible in less than half of children with cranial impact. The finding of a "Battle's" sign (bruising over the mastoid) or "raccoon's eyes" (bilateral periorbital bruising) raises suspicion of a basilar skull fracture. Skull fractures are common in inflicted and accidental head injuries. In both, simple linear fractures predominate, most frequently in the parietal region. Fractures that cross suture lines, and are bilateral or multiple, are more likely to have been caused by abuse, especially when the history suggests a single impact.

Intracranial Injury Patterns

Infants younger than 12 months tend to develop diffuse-brain swelling (with or without bilateral acute subdural hematomas). Older children and adults, on the other hand, more commonly develop focal swelling or hemispheric swelling under an ipsilateral convexity subdural hematoma. Diffuse-axonal injuries are common.

In infants younger than 8 months old, shear strains may result in white-matter tears deep into the gray-white matter junction. Older children and adults more commonly sustain cerebral contusions from *coup-contre-coup* (hit and counter-hit) injuries as the brain moves within the skull. The injuries typically are worse on the side opposite the initial impact (the *contre-coup*). Infants appear to be more susceptible than older children to ischemia (hypoperfusion injuries). Infants frequently experience strokes, presumably from vascular compression as a result of brain swelling.

Subdural hematomas are the most common form of intracranial bleeding in children. In abused infants, they are typically inter-hemispheric and either unilateral or bilateral over the convexities. Such injuries resolve in the majority of infants and young children. In some infants, however, the liquifying subdural fails to reabsorb, and subdural effusions develop. These infants present with or without spasticity and with or without a history of trauma. They might also show macrocephaly or irritability. Some of these infants require neurosurgical intervention. Small

patchy subarachnoid hemorrhages, commonly found during autopsies, usually aren't clinically significant.

Differential Diagnosis

Falls and birth trauma are the most frequently offered explanations for infants and children presenting with inflicted head injuries. Numerous studies of short falls and falls down stairs consistently have found that low-velocity, low-impact events rarely cause serious brain injuries. Nonetheless, complicated short falls can infrequently result in intracranial findings (such as a subdural hematoma), but they usually don't cause severe brain injuries. Unintentional trauma is unlikely to cause a severe head injury unless there are significant applied forces, such as a vertical fall of more than 10 feet or a high-speed motor vehicle accident.

Birth injury is not a reasonable explanation for an infant who was developing normally and who suddenly presents with evidence of trauma and a severe brain injury. An infant who presents with a large intraventricular or subarachnoid hemorrhage should first be examined for a vascular malformation. Retinal hemorrhages caused by vascular malformations are typically extensive, and their distribution resembles that found in infants with severe inflicted head injuries.

The differential varies depending on the physical injuries. Other diagnoses to be considered include accidental (unintentional) trauma, coagulopathies, leukemia, meningitis, vascular malformations, brain tumors, and glutaric aciduria I. Retinal hemorrhages don't result from cardiopulmonary resuscitation, seizures, or vomiting. In situations where there's uncertainty, additional assessments by physicians with expertise in abuse and neglect might be helpful.

Timing of Injury

Clinicians can estimate the time at which an injury occurred by reviewing the history, clinical and physical findings, and imaging data. In general, the more severe the injury, the easier it is to determine when the injury took place. From the time of a severe brain injury, infants and young children are immediately symptomatic and often unconscious; there is no lucid interval. The timing of seizures cannot be used to time injury events.

Documentation

Detailed documentation — including the patient's injury history and the clinical course over the preceding 72 to 96 hours — is essential. If a low-velocity fall history is obtained, ask the investigating agencies to obtain scene photos. In the medical record, put caregiver statements in quotations as much as possible. Doing so helps identify inconsistent or changing histories, and quoted statements are often admissible in court. Although physicians aren't investigators, they are the only people capable of evaluating a patient's purported history and biomechanical data in a medical context.

Mandated Reporting

Before reporting, explain to the caregiver(s) that:

- The child sustained a serious brain injury not explained by the history
- You are a mandated reporter who is legally required to make a child-abuse report
- You will contact social-services and law-enforcement agencies, which will investigate

Having a social worker present may be helpful. Don't share details of your clinical findings or suggest possible explanations for the injuries. Such discussions could affect later forensic interviews.

Mandated reporting to county social-services and law-enforcement agencies is required as soon as you have a reasonable suspicion that abuse has occurred. Don't wait until all assessments are complete. Although there is a cross-reporting

mandate between social-services and law-enforcement officials, it might not happen immediately. Once law-enforcement officials are notified, they will launch an investigation parallel to the social-services agency's investigation.

Summary

Inflicted head injuries are an important cause of infant morbidity and mortality. Establishing reasonable suspicion that abuse has occurred, or eliminating it as a possibility, requires:

- An index of suspicion
- An understanding of the pathogenesis of various clinical findings
- A differential diagnosis of each physical finding

Developing a consistent case approach is very helpful, as is seeking expert opinions when you are unsure whether abuse has occurred.

Guidelines for Exams

Physical Examinations

Document serial examinations and note all vital signs, including rectal temperature. In addition to your usual exam:

- Record head circumference, state of hydration and any obvious signs of neglect.
- Palpate and inspect all skin surfaces, particularly the cranium, behind the ears, and the back of the head (occiput).
- Inspect the genital and anal areas.
- Measure and sketch all bruises, noting their color.
- Obtain medical photography using both a color bar and a ruler.
- Note the presence of ear discharge (otorrhea) and nasal mucus (rhinorrhea), which can be easily confirmed as cerebrospinal fluid by using a Clinitest Stix.
- Inspect the neck closely, particularly along the lower jaw, for subtle signs of strangulation. Petechiae above the neck, behind the ears, and especially around the eyes suggest strangulation or smothering.
- Look for small contusions or lacerations of the lips.

Before performing a dilated funduscopic examination, obtain permission from the trauma surgeon or neurosurgeon in charge (or ask a pediatric ophthalmologist to complete such an exam).

Neurological Examinations

- Record the patient's level of arousal and reactivity to auditory, visual and sensory stimuli.
- Examine the cranial nerves, noting pupillary reactivity; oculocephalic, corneal and facial movements; the presence of cough and gag reflexes; and any elevation of the palate. If all of these are severely abnormal, consider performing (or asking a pediatric neurologist to perform) cold-calorics and an apnea test.
- Document the pattern of motor and sensory findings (e.g., hemiparesis or paraparesis) and reflexes.

Radiographic Evaluations

A non-contrast CT scan to include bone windows is the initial imaging study of choice. A magnetic resonance imaging scan might be useful in determining the timing of brain injuries and identifying the extent of brain injuries. Physicians should obtain a full skeletal survey in any child younger than 3 years old. A bone scan might be indicated if there is suspicion of fractures evident on X-rays.

Laboratory Evaluations

Infants who have sustained inflicted head injuries are frequently anemic and acidotic on admission. Hyperglycemia is common and correlates in general with more severe injuries. More severely injured infants might require an insulin drip. Extremely young infants might develop adrenal insufficiency. As with other head-injured populations, secondary consumptive coagulopathy (disseminated intravascular coagulation) is associated with a higher mortality rate and more severe brain injuries. A suggested initial lab profile includes:

- A complete blood count and differential platelets
- A basic metabolic panel
- Liver and renal function tests
- Protine, partial thromboplastic time and fibrinogen tests
- Lactate tests
- Arterial blood-gas tests
- Urinalysis

If there is significant bruising, consider obtaining a creatine phosphokinase test.

In situations where a clinical index of suspicion arises or an alternate diagnosis has been proposed, additional studies might be useful. Consultation with a metabolic geneticist might be helpful if there is a question of an inherited metabolic or genetic disorder.

Author's Profile

Elizabeth Gilles, M.D.

Elizabeth Gilles, M.D., is a pediatric neurologist at Gillette Children's Specialty Healthcare in St. Paul, Minn. At Gillette, she treats children with complex neurologic issues, including traumatic brain injuries and epilepsy. Gilles has a special interest in childhood neurotrauma and neurotrauma related to child abuse. She is a member of the National Neurotrauma Society, the Child Neurology Society, and the Society for Neuroscience.

Known nationally for her expertise in diagnosing and treating inflicted neurotrauma, Gilles has written articles and chapters on the subject and has been an invited presenter at numerous local and national conferences. She ran child-abuse programs while in the U.S. Navy at Camp Lejeune Marine Corps Base (Jacksonville, N.C.) and in Torrance, Calif., when she was director of Child Abuse

Services and the Child Abuse Crisis Center at Harbor – University of University of California, Los Angeles, Medical Center.

Gilles received her medical degree from the University of Pittsburgh School of Medicine. She completed a residency in pediatrics at the United States Naval Regional Medical Center in San Diego, and she later completed a residency and a research fellowship in child neurology at Children's Hospital Los Angeles and the University of Southern California. Gilles is an assistant professor of pediatrics and neurology at the University of Minnesota in Minneapolis.



Gillette Welcomes New Physicians

Randa Jarrar, M.D., pediatric neurologist, and Lee Schuh, M.D., physical medicine and rehabilitation physician, have joined Gillette Children's Specialty Healthcare.



Randa Jarrar, M.D.

Jarrar, who is originally from Jordan, completed her medical degree at the University of Jordan. She completed a residency in pediatrics at the University of Illinois in Chicago and one in pediatric neurology at Mayo Clinic in Rochester, Minn. Jarrar completed a fellowship in electroencephalography and epilepsy at Mayo Clinic in Rochester, Minn., and one in electromyography and neuromuscular conditions at

Mayo Clinic in Jacksonville, Fla. At Gillette, Jarrar will focus on neuromuscular conditions and epilepsy. She will use electromyography in her practice.



Lee Schuh, M.D.

Schuh completed his medical degree at the Medical College of Georgia. He completed a combined residency in pediatrics and physical medicine and rehabilitation at the University of Cincinnati and Children's Hospital Medical Center in Cincinnati. At Gillette Lifetime Specialty Healthcare, located at the New Brighton Clinic, Schuh will work with adolescent and adult

patients who have cerebral palsy, spina bifida and neuromuscular conditions.

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