A Matter of Gravity

Elaine Whitfield Sharp, TLC '98

A Matter of Gravity[1]" is Part II of a three-part series. In Part I, "The Elephant on the Moon,[2]" we saw that in the world of science, if one sets out to prove a hypothesis, one risks proving a fallacy and creating pseudo science rather than reliable science. The syndrome called "shaken baby syndrome" or "SBS" is based on faulty assumptions that, in the past half century, many set out to prove, but few set out to test. While shaking may cause injury to a child's brain stem, cranio-cervical junction and upper cervical cord, it has now been falsified as a mechanism of causing intracranial bleeding above the convexities of the brain and to other areas of the brain.

In Part II, we look at another area of pediatric head injury—short falls—and we ask the question: Can they kill? Or, are the stories of short falls nothing more than tall tales woven by the guilty to obscure their evil acts of abuse? And, what of stories of children who fall and seem fine, only to fail and die later? Can some children experience a lucid interval with few or no symptoms after a traumatic brain injury (TBI) caused by a short fall or an alleged act of lethal shaking?

These are forensic issues of "mechanism of injury"—how much gravity on the head is too much?—and "timing of injury"—can there be a delay between TBI and death? These are questions that defendants charged with child abuse by blunt impact and/or shaking must be able to answer. If they do not, twelve angry people, bent on avenging the death of an innocent, surely will.

NOT SO TALL A STORY

She was the only one who saw what happened to two-year-old Andy that day. So, even though Billy Jo was just six years old at the time, it made sense to put her on as the first witness for the defense. She walked to the stand, carrying a pillow to boost her up to the microphone so the jurors could hear her small voice in the cavernous, New Deal courtroom. Here is what she said:

> I was visiting my older sister [Sally]…and I asked if [my cousin] Andy and I could go out to play for awhile, and we played [in the back yard]…of Sally's house…Then Andy found a hole in the fence and then he went over in the neighbor's yard and I followed him …He got on the neighbor's steps and I got on…and I tried grabbing him…and I grabbed him around the waist but he pulled away and he fell down the [concrete] steps. His legs sort of hit mine and we went doing somersaults down and I ended up on top of him and he was holding his hand over his head sort of like this and then I ran in the house and got [my sister]…He was…still laying there, starting to cry.

As Billy Jo finished her story, she proudly displayed the battle scar on her knee that she got falling down the steps with Andy that day. Andy did not survive to tell the story. He died four days later, suffering the complications of the intracranial injuries he sustained in the fall.

When Andy stopped breathing and turned blue days after his tumble down the concrete steps, he was in

the sole care of his mother's boyfriend, Steve. It didn't take long for the doctors at the local hospital to accuse Steve of killing Andy by violently shaking and slamming his head down with force equivalent to a two-story drop, head first onto concrete. The nature of the injuries had to be intentional and could not have been accidental, they reasoned. And, claimed the doctors, Andy's injuries had been "inflicted" just minutes before Steve ran into the emergency room (ER) with the limp and lifeless toddler in his arms. They as much as said, "Steve did it."

The two main pillars of the State's forensic case—mechanism of injury and timing of injury—had been formed by the treating physicians even before the police were called. These were the twin pillars upon which the State would build its case against Steve for felony murder. If convicted, he would spend 25 years to life in prison.

Only Billy Jo knew the real story.

FAULTY FOUNDATIONS

The same pillars of the State's forensic case against Steve are typically employed in most cases of alleged shaken-baby-impact syndrome. But they have no solid, scientific foundation.

The fact is that short falls do kill. Frequently, the injuries caused by short falls involving impact to the head are the same as those described in so-called "shaken-baby-syndrome" (SBS) cases: Subdural hematomas,[3] subarachnoid hemorrhages,[4] retinal hemorrhages,[5] brain edema[6] and diffuse axonal injury.[7] The diagnosis of pure shaking (without impact) is often made because there are no bumps or bruises on the head. However, bangs to the head on some surfaces do not always leave a mark.[8]

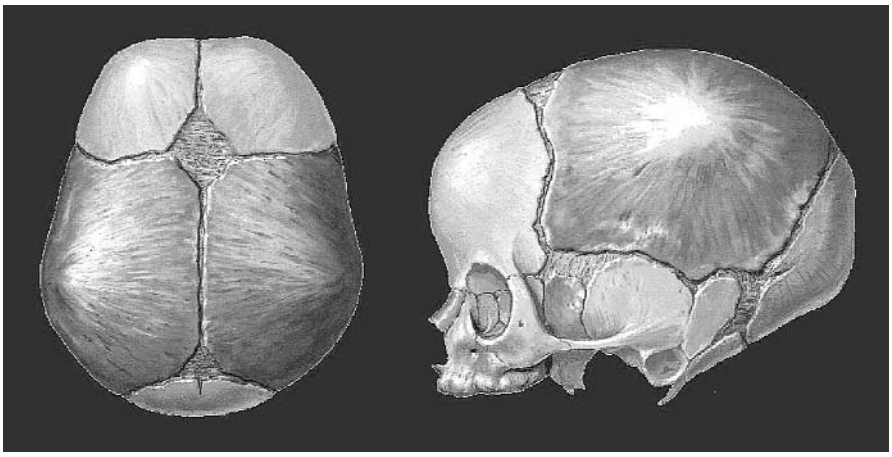
The fact is that claims by the State's "experts" that they can pinpoint the time of injury to minutes or hours and, by doing so, identify the culprit, are scientifically unreliable.

As with most suspect "science," the problem in the area of pediatric head injury causation and timing of injury is one of focus. Many physicians were taught in medical school and in practice to believe that children with SDH's, SAH's, RH's and/or cerebral injury (such as DAI) have been either violently shaken and/or slammed down with massive force. Accounts of accidental short falls related by frantic parents and caretakers in ER's are ruled out in the differential diagnosis as "inconsistent" with the "evidence," that is, as mere tall stories to cover up their crimes. Pediatrician David Chadwick, M.D. wrote in 1991 in *The Journal of Trauma*:

> In children whose injuries are inflicted, parents typically invent accident histories which they hope will be accepted by health care providers. Since most falls of over 10 feet usually require that the fall occur outdoors (from a window, balcony, or other such location), caretakers may not wish to risk the possibility that a history could be proven false by a neighbor or passerby. *It is also very possible that many lay persons believe that short falls may be fatal for children and are surprised to encounter skepticism. The best explanation of the findings for the…children who die[] is that the history was falsified.* (Emphasis added.)

The mere existence of the injury is commonly used to infer the element of intentionally-inflicted injury through the use of massive force. One court outlined the danger of this type of faulty reasoning with the following syllogism:

1. Some children who suffer subdural hematomas are children who have been subjected to trauma or force such as that sustained by a fall from a multistory building or being unrestrained in a high-speed automobile accident.
2. This child sustained a subdural hematoma;
3. Therefore, this child was subjected to trauma or force equal to or exceeding that caused by a fall from a multistory building or being unrestrained in a high-speed automobile accident.[9]



Infant Skull Showing "A-shaped" Lamdoidal Suture.

A child who falls and hits his or her head on the occiput, i.e., the back of the head, where the plates of the skull have not fused at the "A-shaped" lamdoidal sutures, is at much greater risk for injury. The skull is weak here and so the brain is more vulnerable to injury. Think of it like this: The ice on a lake is weakest at the points where the cracks converge. Blows to the back of an infant's head may be lethal because the material properties are different.

The error of the syllogism is that just because *some* children suffer TBI by falling from buildings or from car accidents does not prove that *all* children who suffer TBI have fallen from a building or have been in a car accident or have been subjected to equivalent forces.

THE BIRTH OF THE BEAST

We join this sorry tale of accusing parents of falsifying stories about short falls causing injury to their children in 1977, the year when Ray E. Helfer, M.D., a physician from Michigan State University (MSU) looked through old medical records and reported incidents where children fell out of beds and from counters. Earlier, physicians who claimed SBS was the real mechanism of SDH's, SAH's, DAI and RH's, had warned that tales of short falls were to be rejected. As child abuse accusations gathered momentum and as more parents professed their innocence, Helfer and his colleagues were determined to prove that injuries from short falls do not cause severe head injuries. He wrote in *Pediatrics*:

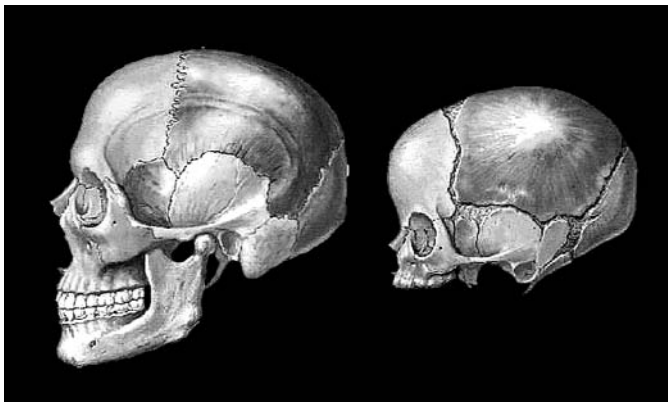
> Occasionally, a child who is reported to have fallen out of bed presents with a skull fracture, cerebral edema, retinal hemorrhage, subdural hematoma, and/or epidural hemorrhage. *These severe injuries are discrepant with the history; it is often the discrepancy that indicates child abuse."* (Emphasis added.)

At the outset, Helfer had fallen into the trap of confirmation bias, one of the hallmarks of unreliable "science." He assumed that skull fractures, cerebral edema, RH's, SDH's, and/or epidural hemorrhages "indicate[] child abuse."

With faulty hypothesis in hand, Helfer studied the reports of 246 children aged six-months to five years old who had fallen out of a bed, a crib or from an examining table in the hospital, and from beds and couches at home. All were falls of 36 inches or less. Of the 85 incidents reported in hospitals, one child fractured his skull when he fell from an examining table. Of the 161 children who fell from short heights in the home, two fractured their skulls. According to Helfer, none of the three children with skull fractures sustained serious head injury.

Among many design and interpretation flaws in Helfer's study, the claim that "no serious head injury" resulted was made for children injured from 1969 to 1975, a time when testing for the sequelae of traumatic brain injury (TBI), such as neuropsychological tests, was less developed and much less available than it is today. In other words, there is nothing in the study to convince the reader that a TBI associated with the skull fracture was, in fact, reliably ruled out.

There is also no mention of follow up MRI scans or EEG's to rule out TBI and, instead, only a vague reference to "physicians records." One of the hallmarks of peer review literature in medicine and science is that the reader (i.e., the peer) has reliable data to enable her to form an independent judgment about the validity of the author's conclusions. Even without more data, Helfer's conclusions are not reliable for, as any lawyer representing traumatically-brain-injured clients knows, lack of gross neurological deficit does not mean that the person has not sustained a TBI. It is only when a child grows that the sequelae of a TBI may become obvious.



Pediatric vs. Adult Developmental Differences in the Skull
To understand the causes of pediatric head injury, we must understand not only issues of force (F=Ma), but also the material properties of the skull and brain.

Another flaw in the Helfer study was that it was based on inductive reasoning. From that fact that *he* had not been able to find many severe injuries in his study, he concluded that such examples are "rare" and/or a parental cover up, writing, "From this study we must conclude that severe head injury and CNS damage or injury of any type are extremely rare when children, aged five years or less, fall out of bed."

Even if one accepts Helfer's flawed analysis, "rare" does not rule out the possibility that serious and fatal head injuries may be caused by a short fall. There are several examples in the clinical literature where children who fell from short heights suffered fatal head injury. (More on this later.)

The main forensic flaw in Helfer's study was that it made no attempt to account for the biomechanics of the falls. Biomechanics is the science of how injury to human tissue occurs. Then, as today, no medical school curricula required medical students to study the field of biomechanics, that is, the science of injury causation. Despite this void in training, pediatricians and forensic pathologists frequently testify as "experts" about the degree of force necessary to cause injury.

Most pediatricians and forensic pathologists are, in fact, unable to scientifically define the degree of force needed to cause a specific injury. According to the principle of Newtonian physics, force is the product of mass (size and weight of the object) and acceleration (the change in speed of the object). Force is expressed as "F=ma."

Irving Root, M.D., was a forensic pathologist who critically questioned the assumptions of doctors like Helfer that short falls could not generate sufficient force to cause serious head injures to children. He tried to introduce some common sense to the debate by applying F=ma to free-falls.

Root calculated the terminal (impact) velocities starting from heights ranging from two feet up to 30 feet, and wrote:

"To put this in common perspective, the average adult will walk at a sustained speed of 2.5–4 mph and will be able to run a short sprint at top speed of [about] 9–12 mph. (World class sprinters achieve a 100 yd dash in 10 [seconds] and attain a speed of 22 mph.)…. To put this further in perspective, assume yourself to be an average adult and imagine running, at your top speed, headlong into a brick wall. It does not take a great deal of imagination to grasp the magnitude of the impact."

Root's chart shows that in a free fall of only three feet, one would hit the ground at 9.4 mph. *(Please see Root's Chart, at right.)*

ALL SHORT FALLS ARE NOT EQUAL

The drop height of the fall does not, alone, determine the potential for injury. Some people do fall great distances and survive while others fall short distances and die. This is where it becomes critical to identify and understand the biomechanics of the fall.

Unfortunately, while biomechanics has been used in solving many medical problems, it has been largely ignored in documenting the forces and causes of pediatric head trauma. Biomechanics is the science by which the pumping strength and motion of the heart is measured to better design prosthetic heart valves. It is the science of measuring stress and strain on cartilage to better design prosthetic cartilage, tendon and bone. Heart-assist devices, heart-lung and dialysis machines, and prosthetic limbs all owe their function to the science of biomechanics. University of California bioengineer Y.C. Fung wrote, "biology can no more be understood without biomechanics than an airplane can without aerodynamics."[10]

Living systems have mechanical properties. They have tolerance criteria and failure rates to stress and strain, torque and torsion just like any other material on the face of the earth. Poet Thomas Lynch, who is also a funeral director in Michigan who has seen his fair share of dead children, reminds us, "God lives by The Laws of Nature and obeys its statutes, however brutal. Kids die of gravity and physics…"[11]

ROOT'S CHART

TABLE: Terminal velocities from given heights*	
S	Speed
(ft)	(mph)
2	7.7
3	9.4
4	10.9
5	12.2
6	13.3
7	14.4
8	15.4
9	16.2
10	17.2
20	24.4
30	29.8

*Based on the basic formula, $V^2=2GS$, where in free fall capacities, V=velocity, G=32ft/s^2, and S=distance

Consider what would happen to you if you ran head first into a brick wall. Short distance falls do kill, depending on the material properties of the skull and brain, the contact surface and the mechanics of the fall.

So let us learn to ask the questions that are critical to the science of pediatric head injury causation. Once again, Root lends a hand in the Department of Common Sense.

- Was the fall a free fall?
- What was the actual distance of the fall? (Note that this is only one of the questions to ask.)
- Which specific part/parts of the anatomy was/were impacted?
- Where and how was the force delivered and distributed? Over what area and time is the energy impacted?
- Was all the force taken up at once?
- Did the body roll and dissipate the force?
- Did the child slide down with friction, for example, on the edge or side of a bed or a chair? (This would slow the free fall and lessen the energy of impact.)
- Was the child sitting up or standing when the fall began, adding distance from the head to the floor?
- Was there some initial impelled added energy, i.e., some rocking motion or an attempt to catch the balance and, possibly, throw oneself further off?

The location of the impact to the head is, depending on the age of the child and contact surface, even more important than the impact velocity, whether by accident or intent. A child, whose sutures between skull plates have not fused, is at much greater risk for brain injury from a short fall or other impact. If the skull changes shape on impact, the brain deforms, tearing bridging veins and other vessels and irreparably ripping neurons and axons apart. The risk of serious injury is further increased for a baby if the trauma is at the back of the head (i.e., the "occiput") where the three plates of the skull converge in the A-shaped lamdoidal suture. Think of it this way: the ice on a lake is weakest at a point where the cracks are converging (*Please see graphic on page 28, showing the "A-shaped" lamdoidal suture at the back of the infant skull*).

The contact surface also makes a difference to the potential for head injury from a short fall. Concrete is a lot less forgiving than a gym mat.

In the case of Billy Jo and Andy falling down the steps, Billy Jo had taken the two-year-old down with her when she

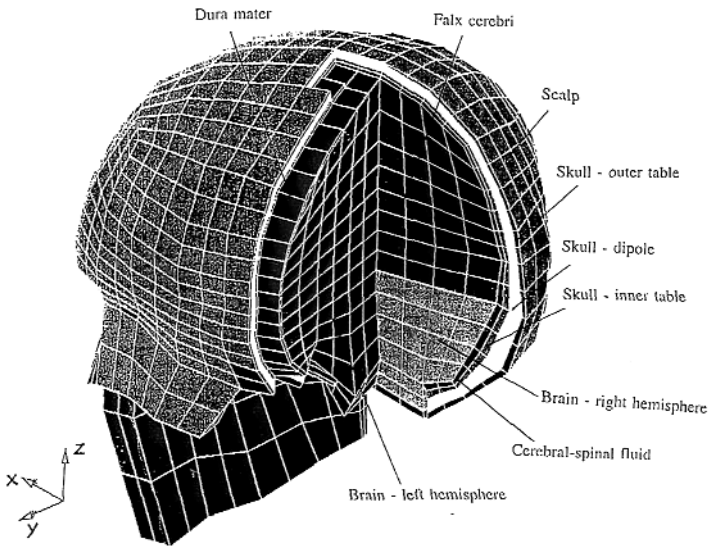
lost her balance, fell and, landing on top of him, increased the force (by increasing the weight) with which the toddler's head hit the ground. One of the pediatricians called by the State to testify that Andy's head injury was not an accident, was asked on cross examination:

Q: Doctor, you didn't investigate in detail the biomechanics of the fall, did you?

A: I didn't find it necessary.

What is not appreciated or understood by the pediatrician "expert" is equated with "not necessary." Understanding pediatric head injury causation is confounded by conflicting reports in the clinical medical literature. The conflicting cases can only be reconciled by understanding the necessity of the biomechanical analysis of falls. Few physicians do. Even fewer try.

Almost completely lacking is any evidence-based medicine applying biomechanics to the area of pediatric head injury. This is so even though now, unlike in the days of Helfer's study, we possess the technology to conduct such studies. That technology, called "finite element analysis," involves the use of a computer into which data about the material properties of the infant skull and underlying brain can be loaded. The models can then be manipulated with known degrees of force to determine the potential for injury. Arguments are often made that finite element analysis has no biofidelity to the human body. In fact, it is accurate; so much so that it is used by automobile manufacturers to test the design of vehicles and their contents to manufacture safer vehicles and, thus, avoid large products-liability judgments.



Modeling Head Injury

Biomechanicians who are experts in human injury causation usually attend the first two years of medical school to study subjects such as human anatomy and physiology. They are able to combine this knowledge with geometry, mathematics and physics to create models of the human head on computers.

THE LONG AND SHORT OF IT
MAXIMUM VS. MINIMUM FALLS

Most studies of pediatric head injury caused by short distance and long distance falls contain almost no analysis of fall mechanics or of the material properties of the pediatric skull and brain. What an object is made of determines how it responds to stresses and strains caused by impact. Without this scientific information, all of the fall studies are fallible. What can be said that is helpful is, that because there are clinical examples in the medical literature where children fell short distances and died from serious head injuries or from untreated complications of relatively minor head injuries, no physician can reliably rule out a short fall as the cause.

Even so, the problem for the defense is often that long falls or maximum impacts known to cause fatal head injury are invariably used to infer the level of force "inflicted" on a child. The level of force is then used to prove the element of intent to injure and to rebut a defense of accident.

MAXIMUM HEIGHTS

In 1991, David Chadwick, M.D., a pediatrician practicing at Children's Hospital, San Diego, Calif., studied falls of all children brought to The Children's Trauma Center between August 1984 to March 1988. It was a retrospective study, that is, one that looks back in time and selects its participants. Retrospective studies, despite best human efforts, are subject to selection bias. Chadwick decided at the outset that children whose caregivers claimed they sustained serious head injury from short falls, were not telling the truth. This is called "confirmation bias." While some of the 317 children in Chadwick's study may have been victims of abuse because they had multiple injuries, some simply had head injuries. Of these, Chadwick wrote in *The Journal of Trauma*:

"Inflicted injury is often diagnosed when the clinician can state with a high level of certainty that the single injury seen in a child could not possibly have been produced by the event described by the caretaker."

* * * * * *

"For the most part this discrimination is based upon the physician's clinical experience of children's injurability [sic] and the limited empirical studies[12] in the literature."

This pediatrician, with no training in biomechanics of pediatric head injury causation, then proclaimed that the caregivers of seven of the children in his study who died from falls had "falsified" the "histor[ies]."

In making this judgment, Chadwick relied on two studies. In one study, children who fell 30 feet and more sustained fatal head injuries. In another study, the lowest fall was from 15 feet. This was the lowest fall that caused life-threatening injury and death, Chadwick claimed. He is not alone. It is from this type of study, in which it is claimed that only falls from

great heights can cause catastrophic and fatal head injury, that many physicians conclude that massive impact velocities—equivalent to a drop of two, three or four stories head first onto concrete—are required to cause such injuries.

It doesn't take a brain surgeon or a physicist to figure out that falls from great heights cause serious head injury. These documented falls and the injuries sustained by the children provide us with a reference point of known *maximum* heights. It is common sense that falls from maximum heights cause serious injury. But it takes a biomechanician to figure out what is the *minimum* impact velocity required to cause serious head injury to children.

To date, no one has answered the question of what is the *minimum* impact velocity it takes to cause skull fracture and/or brain injury in a child who is one month old, two months old, three months old, and so on. The research has not been done. One biomechanician received a grant in 1996 from the U.S. Department of Health and Human Services to study the issue using finite element analysis, but lost the funding before the project was completed. His idea was to determine the material properties of the infant skull and the infant brain and, applying different impact velocities, determine the minimum impact velocities that would cause injury.

Despite the fact that we still do not have vital information about the minimum forces needed to cause serious and fatal head injury in babies and toddlers, "experts" for the State are allowed to testify about the injuries in cases of children who fall from great heights, as though falls from great heights are *required* to cause such injuries. This happened in People v Martinez, 51 P.3d 1046 (2001). Martinez was charged with murder of his girlfriend's four-month-old daughter, whom the physicians diagnosed as a victim of shaken-baby-impact syndrome. The baby had SDH's, RH's, SAH's, a skull fracture and scalp bruises. After several interviews, including one in which Martinez was encouraged to confess by detectives who had been told by the doctors that the injury happened that day, the defendant claimed he had grown frustrated and shaken the baby, *accidentally* banging her head on the crib. The degree of intent, i.e., whether Martinez acted "knowingly," "recklessly" or was "criminally negligent," was an issue the State tried to resolve by quantifying the level of force.

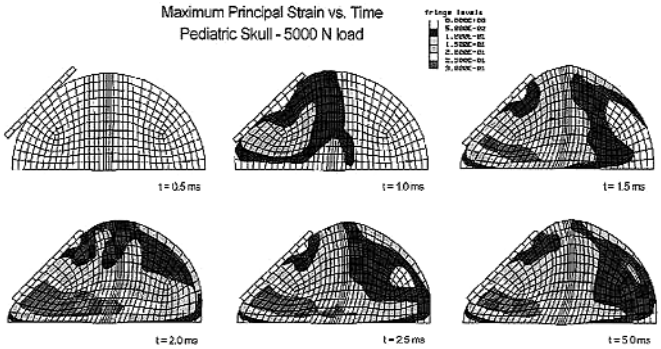
The State's "expert" pediatrician on head injury causation, testified:

> In talking about how much force that it requires to cause this kind of injury, we can't take babies and shake them and do that for the obvious reason, so what we have had to do is take—there have been multiple studies of series of witnessed falls or witnessed accidents where babies have had similar kinds of injuries. Okay? And in those studies, babies who had similar kinds of injuries, the subdural hematoma, have been things like a fall from a multiple story building. Being in a high speed motor vehicle accident either as a pedestrian hit by a high speed motor vehicle or, for example, an unrestrained passenger in a high speed motor vehicle accident, so those are the kinds of witnessed injuries that can lead to a similar sort of injury.

Martinez was convicted of first degree, knowing murder of a child by a person in a position of trust. Reversing and remanding, the Colorado Court of Appeals agreed with Martinez that it was unfairly prejudicial for the State to infer the minimum amount of force needed to cause the baby's injuries from maximum-force accident scenarios. The court wrote:

> *It is one thing clearly to state that a certain quantum of force is necessary to produce a subdural hematoma; it is quite another to use examples of obviously extreme forces and violence that have been demonstrated to have caused subdural hematomas and then suggest that they constitute the* ***minimum*** *force necessary to cause such an injury in any particular case. In our view, reasonable inferences as to the underlying issue cannot be drawn from that testimony.* (Emphasis added.)

The Colorado Supreme Court ultimately reversed the panel's decision on other grounds, and remanded.[13]



Impact Modeling of the Infant Head

Using a method called "finite element analysis," biomechanicians can predict the deformation in mock pediatric brain tissue that is caused by a maximum "load" of 5000 Newtons, that is, about 1,100 pounds. This is equivalent to the force generated in a drop of about 13 feet in a one month old infant. Looking at the series from top left to right, then bottom left to right, early in the impact sequence, that is, at time "0.5 milliseconds" (ms, one one-thousandth of a second), one can see that there is almost no local deformation of the brain tissue. From 1.0 ms to 5.0 ms, the wave of energy from the impact moves through the brain tissue causing deformation in a larger area with each passing millisecond. This results in tissue "stretch" at sites distant from the site of impact. Graphic: "Pediatric Head Injuries: The Influence of Brain and Skull Mechanical Properties," Thibault, K., PhD, 1997.

(For assistance in elaborating on this graphic, thanks is due to Robert Cargill II, PhD, managing engineer in injury biomechanics at Exponent Failure Analysis, Philadelphia.)

MINIMUM HEIGHTS

Japanese neurosurgeon Nobuhiko Aoki presented a study in 1984 in the *Journal of Neurosurgery* in which 26 children between four to eleven months old developed subdural hematomas and retinal hemorrhages from short falls onto various types of contact surfaces. (One child was slapped.) Two of the children who fell short distances died.

In 1989, J.R. Hall, M.D., reviewed files of the Cook County [Illinois] Medical Examiner's office during 1983-86 for cases related to childhood falls. Eighteen of 44 children who died had only "minor" falls which happened either while they were running or from falls from furniture (less than three feet). These 18 all died from head injuries, alone, without any other fall injuries. One child in this group was dead on arrival (DOA) at the ER. She was an eight-month-old girl who fell off a couch onto a hard wood floor. Her autopsy revealed a large, acute subdural hematoma. Investigations of the 18 cases ruled out abuse as the cause of the injuries. Indeed, two of the minor falls occurred while the children were under medical investigation. Hall wrote: "'Minor falls' can be lethal, especially in a toddler, and must be evaluated."

In 1996, neurosurgeon Anne-Christine Duhaime, M.D. wrote about the cases of four children who sustained unilateral SDHs after three of the children were witnessed to have fallen short heights in the home, and one where the child had fallen from a window. What we are told in the article is that the SDHs resolved. But, there was no mention of follow up evaluation as to whether the children in the study suffered permanent brain damage.

In 2001, John Plunkett, M.D., reviewed 18 short-distance, accidental falls by children. The falls were from two to ten feet. Twelve of these were witnessed by people who were not the caretakers so, arguably, their accounts were independent. Thirteen of the children had subdural hematomas. Four of the six children for whom ophthalmology exams were documented in the medical record had bilateral retinal hemorrhages. All of the children died. (Subdural hematomas and bilateral retinal hemorrhages are said by many physicians to be caused by shaking.)

In one tragic case related by Plunkett, a grandmother was videotaping her 23-month-old granddaughter clambering on a jungle gym. When the toddler got to the top, she was standing 28 inches above the ground. Suddenly, she lost her balance and plummeted onto the concrete garage floor, covered by a one-inch plush carpet remnant. Hands outstretched, the toddler struck the carpet, then hit the front, right side of her head, finally landing on her shoulder. Afterwards, she got up and walked and talked, but started vomiting and went into a stupor five minutes later. This toddler had scalp damage, SDH's and bilateral retinal hemorrhages. She died a few days later of the secondary effects of the primary impact. It is chilling to realize that this tragedy might have been compounded. Without the videotape, grandma would probably now be behind bars.

That short falls do kill is beyond dispute. The literature proves it. Such cases exist, even though we don't fully understand why. However, to look at clinical case series studies to answer the question of what forces are involved in causing injury without a scientific frame of reference, is like staring at a few pieces of the jigsaw puzzle and never having enough to complete the entire picture.

One way to complete the picture is for federal and state governments and private foundations to fund evidence-based-medicine research in the science of pediatric head injury causation. The tolerance and failure rates of human tissue can be measured, especially as the practice of anatomical giving is growing. Data from tests on this tissue, as well as data already collected, can be programmed into a computer and, using geometry, physics and mathematics, tested at various anatomical sites with a range of impact velocities. But, so long as millions of dollars each year are pumped only into programs to recognize and prevent the dubious shaken baby syndrome, the critical questions will go unanswered and false accusations will abound. Not even grandma is safe unless, of course, she has a videotape.

TIMING OF INJURIES TELL-TALE SIGNS AND SYMPTOMS OF OLDER INJURIES

State "experts" frequently testify about the timing of the injury in order to assist the government in pinning the "crime" on the accused. But brain injury and its sequelae are complex. All is not what it seems.

A parent or caregiver inexperienced and unknowledgeable about the sequelae of a TBI may think a child is fine after a fall . *Some* of the sequelae of TBI include loss of consciousness, history of behavior change, seizures, vomiting (especially projectile), depressed mental status, irritability, bulging fontanel, focal neurologic findings, such as, pupils dilated and eyes not following, or loss of vital signs.

Symptoms of a TBI may be caused by an expanding SDH pressing on the brain. A SDH may expand slowly, depending on how many of the bridging veins are torn in the fall, or may stop bleeding and start to resolve, until some event, such as a new and even inconsequential trauma causes it to bleed again. The issue of rebleeds is controversial, but it is only through the rebleeding of a chronic SDH that a person exhibits symptoms of a SDH. Rebleeds have been described in the neurosurgical literature for more than a century. They can occur from new trauma or, seemingly, spontaneously. They occur when children, who have acute SDH's, continue to rebleed while they are in the hospital under the care of dedicated doctors and nurses. While we don't know all the answers to the questions about why rebleeds happen, we know they do.

These symptoms of the cascading, secondary effects of initial head trauma, such as edema or subdural re-bleeding, are well recognized symptoms of a TBI in the ER, so much so that ER doctors give parents a head injury check sheet. These sheets, developed in part by various brain injury associations, warn that if these symptoms develop after the child has been sent home, parents should immediately bring the child back to the ER.

Despite this standard of care in clinical practice, once in the witness box as an "expert" for the State, many physicians testify that there are no delayed symptoms or lucid intervals after TBI, or at least, "not in *this* case." Why? Because the prosecution needs to squeeze clinical reality out of the picture in order to create a legal fiction. It needs to fix the time of the injury and, in so doing, identify the period of exclusive access providing the opportunity of the accused to inflict the injury. Therefore, the State's experts argue, the onset of symptoms after the abuse was "immediate" or "followed closely."

It's important, therefore, to fully document, through interviewing all those who had contact with the child following an accidental fall, what the child's behavior was after the fall.

But, sometimes, children are asymptomatic after a head injury, as shown in a study published in 1999 in *Pediatrics* by Boston-based doctors David S. Greenes, M.D., and Sara A. Schutzman, M.D. In that study, of 608 children brought to one local ER for head injury, 30 children were found to have intracranial injuries. Of those, 16 were active and alert, showing no symptoms of what was happening inside their heads. Only CT scans and/or X-rays diagnosed the injuries.

In 1999, a proponent of shaking as a mechanism of injury published an article in the *Journal of Forensic Sciences* in which she reported that some of the 76 infants she studied—whom she believed were victims of shaking, blunt trauma, or both—had a lucid and symptom-free interval after being lethally shaken or otherwise head injured.

Mary G. F. Gilliland, M.D. examined five so-called pure shaking cases, i.e., in which no impact was proved, and found that four of them resulted in severe symptoms in less than 24 hours, but one child (20%) did not have severe symptoms for 24-48 hours. Gilliland also reported that in 39 blunt trauma cases resulting in death, six did not develop severe symptoms for 24-48 hours, three for 48-72 hours, and three did not develop severe symptoms for more than 72 hours. Even in fatal cases labeled as "combined" shaking and blunt trauma, eight of 32 children did not develop severe symptoms for 24-48 hours, and one did not develop severe symptoms for more than 72 hours. The article concludes:

> Enough variability in the interval between injury and the time of severe symptoms or presentation for medical care in fatally injured children exists to warrant circumspection in describing such an interval for investigators or triers of fact. Our data indicate that the interval is brief (less than 24 hours) in almost 3/4 of cases of head injury, especially in shaking injuries. However, in more than 1/4 of the cases, the interval from injury to the onset of severe symptoms is longer.

Gilliland's work confirms that brain injury is complex and that we are still in an unfathomable, black hole when it comes to understanding its intricacies.

Ayub K. Ommaya, M.D. wrote about a syndrome he called, "Talk, Detoriate and Die" (TADD). Ommaya studied adult victims of TBI and noted that some of them were talking and walking right after the event, but later deteriorated and died.

Experts for the State sometimes claim that the TADD syndrome does not occur in children. At least one study falsifies that claim. R.P. Humphreys, M.D., described four cases in which children who had been in car accidents or who had fallen each had a lucid interval. Deterioration ranged from 30 to 50 hours.

While the reason for and extent of the delay may lie in the nature of the primary injury, in genetic and age-related factors, delayed symptoms are not unusual because the secondary effects of an initial blow to the head are not unusual.

A blow to the head may cause a SDH that does not clot. It may cause damage to neurons and axons that, in turn, leak fluid from their damaged cell walls causing edema. There are many secondary sequelae of a bump on the head and often, if unchecked and untreated, they are lethal.

Edema is believed to be a particularly dangerous foe of head injured children. In 1984, Netherlands physician J.W. Snoek, M.D., described the cases of 42 children who, following seemingly trivial trauma, developed neurological signs after a lucid or symptom-free period. He believed that because the brain of a child (defined as 0 - 18 years) is different from an adult's brain, it is exquisitely susceptible to slowly developing and, sometimes, lethal edema. He termed it "malignant cerebral edema," an awful process with which neurosurgeons are all too familiar and of which they are all fearful.

"WHAT" VERSUS "WHO" DUNNIT

When the State points the accusing finger of child abuse, jurors are not merely interested in hearing what did not happen. They want to hear what did happen. How did the baby or toddler die? The defense needs to appreciate that there is a functional presumption of guilt at work, and needs to prepare to carry the burden of proof as to how the child died. This is no time to be silent. For the accused, investigating alternative theories of causation can mean the difference between life and death. This is precisely what it meant in the case of Tamara Sawyer (the last name is her real name).

Tamara's story begins one muggy morning in northern Florida. Baby Thomas' parents have arrived at Tamara's house to drop him off, as usual, at 6 a.m. They entrust their six-month-old son to Tamara, a sister in the evangelical congregation to which they all belong. "Sister Tamara" cares for Thomas for just a few dollars a week. She believes this is a way of loving her neighbors by helping them to work and to survive. They are new immigrants from Nigeria.

On this morning, there is nothing unusual about the routine: Tamara takes the sleepy baby from his mother's arms and lays down with him and her own toddler to nap on a futon mattress on the floor.

Her peaceful slumber is broken by the sound of baby Thomas gasping for breath. She reaches for him, picks him up and peers at his face. His eyes, like a doll's, are rolling back in his head. White. No pupils. Arms and legs stiffening straight out. Palms up. He turns blue. He does not seem to hear Tamara's voice.

Tamara tries to revive him and, gently shaking him, she whispers "Wake up Thomas, Thomas, Thomas…wake up…" He is gasping for breath and is turning bluer. Tamara, now frantic, calls 911.

The ER doctor at the local children's hospital diagnoses Thomas with subdural hematomas, i.e., bleeding beneath the dural covering of the brain, retinal hemorrhages, i.e., bleeding in and between the retinal layers behind the eyes. He learned in medical school that when a child has subdural hematomas and retinal hemorrhages, this means that the child was violently shaken or slammed. Recently, the American Academy of

Pediatrics issued a position statement that, if the caretaker does not have a plausible explanation for these injuries, it means the child is a victim of "shaken baby syndrome." This doctor, like so many others, is unaware that the scientific foundation for the syndrome has been invalidated by two experiments using a model baby. He does not know that this invalidation has been corroborated by studies from other disciplines such as neuropathology and forensic pathology. He may not know about the clinical cases where children fell short distances and died. He may not know that no one knows the minimum impact velocity it takes to injure an infant of Thomas' age and sex. And, he may not know…. well, you can now fill in the blank.

The ER doctor diagnoses the time of the injury. He says it was "inflicted" just minutes before Tamara called 911, when Thomas was in her sole, physical custody. In his role as a mandated reporter of suspected child abuse – and as one who may be criminally prosecuted for failing to report—the ER doctor notifies the police and the local department of social sevices. The police arrive to question Tamara, but the ER doctor has already informed them that she is a child killer.

Tamara soon faces prosecution and the death penalty. There is evidence of blunt impact, and the other injuries, such as retinal hemorrhages, had to be caused by violent shaking, the State claims.

But, at autopsy, the top of Thomas' skull was as thin as a plastic milk jug. This could be seen in the photographs that showed a translucent calvarium sitting on the autopsy table after it had been removed so the medical examiner could remove the brain. The lights of the autopsy room shone right through it. In his rush to judgment, this curious detail seems to have escaped the medical examiner's eyes.

One had to ask: Why was Thomas' skull was so thin? It took a Chicago-based forensic neuropathologist, Jan E. Leestma, M.D. to answer the question. Thomas suffered from birth injury to cisterns—known as the "ventricles"—deep within his brain. Thomas had been five weeks premature. It is well known by obstetricians and biomechanicians that premature children are at much greater risk for birth injury than are full term babies. The ventricles are involved in the manufacture, circulation and reabsorption of cerebral spinal fluid (CSF), a water-like fluid that bathes the brain in nutrients.

The forensic neuropathologist found that small filters in the ventricles were clogged with calcium, which is part of the scar tissue after injury. The result was that Thomas' brain had become hydrocephalic, meaning that it had become enlarged because it contained too much of the watery CSF. The response of bone to strain and pressure is to remodel. This is similar to Wolff's law, i.e., that the body lays down bone tissue where it is needed and does not put it down where it is not. In Thomas' case, a juvenile osteologist opined that his body removed the membranous bone from his skull and did not lay down any new bone tissue. It was not "needed" and it was in the way of his expanding brain. His skull became thinner and thinner to allow his brain more and more room to expand. Thomas' skull was so thin that, by the time he stopped breathing in Tamara's arms he was, literally, playing life without a helmet, his thin skull obscured by a mop of springy hair. In 1999, Oregon neurosurgeon Joseph H. Piatt, Jr., wrote that in cases of hydrocephalus, babies "are exceptionally susceptible to subdural hemorrhage after what would be otherwise inconsequential trauma." Hydrocephalus and SDH's cause intracranial pressure (ICP) to rise. Increased ICP is one cause of retinal hemorrhaging.

Even though there was a forensically solid, alternative theory of causation, the risks of trying the case were too great not to take the plea offered by the State after it learned, in part through a Frye motion, of the defense. Tamara was an African American. She was overweight. She was poor. She was female. There was a dead baby and the State was pointing its finger at her. The plea was three years, with credit for time served. (This, in contrast to the risk of death.) She took it. Tamara had given birth to her fourth child in pretrial custody. She had four children waiting for her on the outside. Tamara is alive, and today she is free thanks, in part, to a forensic neuropathologist who detected the microscopic evidence of older injury in Thomas' brain. The defense gave Tamara currency with which to negotiate in what had previously been a game in which she had no power.

The case of Tamara Sawyer and the case where Andy and Billy Jo tumbled down the steps have much in common. In each case, forensic neuropathology was critical. In Tamara's case, the issue was injury to the cisterns. In other cases, one may find healing cells at the site of a subdural hematoma or in retinal hemorrhages. These are forensic gifts because they refute the State's oft-chanted mantra that the injury was inflicted minutes or hours before the child was brought to the ER. Billy Jo's testimony about the fall and the defense position that this fall—four days earlier—caused Andy's fatal head injuries, including SDH's, was corroborated by the forensic neuropathology: At the site of the SDH's, there were healing cells that were four to five days old.

PRINCE LLEWELYN'S LAMENT

Things are not always as they seem. In the rush to judgment, false accusations fly fast and furious. Such accusations based on faulty assumptions can, as in the Welsh folklore tale of Prince Llewelyn (Loo-ell-in) and his dog Gelert, cause heartbreak, incarceration and even death. As the story goes, Prince Llewelyn returned after a hunt to his castle in Beddgelert, Caenarvonshire, to find his dog Gelert's jaws dripping with blood. His son had been left in Gelert's care but the baby was not to be found. In his distress, Llewelyn slew the faithful hound. It was only later that Llewelyn found his son, close to the body of a wolf, which the hound had killed.[14]

And, so it goes when a child is injured and dies: We look to place blame. Someone must pay. But blame without reliable science to support it is unjust. Accusing a parent or babysitter of killing a child by slamming the child's head with massive force and of doing it within a specific time frame, may be to slay the faithful hound.

POST SCRIPT

No vocabulary of thanks and praise includes words sufficient for what I, and the accused, owe to death penalty special-

The Lament of Prince Llewelyn (Loo-ell-lyn)
Things are not always what they seem. Prince Llewelyn slayed his hound Gelert when he rushed to the judgment that the dog had killed his son, the baby prince. Later, Llewelyn discovered the truth, but it was too late.

ist Ed Stafman of Tallahassee, Florida, and criminal defense lawyer Warner Eisenbise of Wichita, Kansas to whom I was co-counsel in the specific cases included in this article. Thanks is due to neuropathologist Jan Leestma, M.D., for helpful discussions and to neurosurgeon Ronald H. Uscinski, M.D., who invited me into the OR to see both chronic and acute SDH's to help me understand how rebleeds occur.

NEXT ISSUE

Shaking a baby cannot cause many of the injuries that the State's experts claim. Short falls can be fatal, and the signs and symptoms of TBI after a short fall can mimic those of so-called SBS. The mechanism of injury proffered by the State is frequently unreliable.

There are documented cases of lucid intervals or delayed symptoms after TBI. The timing of the injury proffered by the State is frequently unreliable.

Sometimes, an expert has improperly applied good science to a case.

Faced with the State's "expert" testimony and depending on strategic considerations, the defense may want to consider filing a motion in limine to exclude unreliable science. Three cases give some guidance: (1) Daubert v Merrill Dow, 509 US 579 (1993), (2) General Elec. v Joiner, 522 U.S. 136 (1997) and (3) Kumho Tire Co. v Carmichael, 119 S. Ct 1167 (1999). (All of these cases are now embodied in FRE 702.) Some states have adopted Daubert and its progeny. Others are still using Frye v United States, 54 App. D.C. 46 (1923), or a combination of Frye and Daubert.

Part III will include examples of how to challenge mechanism of injury, timing of injury, misapplication of science to a case, and expert qualifications.

ENDNOTES

1 This is part of a book by Elaine Whitfield Sharp. Copyright by Elaine Whitfield Sharp, October 2003. Permission to publish given to *The Warrior*.

2 Part I may be obtained by ordering a back issue of The Warrior, or may be accessed in PDF by logging on to www.sharplaw.biz.

3 Subdural Hematoma (SDH): Bleeding beneath the dural covering of the brain. In this article, SDH refers to bleeding beneath the dura over the convexities of the brain. It does not refer to bleeding beneath the dura around the brain stem or upper cervical cord. Such injury may indicate that a child was injured by shaking.

4 Subarachnoid hemorrhage (SAH): Bleeding beneath the arachnoid meningeal layer covering the brain. In this article, the use of the term SAH refers to bleeding over the convexities of the brain, only, and not to bleeding beneath the arachnoid layer around the brain stem and upper cervical cord. (Please see previous endnote.)

5 Retinal hemorrhage (RH): Bleeding behind and between one or more of the retinal layers around the eye.

6 Brain edema: Swelling of the brain due to leakage of water from dead or injured brain cells.

7 Diffuse axonal injury(DAI): Injury to the axons and neurons of the brain on a global or diffuse scale, as opposed to localized injury. In this article, the use of the term DAI refers to microscopic brain cell injury in all parts of the brain, except the brain stem, the cranio-cervical junction (where the brain stem joins the upper cervical cord) and the upper cervical cord. DAI in these latter areas *may* indicate that someone shook the baby.

8 The topic of the potential injury to the infant brain on blunt impact was discussed in Part I, "The Elephant on the Moon." (Please see endnote 2.)

9 People v Martinez, 51 P3d 1046 (2001) (R'hrg den. 2002) (cert. granted, 2002); People v Martinez, 74 P.3d 316 (2003) (R'hrg den. 2003).

10 Fung, Y.C., Biomechanics: Mechanical Properties of Living Tissues, Ch. 1, p 1 (Springer, 2d ed, 1993).

11 Lynch, T, The Undertaking: Life Studies from the Dismal Trade, pp 45-46 (Penguin, 1997).

12 There are no "empirical studies in the literature" that are scientifically reliable.

13 Martinez, supra.

14 Dictionary of Phrase and Fable (Wordsworth 1996).