The Elephant on the Moon

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There is no greater assault on American families by the State than the current use of junk science to accuse and convict mothers, fathers, brothers, sisters, grandparents, friends and babysitters of abusing babies by so-called "shaken baby syndrome" (SBS).

This article is the first in a series presented to suggest ways to first understand the history and background of the scientific disputes about the SBS diagnosis and then, in turn, defend cases of alleged shaken baby syndrome (SBS). Part I is about some of the major scientific flaws in the theory of shaking as a cause of pediatric brain injury. Part II is about alternative theories of causation, such as, accidental short falls, as explanations for the signs and symptoms commonly attributed to shaking. Part III is about how to make a (state) Daubert or Frye motion to challenge the State's science in cases of alleged shaken baby syndrome.

PART I

THE ELEPHANT ON THE MOON[1]

Sir Paul Neal, the renowned 17th century astronomer, couldn't believe his eyes. He had been peering through his telescope at the dimly-visualized details of the moon when he spotted an elephant on the lunar surface! As a highly-regarded member of the Royal Society, he felt it was his obligation to announce his finding to a world in which the possibility of men living on the moon had developed into a topic of serious debate among members of learned societies. Neal was publicly humiliated and ridiculed—and the Royal Society with him—when it turned out that, in fact, what he had taken for the trunk of an elephant was actually the tail of a mouse that had crept into his telescope.

News of Neal's illusory elephant on the moon sent a thunderclap through the scientific community of the day forcing scholars to sit up and take note of the fact that, when one sets out to prove a hypothesis, the truth may be the first casualty of the quest.

Truth is often the casualty when junk science is used in the courtroom. Junk science or, as it's sometimes called, "pathological science," relies heavily on faulty scientific methodology where researchers set out to prove hypotheses they have prejudged as correct (as did Sir Paul Neal) rather than first testing the limits of their theories to see if they are false. Courtroom scientific evidence critic Peter Huber describes some of the problems plaguing this myopic approach:

> [P]athological science often depends on experiments at the thresh hold [*sic*] of detectability, or at the lowest margins of statistical significance. The claims frequently emerge from a body of data that is selectively incomplete; wishful researchers unconsciously discard enough "bad" data to make the remaining "good" points look important. That the measurements are at the very threshold of sensitivity is an advantage, not an obstacle: data that don't fit the theory are explained away; those that fit are lovingly retained. Professional statisticians call this "data dredging."[2]

The Elephant and the Moon: Sir Paul Neal announced his finding to the world. But, in fact, all he had found was a mouse trapped in his telescope.

The medical literature upon which the diagnosis of Shaken Baby Syndrome (SBS) is based is replete with more than half a century of confirmation bias of the kind that caused Sir Paul Neal's demise. It is composed of a patchwork of "studies" each often consisting of less than a handful of cases which include suspect "confessions" to shaking and inconsistent methods of analyzing the 'science.'

The "data" that have been cobbled together to support the hypothesis that shaking causes brain injury to children has a statistical significance of zero. And, "bad data" that outright disprove or challenge shaking as the cause

of brain injury in children are routinely discarded and explained away because they do not fit the prevailing misdiagnosis of Shaken Baby Syndrome (SBS). In this area of medicine and forensic pathology a mere hypothesis has become a scientific conclusion without a reliable scientific basis.

In the United States alone, where there may be as many as 5,000 to 6,000 criminal prosecutions annually involving shaking as the claimed cause of brain injury to babies, it is critical to understand whether shaking a baby is, indeed, the cause of brain injury, or merely a mouse trapped in a telescope.

But first, a little history.

The Great Debate: Reason vs. Science

The debate over junk science in SBS resonates in the age-old debate between reason and science. It's a debate that has raged in many scientific circles about one hypothesis or another throughout history. For example, the Greek philosopher Aristotle (384-322 B.C.) reasoned that matter was continuous and that it could be subdivided indefinitely, without ever reaching any limit. He argued that matter had no ultimate underlying structure.

Another Greek philosopher, Democritus (about 460-370 BC), reasoned that matter was discontinuous, i.e., that it did have an underlying structure so that at some point matter could no longer be subdivided. He called this smallest unit of matter the "atom" (from the Greek word *a tomos*, meaning "not cuttable"), a basic unit that he believed was indestructible.

Having now split the atom, we now believe we know who was right in this area of what is called "particle physics." But, at the time, the problem with the Greek philosophers' approach was that it was based only on a debate between competing *reasoning*. The battle of competing reasoning could not resolve the *scientific* dispute about the continuity of matter. In the times of Aristotle and Democritus, *experimentation* was not used in any systematic way to decide between alternative theories or hypotheses. Observations led to hypotheses, but the process, in general, ended there. As a result, the acceptability of a hypothesis was based on the authority of the philosopher. For the next 2,000 years, the validity of any particular "scientific" claim was based upon the reputation of its proponent in the established scientific community and his rhetorical reasoning skills.[3]

The Modern Scientific Method

Science began to prevail over reason with, for example, Francis Bacon (1561-1626), an English philosopher and a pioneer of the modern scientific method. Bacon taught that truth was derived not from the reasoning ability of an authoritative person, but from experience, observation, and *testing*, i.e., experimentation.

How does a particular scientific proposition come into being? While every discovery has its own path, one that is frequently twisted and full of wrong turns, what follows is the basic map. First, someone notices some thing, such as, a phenomenon, and based on that observation develops a theory or hypothesis about what it may mean or how it's caused. Take, for example, Newton's falling apple and his hypothesis of gravity. He saw the apple fall (observation and experience) and he formed a hypothesis about the cause (gravity). To test the validity of the theory or hypothesis, Newton had to design an experiment or have a measuring tool: He developed an area of mathematics (now called "calculus") to help him test his hypothesis.

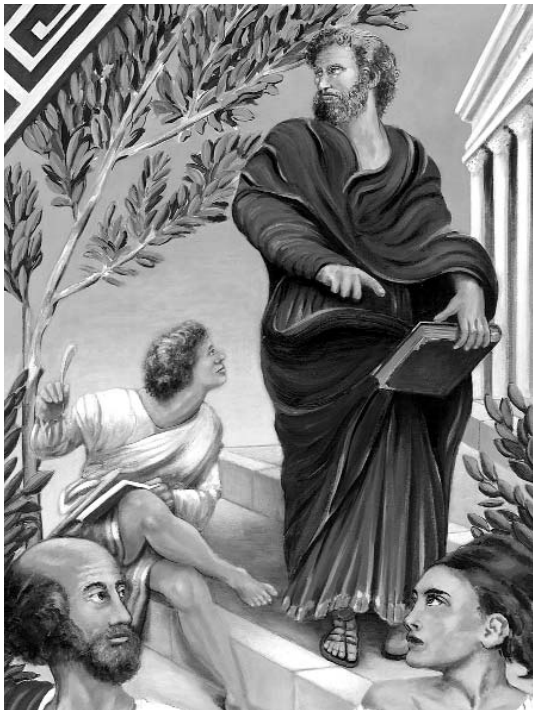
However, as Sir Paul Neal and the Royal Society learned, it is futile to set out to prove a theory and run the risk of confirming a fallacy, rather than first investigating, testing and identifying reality. To avoid the danger of announcing elephants on the moon, the modern scientific method sets out to *disprove* the hypothesis rather than by confirming it (as did Sir Neal). This is the process of "*falsification*" proposed by 20th century philosopher Karl Popper.

The debate between reason versus science has raged for millennia, such as that between aristotle and Democritus over whether matter was continuous.

Science Goes to Court

In Daubert v Merrell Dow, 509 U.S. 579, (1993) the U.S. Supreme Court relied heavily on the work of Karl Popper and others to redefine the meaning of 'science' that is deemed sufficiently reliable for a jury's consideration. Justice Blackmun wrote for the majority:

> Ordinarily, a key question to be answered in determining whether a theory or technique is scientific knowledge that will assist the trier of fact will be whether it can be (and has been) tested. 'Scientific methodology today is based on generating hypotheses and testing them to see if they can be *falsified*; indeed, this methodology is what distinguishes science from other fields of human inquiry.' …Id., at 593. (Italics added.)



Aristotle's authority carried the day because he was more authoritative in the days when experimentation was not used in any systematic way to resolve disputes over competing hypotheses.

Quoting Popper, Justice Blackmun continued: "[T]he criterion of the scientific status of a theory is its falsifiability, or refutability, or testability." Id., 593. Popper said this criterion was the defining characteristic of empirical—i.e., good, reliable and, therefore, relevant—science. If a hypothesis has not been falsified despite searching inquiry, then its scientific proposition is accepted.

In addition to the falsifiability question, the Daubert Court gave other criteria for the trial judge to use on remand to evaluate the scientific reliability of the plaintiff's claim that the prenatal, anti-nausea drug Bendectin caused plaintiff-Jason Daubert's horrendous birth defects. This list, which necessarily changes depending on the area of science being offered as evidence, includes whether the scientific tests being proffered have known or potential rates of error, whether the results have been peer reviewed, and whether the science is generally accepted in the relevant scientific community.

Before Daubert, the sole standard for admissibility of scientific evidence was whether the alleged "science," was "generally accepted in the relevant scientific community." Frye v United States, 54 App. D.C. 46 (1923).

In 1923, James Alfonso Frye was on trial for murder in Washington, D.C.. Frye had taken a systolic blood pressure test that supposedly measured his physiological responses to questions to determine truth or falsehood (innocence or guilt). Frye argued that the test results would prove his innocence. The device was invented by William Marston, creator of the comic book character Wonder Woman and her truth-inducing lasso. The systolic blood pressure test was actually a crude precursor to the modern polygraph. The defense offered to have Frye take the test right in front of the jury. But, the trial judge reasoned that the blood pressure test was not generally accepted in the relevant scientific communities of physiology and psychology and refused to admit its results. When convicted, Frye filed a single-issue appeal of the judge's ruling on the systolic blood pressure results. Affirming the trial judge's refusal to admit them, the D.C. Circuit in a two-page opinion made what is probably the most famous, (or infamous) statement about the admissibility of scientific evidence in American law:

> "Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs." Id., at 1014.

Today, under Daubert, the fact that a particular scientific proposition is "generally accepted" is only one criterion for what makes something reliable science for purposes of admissibility. General acceptance is subject to the fallibility of human politics, and is to be viewed with great caution. For, as Galileo's experience taught us, the powers that be may generally accept and sponsor a belief, such as, "the world is flat." General acceptance in the Holy Roman Empire and elsewhere did not, however, make it so.

SHAKEN BABY SYNDROME AND GENERAL ACCEPTANCE

Most state courts admitted testimony about SBS in the days when physicians generally accepted shaking as the cause of a certain group of head injury symptoms with which the children came into the hospital. While the science of head injury has advanced, many judges and doctors are impervious to these advances. The science of head injury causation, developed by biomechanics over the last 30 years, has slipped through the cracks in our justice system and our medical schools.

It is time to judge the science by which we are being judged.

WHAT IS SHAKEN BABY SYNDROME?

It is claimed in medical literature, medical records and, consequently, in crimi-

English statesman and philosopher Francis Bacon (1561-1626) pioneered the modern scientific method teaching that scientific truth is derived from experimentation, not argument.

nal indictments and parental rights termination proceedings, that another human being, by violently shaking a baby, can inflict one or more of the following injuries:

- Subdural hematomas (SDH's), bleeding beneath the dural covering of the brain over the convexities of the brain. This is termed "intracranial injury";
- Subarachnoid hemorrhages (SAH's), bleeding beneath the arachnoid covering of the brain over the convexities of the brain. This is also termed intracranial injury;
- Diffuse axonal injury (DAI) (tearing and sheering of nerve fibers in the brain, itself). This is termed "cerebral or intercerebral injury";
- Contusions or bleeding in the body of the brain, itself (also termed intercerebral injury); and
- Retinal hemorrhages (RH's), such as, bleeding in the vitreous inside the eye, and/or between the retinal layers behind the eyes.

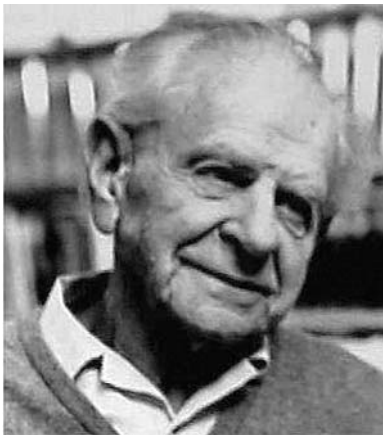
Other alleged 'diagnostic signs' of SBS include bruising to the neck, shoulders, torso or arms where the child was allegedly grabbed and shaken, broken ribs, and broken arms and legs, i.e., fractures of the 'long bones.'

This article focuses on cases involving injuries to the head only, that is, on the baby who is brought to the emergency room with bleeding above the brain or damage to the body of the brain, itself, retinal hemorrhages, or all of these. (Injuries to arms, legs, ribs and other areas raise other forensic issues that can't be covered here.)

SBS: An Unproved Hypothesis Masquerades as 'Science'

The central forensic fault with the theory or hypothesis that people can injure babies' brains by shaking alone is that, from its inception, the hypothesis was based on reason and inference, rather than reliable testing. It has been "confirmed" solely by further reason and inference. If, for example, a baby is brought to the emergency room with SDH's and RH's, the diagnosis is "shaken baby syndrome." The symptoms are used to infer the cause.

An untested syndrome that is both a diagnosis and a statement of causation, made by someone in the medical profession untrained in the science of injury causation, is hardly the way of reliable science. Nor is this helpful in our system of justice where one is supposed to be innocent until proven guilty. It only makes matters worse that people are prosecuted for this form of child abuse in spite of the fact that the hypothesis that shaking alone injures babies' brains has now been falsified (disproved) by experiments in biomechanical testing using a model baby and by other corroborating works. (More on this later.)

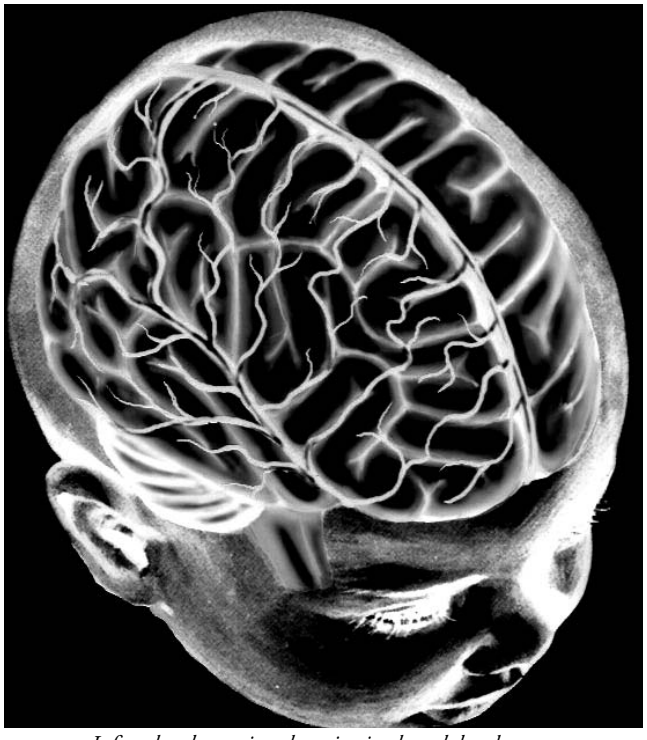


Philosopher Karl Popper (1902-1994): "The criterion of the [modern] scientific status of a theory is its falsifiability, or refutability, or testability.

A fair number of physicians now challenge shaking as the cause of brain injury in babies, and the theory of shaking has come under serious attack in cases and medical literature since 1987. Still, the State continues to sponsor and promote shaking as a cause of pediatric brain injury by prosecuting mothers, fathers, brothers, sisters, grandmothers, friends and neighbors for injuring or killing babies by violently shaking them.

The real science available about SBS suggests that one prosecution for allegedly inflicting brain injury on a child by shaking, alone, is one too many, just as it was 21 too many when 19 men and women and two dogs were falsely accused of, and hanged for witchcraft in 1692 in Salem, Massachusetts.

Yet, shaken baby syndrome (SBS) as a cause of brain injury enjoys institutional support from the American Academy of Pediatrics (AAP), and the National Association of Medical Examiners (NAME), among others. The AAP, which receives substantial federal grants to devise programs to recognize and prevent child abuse, including so-called "shaken baby syndrome," recently received such a grant for $1.5 million, which it announced on its web site. The AAP's committee on child abuse for 2000-2001—through which the AAP affirmed it's belief in SBS as a real form of child abuse—is composed of several



Infant head exposing the veins in the subdural space.

physicians whose writings reflect more medical anecdote and ideology than knowledge of serious science or evidence-based medicine on the subject.

THE ORIGINS OF SBS

Where did it all begin? The origins of "shaken baby syndrome" lie in the early writings of a radiologist, John Caffey, M.D. In 1946, Caffey reported four cases of children who had broken bones and chronic (old) subdural hematomas and retinal hemorrhages. He wondered whether there was an association between the broken arms and legs (i.e., long bones) and subdural hematomas. He was later to suggest they had been shaken. But, of the four cases, none were autopsied, and so there was no information about whether any of these children suffered internal or external blunt trauma to the head—either by accident or intent—to otherwise explain the brain injuries. At this phase of his career, Caffey was concerned to establish pediatric radiology as "a respectable and valid medical entity." So, for him, the association between the brain and long bone injuries he suggested was an exciting development.

An infant subdural hematoma (intracranial injury) shown on CT scan. The white, long concentric shadow on the left represents the subdural hematoma.

The Virginia Jaspers case in 1956 was to increase his excitement. It cannot be entirely blamed for the beginning of the modern nightmare called "shaken baby syndrome," for Caffey and others bear responsibility for failing to scientifically scrutinize Jaspers' claims. However, Jaspers' story was partly responsible for opening floodgates that are still not closed. The daughter of a New Haven railroad executive, Jaspers was viciously described in the national media as an "ugly duckling" and a "large and ungainly girl" with "ham sized hands" who, with limited options, left school at age 19 to study pediatric nursing, then the ghetto of the field.

Five years later, 11-week-old Cynthia died suddenly of a cerebral hemorrhage while Jaspers was her nursemaid. Doctors suspected abuse because there were signs that baby Cynthia had been dropped or thrown. Still, Cynthia's parents trusted their nursemaid and asked Jaspers to return when their next child was born. (Jaspers also cared for the children of several other families.) Three years after baby Cynthia's death, another child in Jaspers' care—three-month-old Jennifer—asphyxiated on her own vomit and died. Jaspers protested that she had done nothing to harm the child and, in fact, had tried to save her by shaking her to get a "bubble" up. Then, in August 1956, Jaspers admitted to *shaking* one of her charges, 11-day-old Abbe, when she refused to take her formula. Abbe died. Jaspers' story was reported in *Newsweek*. A photograph of her carried the cutline:

> Size and strength: The brutal and tragic career of nurse Virginia Jaspers is tied to her massive physical traits. Now 33, she is an ungainly 6 feet, weighs 220 pounds, has a 52-inch waist. Police concluded that she probably had no idea of the strength of her cruelly big arms and hands.

The cat about shaking was out of the bag—or so it seemed. The problem was that whether it was possible under the laws of physics for Jaspers to inflict these injuries by shaking alone—despite her confession—was never even questioned. Confessions do not a science make. Even Galileo confessed at his Inquisition to teaching heresy when he knew that, in fact, the world was round. (Had some of us represented Galileo, we may have advised him to do the same.)

No doubt the confessions of the shake-prone nurse (as she was later called by Caffey) emboldened one doctor, C. Henry Kempe, M.D., to announce in 1962 that any child with subdural hematomas and retinal hemorrhages had been abused by *shaking*. Writing through the institutional voice of the American medical establishment, the Journal of the American Medical Association (JAMA), Kempe urged doctors to look for subdurals and retinal hemorrhages in children with broken bones, and to diagnose shaking as the cause of these injuries if they were found. While Caffey was to call it the Parent-Infant Traumatic Stress Syndrome (PITS), Kempe called it "the battered child syndrome" inflicted by parents on their babies. There was never any question about the matter. The children had been abused. All critical thinking about other possible causes—such as, accidents, short falls, birth injuries and genetic defects—had ceased.

Kempe also claimed that if there was a marked "discrepancy between clinical findings and historical data as supplied by the parents" this was a "major diagnostic feature of the battered child syndrome." He was referring to parents' claims that their children were injured from short falls or other impacts. Despite the fact that there had been reports in clinical neurosurgical literature for more than

100 years in which short falls caused skull fractures, subdural hematomas and retinal hemorrhages related either to brain swelling or impact, Kempe claimed that parents' stories about short falls causing these injuries to their children were categorically false. Kempe had no foundation for such a claim. He had conducted no research to determine the minimum impact velocity required to cause these injuries to the head. Probably, he had not even considered that in a drop of only three or four feet, one hits the ground at 10 miles per hour. Parents' protestations of innocence and denials of wrongdoing were just part of the battered child syndrome, he inferred.

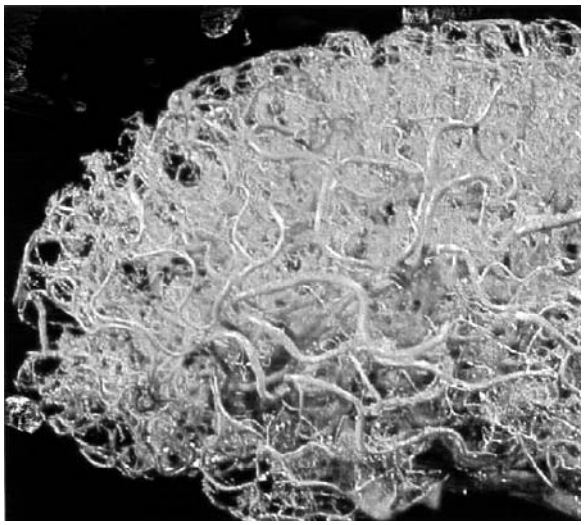
Kempe advocated that physicians ask questions that were designed to trap the parents into admitting they lost control and lashed out, such as: "'Does he cry a lot?'; 'Is he stubborn?'; 'Does he obey well?'; 'Does he eat well?'; 'Do you have problems controlling him?'." Kempe also urged doctors to delve into the parents' own family history—had they been abused?—and, worse, advocated that "nurses or other ancillary personnel," watch (spy?) on the parents while in the hospital with their injured child.

Things were taking a really nasty turn. In the Salem witch trials of 1692, it was said that as suspicion escalated, people began to "break charity" with one another, accusing and naming each other as witches. By advocating that physicians go beyond diagnosis and treatment and become investigators of injury causation, against a child's own parents, Kempe was, in effect, telling the medical community to break charity with its patients.

THE DARK SIDE OF DIAGNOSIS

Hippocrates' ideal was "First, do no harm." In "Ancient Medicine," he wrote that those who leap to conclusions about the origin of an illness are "clearly mistaken in much that they say." If Hippocrates were alive today, it is not much of a stretch to believe that the Father of Medicine would have had harsh words for Kempe and others who encouraged their colleagues to jump to the conclusion of child abuse in cases where the children had SDH's, RH's and no evidence of external trauma to the head.

The role of the doctor is to diagnose and treat. It is not the role of a physician to accuse others, at least not without reliable science. Nothing could be more harmful to a child than to have his parents falsely accused and taken away. Since Kempe's medical profession would not accept explanations of short falls or other conditions as the cause, and since the parents could not explain why the child had SDH's and RH's, parents were doomed by Kempe and others who inferred and reasoned that they must have had a hand in injuring their own children.



The vasculature (arteries and veins) of the brain with the brain tissue removed. when the brain rotates, it tears and sheers these vessels.

Facing accusations of being a witch when he could neither explain strange phenomena nor recall all ten commandments in 1692, John Proctor, the character in Auther Miller's classic play, "The Crucible," put it this way: "I never knew until tonight that the world is gone daft with this nonsense." The night, like the daftness, was only just beginning. Kempe gave scant 'proof' that his theory of shaking as the cause of these injuries was scientifically valid. He reported only *two* cases in his article.

In the first case Kempe reported blunt trauma to the head could not be ruled out because the baby survived. There was no autopsy, and this was before the days of CT scans. As part of the process of diagnosis, physicians must attempt to rule out, that is, disprove or falsify, a diagnostic theory, *and fail to do so*, before accepting it as the cause of a condition. If a doctor sets out to prove rather than falsify his or her first diagnostic impressions, he or she risks treating the patient for something the patient does not have. Indeed, in Kempe's first reported case, the parents explained that another child had thrown a toy hitting the one-month-old baby on the head. Their account was discounted as part of the denial associated with "the syndrome."

Kempe did no experiments to test the material properties of the pediatric skull or of the underlying material properties of the pediatric brain, and no analysis of the impact velocity with which the toy may have hit the baby's head to see if he could rule out the parents' account as the cause of the injury before he 'diagnosed' (accused) them of abuse.

In the second case Kempe reported, there was evidence of blunt trauma to the head—a skull fracture. Brain injury by *shaking* alone was inconclusive even on Kempe's own examples. As has happened so many times in the sordid history of humanity, reason had prevailed over science and had done so with the help of the members of the medical establishment.

ANOTHER VOICE: THE SCIENCE OF HEAD INJURY

While the child abuse doctors were busy beating the drums about shaking, at least one physician was trying to develop and apply the science of head injury biomechanics to determine what forces it actually takes to cause brain injuries from what later became popularly-known as "whiplash." Whiplash is rapid movement of the head back and forth *without impact*.

Whether rear end car crashes could cause whiplash injuries was controversial and disputed in the 1960's, even more so than today. Beginning in 1966 and 1968, Ayub K. Ommaya, M.D., a Pakistani-born and Oxford-educated neurosur-

geon, set out to determine the amount of force it takes to cause certain types of brain injuries ranging from subdural hematomas (intracranial bleeding) to bleeding in the body of the brain, itself (e.g., intercerebral contusions). Ommaya wanted to test the hypothesis that rear end car crashes could cause such injuries when the occupants were (1) not restrained and (2) did not bang their heads.

Ommaya's experiments were gruesome and unpopular, and later ones by other scientists were to be shut down under pressure from animal rights groups. But, in the research climate of the mid-to-late 1960's, Ommaya was able to use Rhesus monkeys in place of humans to mimic car accidents by accelerating them on chairs fixed to a track and decelerating them *without impacting their heads at all.*

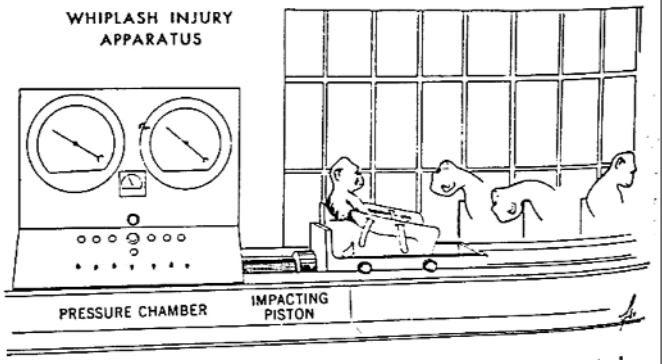
After these grisly experiments, the monkeys were anesthetized, killed and autopsied. Ommaya's 1966 and 1968 experiments showed that it took between 35,000 to 40,000 radians per second (squared[4]) of *angular* or *rotational* acceleration to cause intracranial and intercerebral bleeding in the monkeys. That was the equivalent of forces not merely in a straight line (so-called "linear"), but forces occurring as the monkeys' heads *rotated* or arced on their necks.

To compare what would happen to human brains during the angular or rotational acceleration-deceleration of a car accident, Ommaya mathematically scaled the size of the monkeys' brains to human brains and determined that it would take between 6,000 and 7,000 radians per second (squared). Relying on this and other head-injury data, Ommaya concluded that forces generated by some rear-end car accidents caused whiplash brain injury to humans.

To put in perspective some of the rotational or angular forces that must be exceeded to cause human head injury *without impact*, there are a few reports in the Japanese neurosurgical literature claiming that some riders exposed to the massive angular forces created by roller coasters as they climb, dip, corkscrew and turn, have developed SDH's diagnosed after experiencing "roller-coaster headache."

In 1971, yet another doctor weighed in on shaking. Citing Caffey's 1946 article on the association between broken bones and SDH's, Kempe's 1962 article and Ommaya's 1968 monkey data as proof that *human* shaking causes brain injuries in children, A.N. Guthkelch, M.D., announced in the British Medical Journal that when a child with subdural hematomas (SDH's) and retinal hemorrhages (RH's) and no external marks on his or her head comes to the ER, one can infer (reason) that the child had been repeatedly shaken, rather than being a victim of impact.

This doctor made no distinction between the power that a human being can generate versus the power of a machine, even citing the case of a "prominent American neurosurgeon who developed a SDH after his head had been jerked by the violent motion of the bobsled which he was riding at the fun fair," as an example that human shaking injures babies' brains. Nor did this doctor appreciate that blunt impact, as with an accidental fall, may leave no telltale marks, especially in the case of an infant.



The 1968 Ommaya rhesus monkey experiments. The cars were shot forward and quickly stopped causing whiplash injury at about 120-G forces, more than 10 times the 11-G forces a human being is able to generate by shaking, alone.

Head injury biomechanics was not even part of the question about whether shaking could cause the so-called SBS head injuries. For example, as with Caffey and Kempe, Guthkelch did not appreciate that the infant skull is pliable and is capable of bending on impact and, in some cases, leaves no evidence of injury as it resumes its shape. There was little excuse for failing to appreciate this situation, for the pliable nature of the infant skull was described in the medical literature as far back as 1888. Still, when one is set on proving a hypothesis, contrary information is discarded and supportive data is lovingly retained.

Nor did Guthkelch, or any other physician claiming that shaking injured babies' brains, consider what might happen to the brain as the quick bending of the infant skull occurs from sudden impact.

The work of biomechanicians show that slow changes in skull shape, such as those occurring in the birth canal, allow the brain to adjust its internal pressure and make accommodation for the external squeezing on the skull. Blood flow and flow of cerebral spinal fluid are regulated to decrease or increase volume. But, as with a precipitous birth, there is no time for this adjustment of blood and cerebral spinal fluid pressures in the fast bending of the skull that happens when an infant falls and hits his or her head.

According to Ommaya and others who have studied the material make up of brain tissue, it consists mostly of water and fat. As such, it would take about 100,000 square inch pounds of pressure to compress it to a smaller size. To understand the magnitude of this force, imagine a woman wearing shoes with a one-square-inch heel. If she weighed 100 pounds and stood on one foot with a heel that size, she would exert 100 square inch pounds of pressure on the ground.

Under pressure, like water, the brain follows the path of least resistance. On impact, when the skull indents or, as biomechanicians say, when it "transiently deforms," some computer models show that the brain tissue rotates inside the skull. To visualize this, imagine that under the pressure of impact to the head, the brain behaves a bit like toothpaste in a capped tube which when squeezed from the outside rotates under the pressure.

Because the toothpaste is relatively incompressible, it cannot get any smaller. But it can get relief from the pressure by turning or rotating in the tube.

The rotation of the brain caused by skull change on impact would be harmless if it were not for the fact that the brain is a labyrinth of blood vessels (as are found in the subdural and subarachnoid spaces) and of millions of connections (such as neurons and their axons) that cannot be stretched beyond their limits. Once these structures are stretched by rotation, they will shear, tear and die causing excessive bleeding and, often, lethal swelling of the brain.

In the early days of the SBS diagnosis, the science of head injury biomechanics was still in its infancy. The development of this science would have to await, among other catalysts, the advent of products liability cases against manufacturers of automobile companies, playground equipment, bikes, helmets and toys. For example, in attempts to design more crashworthy vehicles and minimize liability and damages, the auto makers would employ biomechanicians to start working out the thresholds and causes of head injury at crash test facilities, and later with computer-generated models.

Guthkelch and other physicians advocating human, manual shaking, alone, as the cause of brain injury to babies also did not know that their hypothetical descriptions of parents injuring their babies by shaking them from front to back was to be further questioned by later head injury research. In 1982 biomechanician Lawrence Thibault and neurosurgeon Tom Gennarelli (and others) showed that brain injury occurs more easily from side-to-side rotation, like the tick-tock of a metronome, that is, in the coronal plane, and not in from front to back like a child's swing, that is, in the sagittal plane. And this was in an experimental situation where the forces far exceeded what a human being can generate. It's a question of magnitude.

Head Injury Science Slips Through the Cracks of Medicine

As the automobile companies and other manufacturers were studying the science of head injury to minimize money judgments, Guthkelch and Caffey also read Ommaya's 1968 monkey experiment article. Because he was traveling along his own "scientific" track intent on reaching a preconceived destination, Caffey concluded that just as acceleration-deceleration, without impact (i.e., free shaking or 'whiplash') damaged the monkeys' brains, this also explained how parents inflicted brain injury on their babies. He actually telephoned Ommaya to thank him for the 1968 article. Today, Ommaya is adamant that he told Caffey that the acceleration-deceleration forces involved in the monkey experiments were much greater than he believed could be generated by a human. Indeed, Ommaya recently affirmed that communication in the British Journal of Neurosurgery in 2002.

Caffey's subsequent misapplication of the 1968 Ommaya monkey data to alleged shaken babies was to further compound the problem of "shaken baby" theory, already a hopeless house of cards constructed of unproved hypotheses fueled by Kempe's call to physicians to cultivate suspicion of patients' parents.

In 1972, Caffey wrote and published, "On the Theory and Practice of Shaking Infants." By then, Caffey and Kempe shared the limelight with the newly identifiable form of child abuse being called, among other names, "the Caffey-Kempe Syndrome." Their careers as discoverers of the new scientific frontier had taken off. And, Caffey's publicly-expressed desire that pediatric radiology become a "respected and valid medical entity" was being realized. From Caffey's viewpoint, it was through the magical eye of the X-ray (then called the roentgen) that the shadows of pediatric head injury abuse were being exposed. Caffey was later to call the X-ray "the pristine probe," and in a 1972 address to Boston- and Harvard-based radiologists read them this poem he penned:

Poor shaken babe, guileless tyke,

Rocked by love and hate alike,

Your mother's tongue locked in silence,

Hush untold tales of guilty violence,

But when we flood your flesh with radiant streams,

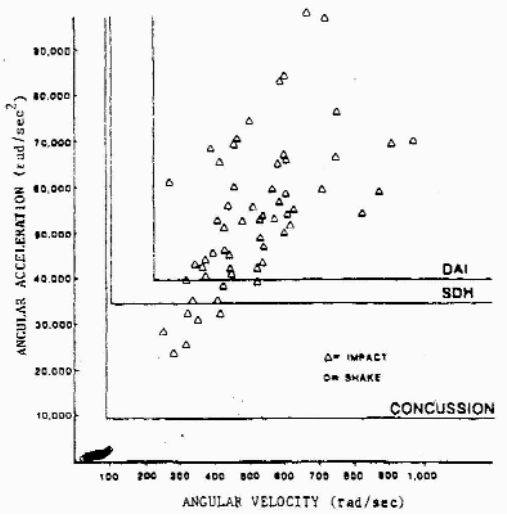
Bruised bones shine through in truthful gleams,

It's stretch, squeeze, stretch; not bash, hit batter,

Which bloody your bones and dura mater.[5]

On one level, given the development of the modern scientific method by Bacon, Popper and others, it is amazing that no one at the time questioned or challenged the assumptions and conclusions reached by Caffey, Kempe or Guthkelch, especially when the liberty of other human beings, and the love between parents and children were at stake. Instead, as with the debate between Aristotle and Democritus, it appears that the authority of these prominent physicians, who were publishing their hypotheses about pediatric head injury causation in the establishment medical journals, rather than any true claim to reliable science, carried the day.

In terms of the medical culture of the day, it is not surprising that there were few challenges, if any, to these physicians. They were publishing their theories at a time when the practice of medicine was a more refined and ostensibly gentile endeavor, when learned men published case studies in journals, and gave deference, rather than challenged, one another's assumptions and conclusions. It was all very gentlemanly and polite, but rarely scientific. Most senior physicians then, and even now those currently in practice, were trained under the old system that started with an undergraduate degree in almost any field followed by years of intense training by professors of medicine. The professors taught by imparting their years of anecdotal experience and their beliefs to the new medical students. Experimental medicine (evidence-based medicine) used to be mentioned only occasionally, and the conclusions of the limited number of experiments (clinical trials) often were of limited validity or were even incorrect because of poorly designed clinical trials and poor understanding of the statistics of clinical trials. The development of "evidence-based medicine"—large medical studies, applying the scientific method in study design, testing and interpretation of results—was still at least two decades away when Caffey published his 1972 paper.



The scattergram from the 1987 Thibault study shows the thresh hold for injury from human shaking, alone. Note that by shaking the model baby without impact, the researchers were not able to generate the forces Ommaya reported are necessary to cause brain injury. The circles in the bottom, left corner are the measurements from the accelerometer on the baby's neck from the pure shaking experiment. No one got over 11 G forces. But, when the model baby was slammed (the slams are represented by the triangles) the force generated was about 50 times greater than pure shaking.

Even today, a bias toward reliance on anecdotal rather than on evidence-based medicine continues in this field. Only in recent years has the concept of medicine as a research science (evidence-based medicine) been introduced into the medical school curriculum. Current medical training, on the other hand, emphasizes the science of medicine (evidence-based medicine) and addresses the validity of specific clinical trials and of different types of clinical trials in making medical recommendations.

The entire concept of "shaken baby syndrome" arose when most physician-training was based on the medical culture of the mid-twentieth century, a time when new ideas did not require rigorous scientific validation to survive. The same concept, if introduced de novo today, would not survive scientific evaluation and would not have become established as part of our medical and legal folklore.

The biomechanics of head injury was not considered by pediatricians who continued to rely on Caffey and others and to "recognize" their own cases of "shaken baby syndrome." Many of them joined the parade by reporting their own anecdotal and self-confirmed theories in the medical literature. Today, there are several hundred such articles. Most of them refer and rely on Caffey, Kempe and Guthkelch.

It is a legal and moral outrage that even though the SBS "diagnosis" is a statement of causation pediatricians are not required to study the science of head injury causation either in medical school or in their pediatric residencies. This is also true of forensic pathologists who are frequently called to testify about issues of force.

One forensic pathologist testifying in a murder trial in a case of alleged SBS haughtily told a Kansas jury in November 2000, "I have no interest in [bio]mechanics. I am a doctor." Yet she was there to testify about head injury causation in relation to the manner of death: Homicide by violent human shaking, alone. She was there for the State to refute the defendant's account of the child who fell head first down concrete steps. The child's injuries were caused when the defendant violently shook him and then slammed him down, the medical examiner claimed. The SDH's, the RH's, could not have been caused by this, she further reasoned before the jury. She had not even bothered to calculate the impact velocity (if she even could) with which the child would have hit the ground to rule out foul play. She had read the medical literature about SBS and was confident and satisfied that she was an expert in shaking as a cause of brain injury in babies.

The Kansas forensic pathologist had, of course, read Caffey's 1972 article. That article now forms part of the "scientific" foundation of the American Academy of Pediatrics' [AAP] technical report affirming that human, manual shaking, alone, without impact, causes baby brain injury. The AAP reaffirmed its position as recently as July 2001.

The American Academy of Pediatrics' (AAP's) reliance on Caffey's work to justify the existence of "SBS" is at best negligently misplaced and at worst ideologically infected. Caffey's article contains within itself an absence of reliable and complete data to support his hypothesis and conclusions about Virginia Jaspers' alleged shakings:

> "The most gruesome and, at the same time, the most significant examples of *proved*…whiplash-shakings and of burpings are recounted in the story of an infant nurse…She is reported to have killed three infants and maimed 12 others during a period of eight years, *largely by shaking and jolting infantile brains and their blood vessels*…. In one instance she was invited back by the parents to care for their second infant after she had shaken their first child to death." (Emphasis added.)

Caffey ignored the fact that the first infant showed evidence of blunt trauma and continued: "Eventually, she admitted killing three infants and maiming two others." Not only was Caffey's 1972 article heavily dependent on Jaspers' description of how she believed (once accused) that she injured the babies, but it also lacked any detailed autopsy (then called "necropsy") information on which anyone could make an independent judgment about the validity of the scientific hypothesis, i.e., that by shaking a child violently, an adult could inflict brain injury.

In 1974 Caffey wrote more about Jaspers "whiplash shaken" baby cases and this time included some autopsy information about one of the babies. One very haunting problem about the case of the (11-week-old) baby whom Jaspers was accused and convicted of killing is that, based on the autopsy information that was provided, this child may well have had birth injuries. (Obstetricians know only too well that even babies born by normal birth sometimes have subdural hematomas.) In that autopsy of the 11-week-old, shaking was *not* ruled out by examination of the brain stem or upper cervical spine. The age of the subdural blood was *not* tested to see if Jaspers could be ruled out as a killer by comparing the age of the initial injuries with the nursemaid's care of the child. And, blunt

impact was *not* conclusively ruled out. There was a clear effort to prove the hypothesis that the baby had been shaken, and shaken by none other than Jaspers, rather than to falsify it by searching inquiry. In some of Caffey's reported cases were there was no evidence of skull fractures or external scalp injuries and, based on this, he reasoned that these babies were victims of whiplash shaking (WLS). On the "data" provided by Caffey, it is clear that no one investigated whether there were *internal* injuries to the scalps of those children. Certainly, no one mentioned the fact that some blunt impact injuries do not cause external or internal scalp damage. And no one mentioned the pliable nature of the infant skull or considered what might happen to the underlying brain on impact.

Although shaking as a cause of injury is blindly accepted by segments of the medical establishment, *this hypothesis of how babies' brains are injured has never been validated by pediatric head injury biomechanicians, i.e., by the relevant scientific community to whom the science of injury causation belongs.*

Quite the contrary.

SBS Falsified By Relevant Scientific Community

It would be 15 years after the 1972 Caffey article before an experiment would be performed that would prove that a human being could not possibly generate the forces necessary to cause internal head injury by human, manual shaking, alone. It appeared that Jaspers had confessed to something she had not done or, more sinisterly, she had done more than that to which she confessed.

Unlike physicians, biomechanicians experiment with the forces needed to cause human injury. In 1987, a biomechanician and a group of neurosurgeons set out to prove that SDH's and other brain injuries in babies were not caused by shaking, alone, but by impact.

The biomechanician was Lawrence E. Thibault. The Thibault team members made a model baby and attached an accelerometer to its neck. First, they asked some burly "Penn State" football players to shake the model as hard as they could. The most force these hulks were able to generate was a mean of 1,138 radians per second (squared). That was a far cry from the required 6,000 to 7,000 radians per second (squared) which Ommaya established were needed to cause brain injury by whiplash to man, i.e., *shaking without impact*, in the 1968 monkey experiments.

Secondly, the experimenters asked the athletes to slam the model baby on three different surfaces. Only when it was slammed on hard metal and padded surfaces did the accelerometer on the model baby's neck register the forces needed to cause concussion, SDH's and diffuse axonal injury. In fact, the forces generated by impact were 52,475 radians per second (squared).

The experiment had falsified the hypothesis that a human being, by manual shaking, alone, could injure a baby's brain. The results of the experiment have never been invalidated, but prior and subsequent studies are consistent with them.

Critics of the 1987 Thibault experiment claim that the results are invalid because the baby was not real. But, that was not the point. The 1987 Thibault biomechanical experiment focused on the question of whether it was possible, as a matter of physics, for the *shaker* to generate the forces Ommaya determined were necessary to cause brain injury *without impact*. Football players capable of inflicting tremendous physical violence could not do so.

If anyone really wants to reproduce this experiment with biofidelic models, it can be done using finite element analysis, a technique through which head injury can be simulated on a computer. It's a technique based, in part, on US military programs released into the public domain, and has been used by the auto industry, among others, to make safer products. But, the cost of this is high, and funds for alleged child abusers are not.

Following the release of the 1987 Thibault study the hypothesis of "shaken baby syndrome" has sometimes been recycled as the "shaken-impact-baby syndrome" (SIBS), but pure shaking is often still used as the theory of causation in criminal indictments regardless of whether there is evidence of impact.

Recent Studies Debunk SBS

Other more recent studies have also refuted that shaking is the cause of brain injury. In June, 2001, two British neuropathologists, Jennian Geddes and Helen Whitwell, announced their findings after studying a number of children who, it was claimed, had been victims of shaking. They found that there was a sig-

Size and Strength

The brutal and tragic career of nurse Virginia Jaspers is tied to her massive physical traits. Now 33, she is an ungainly 6 feet, weighs 220 pounds, has a 52-inch wrist. Police concluded that she probably had no idea of the strength in her cruelly big arms and hands.

Nursemaid Virginia Jaspers: when she confessed in 1956 to shaking a number of infants in her care, Jaspers opened floodgates that are still difficult to close, despite the fact that the 1987 Thibault study conclusively invalidated the Caffey-Kempe-Guthkelch hypothesis that shaking, alone, injures babies' brains. Did she really do what she confessed to doing?

nificant association between shaking and brain stem injury or upper cervical spine injury. The term "association" in medicine is loaded. It means that if one sees "A," one will expect to see "B." If a child has been shaken, there should be corresponding brain stem or upper cervical spine injury. The physics of this proposition make sense and are supported by other head injury research by Ommaya, and others. At least one biomechanician has compared the neck to a straw, and the head to a grapefruit. When shaken, the more fragile neck is the first part to be injured. This analogy is consistent with the work of Ommaya and others who found that the tolerance criteria for neck injury is exceeded long before that for head injury. So, if there is intracranial or intercerebral injury and RH's, but no upper cervical spine or brain stem injury, one has to assume another cause, such as blunt impact. British neuropathologists Geddes and Whitwell found that brain stem and upper cervical spinal cord injury were rare findings. If shaking is so common, one must wonder why the finding is not more common.

Proponents of SBS also claim that diffuse axonal injury (DAI)—axons injured diffusely in the brain—is a "diagnostic marker" for shaking. As with shaking as the cause of intracranial and intercerebral injuries, the DAI-by-human-shaking hypothesis was also falsified in 1998 by German pathologist Manfred Oehmichen. He studied the brains of 252 people, some of whom had been deprived of oxygen, a common, secondary effect of head injury referred to as hypoxic or anoxic insult. Oehmichen found that people who had been on respirators to help them breathe all had damaged axons, which he termed "axonal pathology." In cases of oxygen deprivation, there is no way to tell whether the person's axons were injured by the primary trauma, such as, by whiplash, or by the cascade of events following primary trauma known as secondary injuries, such as, anoxia or hypoxia. It's critical to note that in forensic medicine, the finding of axonal pathology is "non-specific," meaning that one cannot infer anything about its origin or cause. British neuropathologists Geddes and Whitwell also confirmed this in another study in 2000.

CONFESSIONS DO NOT EQUAL SCIENCE

A common theme in SBS cases is that the accused confessed to shaking.

Even though Virginia Jaspers confessed in 1956 to shaking some of the babies in her care, it is clear she did not kill them this way, if at all. After being told by a pediatrician that she murdered the infants in this way, she may well have believed she did. However, the science of head injury developed since her confession tells a different tale. Today, after serving many years in a State prison, Jaspers still lives with her "crimes," an elderly woman who is afraid and wants to slam the lid on the coffin of her past. She actually believes she killed the babies, and in this she is not alone. Many people are actually made to believe they killed. The doctors told them so.

Some of these, like Jaspers' confessions, are included the medical literature and are used to provide ammunition against others. Jan E. Leestma, M.D., a Chicago-based forensic neuropathologist, recently reviewed 324 cases of allegedly abused infants whose cases had been variously reported in more than 100 medical articles about shaken baby syndrome. Of the 324 cases, Leestma analyzed 57 of them specifically because they involved confessions to shaking. These cases had enough "data" on which he was able to make an independent judgment about the author's claim of scientific and medical reliability. Of those, Leestma found that only 11 had both a confession to shaking and *no evidence of impact*. Eleven cases, which were gleaned from three decades of medical literature, hardly add up to enough evidence-based medicine to prove the hypothesis that the babies were injured by human shaking, alone. And, keep in mind that not all blunt impact injuries result in evidence of external or internal impact, especially if the baby's skull changed shape on impact and resumed normal shape after.

To any serious scientist or physician, and to judges, it should be common sense that confessions are not reliable indicators of the *science* head injury *causation*.

The circumstances of the confessions in the eleven cases were not included in the articles. A person, perhaps like Jaspers, might confess to shaking alone, because the impulse behind it is emotionally understandable. Hitting or slamming a baby's head is much less forgivable. A confession to shaking, *alone*, is more likely to help in plea negotiations and at sentencing than if the defendant were to say, "I shook the baby violently then slammed her head against the mattress." Simply put, as with other areas of criminal law, many confess out of sheer terror—or because they are actually made to believe they did cause the injury. A sentencing deal gets a defendant a lower sentence, instead of risking life without parole or the death penalty after jury conviction.

Others, who have found a baby not breathing and blue (cyanotic) confess to shaking the baby to revive them. One young father in Erie, New York wept before grand jurors in 1999 telling them that when he shook his baby boy to revive him on finding him not breathing, he did not know he was causing the terrible brain damage the doctors told him killed his son. In fact, the father's own injuries corroborated that had fallen down the stairs with the child and the baby's head had been banged. But, no one wanted to rule out SBS. Why bother?

The fact is no one has ever confessed to shaking a baby with force equivalent to more than 6,000 to 7,000 radians per second (squared) necessary to cause brain injury in the absence of impact. If they have confessed to injury by shaking, alone, the 1987 Thibault study proves they are lying or have been manipulated. In fact, some biomechanicians and neurosurgeons believe that because the baby's brain is smaller than an adult's, it would take even more force to injure a baby's brain by "whiplash."

DOCTORS DESTROY THE PRESUMPTION OF INNOCENCE

"Confessions" to revival shaking are usually recorded and repeated in medical records by doctors and nurses who, because of their training that SDH's+RH's=SBS, are presuming foul play when the child comes to the emergency room. Most states—as a requirement of federal funding for all kinds of child-centered programs—have enacted statutes mandating that doctors and

nurses (and others) report child abuse. In most states, the standard for reporting abuse is a mere "suspicion" that an injury was caused by abuse. A mere suspicion is dangerous to report when it involves a "syndrome" like SBS that is both a statement of diagnosis and a statement of injury causation. As the machinery of the State gears up, this mere suspicion-cum-diagnosis quickly morphs into probable cause and, by the time of trial, has become a diagnosis to a reasonable degree of medical probability or certainty. In effect, what frequently happens is that this systemic glitch allows self-appointed judges and jurors wearing white coats to pull the plug on the presumption of innocence.

A Question of Intent

Why, in face of the increasing scientific flap about shaking, doesn't the State just drop the "violent shaking" language from its indictments, opening statements and closing arguments? Why, like the Salem witch trials, does the State insist on sponsoring only one side of the scientific debate? The answer lies in the need for intent. The argument goes that there is no way a person could accidentally *and* violently shake a baby to death. And, just in case someone should claim diminished intent for such an act, in at least one state, parents of newborns are now made to watch a video in which they are taught at the hospital—and sign a declaration that they understand—that shaking causes brain injury to babies. Should their child appear in the ER with injuries "consistent with SBS," the prosecutor's cross-examination of the testifying defendant-parent with this document is not hard to imagine.

Philosopher Thomas Kuhn in his book, "The Structure of Scientific Revolutions," explains that scientific revolutions happen when people start thinking outside the box, in what he calls "new paradigms."

In the area of SBS, we are locked in an old and destructive paradigm that, as in the times of Aristotle, is promoted by the authority of the speaker—in this case some ideological segments and members of the medical establishment—and not the quality or reliability of the head injury science.

The federal and state governments and private foundations currently pump millions of dollars every year into "recognition and prevention" programs to stop so-called SBS. It has become a self-perpetuating industry of child abuse 'expertise.' Money for much-needed research into the actual cause of pediatric head injury, the results of which could end the risk of false accusations and, possibly, free some moms and dads from behind bars and reunite them with their children, is funneled into the wrong pockets for the wrong cause. Physicians who have staked their careers on SBS being a real diagnosis, who have published, received grants, and who have testified in countless trials are understandably reluctant to buck the system that feeds them. And, in face of this powerful lobby, accused and convicted child abusers are not much of a match.

When Illinois Governor George Ryan freed some of that state's death row inmates and commuted the death the sentences of others in January, 2003, he said: "I started this issue concerned about fairness. Fairness is fundamental to the American system of justice and our way of life."

Unfortunately, the topic of SBS, while no more important, is much more complex than ruling someone out as a culprit by DNA testing. And, there may be more people in prison wrongly convicted of child abuse than any other segment of the prison population. Nevertheless, when it comes to the relationship between parents and children, as well as questions of liberty, it is perhaps even more important to be patient in unraveling this mess as it is with DNA innocence cases.

Fairness is fundamental, and junk science used to convict is fundamentally unfair.

SBS is a 'diagnosis' from Hell for it sets in motion the machinery of the State against parents and others who merely went to the hospital desperately seeking help for a sick child and ended up in prison and, more often than not if the child survives, with their parental rights terminated.

If you have a case of alleged SBS, there is a defense. The evidence is that human shaking, *alone*, does not injure babies' brains. The evidence is that short falls may cause catastrophic and sometimes fatal brain injury. The evidence is that there are many other causes of intracranial and intercerebral injury and retinal hemorrhages in babies that are just being ignored and that other potential causes are not being researched.

Instead of applying the scientific method to this area and using the evidence, many physicians seem content merely to gaze upon the elephant in the moon. As lawyers, it is our job to expose the mouse's tail in the telescope.

Endnotes

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

2 Huber, P. W.,"Galileo's Revenge—Junk Science in the Courtroom," p 27, BasicBooks, 1991.

3 Credit for this excellent discussion of the development of the scientific process goes to, "The Five Biggest Ideas in Science," Chapter 1, Wynn, C.M and Wiggins, A.W., (Wiley, 1997).

4 Squared: With each passing second as an object falls the force of gravity, which is approximately 32.2 feet per second, is doubled or "squared." Thus, for the first second, the speed of the fall is 32.2, and for the next second, it is 64.4, and so on.

5 The "dura mater" is a meningeal covering of the brain beneath which "sub" dural bleeding occurs.

Next Issue:

When it comes to protecting children, it might seem like scientific sophistry to argue that only impact is capable of causing brain injury to a baby. But, it has critical implications. Many accused of shaking a child have explained that the child suffered a short fall. According to the 1987 Thibault experiment, and all the other head injury research, these accused people were telling the truth about one thing: they had not caused these injuries by shaking. Blunt impact, on the other hand, could just as well be caused by an accidental fall from a short height as it could from being hit. It one falls three to four feet, one hits the ground at 10 miles per hour. This introduces the notion of accident in an area where the State claims only intentional shaking caused the injuries. In the next issue in Part II, the science of blunt impact and issues of timing of the injury will be discussed. Part III will outline how to challenge the State's 'science' using the state versions of Daubert and Frye.