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COMMENT & NOTE: Shaken Baby Syndrome: A Questionable Scientific Syndrome and a Dangerous Legal Concept

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SUMMARY:

Shaken baby syndrome in its most extreme form - assuming abuse when a child has two specific brain injuries but no other signs of trauma - quite possibly does not exist. Other countries aren't so quick to find abuse where there are no external indicia: Eva Lai Wah Fung, a Hong Kong researcher writing in *Pediatrics International*, states, "Retinal hemorrhage and subdural hematoma without external signs of injury in Japan [and Hong Kong] is usually attributed to accidental, trivial head injury, whereas subdural hemorrhage associated with external signs of trauma to the face or head were commonly found in cases of genuine child abuse. In spite of the many scientific studies that uncritically accept the existence of SBS, an adequate link between shaking a baby and the two SBS markers has never been scientifically verified and the latest evidence points strongly to organic reasons for the babies' distress, as opposed to shaking. Courts should admit, under *Daubert*, that evidence showing that the two classic medical signs used to show that a child had been deliberately shaken to the point of injury or death (subdural hematoma and retinal hemorrhaging in a child) is insufficient proof that a crime has been committed.

HIGHLIGHT: The problem isn't what we don't know.

The problem is what we do know that isn't so (1).

TEXT:

I. Introduction

Shaken baby syndrome in its most extreme form - assuming abuse when a child has two specific brain injuries but no other signs of trauma - quite possibly does not exist. An estimated 1,070,000 children were victims of abuse and neglect in 1999 (2). Of those, shaken baby syndrome is said to have injured or killed thousands (3). Even though the syndrome is almost universally accepted, the scientific underpinnings are surprisingly weak. Furthermore, recent

findings point toward apnea (the baby stops breathing) - not deliberate harm - as the cause of the injury.

Since 1974, when shaken baby syndrome was first described (4) many caretakers have been convicted of violently shaking a baby to death. When there were no other signs of abuse, if a baby was found to be suffering with two symptoms - bleeding on the brain (subdural or subarachnoid hematoma) and bleeding behind the eyes (retinal hemorrhaging) - it was sufficient for conviction.

However, recent research, examined in this Note, casts doubt on the presupposition that the presence of SBS in a baby indicates that the baby was abused.

Under the existing test for admission of expert testimony into court, evidence of SBS does not show that a crime has been committed, and thus should not be used as grounds for criminal liability without other corroborating evidence.

A. Defining Shaken Baby Syndrome

SBS, as widely reported in the medical, legal, and public spheres is generally described as having the following features:

Caretakers may misrepresent or claim to have no knowledge of the cause of the brain injury. Externally visible injuries are often absent.

The act of shaking leading to shaken baby syndrome is so violent that individuals observing it would recognize it as dangerous and likely to kill the child. Shaken baby syndrome injuries are the result of violent trauma.

Serious injuries in infants, particularly those that result in death, are rarely accidental unless there is another clear explanation, such as trauma from a motor vehicle crash (5).

Consistent with the attitudes shown in the above quotes, if the medical and legal communities find SBS present in a child, the nearest adult is said to have deliberately and maliciously hurt that child (with all the concomitant legal implications) if the child is found to have subdural or subarachnoid hematoma and retinal hemorrhaging even when there are no other symptoms of abuse, such as finger marks, skull fractures, bruising at the back of the neck, indications of earlier injuries, and so on.

B. Medical Definitions of Shaken Baby Syndrome

1. Subdural and Subarachnoid Hematoma

The brain has three membranes surrounding it: an outer layer, called the dura matter, a middle layer, called the arachnoid, and a thin inner layer, called the pia matter (6). A subdural hematoma is bleeding between the dura and the arachnoid (7). An arachnoid hemorrhage is

bleeding between the arachnoid layer and the pia matter (8). Adults experience two types of hematomas. An acute hematoma can be caused by a fall or a sudden blow, while a chronic hematoma can develop slowly over a period of weeks or months (9). Acute hematomas have severe symptoms such as loss of consciousness, severe headache, weakness on one side of the body, seizures, and changes in vision (10). Chronic subdural hematomas, in contrast, produce less-severe symptoms such as: mild headache; nausea or vomiting; change in personality; and weakness, numbness, or tingling in the arms and the legs (11).

Subdural and arachnoid hematomas as diagnosed in SBS are said to be produced by rotational forces that shear blood vessels as the brain is shaken and battered against the skull (12). These hematomas can also be produced by natural causes such as a ruptured berry aneurism (13), congenital bleeding problems (14), osteogenesis imperfecta (brittle-bone disease), external hydrocephalus (water on the brain), and rebleed of prior hematoma (15). Some researchers suggest that vaccine reactions could also cause the symptoms of SBS (16). Recent medical research shows that lack of oxygen to the brain can, by itself, cause subdural hematoma (17).

2. Retinal Hemorrhaging

Besides hematoma, the only other physical evidence for a diagnosis of SBS required by most courts is retinal hemorrhaging (18). The presence of such hemorrhaging is often seen as a marker of abuse (19). Such hemorrhages "are greatly overrepresented among cases of nonaccidental trauma in young children," (20) with incidence found between 50 and 100% of the time in injuries deemed non-accidental (21). But full-term babies delivered vaginally often have similar hemorrhages to those found in SBS, though they often disappear within a week (22).

C. The Size of the Child-Abuse Problem

Fifteen out of every hundred children are said to suffer abuse in a year (23). Seventy-six percent were under five, with 40% under a year old (24). Of those abused, 18% suffered from physical abuse: about 192,600 children (25). In 1999, 1,108 children died because of abuse (26). The number of children affected by SBS is not so clear. Commentators estimate that an immense number of children, up to 50,000 a year, are harmed by shaking (27), with up to a quarter of the children dying as a result (28). This number, however, is wildly inflated. The number 50,000 represents the total number of children who die of all causes in any year (29). If a quarter of the shaken babies die, that would be a total of 12,500 deaths per year, more than ten times the number that are killed from abuse by all causes. The improbable numbers given would support the conclusion that emotional issues surrounding SBS are getting in the way of clear thinking, even in trained scientific populations.

Exact SBS numbers are difficult to calculate, but one nationwide study found a total of 523 deaths from 1994 to early 1998 (based on a 42% return rate on surveys) (30). Scaling the number up (multiplying 523 by 1.58) yields around 825 deaths total, which works out (roughly) to about 206 deaths per year nationwide (31). With regard to prosecutions, a recent Westlaw search reports eighty-four cases in the United States in 2002 that concerned SBS.

D. Legal Ramifications of a Diagnosis of SBS

A medical finding that a baby has the two markers for SBS often leads to dire consequences for the caregiver, even with no other finding or even suspicion of abuse.

In *People v. Rader* (32) a father was convicted of aggravated battery of a child when he confessed to slapping and shaking the baby in an attempt to revive it after it stopped breathing (33). The father also confessed to slapping the child across the face twice, and even though the court took this as a sign of abuse (34) the father's testimony was that he was trying to revive the child (35). He was convicted on the theory that the injuries were so severe they could only have been caused by violent shaking (36) and he was sentenced to twelve years in prison (37).

In another case, *People v. Wong* (38) both caretakers were convicted of second-degree manslaughter and endangering the welfare of a child when their baby died and was diagnosed with the two SBS markers (39). Mr. Wong was convicted of shaking the baby to death, and Mrs. Wong was convicted of letting the death happen, under the theory that she must have been "personally aware that the shaking had occurred." (40). Here, as in *Rader*, the court mentioned no other signs of abuse, and they assumed that a brutal homicide must have happened based solely on the evidence of "ruptured blood vessels." (41) As the record states:

"An autopsy performed on the child revealed that he had died as a result of internal brain injuries, including ruptured blood vessels, that could only be attributed to "shaken baby syndrome." That condition occurs when an infant under the age of one is subjected to violent shaking causing his or her head to snap back and forth. Under those conditions, the infant's brain, which is very soft, will move around inside the head, leading to ruptured blood vessels, hemorrhaging and swelling (42).

The *Wong* court uncritically accepted the standard definition of SBS, where it might have required more evidence if the parties involved had a better understanding of the underlying scientific debates.

This Note first examines the evidentiary standard required to present scientific information as defined by the U.S. Supreme Court in *Daubert v. Merrill Dow Pharmaceuticals, Inc.* (43). It then reviews the current scientific literature on SBS, and finally, it concludes that SBS in its current form should not be accepted by courts as good science. Rather, SBS should be seen as scientifically unproven and insufficient, standing alone, to be the legal basis for proving that a crime has been committed.

II. The Evidentiary Standard Under Daubert

A. Daubert v. Merrell Dow Pharmaceuticals, Inc.

Federal Rule of Evidence 702 gives the standard for presenting scientific evidence in court (44). The main Supreme Court case that interprets this rule, *Daubert*, informs courts that they must make an independent inquiry into the validity of any scientific testimony presented. *Daubert* asks

the courts to make a determination of "whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue." (45).

Four factors are outlined, and a fifth suggested, for judges to use when determining if proposed testimony crosses the scientific threshold (46). Each is discussed below.

1. Can and Has the Theory Been Tested?

The first (and most confusing) factor is "whether a theory or technique ... can be (and has been) tested." (47) Quoting the philosopher of science Karl Popper, the Court stated, "the criterion of the scientific status of a theory is its falsifiability, or refutability, or testability." (48) This actually poses two separate questions: (1) Can the theory be falsified in the Popperian sense? (2) Has the theory been sufficiently tested? Each question will be discussed in turn.

a. Is the Theory Falsifiable?

According to Popper, "the work of the scientist consists in putting forward and testing theories." (49). Scientists make a guess (a theory) and then test that guess to see if it comports with reality. Not all guesses count as scientific, though. A guess must be capable of disproof: there must be some identifiable fact that - if true - would disprove the theory. That is, the theory can be proven or disproven by looking at empirical evidence. Popper himself says, "[A] theory is falsifiable if the class of its potential falsifiers is not empty." (50). Popper gives the example that "to falsify the statement 'All ravens are black' the inter-subjectively testable statement that there is a family of white ravens in the zoo at New York would suffice." (51).

However, a scientific guess is not upgraded to a scientific theory until it has garnered experimental or observational support (52). Even as a theory it is still tentative, always susceptible to falsification.

If something is unfalsifiable, it doesn't mean that it's not true, just that it's not strictly scientific. A classic unfalsifiable phrase is "God moves in mysterious ways." There is no experiment that could be devised to disprove such a statement. Paradoxically, such unfalsifiable theories appear to have greater explanatory power than those that are testable (53). For example, creation science, an unfalsifiable theory, (54) contemplates the origins and the ultimate meaning of life - topics that are outside the scope of scientific proof (55).

b. Has the Theory Been Falsified?

Once a theory has been found to be scientific, the next question is whether it has been falsified or corroborated by observations or experiments. That is, has the theory been verified? Confusing the second Daubert criterion (whether the theory has been falsified through experimentation) with the first (is this idea sufficiently scientific in the first place) is a serious mistake, as it changes the question from analyzing the essential nature of the theory (correct) to looking at the current state of the data on the theory (incorrect) (56). This is a subtle point (57) but an

extremely important one, because it marks the boundary between objective science, which belongs in the courtroom, and inexact belief, which does not.

In particular, a scientific theory may be disproven by a single journal article, no matter how many other articles have been published that agree with it. One view of Earth from space is enough to disprove the flat-earth theory, no matter how many people warn that you will fall off the edge if you travel too far.

2. Has the Theory Been Peer-Reviewed?

The second Daubert factor is whether, and to what extent, the theory has been published in peer-reviewed journals. "The fact of publication (or lack thereof) in a peer reviewed journal thus will be a relevant, though not dispositive, consideration in assessing the scientific validity of a particular technique or methodology on which an opinion is premised." (58)

3. What Is the Rate of Error?

Third, the Daubert Court looks at rate of error. "Additionally, in the case of a particular scientific technique, the court ordinarily should consider the known or potential rate of error...." (59)

4. What Is the Acceptance Level?

Fourth, the degree of acceptance in the scientific community can be considered. A "reliability assessment does not require, although it does permit, explicit identification of a relevant scientific community and an express determination of a particular degree of acceptance within that community." (60). However, "general acceptance is not a necessary precondition to the admissibility of scientific evidence under the Federal Rules of Evidence." (61).

5. Flexibility Concerns

Finally, the Court emphasizes the flexibility of the inquiry, whose "overarching subject is the scientific validity - and thus the evidentiary relevance and reliability - of the principles that underlie a proposed submission. The focus, of course, must be solely on principles and methodology, not on the conclusions that they generate." (62). This implicitly recognizes that scientific truths are conditional, and new results, as long as they are reached by appropriate methodologies, should not be discarded simply because they are controversial.

The Court blurred this rule a bit in *General Electric Co. v. Joiner* (63) when it stated that "conclusions and methodology are not entirely distinct from one another." (64). However, as it later stated that "[a] court may conclude that there is simply too great an analytical gap between the data and the opinion proffered," (65) it seems clear that the *Joiner* Court's opinion was that good data alone will not bless scientific testimony with enough reliability to leap over the Daubert threshold. The data must also be accompanied by reasonable conclusions.

B. *Kumho Tire Co. v. Carmichael* (66)

The Daubert Court left open the question of whether the Daubert factors should be applied to nonscientific testimony. Two competing views arose: one held that the Daubert factors should be applied to all reliability testimony, while the other held that the pre-Daubert application of Rule 702 still stood for testimony that wasn't strictly scientific. (67).

In *Kumho Tire*, the Court concluded "that Daubert's general holding - setting forth the trial judge's general 'gatekeeping' obligation - applies not only to testimony based on 'scientific' knowledge, but also to testimony based on 'technical' and 'other specialized' knowledge." (68). The Court, however, took great pains to emphasize the flexibility of the analysis, stating that the list of factors in Daubert was "meant to be helpful, not definitive," (69) and that the specific criteria used "must be tied to the facts of a particular case." (70).

III. The Science Behind Shaken Baby Syndrome

A. History

In the landmark 1962 paper *The Battered-Child Syndrome* (71), C. Henry Kempe described a constellation of symptoms in children that were most likely caused by abuse rather than accident, as had been previously assumed. These included outward physical indicia of abuse such as poor skin hygiene, multiple soft-tissue injuries, malnutrition, fractures (especially those of different ages indicating ongoing abuse), and "a history of previous episodes suggestive of parental neglect or trauma." (72). Internal indicia such as subdural hematoma is also mentioned as "an extremely frequent finding." (73). This article brought the problem of abused children to the forefront of American society, and it intensified the role of the physician as a first-line defense against child abuse (74).

Expanding on the earlier work, John Caffey in 1974 suggested that babies could be seriously injured with no external signs of trauma to the body (75). Rather, a finding of subdural hematoma and intraocular hemorrhages was sufficient to determine abuse (76). Although Caffey posited a mechanism for the syndrome, the delicate infant head striking the chest and back (77), he admitted that his "current evidence [was] manifestly incomplete and largely circumstantial." (78).

B. Early Proof

In 1987, a biomechanical study was undertaken by Ann-Christine Duhaime and others to discover what forces affected babies' heads when they were shaken (79). Carefully designed models of infant heads were equipped with accelerometers and then shaken. The gathered data were then compared with known primate-shaking data. The comparison showed that shaking alone (the method postulated by Caffey) produced less than one quarter of the force necessary to produce the SBS markers of subdural hematoma and retinal hemorrhaging in primate models (80). A force fifty times greater than shaking was produced by the sudden deceleration when the model was thrown against an object (81). The authors concluded that shaking didn't produce the

SBS markers, but hedged their language: "It is our conclusion that the shaken baby syndrome, at least in its most severe acute form, is not usually caused by shaking alone." (82). They suggested that the term "shaken impact syndrome" be used instead (83).

The authors stated in conclusion that "unless a child has predisposing factors..., fatal cases of the shaken baby syndrome are not likely to occur from the shaking that occurs during play, feeding, or in a swing, or even from the more vigorous shaking given by a caretaker as a means of discipline." (84). Indeed, shaking itself (with a force of 9.29 Gs) was shown by the study not to cause the injuries at all (85). Rather the injuries were caused by the impact acceleration (with a force 428.18 Gs) when the model slammed into a metal bar or a padded surface (86).

A 1989 study by Mark Hadley (87) came to the opposite conclusion, saying that "direct cranial trauma is not an essential element of the injury mechanism in young patients who sustain severe whiplash-shake injuries." (88). The Hadley study examined thirty-six infants with head injuries (89). Thirteen of these patients had no "direct cranial trauma," but had both retinal hemorrhaging and either subarachnoid or subdural hemorrhaging (90). This was seen as proof that the children had "a history of whiplash-shake injury without direct impact trauma" even though "doubt remains about the true mechanism of these injuries." (91). This is circular reasoning. There is nothing in the record saying that the babies were shaken; the authors are simply assuming their conclusion.

This point is made by a Hong Kong researcher (whose paper on the restricted definition of child abuse in the Far East is referenced later), who mentions the circular reasoning at the heart of the western SBS definition:

If all members of the [child abuse] team are "educated" to the fact that the presence of subdural hematoma and/or retinal hemorrhage with "no history accounting for patient's serious head injury," is diagnostic of child abuse, then all cases will increasingly be so classified irrespective of what the caregivers say. For some this may mean a lengthy term in jail (92).

Another study by Duhaime, published in 1992, looked at both accidental and inflicted head injuries in children younger than two to help determine which specific markers were indicia of abuse (93). However, the presence of a hematoma with "changing history or developmentally incompatible history" was considered presumptive proof of abuse (94). The authors found that nearly a full quarter of the children with head injuries met their criteria for intentional infliction (95). However, as (1) possessing an intracranial hemorrhage with (2) a "history insufficient to explain injuries" was considered a primary marker of abuse (96), they were using inclusion criteria to define the conclusion: circular reasoning - a methodological flaw.

Interestingly, though in the body of the paper the authors say that "retinal hemorrhages can occur under a variety of circumstances," (97) in the conclusion they say, "retinal hemorrhages are highly associated with inflicted injuries in very young children...." (98). Again, the inclusion criterion of retinal hemorrhaging is being used to justify its presence (99).

Duhaime updated her findings in a 1998 paper in the *New England Journal of Medicine* (100). Though she mentioned that "the causes of the severe brain swelling and subsequent extreme tissue loss in infants with the shaking-impact syndrome who survive are incompletely understood," (101) she goes on to state that subdural and subarachnoid blood is the most common finding and "a marker for the threshold of force required to cause the injury." (102). Again, a circular definition is used to determine when injuries are non-accidental, which includes a history of no or little trauma and the presence of subdural hematoma (103).

The Caffey markers, bleeding in the brain and retinal hemorrhaging, standing alone, are now almost universally seen as proof of SBS - that the baby was deliberately harmed by a much larger, malevolent caretaker (104). This view has also been adopted by the legal community. For example, in 1999 the Indiana Legislature adopted a definition of "shaken baby syndrome" that requires bleeding inside the head and one of twelve other symptoms, including subdural hematoma (bleeding inside the head) and retinal hemorrhage (105). Courts also try and convict people under this medical hypothesis (106). However, new research casts doubt on the scientific basis of the theory.

C. Current Findings

A paper recently published in the *British Journal of Neurosurgery* by R. Uscinski calls into doubt the original Caffey study (107). It points out that the only study offered in Caffey as experimental verification of SBS as a cause of traumatic injury in babies actually looked at whiplash injury incurred in simulations of rear-end vehicle collisions (108). No shaking was involved (109). Rather, the conclusions of the work cited by Caffey were that severe whiplash (110) caused head injuries (111). The 1987 Duhaime study cited earlier showed that humans could only shake with enough force to produce one quarter of the "predicted concussive injury thresholds" (112) meaning that shaking as a cause of injury has no theoretical basis, although hurling a child will do much damage. Furthermore, "subdurals in infants can occur after apparently normal birth, and a true incidence (and prevalence) of birth related subdural bleeding has yet to be determined. [A child with such bleeding could] present clinically weeks or even months later with a chronic subdural haematoma." (113). This child would fit the current definition of SBS even if it had never been shaken. Uscinski also points out that prior to 1972 retinal hemorrhaging "was a diagnostic aid in detecting the presence of chronic subdural haematoma in children." (114). So, rather than being an independent marker of abuse, retinal hemorrhaging might simply be a result of an underlying subdural hematoma.

Other countries aren't so quick to find abuse where there are no external indicia: Eva Lai Wah Fung, a Hong Kong researcher writing in *Pediatrics International*, states, "Retinal hemorrhage and subdural hematoma without external signs of injury in Japan [and Hong Kong] is usually attributed to accidental, trivial head injury, whereas subdural hemorrhage associated with external signs of trauma to the face or head were commonly found in cases of genuine child abuse." (115). By studying brain injuries in piglets, other researchers have discovered that infant brains were no more susceptible to traumatic brain injury than adult brains (116).

Perhaps the most informative study to date, by J.F. Geddes and others, is one that examined "37 infants aged 9 months or less, all of whom died from inflicted head injuries." (117). It shows, by careful microscopic examination of infant brains said to have died from SBS, that they do not have the damage at the cellular level that would indicate trauma caused by shaking or by shaking and throwing (118). Not only does shaking not cause SBS, but neither does shaking and then tossing: the shaken-impact syndrome.

The study states, "Seen from this point of view, the debate over shaken versus shaken-impact becomes irrelevant, and because there is no DAI [diffuse axonal injury] it is possible that the severe acceleration-deceleration injury that is so often cited does not in fact occur in shaken-baby syndrome." (119).

Furthermore, the study shows that apnea (cessation of breathing) causes the SBS markers (120). In the court cases cited previously (and many others) (121), the accused said that they shook the babies because they weren't breathing. These authors say we should believe them. "While one might tend to dismiss the statements of carers in child abuse cases, the story of respiratory abnormalities or apnea recurs with great regularity in the clinical notes of the infants." (122). This finding is one of many in the text of the article, but is highlighted in an accompanying editorial, which strongly implies that lack of oxygen alone may be enough to cause the observed injuries (123).

The authors posited a reason for the apnea. Eleven of the infants had damage to a regulatory area of the brainstem that controls breathing (124). The authors hypothesized that this area could be easily damaged by shaking, and that the damage then causes apnea (125). However, twenty-three of the thirty-seven babies had no signs of such damage to their brainstems, and their deaths are not otherwise explained (126). One is left with the reasonable inference that their brain swelling was caused by apnea alone, or at least by apnea combined with some cause other than shaking.

A related study in the same issue of *Brain*, by the same authors, looked at fifty-three cases of non-accidental head injury (127). Researchers looked for microscopic evidence of impact (diffuse axonal trauma), but found it in only two infant cases, both of whom also had severe head injuries (128). However, global hypoxia (insufficient oxygen to the brain) was found in 84% of the infant cases (129). This indicates that the brain was not damaged by shaking (130). Retinal hemorrhaging was "seen both in cases in which impact had occurred, and in cases in which there was no macroscopic evidence of impact. There was, however, a statistically significant association between subdural and retinal bleeding." (131). In layperson's terms, if there's bleeding on the brain, there is often bleeding behind the eyes as well.

Two ophthalmologists summing up the current state of research stated, "The actual existence of SBS as a pure pathologic entity unassociated with blunt force head trauma must be seriously questioned." (132). "If one thing is clear now, it is that we do not understand the pathophysiology of infant brain injury nearly as well as we thought." (133).

IV. Examining Shaken Baby Syndrome Testimony in Light of the Daubert Factors

A. Can the Theory Be Tested, and Has It Been Tested?

1. Is the Diagnosis of SBS as It Currently Stands Falsifiable?

A logical circularity resides at the heart of most SBS studies. One of the main diagnostic findings leading to an SBS diagnosis is the absence of any other signs that abuse has occurred. The original Caffey study said: "The absence of a history of trauma of any kind in 54% [of children diagnosed with shaken-whiplash syndrome] is significant and suggests that whiplash shaking may be the cause in many patients." (134). In other words, if there is no other cause at all then we assume whiplash from shaking. Non-accidental head injury was likewise presumed in a 1999 study if a child had intradural hemorrhages (bleeding on the brain) and "history insufficient to explain injuries." (135).

Similarly, the Hadley article discussed supra, widely cited for the proposition that no direct trauma is necessary for a finding of SBS, has similar language worth quoting. It too says that finding no trauma (that is, no sign of abuse) is prima facie proof that such abuse occurred:

"Our data do not conclusively demonstrate that severe neurological trauma can occur with rapid, forceful, repetitive acceleration-deceleration of the head and neck with respect to the torso. Because most of these assaults are not witnessed, doubt remains about the true mechanism of these injuries. However, to the best of our abilities and those of the other professionals investigating these cases, we were able to document that each of the 13 patients had a history of whiplash-shake injury without direct impact trauma. Supporting the history in each case is the fact that none of the patients had clinical signs or radiographic evidence of craniofacial trauma." (136).

This conflicts strongly with the major forces that are said to be necessary to produce such symptoms, "The act of shaking ... is so violent that [untrained] individuals observing it would recognize it as dangerous." (137). Other related causes of childhood trauma, which differ from SBS mainly because of the greater degree of visible harm to the child, do not show subdural hematoma and retinal hemorrhage.

It is striking to see just how few cases of RH [retinal hemorrhaging] occur after TA [traffic accidents] when one considers the magnitude of energy transfers involved, compared to the relative weakness of irate caretakers. RH is also less common in the child-beating syndrome than in SBS, and is not part of the so-called "projectile child syndrome." This suggests that the violence of trauma by itself is not enough to cause RH in SBS; rotational trauma and repeated shaking are probably key features leading to RH in SBS, although the striking similarity between RH in SBS and in aneurysmal bleeding suggests some common, as yet unknown, mechanism (138).

To put this in layperson's terms: if a baby has visible signs of harm that indicate battering or being thrown, they have a much lesser chance of having the two markers for SBS (subdural hematoma and retinal hemorrhaging), which are themselves supposed to indicate even more severe abuse but which mysteriously leave no visible marks.

If not possessing a symptom (that would be expected to be seen) is proof that the syndrome occurs, then the argument is circular, (as the effect and the cause are the same thing) (139) and unfalsifiable in the Popperian sense, because there is no way to disprove the theory that shaking causes SBS.

2. Has SBS Been Satisfactorily Tested?

In spite of the many scientific studies that uncritically accept the existence of SBS, an adequate link between shaking a baby and the two SBS markers has never been scientifically verified and the latest evidence points strongly to organic reasons for the babies' distress, as opposed to shaking. Studies show:

- a. Retinal hemorrhaging is not a marker of shaking a baby (140).
- b. Babies with the SBS markers rarely show signs of trauma predicted by the theory (141).
- c. Shaking does not produce enough force to cause the hemorrhaging and hematoma (142).
- d. Babies diagnosed with SBS do not show signs of having physical trauma to their brains (143).
- e. Apnea causes the same symptoms - bleeding on the brain and behind the eyes - as those relied on for a diagnosis of SBS (144).

The scientific basis for SBS is itself very shaky.

B. Has the Diagnosis of SBS Been Published in Peer-Reviewed Journals?

There have been many studies of SBS appearing in the most reputable of journals. However, the findings are open to question, with the later studies tending to narrow or disprove the earlier ones. The Daubert Court says that "submission to the scrutiny of the scientific community is a component of 'good science,' in part because it increases the likelihood that substantive flaws in methodology will be detected." (145). That is exactly what has happened here, with the "substantive flaws" in the methodology coming to light through recent application of the scientific process.

C. What Is the Error Rate?

The current theory of SBS has serious error-rate problems, as acknowledged by the scientific authors. Rarely is child abuse admitted in these cases, rather it is assumed if the SBS markers are present, as has been previously discussed. Therefore, the error rate is entirely unknown. This problem was clearly explicated in a letter published in 2001 in the American Journal of Forensic Medicine:

In this field [SBS research] more than others we are more readily prone to alter the facts to fit the hypothesis rather than alter the hypothesis to fit the facts. For example, if the accused admits to severely harming the child, we tend to believe because this fits our hypothesis, but if the accused offers an alternative apparently innocuous explanation we discount the explanation because it doesn't fit the hypothesis. Published cases purporting to demonstrate less traumatic causes are

attacked for their anecdotal data and for overlooking the real, more sinister explanation. This "illogical inconsistency" overlooks scientific process and forgets that the requirement for severe shaking forces is no more than a favored but unproven hypothesis (146).

But the problem is even worse because often the slightest admission that a baby was shaken is seen as admitting abuse. When a baby stops breathing, it is natural to jostle or even shake the baby to wake it up. When caregivers are interviewed by police, they often mention this shaking, which is then taken as an admission that (1) abuse occurred, and (2) the abuse was the cause of the injuries. For example, the defendant Jones, in *Jones v. State* (147) admitted to shaking a baby several times "trying to get the child to breathe" after the child was dropped and stopped breathing (148). The prosecutor interpreted this at trial as Jones having "freaked out," "lost it," and that he "went into a rage" when he shook the child (149). Jones was convicted of felony murder, among other charges (150).

Similarly, the defendant in *State v. Mascarenas* (151) confessed to shaking a very fussy baby hard once (152). The court took that as an admission of guilt (153), and he was convicted of and sentenced to twelve years for negligent child abuse resulting in death (154).

However, research for this Note uncovered no studies showing that cases of child abuse can be separated from other accidental or medical reasons for harm. Medical evidence is accumulating that other reasons for the possible harm, previously disregarded, should be given weight. If a caretaker says that a baby's injuries were caused by a fall from a low height, they are assumed to be lying. Courts and medical authorities often state uncategorically that a fall would have to occur from the top of at least a two-story building to cause the SBS symptoms (155). However, a study published in 2001 indicates that a "fall from less than 3 meters (10 feet) ... may cause fatal head injury and may not cause immediate symptoms," (156) with the injury including the classic SBS pattern of retinal hemorrhaging and subdural hematoma. Eighteen observed deadly falls by children from heights varying from two to ten feet were examined (157). Thirteen of the children had subdural hematoma, five had skull fractures, and four (of only six examined for eye injuries) had retinal hemorrhaging (158). Furthermore, twelve of the children had a lucid interval before expiring (159).

Evidence of earlier head injuries is often used by medical personnel and courts to indicate a pattern of abuse. However, recent findings question such techniques, suggesting instead that a single recent injury can give the appearance of both old and new injuries (160).

There is much uncertainty surrounding the error rate in SBS, starting with the circularity of defining the symptoms as proof of the problem, and continuing with the problem that modest falls can cause the symptoms despite protests to the contrary. There is nothing approaching proof beyond a reasonable doubt that shaking is even involved (161). The error rate is much too high to allow the current definition of SBS to be presented to courts as a reliable scientific finding.

D. Does the Theory Have General Acceptance?

SBS does have general acceptance in both the medical and the legal community. However, this doesn't mean that the theory is correct, as was understood by the Court. The Daubert Court

overturned the earlier Frye standard, which stated that "expert opinion based on a scientific technique is inadmissible unless the technique is 'generally accepted' as reliable in the relevant scientific community." (162). In *Daubert, Merrill Dow*, the respondent, presented evidence that its theory (that anti-nausea medication Bendectin did not cause birth defects) was overwhelmingly accepted by the courts and the scientific community (163). However, respondents did not even attempt to show that the methods used by the petitioners to show a causal link between Bendectin use and birth defects were incorrect, just that the answers arrived at by the plaintiff's scientists were different than that given by earlier research (164). The Court in *Daubert* refused to disallow the petitioner's less accepted but methodologically acceptable testimony based on the Frye standard (165).

Similarly, the fact that many courts have accepted the standard SBS definition should not be an obstacle preventing the new scientific data from being presented in court. Respect for precedent does not require courts to ignore flaws in logic. The law must adapt when prior scientific theories are undermined by further scientific advances. In law, precedent is respected. Older results get more deference. The reverse is true in science, where older scientific theories are modified or discarded by new scientific advances. Respect for precedent in law should not be followed when the law is interpreting scientific evidence.

V. Conclusion

For many years now, attorneys have been willing to prosecute, and juries have been willing to convict, people whose only clearly established mistake was caring for a baby that died. Considering the confused state of the medical evidence surrounding SBS, especially since it appears that shaking cannot harm a baby in the manner that has been described for the last thirty years, we should return to the standard proposed in 1962 (166). That is, people should not be accused of child abuse on the basis of subdural hematoma and retinal hemorrhaging alone. Courts should admit, under *Daubert*, that evidence showing that the two classic medical signs used to show that a child had been deliberately shaken to the point of injury or death (subdural hematoma and retinal hemorrhaging in a child) is insufficient proof that a crime has been committed.

It should be acknowledged that although shaking a baby is never a good idea, innocent light shaking alone, without some other sign of intentional abuse, does not produce the SBS symptoms. Confession to shaking a baby after it stops breathing (an understandable last resort in dire circumstances) should never be used as an admission of guilt. Rather, child abuse should only be assumed as a last resort: if other indicia of abuse are present such as long-bone injuries, a fractured skull, bruising, or other indications that abuse has actually occurred. Sometimes children just die, and there is no one to blame.

FOOTNOTES:

1. This quotation is often attributed to either Mark Twain or Will Rogers, but was actually coined by Josh Billings, nineteenth century humorist. Mark Twain, *Misattributed Quotes: What Mark Twain Didn't Say*, n.6 (Jim Zwick, ed.) at

[http://www.boondocksnet.com/twaintexts/quotes not twain.html](http://www.boondocksnet.com/twaintexts/quotes_not_twain.html) (last visited Oct. 10, 2003).

2. Nancy Peddle & Ching-Tung Wang, Current Trends in Child Abuse Prevention, Reporting, and Fatalities: The 1999 Fifty-State Survey - Working Paper no. 808, at 17 (National Center on Child Abuse Prevention Research, Aug. 28, 2001)
3. Susan Linn & Alvin F. Poussaint, Fragile: Handle with Care, *Newsweek*, Spring/Summer 1997, at 33.
4. John Caffey, The Whiplash Shaken Infant Syndrome: Manual Shaking by the Extremities With Whiplash-Induced Intracranial and Intraocular Bleedings, Linked With Residual Permanent Brain Damage and Mental Retardation, 54 *Pediatrics* 396 (1974).
5. American Academy of Pediatrics, Shaken Baby Syndrome: Rotational Cranial Injuries - Technical Report, 108 *Pediatrics* 206, 206 (2001).
6. Intellihealth, Subdural Hematoma, at <http://www.intelihealth.com/IH/ihtIH/WSIHW000/9339/9621.html>.
7. Id.
8. Id.
9. Id.
10. Id.
11. Id.
12. Caffey, *supra* note 4, at 401.
13. See Joseph A. Prahlow et al., Death Due to a Ruptured Berry Aneurysm in a 3.5-Year-Old Child, 19 *Am. J. Forensic Med. & Pathology* 391, 391 (1998).
14. See Richard S. Newman et al., Factor XIII Deficiency Mistaken for Battered Child Syndrome: Case of "Correct" Test Ordering Negated by a Commonly Accepted Qualitative Test With Limited Negative Predictive Value, 71 *Am. J. Hematology* 328, 328 (2002).
15. J. Kirk Osborn, Meeting the State's Medical Case in "Battered Child Cases," 23 *True Bill*, Nov. 2002, at 4, 5-6.
16. See, e.g., Jan Goodwin, Was It Murder, Or A Bad Vaccine?, *Redbook Mag.*, Sept. 2000, at 158, available at <http://www.whale.to/m/sbs21.html> (giving examples of doubtful diagnoses of SBS and proposing vaccination reaction as more likely explanation).
17. J.F. Geddes et al., Neuropathology of Inflicted Head Injury in Children I: Patterns of brain damage, 124 *Brain* 1290, 1298 (2001) [hereinafter Geddes, Patterns of brain damage].
18. Joseph D. Hatina, Shaken Baby Syndrome: Who are the True Experts?, 46 *Clev. St. L. Rev.* 557, 576 n.148 (1998). See also *infra* note 106 (discussing medical expert testimony in shaken-baby prosecutions).
19. See Osborn, *supra* note 15, at 4.
20. Mary E. Case et al., Position Paper on Fatal Abusive Head Injuries in Infants and Young Children, 22 *Am. J. Forensic Med. & Pathology* 112, 116 (2001).
21. See Jane D. Kivlin, Manifestations of the Shaken Baby Syndrome, 12 *Current Opinion Ophthalmology* 158, 159 (2001).
22. Case, *supra* note 20, at 116.
23. See Peddle & Wang, *supra* note 2, at 6.
24. Id. at 20.
25. Id. at 6.

26. *Id.* at 17. However, this number is said to be low because of misclassification. *Id.* at 16.
27. The 50,000 number is quoted without attribution in a wide variety of sources. For example, the American Association of Neurological Surgeons cites these statistics, in its position paper, Shaken Baby Syndrome - A Potentially Deadly Concern, found online in Medem Medical Library at http://www.medem.com/MedLB/article_detailb_for_printer.cfm?article_IDZ9G8DUE_8C&sub_cat=355. The New York City Administration for Children's Services also quotes 50,000 cases per year, while mentioning that only forty-four cases were seen in New York City between 1999 and 2001. Administration for Children's Services, Mayor Michael R. Bloomberg Marks Child Abuse Awareness Month With Public Education Campaign To Reduce Shaken Baby Syndrome, Apr. 23, 2002, at http://www.nyc.gov/html/acs/html/whatwedo/pr02_04_23.html.
28. United States Advisory Board on Child Abuse and Neglect, A Nation's Shame: Fatal Child Abuse and Neglect in the United States, at <http://ican-ncfr.org/shame/chapter1/data.html> (last visited Oct. 10, 2003).
29. National Center on Fatality Review, at <http://ican-ncfr.org>.
30. Child Abuse Prevention Center's National Information, Support and Referral Service on Shaken Baby Syndrome, National Study on Shaken Baby Syndrome Fatalities (Sept. 1988).
31. *Id.* Without assuming that these statistics accurately reflect the level of SBS diagnosis, they are noteworthy because they give a feel for the difference between the magnitude of the problem as sometimes presented (50,000 children/year) and as (imperfectly) documented (206 children/year).
32. *651 N.E.2d 258 (Ill. App. Ct. 1995)*.
33. *Id.* at 260-61.
34. *Id.*
35. See *id.*
36. *Id.* at 264.
37. *Id.* at 260.
38. *619 N.E.2d 337 (N.Y. 1993)*.
39. The conviction was reversed because of the jury's "impermissible speculation." *Id.* at 382.
40. *Id.*
41. *Id.* at 380.
42. *Id.*
43. *509 U.S. 579 (1993)*.
44. Rule 702 reads: If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.
45. *509 U.S. at 592-93*
46. A great deal of ink has been spilled discussing not only just what the Daubert Court meant, but also whether the underlying scientific view was valid. For a good overview of the debate see Jan Beyea & Daniel Berger, Scientific Misconceptions Among Daubert Gatekeepers, 64 Law & Contemp. Probs. 327, 360, for a discussion of "the two views of

science - process versus formal-logic that are in tension in Daubert and successive opinions."

47. *Daubert*, 509 U.S. at 593.
48. Id. (quoting Karl R. Popper, *Conjectures and Refutations: The Growth of Scientific Knowledge* 37 (5th ed. 1989)).
49. Karl Popper, *Scientific Method* (1934) in *A Pocket Popper* 133 (David Miller ed., 1983).
50. Karl R. Popper, *The Logic of Scientific Discovery* 86 (Routledge 1997) (1959).
51. Id. at 87 n.1. See also David L. Faigman, *To Have And Have Not: Assessing The Value Of Social Science To The Law As Science And Policy*, 38 *Emory L.J.* 1005, 1017 (1989) (discussing difference between theory that is falsifiable and one that is not).
52. For an excellent description of the difference between theories that cross the scientific threshold and those that do not, see the *Amicus Curiae Brief Of 72 Nobel Laureates, 17 State Academies of Science, and 7 Other Scientific Organizations, In Support of Appellees, Edwards v. Aguillard*, 482 U.S. 578 (1987) (No. 85-1513), at 22-24.
53. See Faigman, *supra* note 51, at 1017.
54. *Edwards v. Aguillard*, 482 U.S. 578, 603-04 (1987) (holding creation science is religious belief rather than scientific theory because "the tenets of creation science parallel the Genesis story of creation, and this is a religious belief").
55. For a full discussion on the non-overlapping spheres of science and religion, see Stephen J. Gould, *Rock of Ages: Science and Religion in the Fullness of Life* 4 (1999). He states: "Science tries to document the factual character of the natural world, and to develop theories that coordinate and explain these facts. Religion, on the other hand, operates in the equally important, but utterly different, realm of human purposes, meanings, and values - subjects that the factual domain of science might illuminate but can never resolve."
56. The concept of falsifiability seems to have confused the legal community which, in both court opinions and commentary, have misinterpreted the concept as whether the theory has been corroborated by observations. See, e.g., *Cummins v. Lyle Indus.*, 93 F.3d 362, 368 (7th Cir. 1996) (equating falsifiability with experimentation: "The Supreme Court has articulated several nonexclusive guideposts to assist the district courts in determining whether expert testimony fairly can be characterized as a scientific opinion: (1) whether the proffered conclusion lends itself to verification by the scientific method through testing ... "); *United States v. Havvard*, 117 F. Supp. 2d 848, 852 (S.D. Ind. 2000) (confusing falsification with corroboration: "In the roughly 100 years since fingerprints have been used for identification purposes, no one has managed to falsify the claim of uniqueness by showing that fingers of two persons had identical fingerprints."); Gary Edmond & David Mercer, *Conjectures and Exhumations: Citations of History, Philosophy and Sociology of Science in US Federal Courts*, 14 *Law & Literature* 309, 316 (2002) ("The Daubert criteria were intentionally focused on testing - particularly whether an opinion had actually been tested - and the (positive) existence of published materials."); Sara K. Ledford, *The Implications of Kumho Tire: Applying Daubert Analysis to Warning-Label Testimony in Products Liability Cases*, 76 *Ind. L.J.* 465, 473 (2001) (equating falsifiability with testing). For an empirical finding of confusion among the legal profession, see Joseph Sanders et al., *Legal Perceptions of Science and Expert Knowledge*, 8 *Psychol. Pub. Pol'y & L.* 139, 152 (2002). Although over 90% of the judges seemed to

understand the criteria of peer review/publication and general acceptance, their understanding of the other two criteria was poor. Only 6% of the judges gave answers that indicated a clear understanding of falsifiability. Only 4% indicated a clear understanding of error rates.

57. Chief Justice Rehnquist confessed himself at a loss here in his partial dissent in *Daubert*. He said, "I defer to no one in my confidence in federal judges; but I am at a loss to know what is meant when it is said that the scientific status of a theory depends on its 'falsifiability,' and I suspect some of them will be, too." *Daubert*, 509 U.S. at 600 (Rehnquist, C.J., concurring in part and dissenting in part).
58. *Daubert*, 509 U.S. at 594.
59. *Id.*
60. *Id.* (internal quotation marks omitted).
61. *Id.* at 597 (internal quotation marks omitted).
62. *Id.* at 594-95.
63. 522 U.S. 136 (1997).
64. *Id.* at 146.
65. *Id.*
66. 526 U.S. 137 (1999)
67. D. Michael Risinger, Defining the "Task at Hand": Non-Science Forensic Science After *Kumho Tire Co. v. Carmichael*, 57 *Wash. & Lee L. Rev.* 767, 769 (2000).
68. *Kumho Tire*, 526 U.S. at 141.
69. *Id.* at 151.
70. *Id.* at 150 (internal quotation marks omitted).
71. C. Henry Kempe et al., The Battered-Child Syndrome, 251 *J. Am. Med. Assoc.* 3288 (1984) (1962). This paper was groundbreaking in that it also stated what we now consider obvious, but was a revelation at the time, that "beating of children ... occurs among people with good education and stable financial and social background." *Id.* at 3289.
72. *Id.* at 3288-89.
73. *Id.* at 3288.
74. See Marilyn Heins, The "Battered Child" Revisited, 251 *J. Am. Med. Assoc.* 3295, 3295 (1984).
75. Caffey, *supra* note 4, at 397.
76. *Id.*
77. *Id.* at 401.
78. *Id.* at 403. Caffey explained the paradoxical nature of his findings: "The most characteristic pattern of physical findings in the whiplashed infant is the absence of external signs of trauma to the head and the soft tissues of the face and neck, and of the facial bones and calvaria, in the presence of massive traumatic intracranial and intraocular bleedings. This is an extraordinary diagnostic contradiction." *Id.* at 399.
79. Ann-Christine Duhaime et al., The Shaken Baby Syndrome: A Clinical, Pathological, and Biomechanical Study, 66 *J. Neurosurgery* 409 (1987) [hereinafter Duhaime, 1987].
80. *Id.* at 413 fig.2.
81. *Id.* The models were thrown against a metal bar and a padded surface. *Id.*
82. *Id.* at 414.

83. *Id.* But see Robert Reece, *Medical Evidence in the Context of Child Abuse Litigation*, 36 *New Engl. L. Rev.* 607, 610 (2002) (stating that shaking versus shaking plus impact is not real controversy because "in all of these shaking cases there is acceleration at the end of the arc of the swing").
84. Duhaime, 1987, *supra* note 79, at 414.
85. *See id.*
86. *Id.* at 413-14. "Figure 2," which shows the force necessary to cause injury, is particularly informative, with all of the shake data clustered in the extreme lower-left-hand corner, far outside of the range to produce any injury. The impact data is scattered across the rest of the table, showing enough force to produce concussion, subdural hematoma, and diffuse axonal injury (severe brain damage). Perhaps part of the problem lies in "Figure 1," which shows the respective accelerations for shaking and impact. The authors used widely different scales which gives the two graphs a misleadingly similar shape.
87. Mark N. Hadley et al., *The Infant Whiplash-Shake Injury Syndrome: A Clinical and Pathological Study*, 24 *Neurosurgery* 536 (1989).
88. *Id.* at 536.
89. *Id.*
90. *Id.* at 537.
91. *Id.* at 539.
92. Eva Lai Wah Fung et al., *Unexplained Subdural Hematoma in Young Children: Is it Always Child Abuse?*, 44 *Pediatrics Int'l* 37, 40 (2002) ("It is therefore not clear to what extent these conclusions are a self-fulfilling prophecy, that is, defining child abuse [simply] on the basis of [the existence of the two markers.]").
93. Ann-Christine Duhaime et al., *Head Injury in Very Young Children: Mechanisms, Injury Types, and Ophthalmologic Findings in 100 Hospitalized Patients Younger Than 2 Years of Age*, 90 *Pediatrics* 179 (1992) [hereinafter Duhaime, 1992].
94. *Id.* at 180 fig.1.
95. *Id.* at 184.
96. *Id.*
97. *Id.* at 183.
98. *Id.* at 184.
99. If a child has retinal hemorrhaging it is considered presumptive proof that it was caused by non-accidental means. So, the population of head injuries considered non-accidental is filled with babies with retinal hemorrhages. The population is then examined and surprise is announced when large numbers of infants with retinal hemorrhages are found.
100. Ann-Christine Duhaime et al., *Nonaccidental Head Injury in Infants - The "Shaken-Baby Syndrome,"* 338 *New Eng. J. Med.* 1822 (1998) [hereinafter Duhaime, 1998].
101. *Id.* at 1826-27.
102. *Id.* at 1827.
103. *Id.*
104. *See* American Academy of Pediatrics, *supra* note 5, at 206 ("The act of shaking leading to shaken baby syndrome is so violent that individuals observing it would recognize it as dangerous and likely to kill the child. Shaken baby syndrome injuries are the result of violent trauma."); Barton D. Schmitt, *The Child with Nonaccidental Trauma*, in *The Battered Child* 178, 188 (Ray E. Helfer & Ruth S. Kempe eds., 4th ed. 1987) ("Inflicted

- subdural hematomas can also occur without skull fractures, scalp bruises, or scalp swelling... . These findings used to be erroneously called "spontaneous subdural hematomas,' but evidence clearly points to a violent, whiplash shaking mechanism."); Kivlin, *supra* note 21, at 158 ("Retinal hemorrhages are the most common fundus finding in the shaken baby syndrome."). After the trial of Louise Woodward for the shaking death of Matthew Eappen, fifty-four medical experts stated that "well established medical evidence ... overwhelmingly supported [that] a violent shaking/impact episode" killed the baby and that, furthermore, SBS comprises "swelling of the brain ... , bleeding within the head ... , and bleeding in the interior lining of the eyes." Shaken baby syndrome - A Forensic Pediatric Response, Nov. 16, 1997, at <http://www.olywa.net/cagle/webchild/matt.html> (last visited Oct. 10, 2003).
105. Ind. Code 16-41-40-2 (2002).
 106. See, e.g., *Johnson v. Sec'y of Health & Human Services*, 1997 WL 368375, at 5 (Fed. Cl. Apr. 29, 1997) (holding child's serious injuries caused by abuse, not vaccination. "To summarize, this evidence indicates that when an infant has the particular combination of injuries that Devin had (i.e., subdural hematoma, brain swelling, and retinal hemorrhaging) such injuries are very likely to have been caused by physical trauma" (citation omitted)); *United States v. Wright*, 1998 WL 142432, at 3 (A.F. Ct. Crim. App. Mar. 13, 1998) (holding caretaker guilty of negligent homicide when baby in her care died, where autopsy revealed subdural hematoma, retinal hemorrhaging, and cerebral swelling); *State v. Gunn*, 57 S.W.3d 347, 349 (Mo. Ct. App. 2001) (setting forth doctor's testimony that "retinal hemorrhage and subdural hematoma are classic injuries associated with a baby who has been violently shaken. Dr. Blair [also] testified that he was one hundred percent certain that the retinal hemorrhages were caused by shaking."); *State v. Mascarenas*, 4 P.3d 1221, 1222 (N.M. 2000) ("The treating physician diagnosed Matthew's injuries as subdural hematoma, cerebral edema, and cardio-pulmonary arrest all of which were consistent with shaken baby syndrome."); *State v. Talbot*, 972 P.2d 435, 436 (Utah 1998) (holding that child said to have fallen off bunk-bed reported by medical examiner to have suffered from SBS and she "died as a result of abnormal, massive craniocerebral injuries inflicted upon her by an outside force").
 107. R. Uscinski, Shaken Baby Syndrome: Fundamental Questions, 16 Brit. J. Neuro-surgery 217 (2002).
 108. *Id.* at 217.
 109. See *id.*
 110. Angular acceleration of about 4000 radians/s². *Id.*
 111. The injuries included concussion, subdural hematoma, and injuries to functional tissues. *Id.*
 112. *Id.* at 218.
 113. *Id.*
 114. *Id.*
 115. Fung et al., *supra* note 92, at 41 (discussing different markers for child abuse in Japan, Hong Kong, and United States).
 116. Susan R. Durham et al., Age-Related Differences in Acute Physiologic Response to Focal Traumatic Brain Injury in Piglets, 33 Pediatric Neurosurgery 76, 76-82 (2000).

117. J.F. Geddes et al., *Neuropathology of Inflicted Head Injury in Children II: Microscopic brain injury in infants*, 124 *Brain* 1299, 1299 (2001) [hereinafter, Geddes, *Microscopic brain injury*]. As mentioned before, there is a problem with the concept of "inflicted" injury here, in that it includes twenty-one cases where there was no "significant extracranial injury" or "other significant neuropathology." *Id.* at 1302 tbl.2. To wit, the injuries were most likely deemed to be inflicted because of the nature of the injury itself, rather than by some external reason.
118. *Id.* at 1303-05.
119. *Id.* at 1305. Diffuse axonal injury is the indication of severe damage to the brain caused by traumatic deceleration injuries such as those described by Caffey, *supra* text accompanying note 4.
120. "Apnea may well be, ... an integral part of many severe cases of non-accidental infant head injury or shaken-baby syndrome. The hypoxic damage resulting from apnea would lead to severe brain swelling, which is the usual cause of death." Geddes, *Microscopic brain injury*, *supra* note 117, at 1304.
121. See, e.g., *Powell v. State*, 522 *S.E.2d* 656, 656 (*Ga.* 1999) (convicting father of felony murder after he confessed to shaking daughter in attempt to revive her after she stopped breathing); *Andrews v. State*, 811 *A.2d* 282, 286 (*Md.* 2002) (convicting father of reckless endangerment when he admitted to lightly shaking baby daughter after she stopped breathing); *State v. Maze*, 2002 *WL* 1885118, at 2 (Tenn. Crim. App. Aug. 16, 2002) (sentencing father to twenty-one years after he admitted shaking five-week-old baby in attempt to resuscitate him after child stopped breathing).
122. Geddes, *Microscopic brain injury*, *supra* note 117, at 1304.
123. David I. Graham, Editorial: Paediatric head injury, 124 *Brain* 1261, 1262 (2001) ("The most important finding was that the predominant neurohistological abnormality in the cases of non-accidental injury in infants was due to hypoxia and not diffuse axonal injury. Although not commented upon it is not clear if, when interpreting this type of case material, there may be a need to consider the vascular complications of hypoxia and/or raised intracranial pressure.").
124. Geddes, *Microscopic brain injury*, *supra* note 117, at 1300.
125. *Id.*
126. *Id.*
127. Geddes, *Patterns of brain damage*, *supra* note 17.
128. *Id.* at 1298.
129. *Id.*
130. *Id.*
131. *Id.*
132. Cyril H. Wecht, Letter to the Editor, 20 *Am. J. Forensic Med. & Pathology* 301, 301 (1999) (stating that diagnosis of SBS "is made much too frequently and is definitely much too zealously ... pursued").
133. Brian J. Clark, Letter to the Editor, 125 *Brain* 677, 677-78 (2002) ("urging caution in assuming that all children with retinal haemorrhages have been violently shaken").
134. Caffey, *supra* note 4, at 400-01 (suggesting that even though "many features of post-traumatic subdural hematomas are not satisfactorily explained or understood," the cause is probably "repeated whiplash shaking").

135. Shervin R. Dashti et al., Current Patterns of Inflicted Head Injury in Children, 31 *Pediatric Neurosurgery* 302, 302-03 (1999) (examining "patterns of head trauma associated with child abuse").
136. Hadley, *supra* note 87, at 539.
137. American Association of Pediatrics, *supra* note 5, at 206.
138. Matthieu Vinchon et al., Infantile Subdural Hematomas due to Traffic Accidents, 37 *Pediatric Neurosurgery* 245, 251-52 (2002).
139. Popper provides a wonderful example of circularity: "Why is the sea so rough today? - 'Because Neptune is very angry' - 'By what evidence can you support your statement that Neptune is very angry?' - 'Oh, don't you see how very rough the sea is? And is it not always rough when Neptune is angry?' This explanation is found unsatisfactory because ... the only evidence for the [state of affairs to be explained] is the [explanation] itself." Karl Popper, *The Aim of Science* (1957), in *A Pocket Popper* 163 (David Miller ed., 1983).
140. Geddes, Patterns of brain damage, *supra* note 17, at 1297. See also John Plunkett, Fatal Pediatric Head Injuries Caused by Short-Distance Falls, 22 *Am. J. Forensic Med. & Pathology* 1, 9 (2001) ("Any sudden increase in intracranial pressure may cause retinal hemorrhage. Deformation of the skull coincident to an impact non-selectively increases intracranial pressure.").
141. Two examples can be found *supra* text accompanying notes 78 and 82.
142. See Duhaime, 1987, *supra* text accompanying notes 79-86.
143. Geddes, Microscopic brain injury, *supra* note 117, at 1299.
144. *Id.* at 1304-05.
145. *Daubert*, 509 *U.S.* at 593.
146. Brian J. Clark, Letter to the Editor, 22 *Am. J. Forensic Med. & Pathology* 415, 415 (2001) (arguing that hypothesis of SBS is not established fact and should not be thought of as such).
147. 439 *S.E.2d* 645 (1994).
148. *Id.* at 647.
149. *Id.* at 649.
150. *Id.* at 647.
151. 4 *P.3d* 1221 (N.M. 2001).
152. *Id.* at 1223 ("The treating physician diagnosed Matthew's injuries as subdural hematoma, cerebral edema, and cardio-pulmonary arrest all of which were consistent with shaken baby syndrome.").
153. *Id.* ("One State expert witness did concede that there was a debate within the medical community as to whether one shake was sufficient to cause the injuries associated with SBS.").
154. *Id.* at 1221
155. For an example of a court case with such an assertion, see *Jones*, 439 *S.E.2d* at 647 (stating that to cause symptoms of SBS seen in child "the fall would have to be from a third or fourth floor of a building"). For an example from the medical field, see Dashti, *supra* note 135, at 303 ("For young children, it is widely accepted that minor falls and often even major falls of 10 feet or more do not produce severe intracranial damage, although skull fractures are common.").
156. Plunkett, *supra* note 140, at 10.

157. Id. at 3 tbl.1.
158. Id.
159. Id.
160. See Mark S. Dias et al., Serial Radiography in the Infant Shaken Impact Syndrome, 29 *Pediatric Neurosurgery* 77 (1998) (finding that symptoms previously interpreted as chronic subdural hematoma can appear after just one injury); Vinchon, *supra* note 138, at 245 (examining eighteen cases of subdural hematoma in infants caused by traffic accidents and finding that "hallmark of repeated trauma," mixed-density collections on CT scans, can be created by single recent trauma).
161. See Duhaime, 1987, *supra* text accompanying note 79.
162. *Daubert*, 509 U.S. at 584.
163. *Brief for Respondent at 5, 11, Daubert*, 509 U.S. 579 (1993) (No. 92-102) (arguing that plaintiffs' evidence has been found insufficient to prove causation because "of the roughly 2000 Bendectin cases that have been filed - the vast majority of which have already reached final judgment - only one case has resulted in an affirmed jury verdict for the plaintiff" and arguing that "overwhelming body of data [] contradict [the petitioner's] conclusion").
164. *Reply Brief of Petitioners at 3, Daubert*, 509 U.S. 579 (1993) (No. 92-102) ("The methods employed by petitioners' experts are precisely the methods routinely employed by scientists, indeed, prescribed by federal regulations, to assess the probability that a particular drug is causing observed injuries."). For a fuller discussion of the scientific issues underlying the *Daubert* decision, see Kenneth J. Chesebro, Taking *Daubert's* "Focus" Seriously, 15 *Cardozo L. Rev.* 1745, 1749-50 (1994).
165. On remand, the Ninth Circuit held that the plaintiff's evidence was not admissible under the *Daubert* standard, stating that "the strongest inference to be drawn for plaintiffs based on the epidemiological evidence is that Bendectin could possibly have caused plaintiffs' injuries." *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 43 F.3d 1311, 1322 (9th Cir. 1995).
166. Kempe, *supra* note 71, at 3288-89.