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**SHAKEN BABY SYNDROME, ABUSIVE HEAD
TRAUMA, AND ACTUAL INNOCENCE:
GETTING IT RIGHT**

Keith A. Findley, University of Wisconsin Law School

Patrick D. Barnes, Stanford School of Medicine

David A. Moran, University of Michigan Law School

Waney Squier, John Radcliffe Hospital, Oxford, England

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SHAKEN BABY SYNDROME, ABUSIVE HEAD TRAUMA, AND ACTUAL INNOCENCE: GETTING IT RIGHT

Patrick D. Barnes^{*}
Keith A. Findley[†]
David A. Moran[‡]
Waney Squier[§]

In the past decade, the existence of shaken baby syndrome (SBS) has been called into serious question by biomechanical studies, the medical and legal literature, and the media. As a result of these questions, SBS has been renamed abusive head trauma (AHT). This is, however, primarily a terminological shift: like SBS, AHT refers to the two-part hypothesis that one can reliably diagnose shaking or abuse from three internal findings (subdural hemorrhage, retinal hemorrhage and encephalopathy) and that one can identify the perpetrator based on the onset of symptoms. Over the past decade, we have learned that this hypothesis fits poorly with the anatomy and physiology of the infant brain, that there are many natural and accidental causes for these findings, and that the onset of symptoms does not reliably indicate timing.

In the last issue of this journal, Dr. Sandeep Narang marshaled the arguments and evidence that he believes support the diagnostic specificity of the medical signs that are used to diagnose SBS/AHT. Dr. Narang does not dispute the alternative diagnoses but nonetheless argues that, in the absence of a proven alternative, the SBS/AHT hypothesis is sufficiently reliable to support criminal convictions. The cited studies do not, however, support this position since they assume the validity of the hypothesis without examining it and classify cases accordingly, often without considering alternative diagnoses. To address this problem, Dr. Narang argues that, in diagnosing SBS/AHT, we should rely on the judgment of child abuse pediatricians and other clinicians who endorse the hypothesis. Reliance on groups that endorse a particular hypothesis is, however, antithetical to evidence-based medicine and Daubert, which require an objective assessment of the scientific evidence.

In the past decades, thousands of parents and caretakers have been accused – and many convicted – of abusing children based on a hypothesis that is not scientifically supported. While we must do everything in our power to protect children, we must refrain from invoking abuse as a default diagnosis for medical findings that are complex, poorly understood and have a wide range of causes, some doubtlessly yet unknown. To this end, we are calling for collaboration between the medical and legal communities for the sole purpose of “getting it right.”

^{*} Chief, Section of Pediatric Neuroradiology; Director, Pediatric MRI and CT, Lucile Packard Children's Hospital, Stanford University School of Medicine.

[†] Assistant Professor of Law, University of Wisconsin Law School; Co-Director, Wisconsin Innocence Project; President, The Innocence Network.

[‡] Clinical Professor of Law, University of Michigan Law School; Co-Director, Michigan Innocence Clinic.

[§] Paediatric Neuropathologist, John Radcliffe Hospital, Oxford, England.

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I. INTRODUCTION

For decades, shaken baby syndrome (SBS) was an accepted medical and legal diagnosis. As the shaking mechanism came into serious question, SBS was renamed abusive head trauma (AHT). Regardless of terminology, SBS/AHT refers to the two-part medicolegal hypothesis that, in the absence of a confirmed alternative explanation, one can reliably diagnose shaking or abuse from three internal findings – subdural hemorrhage, retinal hemorrhage and encephalopathy (brain abnormalities and/or neurological symptoms), and that one can identify the perpetrator based on the onset of symptoms. Because the consequences of an SBS/AHT diagnosis can devastate children and families, it is critical to assess the reliability of the diagnosis under the standards of evidence-based medicine⁵ and *Daubert v. Merrell Dow Pharmaceuticals, Inc.*⁶ Dr. Sandeep Narang’s article in this journal identifies the research basis for the SBS/AHT hypothesis and the applicable medicolegal standards.⁷ However, in concluding that the SBS/AHT hypothesis meets the standards of evidence-based medicine and *Daubert*, the article neglects the underlying flaws in the supporting research and the shift in our understanding of the science over the past decade.

For all the heat in the debates about the validity of SBS/AHT, there is in reality a growing, if frequently unexpressed, consensus on the nature of the problem and the flaws in the hypothesis. Today, there is general agreement that child abuse was historically under-recognized and that abuse can produce subdural hemorrhage, retinal hemorrhage and brain damage – the “triad” of medical findings that has traditionally been used to confirm shaking or other forms of abuse.⁸ There is also general agreement that violently shaking a child is unacceptable and could cause serious injury or even death.⁹ At the same time, there is now

⁵ See, e.g., Connie Schardt & Jill Mayer, *Introduction to Evidence-Based Medicine*, Duke University Medical Center Library and Health Sciences Library, UNC-Chapel Hill (2010) at <http://www.hsl.unc.edu/services/tutorials/ebm/index.htm>; Gordon H. Guyatt et al., *Users’ Guides to the Medical Literature XXV, Evidence-Based Medicine: Principles for Applying the Users’ Guides to Patient Care*, 10 J. AM. MED. ASS. 1290 (2000).

⁶ 509 U.S. 579 (1993).

⁷ Sandeep K. Narang, *A Daubert Analysis of Abusive Head Trauma/Shaken Baby Syndrome*, 11 HOUS. J. HEALTH L. & POL’Y 505, 506, 507, 538-559 (2011).

⁸ See, e.g., *id.*, at 522, 523, 569.

⁹ See, e.g., Emily Bazelon, Mary Case, Christopher Greeley, Ronald H. Uscinski, Waney Squier, Round Table Discussion: Anatomy of an AHT Diagnosis, Investigation and Prosecution, New York City Abusive Head Trauma/Shaken Baby Syndrome Training Conference (Sept. 23, 2011) (notes on file with authors) (all participants agreed that violent shaking is dangerous and may injure or kill an infant); Kay Rauth-Farley, Lori D. Frasier, Robert N. Parrish, *Current Perspectives on Abusive Head Trauma*, ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN, A MEDICAL, LEGAL, AND FORENSIC REFERENCE 1, 1 (2006) (“It is widely accepted that shaking a young child or infant is dangerous”).

widespread, if not universal, agreement that the presence of the triad alone – or its individual components – is not enough to diagnose abuse. In the United Kingdom, the Crown Prosecution Service Guidelines of March 2011 endorsed this view,¹⁰ while in the U.S. the diagnostic specificity of the “triad” was recently described as a “myth” by a leading proponent of the SBS/AHT hypothesis.¹¹ As we develop more fully below, there is also a growing consensus that certain features of the diagnosis were inaccurate, including some that were frequently used to obtain criminal convictions. For example, it is no longer generally accepted that short falls can never cause the triad, that there can be no period of lucidity between injury and collapse (a key element in identifying the perpetrator), or that massive force – typically described as the equivalent of a multi-story fall or car accident – is required.¹²

As Dr. Narang points out, the list of alternative causes for the triad or its components is now so broad that it cannot be addressed in a single article.¹³ One of the child abuse textbooks recommended by Dr. Narang lists the differential diagnosis (alternative causes or “mimics”) as accidental causes; prenatal and perinatal conditions, including birth trauma; congenital malformations; genetic conditions; metabolic disorders; coagulation disorders, including venous sinus thrombosis (a form of childhood stroke); infectious disease; vasculitis; autoimmune conditions; oncology; toxins and poisons; nutritional deficiencies; and complications from medical-surgical procedures, including lumbar puncture.¹⁴ In all likelihood, other causes are still undiscovered.¹⁵ Like

¹⁰ Crown Prosecution Service, *Non Accidental Head Injury Cases (NAHI, formerly referred to as Shaken Baby Syndrome [SBS]) - Prosecution Approach*, March 24, 2011 (“it is unlikely that a charge for a homicide (or attempted murder or assault) offence could be justified where the only evidence available is the triad of pathological features”), available at http://www.cps.gov.uk/legal/l_to_o/non_accidental_head_injury_cases/.

¹¹ Carole Jenny, Presentation, *The Mechanics: Distinguishing AHT/SBS from Accidents and Other Medical Conditions*, slide 11, New York City Abusive Head Trauma/Shaken Baby Syndrome Training Conference (Sept. 23, 2011) at http://www.queensda.org/SBS_Conference/SBC2011.html.

¹² See *infra* notes 111, 124, 125, 220 and accompanying text.

¹³ Narang, *supra* note 3, at 507, note 13 (“A thorough examination of the literature behind all the possible injuries and all potential causes (short falls, biomechanics of head injury, etc.) is simply too broad and beyond the scope of this paper”). See also Narang, *supra* note 3, at Appendices B and C (differential diagnosis for subdural hemorrhage includes inflicted trauma, accidental trauma, birth trauma, metabolic disease, nutritional deficiencies, genetic syndromes, clotting disorders, tumors and infection; differential diagnosis for retinal hemorrhages include all of the above as well as anemia, vasculitis, hypoxia, hypotension, hypertension and increased intracranial pressure); Julian T. Hoff et al., *Brain Edema*, 22 NEUROSURG. FOCUS 1 (2007) (causes of brain edema include trauma, stroke and tumors).

¹⁴ Andrew P. Sirotnak, *Medical Disorders that Mimic Abusive Head Trauma*, in ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN, A MEDICAL, LEGAL, AND FORENSIC REFERENCE 191, 193-214 (2006); M. Denise Dowd, *Epidemiology of Traumatic Brain Injury: Recognizing Unintentional Head Injuries in Children*, in

Dr. Narang, we refer the reader to the literature for a discussion of the alternative causes.¹⁶

Given this emerging consensus, our disagreement with Dr. Narang is narrow but critical. Since biomechanical studies have consistently concluded that shaking does not generate enough force to produce the types of traumatic damage associated with SBS/AHT, particularly in the absence of neck damage, Dr. Narang does not defend shaking as a mechanism or argue that there are no diagnostic alternatives. Instead, as is typical in the current debates about these issues, he contends that the less-specific diagnosis of AHT is supported by current medical science when subdural and retinal hemorrhage are identified and other known causes ruled out.¹⁷

Changing the name of the syndrome from SBS to AHT does not, however, resolve the disagreement. In describing AHT, Dr. Narang does not offer new evidence but instead relies on the assumptions that provided the basis for the SBS hypothesis.¹⁸ This hypothesis assumed that each element of the triad was, virtually by definition, traumatic, *i.e.*, that subdural and retinal hemorrhages were caused by the traumatic rupture of bridging veins and retinal blood vessels and that encephalopathy was caused by the traumatic rupture of axons (the nerve fibers that connect the cells throughout the brain). We now know, however, that the triad does not necessarily or generally reflect the traumatic rupture of bridging veins or retinal blood vessels; that the encephalopathy virtually always reflects hypoxia-ischemia (lack of oxygen) rather than the traumatic tearing of axons; and that the triad can

ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN, A MEDICAL, LEGAL, AND FORENSIC REFERENCE 11, 12-14 (2006).

¹⁵ We are, for example, just beginning to identify the many variations of the human genome, the thousands of metabolites and enzymes that must function properly to sustain life, and the unique anatomic and physiological characteristics of the infant brain.

¹⁶ In 2011, two of the co-authors of this article – Dr. Barnes and Dr. Squier – addressed the differential diagnoses in major invited reviews of the medical evidence on SBS/AHT in the fields of pediatric neuroradiology and pediatric neuropathology, their own specialties. Patrick D. Barnes, *Imaging of Nonaccidental Injury and the Mimics: Issues and Controversies in the Era of Evidence-Based Medicine*, 49 *RADIOL. CLIN. N. AM.* 205 (2011); Waney Squier, *The “Shaken Baby” Syndrome: Pathology and Mechanisms*, 122 *ACTA NEUROPATHOL.* 519 (2011). For a more complete discussion of the literature, we refer the readers to these reviews and to the articles cited by Dr. Narang.

¹⁷ Narang, *supra* note 3, at 569.

¹⁸ In describing AHT causation, Dr. Narang relies upon the classic SBS hypothesis, with no reference to the more recent literature (discussed below). *See, e.g., id.* at 541 (“In inertial [i.e. shaking] events, the acceleration-deceleration motion of the brain results in strain upon the cortical bridging veins which exceeds their tolerance levels and subsequently leads to rupture and hemorrhage (subdural and/or subarachnoid) and 552-553 (“[S]everal lines of research and analysis point towards acceleration-deceleration forces at the vitreo-retinal interface...as the causative mechanism for severe [retinal hemorrhages]”).

also result from natural disease processes and accidents. Consequently, it is no longer valid to reason backwards from the triad to a diagnosis of trauma or abuse.

The AHT label also raises new problems. Without an identified mechanism, it is not possible for biomechanical engineers to reconstruct or for doctors, judges or juries to critically evaluate the proposed mechanism or mechanisms. The AHT label does not, moreover, address the more recent criticisms of SBS/AHT, which have shifted from biomechanics to the unique characteristics of the developing brain. Finally, like the SBS label, the AHT label subsumes the answer to the question “what causes the triad or its elements” within its very name, making it difficult to discuss the issues objectively.

Since the existing evidence does not meet the standards of evidence-based medicine and we cannot ethically experiment with babies, Dr. Narang suggests that we rely on the “clinical judgment” of the doctors, particularly child abuse pediatricians, who endorse the SBS/AHT hypothesis and defer to the literature that assumes the accuracy of their judgments.¹⁹ As a practical matter, this would shield the SBS/AHT hypothesis from the scientific scrutiny envisioned by evidence-based medicine and *Daubert* and eliminate any claim that the hypothesis has been scientifically validated. We suggest that this approach also violates the medical and legal precepts of “first do no harm” and “innocent until proven guilty.”

While child abuse that results in neurological damage or death is horrific, particularly when committed by parents and caretakers who literally hold in their hands the lives of their infants, we have learned from the daycare cases of the 1980s and 1990s that the strong emotions that accompany allegations of child abuse can increase the likelihood of false convictions.²⁰ In a 1990 symposium on pretrial publicity, Judge Abner Mivka, a highly respected member of the U.S. Court of Appeals for the District of Columbia, observed:

¹⁹ Narang *supra* note 3, at 579-580 (arguing that the relevant scientific community be limited to those who have obtained subspecialty certification or are eligible for subspecialty certification in the field of child abuse pediatrics). This certification program, which was created by leading advocates of the SBS/AHT hypothesis, incorporates the traditional SBS/AHT hypothesis into its curriculum. *See* American Board of Pediatrics Subboard of Child Abuse Pediatrics, *Child Abuse Pediatrics Content Outline*, (January 2009) (on file with authors); Robert W. Block & Vincent J. Palusci, *Child Abuse Pediatrics: A New Pediatric Subspecialty*, 148 J. OF PEDIATRICS 711 (2006).

²⁰ *See, e.g.*, DOROTHY RABINOWITZ, *NO CRUELER TYRANNIES* (1st ed. 2003) (reporting on daycare, Wenatchee and other child sex abuse scandals of the 1980s and 1990s); Maggie Jones, *Who Was Abused?*, N. Y. TIMES, Sept. 19, 2004, at <http://query.com/gst/fullpage.html?res=9F03EFD61330F93AA2575AC0A9629C8B63&scp=1&sq=maggie+jones+who+was+abused&st=cse&pagewanted=1> (reporting on Bakersfield scandals); *Summary of the Cleveland Inquiry*, 297 BRIT. MED. J. 190 (1988).

I do not think that you can get a fair child abuse trial before a jury anywhere in the country. I really don't . . . I don't care how sophisticated or smart jurors are, when they hear that a child has been abused, a piece of their mind closes up and this goes for the judge, the juror, and all of us.²¹

Given these dangers, it is critical to carefully assess the quality of the evidence used to diagnose child abuse and to make clear the extent to which the diagnosis rests on hypotheses or personal opinion rather than scientific knowledge. This is particularly important when judges and jurors are being asked to render judgments on unresolved and highly controversial issues in complex areas of medicine.

In Part II, we briefly review the changes in the SBS/AHT hypothesis over the past decade and identify the issues that are currently the subject of debate. The shifts can be captured in a sentence: since 2000, we have learned that much of what we thought we knew was wrong. In Part III, we examine the quality of the research that Dr. Narang cites to support the SBS/AHT hypothesis as well as the research that casts doubt on this hypothesis. In Part IV, we apply the applicable medical and legal standards to this research. In Part V, we suggest a path forward to help us better differentiate between child abuse and the wide array of accidental and natural causes that may produce the same or similar findings. It is our hope that Dr. Narang and others will join us in this endeavor to “get it right.”

II. FROM SBS TO AHT: A DIAGNOSIS IN FLUX

Our increased understanding of the infant brain and the biomechanics of injury is reflected in an evolving terminology that acknowledges the flaws in the original SBS hypothesis. Despite widespread acknowledgement of these flaws, the new terminology (AHT) retains the automatic diagnosis of abuse for the medical findings previously attributed to shaking and rests on the same assumptions as SBS, many of which have been discredited or disproven. After clarifying the terminology, we discuss the shifts in the literature that resulted in the new terminology. We then identify the areas of current agreement and debate.

A. A Plethora of Terms

In addressing the changes in the SBS/AHT hypothesis, it is important to distinguish between five terms and diagnoses: “shaking,” “shaken baby syndrome,” “shaken impact syndrome,” “abusive head

²¹ Forum, *Panel One: What Empirical Research Tells Us, and What We Need to Know About Juries and the Quest for Impartiality*, 40 AM. U. L. REV. 547, 564-565 (1991).

trauma” and “blunt force trauma.” Much of the disagreement in this area reflects the confusion of these terms and conflation of the underlying concepts.

1. **Shaking.** “Shaking” refers to the physical act of shaking a child, irrespective of injury. Shaking to punish or in frustration is always inappropriate. In infants with large heads and weak necks – or even in older children – violent shaking may lead to disastrous consequences, particularly in a child with predisposing factors.

2. **Shaken baby syndrome.** “Shaken baby syndrome” (SBS) refers to hypothesis that violent shaking may be reliably diagnosed based on the triad of subdural hemorrhage, retinal hemorrhage, and encephalopathy (brain damage) if the caretakers do not describe a major trauma (typically described as equivalent to a motor vehicle accident or fall from a multistory building) and no alternative medical explanation is identified. Under this hypothesis, the rapid acceleration and deceleration of shaking causes movement of the brain within the skull, resulting in the traumatic rupture of bridging veins, retinal blood vessels and nerve fibers throughout the brain (diffuse axonal injury). This hypothesis came into question when biomechanical studies consistently concluded that shaking generated far less force than impact, did not meet established injury thresholds, and would be expected to injure the neck before causing bridging vein rupture or diffuse axonal injury.

3. **Shaken impact syndrome.** “Shaken impact syndrome” was advanced to address the biomechanical criticisms of shaking as a causal mechanism for the triad. Under this hypothesis, subdural hemorrhage, retinal hemorrhage and encephalopathy were attributed to shaking followed by impact, such as tossing or slamming the child onto a hard or soft surface. If there were no bruises or other signs of impact, it was hypothesized that the child was thrown onto a soft surface, such as a mattress or pillow.

4. **Abusive head trauma.** As shaking came under increasing scrutiny, a plethora of new terms arose that did not invoke shaking as a mechanism.²² At present, the most popular replacement term – and the term used by Dr. Narang – is abusive head trauma, or AHT. AHT refers to any deliberately inflicted injury to the head, regardless of mechanism. In 2009, the American Academy of Pediatrics recommended that pediatricians use this term instead of SBS but endorsed shaking as a plausible mechanism based on confession evidence.²³ AHT also includes hitting the child on the head, crushing the child, throwing the child onto a hard or soft surface, or any other conceivable manner of

²² These terms include “intentional traumatic brain injury (iTBI),” “nonaccidental injury (NAI),” “nonaccidental head injury (NAHI),” “nonaccidental trauma (NAT),” “inflicted neurotrauma” and “abusive head trauma (AHT)”.

²³ Cindy W. Christian, Robert Block and the Committee on Child Abuse and Neglect, *Abusive Head Trauma in Infants and Children*, 123 PEDIATRICS 1409 (2009).

harming the head. Under the AHT hypothesis, such acts may be inferred from the triad of findings previously attributed to shaking, with or without other evidence of trauma, at least in the absence of another acceptable explanation. Used in this sense, AHT is most often used by pediatricians.

5. *Blunt force trauma.* Blunt force trauma to the head refers to any impact that does not penetrate the scalp, including accidents (e.g., falls onto the floor or other surfaces) and abuse (e.g., hitting the child on the head or throwing the child on the floor). This term does not imply intent and is used in cases with skull fractures and bruises as well as in cases that rely primarily or exclusively on the triad. This term is most often used by forensic pathologists.

6. *Semantics and the courts.* As reflected in Dr. Narang’s article, the trend in recent years has been to move away from terms involving shaking towards generalized terms such as AHT, which avoids the criticisms of shaking by relying upon an undetermined mechanism. Without a defined mechanism, however, it is difficult for parents or caretakers to defend themselves: how does one defend against an unknown mechanism, particularly one that leaves no clues as to its cause? In effect, by changing the name, supporters of the AHT hypothesis continue to rely on traditional SBS assumptions – specifically, the assumption that the triad findings are caused largely or entirely by trauma – while discarding the shaking mechanism, producing what may be viewed as a medicolegal “bait and switch.”

When combined with unfamiliar medical concepts, these terminological shifts can result in considerable confusion, even at the level of the U.S. Supreme Court. This confusion is exemplified by the U.S. Supreme Court decision in *Cavazos v. Smith*.²⁴ In *Smith*, a California grandmother with no history of abuse or neglect was convicted of causing the death of her 7-week-old grandson by violent shaking. This was not a classic SBS/AHT case since the child had minimal subdural/subarachnoid hemorrhage with no retinal hemorrhage or brain swelling. There were no fractures, no sprains and no other indicia of trauma other than a “tiny” abrasion and corresponding bruise, which the prosecution’s medical expert agreed did not produce brain trauma.²⁵ The state’s experts testified nonetheless that the death was consistent with violent shaking that caused the brain or brainstem – not just the bridging veins and axons – to tear in vital areas.²⁶ The Ninth Circuit overturned the conviction, stating that there was “no physical evidence of . . . tearing or shearing, and no other evidence supporting death by violent shaking.”²⁷ A 6-3 majority of the Supreme Court reversed the Ninth Circuit, stating that the Ninth Circuit’s assertion that

²⁴ *Cavazos v. Smith*, 132 S. Ct. 2 (2011) (per curiam).

²⁵ *Id.* at 3 (Ginsburg, Breyer & Sotomayor dissenting).

²⁶ *Id.* at 3.

²⁷ *Id.* at 6 (quoting *Smith v. Mitchell*, 437 F.3d 884 (2006) at 890).

“there was no evidence in the brain itself of the cause of death” was “simply false” and that there “*was* ‘evidence in the brain itself’” (emphasis in original).²⁸ In support of this claim, the majority cited evidence of subdural, subarachnoid, optic nerve and interhemispheric bleeding. However, these findings are *outside* the brain and are associated with a multitude of nontraumatic causes. The majority went on to say that these affirmative indications of trauma formed the basis of the experts’ opinions that the child died from shaking so severe “that his brainstem tore.”²⁹ The autopsy did not, however, find any tears in the brainstem, which was not examined microscopically since the pathologists felt that they “wouldn’t have seen anything anyway.”³⁰ In short, the Supreme Court was willing to send Ms. Smith – a grandmother described as “warm hearted, sensitive, and gentle” – back to prison to serve a sentence of 15 years to life based on an injury that no one could find.³¹ Ultimately, the majority suggestion that clemency might be appropriate given doubts about guilt prevailed, and Governor Brown granted clemency on April 6, 2012.³²

To understand how we got to the point where invisible injuries are acceptable as proof beyond a reasonable doubt of murder, one must understand the history of SBS/AHT.

²⁸ *Id.* at 7.

²⁹ *Id.* at 7.

³⁰ *Id.* at 1 (dissent).

³¹ *Id.* at 4. This case was not so much an endorsement of the SBS hypothesis as an expression of the deference the law gives to evidence accepted by a jury, including medical opinions – even speculative and unproven ones – in criminal cases. The majority emphasized that it was bound by legal principles requiring deference to jury verdicts, especially in federal habeas corpus review of state court convictions. To the extent the Court commented on the science, it suggested that there was indeed considerable reason to doubt the medical opinions and conviction. The dissent pointed out expressly that changes in the medical literature since the child’s death in 1996 cast considerable doubt on the conviction and the SBS theories underlying it. *Id.* at 4-6. Even the majority acknowledged that “[d]oubts about whether Smith is in fact guilty are understandable,” and lamented that “the inevitable consequence of this settled law [of deference to juries] is that judges will sometimes encounter convictions that they believe to be mistaken, but that they must nonetheless uphold.” *Id.* at 1, 7.

³² Carol J. Williams, *Brown commutes sentence of woman convicted of killing grandson*, L. A. TIMES, Apr. 7, 2012 at <http://www.latimes.com/news/local/la-me-shaken-baby-clemency-20120407,0,3766620.story>. In a review of the medical evidence prior to the grant of clemency, a pathologist at the Los Angeles County coroner’s office described eight “diagnostic problems” with the coroner’s original ruling that the child had died from violent shaking or a blow to the head. He wrote that the “conservative approach would be to acknowledge these unknowns. The cause of death should be diagnosed as undetermined.” Joseph Shapiro & A.C. Thompson, *New Evidence in High-Profile Shaken Baby Case*, NATIONAL PUBLIC RADIO, Mar. 29, 2012 at <http://www.npr.org/2012/03/29/149576627/new-evidence-in-high-profile-shaken-baby-case>.

B. A Brief History of SBS/AHT

1. *The Origins.* For time immemorial, seemingly healthy infants have collapsed or died without any known medical explanation.³³ In the early 1970s, Dr. Guthkelch (a British neurosurgeon) and Dr. Caffey (an American pediatric radiologist) suggested that shaking might explain the unexpected collapse or death of a subset of infants who presented with subdural hemorrhage but typically had no external signs of injury. While shaking was at that time viewed as benign – in one of Dr. Guthkelch’s examples, the parent was attempting to save a child from choking – Dr. Guthkelch was concerned that the whiplash effect of shaking could produce subdural hematomas in infants, especially given their weak neck muscles and relatively large heads.³⁴ In 1974, Dr. Caffey described a two-part sequence in which shaking causes an infant’s head to strike its chest and back in “rapid, repeated, to-and-fro, alternating, acceleration-deceleration flexions.”³⁵ Like Dr. Guthkelch, Dr. Caffey was concerned that parents and caretakers did not realize the dangers of shaking, and he recommended a nationwide education campaign to warn of the potential consequences of any action in which the heads of infants were jerked and jolted.³⁶

Over the years, the shaking/whiplash hypothesis evolved into the medicolegal hypothesis of “shaken baby syndrome.” This hypothesis held that shaking may cause a “triad” of medical findings – subdural hemorrhage, retinal hemorrhage and encephalopathy (brain damage) – and that in the absence of other known explanations, it may be safely inferred from these findings that the child has been shaken.³⁷ While this conclusion was sometimes supported by other signs of physical injury, such as bruises or fractures, there were often no signs of trauma. In other cases, only one or two elements of the triad were present.³⁸

³³ See, e.g., D. L. Russell-Jones, *Sudden Infant Death in History and Literature*, 60 ARCHIVES OF DISEASE IN CHILDHOOD 278 (1985).

³⁴ A. N. Guthkelch, *Infantile Subdural Haematoma and its Relationship to Whiplash Injuries*, 2 BR. MED. J. 430 (1971). As Dr. Guthkelch recently told NPR, at that time in Northern England, parents sometimes punished their children by shaking them, which was considered socially acceptable. Joseph Shapiro, *Rethinking Shaken Baby Syndrome*, NATIONAL PUBLIC RADIO, June 29, 2011 at <http://www.npr.org/2011/06/29/137471992/rethinking-shaken-baby-syndrome>.

³⁵ 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, 401 (1974).

³⁶ *Id.* at 402-403.

³⁷ See, e.g., Brian Holmgren, *Prosecuting the Shaken Infant Case*, in THE SHAKEN BABY SYNDROME: A MULTIDISCIPLINARY APPROACH 275, 306 (Stephen Lazoritz & Vincent J. Palusci eds., 2001) (“retinal hemorrhages, bilateral subdural hematoma, and diffuse axonal injury are highly specific for SBS as a mechanism”).

³⁸ See, e.g., *Cavazos v. Smith*, *supra* note 20 (affirming conviction in SBS case involving “minimal subdural and subarachnoid hemorrhages” but no retinal hemorrhages or brain swelling); *Hess v. Tilton*, No. CIV S-07-0909, 2009 WL 577661

In the absence of other signs of trauma, the SBS diagnosis was based on the belief that the triad elements were in and of themselves traumatic in origin. Specifically, subdural hemorrhages were attributed to the traumatic rupture of the bridging veins that convey blood from the brain to the large veins (or sinuses) in the fibrous dura lining the skull. Retinal hemorrhages were similarly attributed to the traumatic rupture of retinal blood vessels, while encephalopathy (brain damage) was attributed to the traumatic rupture of the axons (nerve fibers) that connect the nerve cells throughout the brain. Because the brain damage was often bilateral and widespread, it was assumed that the force needed to cause these findings was comparable to or greater than that found in multistory falls or motor vehicle accidents.³⁹ Thus, if the history provided by the caretakers did not include a major accident, the history was considered to be inconsistent with the findings, and abuse was considered to be the only plausible explanation.⁴⁰ In children who had no external signs of trauma, it was further hypothesized that the abuse must have consisted of violent shaking.

A corollary of the SBS hypothesis – and one that was particularly important for the legal system – was that the injury could be timed and the perpetrator identified based solely on the medical findings. Since the

(E.D. Cal., Mar. 5, 2009) (affirming conviction in SBS case involving brain swelling and retinal hemorrhages but no subdural hemorrhage).

³⁹ See Mary E. Case et al., *Position Paper on Fatal Abusive Head Injuries in Infants and Young Children*, 22 AM. J. FORENSIC MED. PATHOL. 112, 120 (2001) (“fatal accidental shearing or diffuse brain injuries require such extremes of rotational force that they occur only in obvious incidents such as motor vehicle accidents. Besides vehicular accidents, other fatal accidental childhood head injuries tend to involve crushing or penetrating trauma, which is readily evident. These injuries tend to be the result of falling from considerable heights (greater than 10 feet) or having some object penetrate the head”); Alex Levin et al., Clinical Statement, *Abusive Head Trauma/Shaken Baby Syndrome*, AM. ACADEMY OPHTHALMOLOGY, available at http://one.aao.org/ce/practiceguidelines/clinicalstatements_content.aspx?cid=914163d5-5313-4c23-80f1-07167ee62579 (retinal hemorrhages typical of AHT/SBS are uncommon in severe accidental head trauma such as falls from a second-story level or a motor vehicle collision).

⁴⁰ See, e.g., Edward J. Imwinkelried, *Shaken Baby Syndrome: A Genuine Battle of the Scientific (and Non-Scientific) Experts*, 46 CRIM. L. BULL. 6 (2010) and cases cited therein (noting that “the most common analogies [used by prosecution experts] are to the amount generated by high speed automobile accidents and a fall from a several-story building. The experts analogize to these “real-life accident scenarios” in order to give the trier of fact a sense of the ‘massive, violent’ force required to produce this kind of brain injury”); cited cases include *Mitchell v. State*, 2008 WL 316166 (Ark. Ct. App. 2008) (examining pediatrician equated the force necessary to produce the triad with that of a high-speed automobile accident); *People v. Dunaway*, 88 P.3d 619, 631, 632 (Colo. 2004) (prosecution expert stated that subdural hemorrhages occur in “such things as falling from a several story building or being in a high speed motorcycle accident or a child say is on a bicycle hit by a car...when we see subdurals in accidental injury, it’s from a major trauma. It requires massive force”); *In re Child*, 25 Misc. 3d 745, 2008 WL 6572459 (N.Y. Fam. Ct. 2008) (prosecution expert stated that SBS findings “simulate being in a car crash at ‘around 35 to 40 miles per hour’”).

damage caused by the traumatic rupture of nerve fibers throughout the brain would be devastating with immediate loss of function (as in concussion), there could be no period of relative normality (“lucid interval”) following the injury. It was therefore widely accepted that the last person with the baby must have been responsible.⁴¹ In effect, SBS quickly became a criminal category of *res ipsa loquitur* cases, *i.e.*, cases in which “the thing speaks for itself.” This eliminated the need for any additional evidence, including motive or history of abuse, and resulted in quick, easy and virtually routine convictions of parents and caretakers based solely on the medical testimony of prosecution experts.⁴²

Given the underlying assumptions of the SBS hypothesis, the suggestion that birth injuries, short falls, or natural causes could result in the triad, or that a child might have a lucid interval after such an injury, was viewed as heretical: how could birth injuries produce findings that did not become apparent for days, weeks or months after birth? How could short falls produce traumatic findings akin to – or worse than – those seen in major motor vehicle accidents and multistory falls? How could a natural disease process rupture veins and axons, causing diffuse traumatic brain injury? And how could there be a lucid interval after bridging veins had been ruptured and axons torn throughout the brain? Not surprisingly, those who suggested such possibilities were often disparaged or vilified.⁴³ Unfortunately, those attacks continue to this day.⁴⁴

⁴¹ See, e.g., Deborah Tuerkheimer, *The Next Innocence Project: Shaken Baby Syndrome and the Criminal Courts*, 87 WASH. UNIV. L. REV. 1, 18 (2009) (noting that parents and caretakers have been accused of shaking the child in their care because they were present immediately before the child’s loss of consciousness).

⁴² See, e.g., Imwinkelried, *supra* note 36 (“it seems clear that during the past two decades, prosecution expert testimony about shaken baby syndrome has contributed to thousands of convictions”).

⁴³ Those who question the scientific basis for SBS/AHT are routinely accused of incompetence, greed, indifference to child abuse and, more recently, of possibly having histrionic/borderline personality disorders. See, e.g., Christopher Spencer Greeley, Presentation, *Dissent or Denialism?: A Scholarly Misadventure with the Medical Literature (and the Media)*, New York City Abusive Head Trauma/Shaken Baby Syndrome Training Conference (Sept. 23, 2011) at http://www.queensda.org/SBS_Conference/Denialism&TheMedicalLiterature,0911,NY_C,Handout.pdf (suggesting that researchers who question SBS/AHT theory use “sleaze tactics” and may have “histrionic/borderline” personality disorders); Brian Holmgren, Presentation, *To Tell the Truth – Examining Defense Witness Testimony in Abusive Head Trauma Cases*, Eleventh International Conference on Shaken Baby Syndrome/Abusive Head Trauma, sponsored by the National Center on Shaken Baby Syndrome (Sept. 2010) (showing excerpts of testimony from defense experts juxtaposed with an image of Pinocchio with a growing nose at a keynote presentation teaching doctors and prosecutors how to discredit defense witnesses; this presentation concluded with a sing-along to the tune of “If I only had a brain” led by a prominent child abuse pediatrician, joined by prosecutors and doctors, mocking those who propose diagnostic alternatives to SBS/AHT) brochure at http://www.dontshake.org/pdf/Program_Atlanta2010_8-18-10%20v2.pdf (presentation notes and lyrics on file with authors); Robert M. Reece et al., *Response to Editorial*

2. **The warnings.** Despite its popularity, there were early warning signs that the SBS hypothesis might be flawed. The first serious warning arose in 1987, when Dr. Duhaime, a young neurosurgeon, and several biomechanical engineers attempted to validate the SBS hypothesis by measuring the force of shaking and comparing it to accepted head injury thresholds. While crude, these early experiments indicated that the force generated by shaking an infant was well below established head injury criteria and was only approximately one-fiftieth the force generated by impact.⁴⁵ This study concluded that,

[T]he shaken baby syndrome, at least in its most severe acute form, is not usually caused by shaking alone. Although shaking may, in fact, be part of the process, it is more likely that such infants suffer blunt impact Unless a child has predisposing factors such as subdural hygromas, brain atrophy, or collagen-vascular disease, 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.⁴⁶

Dr. Duhaime later suggested that the triad was likely caused by shaking followed by impact, possibly on a soft padded surface.⁴⁷

Further warnings arose during the 1997 Louise Woodward trial, popularly known as the “Boston nanny case.”⁴⁸ In *Woodward*, Dr.

from 106 Doctors, 328 BRIT. MED. J. 1316, 1316 (2004) (arguing that SBS skeptics have a “worrisome and persistent bias against the diagnosis of child abuse in general”). Personal and professional attacks of this nature have made scientific debate difficult.

⁴⁴ While Dr. Narang does not endorse these attacks, he does suggest, without offering evidence, that those who point out flaws in the SBS diagnosis or identify alternative causes are motivated by monetary gain. Narang, *supra* note 3, at 592 (“[T]he pecuniary interest in providing expert testimony cannot be underestimated. It has posed and continues to pose a significant risk to the presentation of unbiased medical information”). In our experience, the marginal income for defense experts is generally small relative to the workload and the hostility encountered in the courtroom and professional settings. Because the funding is often inadequate, defense experts often provide pro bono reports and/or testimony based on the research in their own specialties.

⁴⁵ Ann-Christine Duhaime et al., *The Shaken Baby Syndrome a Clinical Pathological and Biomechanical Study*, 66 J. NEUROSURG. 409 (1987).

⁴⁶ *Id.* at 414.

⁴⁷ See, e.g., A. C. 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, 183 (1992) (in “shaken impact syndrome,” head injury is caused by rapid angular deceleration to the brain through impact after a shaking episode; if the head strikes a soft padded surface, contact forces will be dissipated over a broad area and external or focal injuries may be undetectable).

⁴⁸ See *Commonwealth v. Woodward*, 694 N.E.2d 1277 (1998); See, e.g., Carey Goldberg, *Massachusetts High Court Backs Freeing Au Pair in Baby's Death*, N. Y.

Patrick Barnes, a pediatric neuroradiologist then at Harvard and one of the co-authors of this article, testified for the prosecution.⁴⁹ In the same case, several credible and well-established experts presented, perhaps for the first time, serious alternatives to the SBS hypothesis. At the trial, Dr. Jan Leestma, the author of *Forensic Neuropathology*, Dr. Michael Baden, a well-known forensic pathologist, and Dr. Ronald Uscinski, a Georgetown neurosurgeon, testified that the child had a chronic (old) subdural hemorrhage that rebled.⁵⁰ At the time, this was viewed as a “courtroom diagnosis” and its proponents were attacked by supporters of the SBS hypothesis.⁵¹ Today, however, rebleeding from a chronic subdural hemorrhage is widely accepted, even by supporters of the SBS/AHT hypothesis.⁵² Following the *Woodward* case, a number of forensic pathologists questioned the validity of the SBS diagnosis, with one leading forensic pathologist urging his colleagues to refrain from the type of “dramatic, unscientific” remarks that were permeating courtroom testimony, such as the standard phrase “the equivalent of a fall from a two-story building.”⁵³

3. 2001: a developing schism. The public airing of the issues in the *Woodward* case led to a renewed interest in SBS among researchers. In 2001, Dr. Geddes, a British neuropathologist, and her colleagues published careful studies of the brains of infants who had reportedly died from abuse.⁵⁴ The results of these studies were unexpected.⁵⁵ In the first study (“Geddes I”),⁵⁶ the researchers found

TIMES (June 17, 1998) at <http://www.nytimes.com/1998/06/17/us/massachusetts-high-court-backs-freeing-au-pair-in-baby-s-death.html?ref=louisewoodward>.

⁴⁹ Like many others, Dr. Barnes has revisited these issues since 1997, with particular emphasis on the teachings of evidence based medicine and the correlation between the neuroradiology and neuropathology of the infant brain.

⁵⁰ The Woodward case also involved a skull fracture, making timing difficult. See Special Report, *Timetable of Woodward Case*, BBC NEWS (Nov. 10, 1998) at http://news.bbc.co.uk/2/hi/special_report/louise_woodward_case/29232.stm.

⁵¹ David L. Chadwick et al., *Shaken Baby Syndrome—A Forensic Pediatric Response*, 101 PEDIATRICS 321 (1998).

⁵² See, e.g., Marguerite M. Caré, *Neuroradiology*, in ABUSIVE HEAD TRAUMA IN INFANTS AND CHILDREN, A MEDICAL, LEGAL, AND FORENSIC REFERENCE 73, 81 (2006) (septations or membranes that develop within chronic hematomas may predispose infants to repeated episodes of bleeding within these collections; such rebleeding can occur with little or no trauma).

⁵³ Cyril H. Wecht, *Shaken Baby Syndrome, Letter to the Editor*, 20 AM. J. FORENSIC MED. PATHOL. 301 (1999); see also John Plunkett, *Shaken Baby Syndrome and the Death of Matthew Eappen a Forensic Pathologist’s Response*, 20 AM. J. FORENSIC MED. PATHOL. 17 (1999). As discussed below, forensic pathologists have always been more skeptical of the SBS hypothesis than other specialties, particularly pediatricians.

⁵⁴ David I. Graham, *Editorial: Paediatric Head Injury*, 124 BRAIN 1261, 1261 (2001) (Geddes and her colleagues conducted a “meticulous clinicopathological correlation in 53 cases of non-accidental paediatric head injury”).

⁵⁵ Dr. Geddes has described her surprise that the microscopic examinations failed to find the widespread and severe traumatic brain damage assumed to be present in shaken infants. Jennian Geddes, *Questioning Traditional Assumptions*, BARTS AND THE

that the brain pathology was predominantly hypoxic or ischemic (*i.e.*, due to lack of an oxygenated blood supply) rather than traumatic in nature. Unlike the traumatic hemorrhages found in adults and older children, moreover, the subdural hemorrhages in allegedly abused infants were typically thin and trivial in quantity – containing far less blood than would be expected from ruptured bridging veins, as hypothesized in SBS. While some infants showed evidence of localized axonal injury to the craniocervical junction or cervical cord, the majority did not, casting further doubt on the SBS hypothesis. In the second study (“Geddes II”), Dr. Geddes and her colleagues described the scientific evidence supporting a traumatic origin for the brain damage in allegedly abused children as “scanty.” In many respects, the findings in these children were virtually indistinguishable from the findings in infants who had died natural deaths.⁵⁷

While far from dispositive, the implications of Geddes I and II were devastating: if Dr. Geddes and her colleagues were correct, the SBS hypothesis, which rested on the notion that the triad was caused by the traumatic tearing of veins and axons, was likely wrong. While traumatically torn axons are by definition caused by trauma, there are many non-traumatic causes for hypoxic axonal injury. The brain may, for example, be deprived of oxygen because the heart or lungs are not functioning properly or because the child is suffering from widespread infection (sepsis). This research raised, for the first time, the possibility that the brain findings that had been attributed to traumatically torn axons from violent shaking might reflect hypoxia-ischemia from any medical condition that affected the flow of oxygen to the brain. Dr. Geddes’ research also raised problems with timing: if the brain damage was secondary to the deprivation of oxygenated blood from any source, the ensuing brain swelling could develop quickly or slowly, over a period of hours to days, with collapse occurring whenever the brain’s basic needs were no longer met by the dwindling supply of oxygenated blood. Although Geddes I and II were heavily criticized at the time, it is now widely accepted that the brain swelling seen in allegedly shaken infants is hypoxic-ischemic rather than traumatic in nature.⁵⁸

LONDON CHRONICLE, Spring 2006, at http://www.qmul.ac.uk/alumni/publications/blc/blc_spring06.pdf.

⁵⁶ J. F. Geddes et al., *Neuropathology of Inflicted Head Injury in Children, I. Patterns of Brain Damage*, 124 BRAIN 1290 (2001).

⁵⁷ J.F. Geddes et al., *Neuropathology of Inflicted Head Injury in Children, II. Microscopic Brain Injury in Infants*, 124 BRAIN 1299, 1299, 1304 (2001).

⁵⁸ See, e.g., Mark S. Dias, *The Case for Shaking*, in CHILD ABUSE AND NEGLECT, DIAGNOSIS, TREATMENT AND EVIDENCE 364, 370 (Carole Jenny, ed., 2011) (it is increasingly clear from neuroimaging studies and post-mortem analyses that the widespread cerebral and axonal damage in AHT cases is ischemic rather than directly traumatic); Neil Stoodley, *Non-accidental head injury in children: gathering the evidence*, 360 THE LANCET 272 (2002) (noting the growing evidence that hypoxic-ischaemic damage is of greater importance than traumatic axonal or shearing injury in the pathophysiology of nonaccidental head injury).

Biomechanical objections to the SBS hypothesis also returned to the forefront in 2001. In April, Professor Werner Goldsmith, a professor of biomechanical engineering at the University of California at Berkeley, raised the biomechanical concerns with the National Institutes of Health (NIH). In his presentation, Professor Goldsmith noted that while the vast majority of pediatric head injuries were accidental, others resulted from abuse or physiological (natural) causes, unaccompanied by mechanical trauma.⁵⁹ Given the difficulty of determining causation, he urged the development of more sophisticated biomechanical models and more reliable head injury criteria for infants. He also urged biological specialists, medical professionals and biomechanicians to collaborate in investigating the properties of the immature infant brain and surrounding blood vessels that might make them more susceptible to trauma.⁶⁰ Such a program, Professor Goldsmith suggested, would “enormously reduce the number of cases now brought into criminal courts, and the concomitant costs, estimated to be in the multiple millions of dollars, as well as avoid the true trauma, emotionally, financially, and temporally, of individuals falsely accused of abuse when the occurrence was accidental.”⁶¹

In the same year, Dr. John Plunkett, a forensic pathologist, published an article on fatal short falls from playground equipment.⁶² While most of the children were older than typical SBS infants, his report included a videotaped fall of a toddler from a plastic indoor play gym that resulted in the triad findings and death after a short lucid interval. This videotape provided seemingly indisputable proof that the triad could result from falls of less than three feet and that lucid intervals could occur.⁶³

⁵⁹ Werner Goldsmith, Presentation, *Biomechanics of Traumatic Brain Injury in Infants and Children*, NAT. INSTITUTES OF HEALTH (April 2001) (on file with authors). As Professor Goldsmith recognized, “head injury” includes any insult to the brain, whether from accidental, abusive or natural causes. This terminology often causes confusion in the literature.

⁶⁰ Professor Goldsmith specifically urged research on the rate of blood absorption and effusion of ruptured blood vessels, which is the subject of the Squier & Mack papers (discussed below).

⁶¹ *Id.*

⁶² John Plunkett, *Fatal Pediatric Head Injuries Caused by Short-Distance Falls*, 22 AM. J. FORENSIC MED. PATHOL. 1 (2001).

⁶³ *Id.* at 4. In this case the child’s feet were 28” above the floor when she fell; medical records showed a large subdural hemorrhage, bilateral retinal hemorrhages and extensive edema. In the past year, two other videotaped fatal short falls resulting in death have been reported. One was of an infant who fell from a Kroger shopping cart onto concrete in Macon, Georgia, caught on surveillance video (John Stevens, *Three-Month-Old Boy Dies After Falling Out of Shopping Cart as Mother Walked Back to Car*, DAILY MAIL, September 22, 2011, at www.dailymail.co.uk/news/article-2040559). The other was a fall onto a mat at an indoor mall playground shown by the Queens District Attorney’s Office at the 2011 New York City Abusive Head Trauma/Shaken Baby Syndrome Training Conference (Sept. 22, 2011).

By this time, however, the SBS hypothesis had taken on a life of its own. By 2001, shaking as the primary or exclusive cause of the triad had been taught in the medical schools for decades, not as a hypothesis but as scientific fact. Prosecutions were well-publicized, and an effective advocacy group was training social workers and prosecutors to identify, prosecute and win cases against parents and caretakers who had allegedly shaken their children.⁶⁴ Doctors affiliated with this group also produced SBS position papers for the major medical associations. In 2001, the National Association of Medical Examiners (NAME) – the professional association for forensic pathologists – published an article entitled “Position Paper on Fatal Abusive Head Injuries in Infants and Young Children,” which incorporated the SBS hypothesis.⁶⁵ Although this paper did not pass peer review and was not endorsed by the membership,⁶⁶ it was published in the NAME journal, accompanied by a somewhat ambiguous and little-headed editorial caveat.⁶⁷ In the same year, the Committee on Child Abuse and Neglect of the American Academy of Pediatrics (AAP) published a similar paper, entitled “Shaken Baby Syndrome: Rotational Cranial Injuries—Technical Report.”⁶⁸ The AAP paper recommended a presumption of child abuse whenever a child younger than 1 year suffers an intracranial injury. While the NAME paper is no longer in effect and the AAP paper has

⁶⁴The National Center on Shaken Baby Syndrome (NCSBS) began offering SBS prevention programs in 1990 and incorporated as a legal entity in 2000. According to its website, the NCSBS reaches thousands of medical, legal, child protection and law enforcement professionals every year. See NCSBS website at <http://dontshake.org/>.

⁶⁵ Case, *supra* note 35.

⁶⁶ E-mail from Dr. DiMaio, Editor of the *American Journal of Forensic Medicine and Pathology*, to Dr. Plunkett (March 6, 2003) ([T]he “position paper: was reviewed by peer reviewers and determined not to be a position paper but an ordinary article expressing the opinion of the authors . . . The paper [does] not meet the criteria of a position paper Calling a tail a leg does not make it one.”); Email from Vincent DiMaio to NAME-L@Listserve.cc.emory.edu (Feb. 7, 2002) (“As editor of the AJFMP, I had serious misgiving about publishing this paper, not because of its contents but in that it is described as a position paper If one bothers to read the box in the lower left corner of the first page of the article, one will see that the paper was rejected as a position paper by the three reviewers As an aside, the paper in its original form was rejected by 4 of 5 reviewers Shaken baby syndrome is controversial in that a number of individuals doubt its existence . . .”) (e-mails on file with authors).

⁶⁷ Case, *supra* note 35, at 112 (“Editor’s note: The Board of Directors of the National Association of Medical Examiners charged the authors of this article with writing a position paper on the shaken baby syndrome. This article was the result. The manuscript was reviewed by three reviewers on the Board of Editors of the American Journal of Forensic Medicine and Pathology. They believed that while it was worthy of publication, it should not be published as a position paper because of the controversial nature of the subject. The Board of Directors responded to this opinion by stating that position papers always deal with controversial subjects”).

⁶⁸ Comm. on Child Abuse and Neglect, Am. Acad. of Pediatrics, *Shaken Baby Syndrome: Rotational Cranial Injuries – Technical Report*, 108 PEDIATRICS 206 (2001).

been substantially modified,⁶⁹ these papers gave an imprimatur of scientific and medical endorsement to the SBS hypothesis that was accepted, largely uncritically, by the medical and legal communities.

4. *A decade of debate.* The decade following the Geddes and Plunkett papers and the NAME/AAP position papers was filled with raucous debate, sometimes more rhetorical than substantive. However, a few key points emerged.

a. *2002 NIH conference.* In 2002, NIH held a conference to address the disputed issues.⁷⁰ By this time, the terminology was shifting away from shaken baby syndrome to more generalized terms, such as inflicted neurotrauma and abusive head trauma. Although the conference was limited to supporters of the SBS/AHT hypothesis, the lack of evidentiary support for SBS was repeatedly acknowledged, beginning in a preface to the conference proceedings by Dr. Carol Nicholson, a Program Director at NIH:

The debate over “shaken baby syndrome” continues to rage in our country. Because there is very little scientific experimental or descriptive work, the pathophysiology remains obscure, and the relationship to mechanics even cloudier.... What we need is science—research and evidence that just isn’t there right now. The evidence that does exist has not been subjected to evidence-based scrutiny in a multidisciplinary scientific forum.⁷¹

Dr. Robert Reece, a Clinical Professor of Pediatrics, made similar points in his preface:

There have been numerous conferences on this subject over the past several years, but to date, none of these has made the analysis of evidence-based literature the mission of the conference. What literature is there that is based on well-designed studies? How many of the more than 600 peer-reviewed articles in the medical literature can withstand the scrutiny of evidence-based analysis?⁷²

⁶⁹ As addressed below, the NAME paper was withdrawn in 2006; the AAP paper was modified in 2009.

⁷⁰ *Inflicted Childhood Neurotrauma*, 2003 PROC. OF A CONFERENCE SPONSORED BY DEPARTMENT OF HEALTH AND HUMAN SERVICES, NATIONAL INSTITUTES OF HEALTH, NATIONAL INSTITUTE OF CHILD HEALTH AND HUMAN DEVELOPMENT, OFFICE OF RARE DISEASE AND NATIONAL CENTER FOR MEDICAL REHABILITATION RESEARCH. These conference proceedings are one of the two treatises referenced by Narang, *supra* note 3, at 538-539.

⁷¹ *Id.* at IX (noting that the escalating emotional and forensic advocacy was proving destructive).

⁷² *Id.* at VIII.

Dr. Reece emphasized that much of the literature was based on clinical phenomena rather than “bench research” and that the contributions of basic scientists doing research on the physiology and pathophysiology of the central nervous system were essential to understanding these issues.⁷³ He also made clear that much of what was being considered at the conference was based on “a preponderance of the evidence” rather than “evidence beyond a reasonable doubt” – the standard required in criminal cases.⁷⁴

Other conference participants addressed the new literature. Although SBS theory had previously held that short falls were benign, Dr. Feldman advised that in a few cases short falls “may be fatal or have residual effects.”⁷⁵ Dr. Sege noted that while some might argue that additional research, which he characterized as a “massive undertaking,” would simply confirm the current SBS/AHT understandings, “[s]adly, the history of medicine is littered with things known to be true at the time that weren’t.”⁷⁶ Dr. Christian mounted a spirited defense of SBS/AHT theory, claiming that “[h]omicide is the leading cause of injury death in infancy,” but agreed with Dr. Sege that “[t]he literature is replete with case reports of medical diseases that have been misdiagnosed as child abuse.”⁷⁷

The conference participants generally agreed that, despite its volume, the SBS/AHT literature suffered from serious gaps. Dr. Hymel noted that the peer-reviewed SBS/AHT medical literature “largely represents Class 3 scientific evidence from retrospective case series” and “contains little if any firsthand clinical information from admitted perpetrators of inflicted childhood neurotrauma, and no data regarding the *reliability* and/or *validity* of the acute clinical information provided by admitted perpetrators of inflicted neurotrauma.”⁷⁸ Dr. Duhaime warned that SBS/AHT presented a complex puzzle that had been incompletely modeled and that a great deal of work needed to be done using tissues, animals, mathematical models and human observations, superimposed on age-dependent changes and physiological thresholds.⁷⁹

⁷³ *Id.*

⁷⁴ *Id.*

⁷⁵ *Id.* at 33.

⁷⁶ *Id.* at 40-41.

⁷⁷ *Id.* at 43.

⁷⁸ *Id.* at 67. As discussed below, under the standards of evidence-based medicine, the available evidence is ranked in four categories, starting with randomized controlled trials (Class 1), which are the most comprehensive and the most reliable, and ending with case studies (Class 4), which may provide valuable but limited insights. Class 3 evidence includes case-control studies and non-consecutive studies with inconsistently applied reference standards. See Bob Phillips, Chris Ball, Dave Sackett, Doug Badenoch, Sharon Straus, Brian Haynes and Martin Dawes, *Levels of Evidence*, OXFORD CENTRE FOR EVIDENCE-BASED MEDICINE (Updated by Jeremy Howick, Mar. 2009) at <http://www.cebm.net/index.aspx?o=1025>.

⁷⁹ *Id.* at 253.

Dr. Jenny identified the methodological difficulties with the existing literature:

One resounding criticism in this body of literature poses a methodological dilemma when attempting to study mode of presentation of inflicted head trauma. This dilemma is the problem of circularity of reasoning. That is, we use certain predetermined, generally accepted criteria to determine if a child's injuries are inflicted or unintentional, such as delay in seeking care and presence of retinal hemorrhages. Then, when we describe the mode of presentation, those criteria are found to occur most frequently in abused children. A most sticky methodological question is, "What is the gold standard in determining if a child is abused prior to assigning that child to a study cell?" Careful definitions of standards for determining abuse are needed.⁸⁰

Dr. Dias, a conference organizer, agreed that there was "some degree of a circularity in reasoning; if one defines a particular injury or pattern of injuries a priori as inflicted, then by definition one will rarely, if ever, ascribe these injuries to...an unintentional mechanism."⁸¹

b. Biomechanics. In general, the biomechanical literature continued to conclude that shaking was an unlikely cause of the triad. For example, a 2002 biomechanical review concluded that a three-foot fall produces forces approximately ten times greater than shaking; that spontaneous rebleeds may explain the onset of symptoms in children with chronic subdural hemorrhage; that severe shaking would be expected to damage the cervical cord and spine before producing intracranial injuries; and that the levels of force required for shaking to produce retinal bleeding and damage to the eye are biomechanically improbable.⁸² These findings were similar to those in a joint study conducted by Dr. Jenny, a leading SBS proponent, and Aprica, a Japanese baby products company that had created a more biofidelic model of the human infant.⁸³ Other research was in accord: while

⁸⁰ *Id.* at 51-52. Dr. Jenny identified the studies of Duhaime (1987); Ewing-Cobbs (1998); Reece (2000); and Feldman (2001) as "methodologically superior." *Id.* at 51. Three of these are discussed below.

⁸¹ *Id.* at 100.

⁸² A.K. Ommaya et al., *Biomechanics and Neuropathology of Adult and Paediatric Head Injury*, 16 BR. J. NEUROSURG. 220 (2002).

⁸³ These studies confirmed that the maximum linear acceleration produced by shaking was less than 1/3 that produced by rolling off a sofa and less than 1/10 that of a fall from chest level when being held by an adult. Violent shaking and slamming on a thin carpet over a wood floor was comparable to the chest level fall, while slamming onto a mat without shaking produced a force approximately 50% greater than the fall from chest level. C. Jenny et al., *Development of a Biofidelic 2.5 kg Infant Dummy and Its Application to Assessing Infant Head Trauma During Violent Shaking*, 2002 INJURY

impact reaches known injury thresholds, shaking does not produce the force required to rupture bridging veins and axons and would cause extensive cervical spine injury or failure (*i.e.*, neck injury) before causing such effects.⁸⁴ By then, after thirty years, there were still no witnessed accounts of the shaking of a previously well child resulting in the triad, casting further doubt on the mechanism.⁸⁵

c. SBS and evidence-based medicine. The weaknesses in the literature were not passing unnoticed in the outside world. In a 2003 article published in the NAME journal, Dr. Donohoe, a general practitioner in Australia, examined the research support for SBS through 1998 and concluded what others – including the NIH conference participants – had been saying privately for years: the research basis for shaken baby syndrome was remarkably weak.⁸⁶ Dr. Donohoe described the evidence for SBS as “analogous to an inverted pyramid, with a small database (most of it poor-quality original research, retrospective in nature, and without appropriate control groups) spreading to a broad body of somewhat divergent opinions. One may need reminding that repeated opinions based on poor-quality data cannot improve the quality of evidence.”⁸⁷ He concluded that “the commonly held opinion that the finding of SDH [subdural hemorrhage] and RH [retinal hemorrhage] in an infant was strong evidence of SBS was unsustainable, at least from the medical literature.”⁸⁸

d. Alternative diagnoses. Given the biomechanical findings, impact took on new significance as the most likely cause of the triad. But this raised new issues. First, if the triad was caused by impact, why did so few children have external signs of impact, such as fractures or bruises? Second, how much force is required to cause injury from impact? And third, can we reliably distinguish between accidental

BIOMECHANICS RESEARCH, PROCEEDINGS OF THE THIRTIETH INTERNATIONAL WORKSHOP, sponsored by the National Highway Traffic Safety Administration (on file with authors).

⁸⁴ See, e.g., Michael T. Prange et al., *Anthropomorphic Simulations of Falls, Shakes, and Inflicted Impacts in Infants*, 99 J. NEUROSURG. 143 (2003); Ommaya, *supra* note 78; see also R. Uscinski, *Shaken Baby Syndrome: Fundamental Questions* 16 BRIT. J. NEUROSURG. 217, 218 (2002) (biomechanical research has raised questions about whether shaking is the true cause of intracranial injuries in alleged SBS cases); Ronald H. Uscinski, *Shaken Baby Syndrome: An Odyssey*, 46 NEUROLOGIA MEDICO-CHIRURGICA 57, 59 (2006) (SBS-type accelerations should damage the cervical spinal cord and brainstem before head injury is observed).

⁸⁵ There are also no reported cases of video recordings capturing violent shaking resulting in the triad. While several caregivers have been caught on videotape shaking infants in their care, to our knowledge none of these children exhibited any of the triad findings, or any injury at all.

⁸⁶ Mark Donohoe, *Evidence-Based Medicine and Shaken Baby Syndrome Part I: Literature Review, 1966-1998*, 24 AM. J. FORENSIC MED. PATHOL. 239 (2003). Dr. Narang criticizes Dr. Donohoe’s review article and his review of the SBS literature. As discussed *infra*, that criticism mistakes the nature of Dr. Donohoe’s inquiry.

⁸⁷ *Id.* at 241.

⁸⁸ *Id.*

and inflicted impact – and if so, how? Some clinicians and pathologists avoided these issues by redefining the “triad” – which had previously been viewed as diagnostic of shaking – as evidence of impact. At the same time, clinicians quite rightly began to look closely for other possible signs of impact or abuse, ranging from small bruises or discolorations to fractures or other bony abnormalities that might help determine causation.

While some researchers and clinicians struggled to differentiate between accidental and inflicted impact, others began to consider – or more precisely re-consider – the role of natural conditions or birth trauma as causal or contributing factors for the triad. As Dr. Guthkelch noted in 1953, subdural hemorrhages are often associated with abnormal or difficult labor and, less commonly, with venous thrombosis, a form of childhood stroke often associated with infection and/or dehydration.⁸⁹ Metabolic disorders, nutritional deficits and infection have also long been recognized as causes of subdural hemorrhage.⁹⁰

During this period, the child abuse literature increasingly recognized alternative causes for subdural hemorrhages and other elements of the triad. In 2002, Drs. Jenny, Hymel and Block – all prominent child abuse pediatricians – published an article identifying a wide range of nontraumatic etiologies for subdural hemorrhages and describing minor accidental injuries confirmed by medical personnel that resulted in intracranial hemorrhage.⁹¹ The article further recognized that older subdural collections can rebleed spontaneously or from minor impact, and that no prospective, comparative studies had measured the frequency or consequences of rebleeding in young children with chronic subdural collections.⁹²

In 2003, Dr. Geddes suggested that the subdural and retinal hemorrhages seen in natural deaths and alleged SBS cases may reflect a cascade of events, including raised intracranial pressure, central venous and systemic arterial hypertension, immaturity and hypoxia-related vascular fragility – a suggestion that became known as the “Unified Hypothesis” or Geddes III.⁹³

⁸⁹ A. N. Guthkelch, *Subdural Effusions in Infancy: 24 Cases*, 1 BR. MED. J. 233, 233 (1953) (abnormal or difficult labor present in 75% of the cases in this series).

⁹⁰ Narang, *supra* note 3, at 525, footnote 138.

⁹¹ Kent P. Hymel, Carole Jenny & Robert W. Block, *Intracranial Hemorrhage and Rebleeding in Suspected Victims of Abusive Head Trauma: Addressing the Forensic Controversies*, 7 CHILD MALTREATMENT 329, 331, 332, 342-343 (2002) (causes for subdural hemorrhage include prenatal, perinatal and pregnancy-related conditions; birth trauma; metabolic or genetic disease; congenital malformations; oncologic disease; autoimmune disorders; clotting disorders; infectious disease; poisons, toxins or drugs; and other miscellaneous conditions).

⁹² *Id* at 342, 344.

⁹³ J. F. Geddes et al., *Dural Haemorrhage in Non-Traumatic Infant Deaths: Does It Explain the Bleeding in ‘Shaken Baby Syndrome’?*, 29 NEUROPATHOL. APPL. NEUROBIO. 14, 19 (2003).

By 2006, it was widely recognized by supporters of the SBS/AHT hypothesis that there are many “mimics” of SBS/AHT, including accidental causes and a variety of illnesses and medical conditions, ranging from birth trauma to childhood stroke.⁹⁴ Since then, other studies have continued to add to our knowledge. For example, a study by Dr. Rooks and her colleagues found that approximately 46% of asymptomatic newborns had thin subdural hemorrhages, confirming that subdural hemorrhages are not necessarily symptomatic and do not necessarily (or even generally) cause long lasting problems.⁹⁵ Another study found a clear correlation between intradural/subdural hemorrhage and the degree of hypoxia in neonates.⁹⁶ Today, every month seems to bring forth new articles and commentary, adding to the available information but also increasing the confusion. Like Dr. Narang, we do not attempt to review all of these studies but rather address key new articles by subject, noting only that the list of possible causes for findings previously viewed as diagnostic of abuse continues to expand.

e. The position papers revisited. By 2006, it was evident that the literature on pediatric head injury no longer supported the assumptions underlying the SBS hypothesis and that the major medical associations would have to revise their position papers. This process has resulted in considerable confusion within the medical profession and very little guidance on the proper approach to diagnosis.

In October 2006, the NAME Board of Directors withdrew its “Position Paper on Fatal Abusive Head Injuries in Infants and Young Children.”⁹⁷ Although no explanation was offered, the NAME conference of the same date included presentations entitled “Use of the Triad of Scant Subdural Hemorrhage, Brain Swelling, and Retinal

⁹⁴ By 2006, the alternative causes or “mimics” included prenatal and perinatal conditions; congenital malformations; genetic conditions; metabolic disorders; coagulation disorders, including venous sinus thrombosis (a form of childhood stroke); infectious disease; vasculitis; autoimmune conditions; oncology; toxins and poisons; nutritional deficiencies; and complications from medical-surgical procedures. See Sirotnak, *supra* note 10; Dowd, *supra* note 10.

⁹⁵ V. J. Rooks et al., *Prevalence and Evolution of Intracranial Hemorrhage in Asymptomatic Term Infants*, 29 AM. J. NEURORADIOL. 1082, 1085 (2008). While most of these subdural hemorrhages disappeared within the first month, one had evidence of new subdural bleeding at two weeks, with subdural fluid collections still evident at four weeks. With a larger study population, more variations might be expected.

⁹⁶ Marta C. Cohen & Irene Scheimberg, *Evidence of Occurrence of Intradural and Subdural Hemorrhage in the Perinatal and Neonatal Period in the Context of Hypoxic Ischemic Encephalopathy: An Observational Study from Two Referral Institutions in the United Kingdom*, 12 PEDIATRIC & DEVELOPMENTAL PATHOLOGY 169 (2009) (finding a clear correlation between intradural/subdural hemorrhage and the degree of hypoxia in neonates, with bleeding in the parietal dura developing with more severe or prolonged hypoxia).

⁹⁷ E-mail from Gregory G. Davis, Bd. of Directors, NAME, to John Plunkett, MD, and R. Wright (Oct. 17, 2006) (on file with authors). The 2001 NAME position paper had originally been scheduled to sunset in 2006; however, the Board had extended it to 2008. In October 2006, the Board rescinded the renewal.

Hemorrhages to Diagnose Non-Accidental Injury is Not Scientifically Valid” and “Where’s the Shaking?’ Dragons, Elves, the Shaking Baby Syndrome and Other Mythical Entities.”⁹⁸ No subsequent NAME paper has been approved, leaving it to individual forensic pathologists to reach their own interpretations on causality without guidance from their association. Not surprisingly, this has produced inconsistent conclusions. Today, based on similar or even identical medical findings, some forensic pathologists still endorse shaking as the causal mechanism, others diagnose blunt force trauma (*i.e.*, impact, accidental or abusive) and yet others consider a wide range of possibilities, including natural causes. In Professor Tuerkheimer’s words, such variances produce “fluky justice.”⁹⁹

In 2009, the AAP replaced its technical report on Shaken Baby Syndrome with a policy statement entitled “Abusive Head Trauma in Infants and Children.”¹⁰⁰ The authors stated that though the term shaken baby syndrome is often used by physicians and the public, “advances in the understanding of the mechanisms and clinical spectrum of injury associated with abusive head trauma compel us to modify our terminology to keep pace with our understanding of pathological mechanisms. Although shaking an infant has the potential to cause neurologic injury, blunt impact or a combination of shaking and blunt impact can cause injury as well.”¹⁰¹ The policy statement advised that while the term shaken baby syndrome “has its place in the popular vernacular,” pediatricians should use the term “abusive head trauma” in their medical charts.¹⁰² While the policy statement noted that medical diseases can mimic AHT and that pediatricians have a responsibility to consider alternative hypotheses, it did not identify the alternatives or offer any assistance in distinguishing between accidental, nonaccidental and natural causes, leaving this up to individual pediatricians.¹⁰³

f. Increasing divergence. Given the disagreements between various organizations and the lack of consensus within organizations, it is increasingly difficult to gauge the extent to which doctors in general agree – or even have the knowledge needed to reach an informed decision – on whether abuse may be determined based on specific medical findings, or what those findings might be. In general, prosecutors and child abuse pediatricians continue to strongly endorse the SBS/AHT hypothesis, resulting in hundreds of successful prosecutions every year. At the same time, there is considerable discontent, particularly among forensic pathologists and

⁹⁸ Scientific Program, 40th Annual Meeting, National Association of Medical Examiners, San Antonio, TX (Oct. 13-18, 2006 (on file with authors).

⁹⁹ Deborah Tuerkheimer, *Science-Dependent Prosecution and the Problem of Epistemic Contingency: A Study of Shaken Baby Syndrome*, 62 ALA. L. REV. 512, 523-532 (2011).

¹⁰⁰ Christian, *supra* note 19.

¹⁰¹ *Id.* at 1409.

¹⁰² *Id.* at 1410.

¹⁰³ *Id.* at 1409-1410.

neuropathologists. For example, in a recent email, a forensic pathologist testifying on behalf of the prosecution in a criminal case advised the prosecutor that “I don’t know what the breakdown is, but I would not be surprised to learn that it is close to 50/50 among neuropathologists, neurologists, and forensic pathologists as to whether any given case represents non-accidental trauma.”¹⁰⁴ While this figure may be high, it seems clear that the consensus described by Dr. Narang is changing, and that there continues to be very little objective guidance on how to distinguish between accidental, nonaccidental and natural causes of findings previously viewed as diagnostic of shaking.

In 2012, the prediction of the dissenters in *Smith* that “it is unlikely that the prosecution’s experts would today testify as adamantly as they did in 1997” may be coming to pass. In February 2012, in an Arizona post-conviction relief case, Dr. Norman Guthkelch, one of the first to hypothesize SBS, provided a declaration stating that the term “Shaken Baby Syndrome is an undesirable phrase and that there was not a vestige of proof when the name was suggested that shaking, and nothing else, caused the triad. Dr. Guthkelch went on to say that a number of other conditions – natural and non-accidental – may lead to the triad, including metabolic disorders, blood clotting disorders, and birth injury, to name a few. In the case at issue, he stated unequivocally that there was insufficient evidence to support a finding of homicide.¹⁰⁵ In the same case, Dr. A. L. Mosley, the medical examiner who conducted the autopsy and who previously testified that the cause of death was “Shaken/Impact Syndrome,” stated that given the changes in the literature since 2000, there is no longer consensus in the medical community that the findings in his autopsy report are reliable proof of SBS or child abuse, and that if he were to testify today, he would testify that the child’s death was likely due to a natural disease process, not SBS.¹⁰⁶

Based on our own experiences, it appears that when subdural and/or retinal hemorrhages are present, child abuse pediatricians tend to

¹⁰⁴ E-mail from Mark Peters, MD, to Sharyl Eisenstein, Assistant State’s Attorney, McHenry County, IL (Sept. 15, 2011) (on file with authors) (regarding Sophia Avila Case #08-073, which resulted in conviction, Oct. 14, 2011). In the same e-mail, Dr. Peters noted that infants can have a lucid interval of several days after head trauma and that a number of medical conditions can cause cerebral hemorrhage, retinal hemorrhage and bone fractures. These conditions should be ruled out before concluding that the injuries are the result of inflicted trauma. “Unfortunately, many or most, cannot be evaluated after death, and the pediatricians taking care of these children before death are not performing these tests for whatever reason. I am beginning to get the impression that when pediatricians see these kinds of cases, they see shaken baby or other non-accidental trauma right from the beginning (as evidenced in the dictated reports), and do not perform tests to rule out these other conditions.” *Id.*

¹⁰⁵ Declaration of A. Norman Guthkelch, M.D., State of Arizona v. Drayton Shawn Witt, Feb. 3, 2012.

¹⁰⁶ Declaration of A. L. Mosley, M.D., State of Arizona v. Drayton Shawn Witt, Feb. 3, 2012.

diagnose child abuse (SBS/AHT) while forensic pathologists tend to diagnose blunt force trauma, with the manner of death categorized as accident, homicide or undetermined depending upon the circumstances of the case and the beliefs of the pathologist. While both groups recognize the overlap with natural causes, there is no commonly accepted protocol for investigating alternative causes and very little coordination with the relevant subspecialties. As the debate has turned increasingly harsh, moreover, clinicians outside the child abuse arena are often reluctant to participate in what may turn into a free-for-all in the courtroom and beyond.¹⁰⁷ Given this vacuum, many diagnoses and convictions continue to be based on the presumption that the triad or its components confirm abuse if the parents or caretakers cannot substantiate a known alternative.

g. The triad: where are we now? In 1996, it was generally accepted that, in the absence of a major motor vehicle accident or fall from a multistory building, the triad was caused primarily or exclusively by shaking. In 2001, we learned that the diffuse axonal injury attributed to shaking reflected hypoxia ischemia (lack of oxygen) rather than trauma, and that similar findings were found in infants who died natural deaths. By 2006, the “mimics” of SBS/AHT had expanded to include accidental trauma, birth trauma; congenital, genetic and metabolic disorders, infection, nutritional deficiencies, and a host of other conditions.¹⁰⁸ And in 2011, just five years later, a leading supporter of SBS theory stated publicly that “[n]o trained pediatrician thinks that subdural hemorrhage, retinal hemorrhage and encephalopathy equals abuse. The ‘triad’ is a myth.”¹⁰⁹ As this suggests, we are dealing with an area that is far more complex and nuanced than previously recognized. We are, moreover, at the beginning, not the end, of our quest for evidence – a quest that requires much greater knowledge of the anatomy and physiology of the infant brain than is currently available. As we struggle to expand our knowledge, we need to engage in a careful and searching analysis of what went wrong while renewing our commitment to “getting it right.”

C. Ongoing Debates

The debate over the validity of the SBS/AHT hypothesis has generated numerous subsidiary questions, including:

¹⁰⁷ The longstanding and coordinated attacks on those who disagree with the SBS hypothesis provide a strong deterrent for anyone who considers voicing a dissenting opinion. See notes 38 and 274 (with surrounding text).

¹⁰⁸ See, e.g. Sirotnak, *supra* note 10, at 193-214; see also Narang *supra* note 3, at 540 (differential diagnosis for subdural hemorrhages is extensive).

¹⁰⁹ Jenny, *supra* note 7, at slide 11.

1. Can short falls cause the triad, or is extreme force required?
2. Can there be a “lucid interval”?
3. What do retinal hemorrhages tell us about causation?
4. When do fractures, bruises or other features support an SBS/AHT diagnosis?
5. Do confessions confirm SBS/AHT?
6. How do we handle new hypotheses?

While these questions continue to produce vigorous and often acrimonious debate in the literature and the courtroom, there is sometimes surprising – and often under-recognized – consensus on key points.

1. **Short falls.** While it has long been recognized that short falls do not typically result in serious injury to young children,¹¹⁰ it was understood for decades, if not centuries, that children sometimes suffered serious injury or death after falling short distances¹¹¹ and that the outcome of any given fall would be affected by a variety of biomechanical and physiological factors.¹¹² As mainstream medicine absorbed the SBS/AHT hypothesis, however, a new skepticism took hold that short falls could generate the force necessary to produce the triad. Since SBS/AHT theory held that such findings would require the force of a motor vehicle accident or multistory fall, the injuries attributed by parents and caretakers to short falls were automatically ascribed to abuse, typically violent shaking. New research has restored some of the traditional nuance as videotaped and witnessed short falls have confirmed that short falls can be fatal¹¹³ and biomechanical studies have confirmed that the force of impact (including short falls) is much greater

¹¹⁰ See, e.g., Harvey Kravitz et al., *Accidental Falls from Elevated Surfaces in Infants from Birth to One Year of Age*, 44 PEDIATRICS 869, 873 (1969); Ray Helfer et al., *Injuries Resulting When Small Children Fall Out of Bed*, 60 PEDIATRICS 533 (1977); S. Levene & G. Bonfield, *Accidents on Hospital Wards*, 66 ARCHIVES OF DISEASE IN CHILDHOOD 1047 (1991); Thomas J. Lyons & R. Kim Oates, *Falling Out of Bed: A Relatively Benign Occurrence*, 92 PEDIATRICS 125 (1993).

¹¹¹ See, e.g., John R. Hall et al., *The Mortality of Childhood Falls*, 29 J. OF TRAUMA 1273 (1989) (examining 18 pediatric deaths from falls under three feet, including two that occurred under medical observation). Falls from high chairs or changing table were similarly considered to be acceptable explanations for child deaths.

¹¹² See, e.g., Barry Wilkins, *Head Injury – Abuse or Accident?*, 76 ARCHIVES OF DISEASE IN CHILDHOOD 393, 393, 395 (1997) (determinants of injury may include fall height; nature of surface; protective reflexes; whether fall is broken; whether child propelled himself; mass of body and head; proportion of energy absorbed, which may be influenced by which part of the body hits the ground first; whether some of the energy is dissipated in fractures; whether the contact is focal or diffuse; and whether there is secondary injury, including hypoxia/ischemia).

¹¹³ See, e.g., Plunkett, *supra* note 58; *supra* note 59; Hall, *supra* note 107; Paul Steinbok et al., *Early Hypodensity on Computed Tomographic Scan of the Brain in an Accidental Pediatric Head Injury*, 60 NEUROSURGERY 689 (2007) (reporting on radiology findings in five accidental fatalities, including a fall down stairs and a fall from a stool).

than the force of shaking.¹¹⁴ The current consensus is that short falls (typically defined as falls of less than 3-4 feet) may occasionally cause death.¹¹⁵

The issues are therefore: how rare are short fall deaths, and how should this affect the interpretation of individual cases? Proponents of the SBS/AHT diagnosis often contend that, while short falls can be fatal, the chances are so remote as to be inconsequential.¹¹⁶ In making this argument, supporters generally cite a 2008 article by Dr. Chadwick and Gina Bertocci that estimates the annual fatality rate for short falls among young children at less than one in a million.¹¹⁷ To create a “best estimate” of the mortality rate, the authors selected a single injury database compiled by the State of California.¹¹⁸ Like other epidemiological research, its reliability depends upon the accurate categorization of cases as “accidental” or “abusive.” Since the time period of this data base (1997-2003) encompasses the peak of shaken baby theory, this data base may undercount short fall fatalities given the previously accepted belief that short falls could not kill.¹¹⁹ In short, the data may reflect nothing more than the biases of the old understanding.¹²⁰

¹¹⁴ See, e.g., Ommaya, *supra* note 78, at 226.

¹¹⁵ John Plunkett & Mark Dias, Keynote Presentation, *Point/Counterpoint: Analysis of Outcomes from Short Falls*, Second International Conference on Pediatric Abusive Head Trauma (June 26, 2009) brochure at <http://www.childdeathreview.org/Reports/2009PedAHTConference.pdf> (Dr. Dias replaced Dr. Jenny, who was unavailable). See also David L. Chadwick, *Annual Risk of Death Resulting From Short Falls Among Young Children: Less than 1 in 1 Million*, 121 *Pediatrics* 1213 (2008) (13 short fall child fatalities listed in California data base, 6 of which the authors believe may be valid); Steinbok, *supra* note 109; Hall, *supra* note 107; Patrick E. Lantz & Daniel Couture, *Fatal Acute Intracranial Injury, Subdural Hematoma, and Retinal Hemorrhages Caused by Stairway Fall*, 56 *J. OF FORENSIC SCIENCES* 1648, 1649 (2011).

¹¹⁶ David L. Chadwick, *Can a Short Fall Produce the Medical Findings of Shaken Baby Syndrome?*, NCSBS website, at <http://www.dontshake.org/sbs.php?topNavID=3&subNavID=25&navID=278>.

¹¹⁷ Chadwick, *supra* note 111. Chadwick identifies three classes of cases that can be attributed to trauma: accident, (121 per million), homicide (22 per million) and short falls (0.48 per million). Even if these rates are correct, this would mean that 0.48 out of every 143.48 cases of traumatic fatal injury, or about one in 300, is attributable to short falls. Chadwick, *supra* note 111, at 1220. In the aggregate, nationwide, that would represent a significant number of incidents.

¹¹⁸ Chadwick, *supra* note 111, at 1214, 1218. One study mentioned in Chadwick was discounted because the “fall histories [were] not validated” even though abuse had been ruled out by the police in all cases and two deaths had occurred under medical observation. See Hall, *supra* note 107, at 1274.

¹¹⁹ The authors noted that the injury coding in the database often did not match the more detailed information in the death certificates. While the authors excluded cases incorrectly labeled as short fall deaths, they do not describe a corresponding effort to identify short fall deaths that may have been included in other categories, including homicide.

¹²⁰ This is another example of the circularity that affects much of the research in this field. If deaths presenting with the triad following a reported short fall are typically

Even if the Chadwick data is correct, however, it does not tell us whether any *particular* case is the result of accident or abuse. As Dr. Narang observes, “statistics embody averages, not individuals.”¹²¹ In individual cases, the issue is whether an injured child who appears in the emergency room after a reported short fall is suffering the consequences of a fall or is the victim of abuse. In this context, the Chadwick article is often cited to suggest that the likelihood that the death was attributable to the fall is less than one in a million.¹²² In individual cases, however, it may be virtually certain that a short fall caused the injuries, *e.g.*, if the fall is confirmed by an independent witness or videotaped (as sometimes occurs with public surveillance equipment), even though the chances on average remain one in a million. More often, the medical evidence may confirm impact but cannot distinguish between a child who has fallen and hit his or her head and a child who has been hit on the head. The fact that fatal short falls are rare does not help us make this determination since child deaths are in and of themselves rare, and each cause (whether natural or accidental) is by definition even rarer.

In a large country such as the United States, moreover, small risks may translate into significant numbers. In 2010, there were approximately 12 million children under the age of 2 in the United States.¹²³ Using Chadwick’s estimated mortality rate from short falls, one would expect perhaps 6 short fall deaths in the 0-2 age group. If a substantial number of short fall deaths in this age group were misclassified as SBS/AHT deaths based on the assumption that short falls could not kill, and if babies and toddlers are more vulnerable to short falls than older children,¹²⁴ these figures could increase substantially. This would be consistent with the biomechanical studies and case reports, which confirm that the forces generated by the types of short falls described in SBS/AHT cases (fall from parent’s arms, fall down stairs, etc.) typically exceed accepted head injury criteria and may

diagnosed as SBS/AHT, the number of accidental short fall fatalities will appear to be vanishingly small. The rarity of short fall fatalities is then used to reject the caretaker’s history of a short fall and to support an SBS/AHT diagnosis. This circularity issue is addressed below.

¹²¹ Narang, *supra* note 3, at 522 (quoting JEROME GROOPMAN, HOW DOCTORS THINK (2007) at 6).

¹²² See, *e.g.*, Brief for Plaintiff-Appellant at 6, State v. Louis, Wis. App. III Dist. No. 2009AP2502-CR, WL 4253604, (“[Y]es, a short fall could conceivably cause an infant’s death, but it is exceedingly rare”).

¹²³ The 2010 census recorded approximately 12 million children aged 0-2 in the U.S in 2010. Census Summary File 1, *Single Years of Age and Sex: 2010*, United States Census Bureau at http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=DEC_10_SF1_QTP2&prodType=table. Using Dr. Chadwick’s estimate of 0.48 deaths per million children, the number of expected fatal short falls nationwide would be 5.76 (0.48 x 12) for children aged 0-2.

¹²⁴ Jenny, *supra* note 7, at slide 19 (overwhelming evidence shows that the response to a given injury in an infant is much worse than that of an adult to a similar injury).

be fatal.¹²⁵ Such deaths may be most likely to occur in children with pre-existing conditions, including chronic (old) subdural hemorrhages, coagulopathies (bleeding/clotting disorders) or pre-existing neurological impairment.

2. **Timing (“lucid intervals”).** Under the traditional SBS/AHT hypothesis, it was believed that the child would be immediately unconscious upon infliction of the injuries, which were assumed to consist of ruptured veins and axons. The logical corollary was that whoever was with the child at the time of collapse must have inflicted the injuries.¹²⁶ This is, however, contrary to the well-known phenomenon of delayed deterioration from minor head injury, in which a prolonged period of normality or near normality may precede the collapse.¹²⁷ In 1998, Dr. Gilliland concluded that there was an interval of more than 24 hours (and sometimes up to 72 hours or more) between the trauma and the collapse in approximately 25% of alleged shaking, shaking impact or impact cases.¹²⁸ Subsequent studies and case reports have confirmed that collapse may not be immediate, even in cases involving impact.¹²⁹

¹²⁵ See Jenny, *supra* note 79; Lantz, *supra* note 111.

¹²⁶ See Imwinkelried, *supra* note 36, at 5 (“In effect, the testimony time stamps the injuries, powerfully incriminating the last adult in the child’s presence before the onset of symptoms”).

¹²⁷ See, e.g., J. W. Snoek et al., *Delayed Deterioration Following Mild Head Injury in Children*, 107 BRAIN 15 (1984) (reporting three delayed deaths in children apparently due to severe and uncontrollable unilateral or diffuse brain swelling). For this reason, hospitals typically urge parents and caretakers to monitor a child’s symptoms after a head injury in order to detect delayed deterioration. See, e.g., Head Injury guidelines, Seattle Children’s Hospital, at <http://www.seattlechildrens.org/medical-conditions/symptom-index/head-injury/> (directing parents to seek medical care immediately if child shows delayed neurological symptoms after head injury).

¹²⁸ M.G.F. Gilliland, *Interval Duration Between Injury and Severe Symptoms in Nonaccidental Head Trauma in Infants and Young Children*, 43 J. FOR. SCI. 723, 723 (1998).

¹²⁹ See, e.g., Kristy B. Arbogast et al., *Initial Neurologic Presentation in Young Children Sustaining Inflicted and Unintentional Fatal Head Injuries*, 116 PEDIATRICS 180 (2005) (on rare occasions, infants or toddlers may sustain a fatal head injury yet present to hospital clinicians as lucid before death); Scott Denton & Darinka Mileusnic, *Delayed Sudden Death in an Infant Following an Accidental Fall, A Case Report with Review of the Literature*, 24 AM. J. FORENSIC MED. PATHOL. 371 (2003) (9-month-old acted normally for 72 hours after fall before fatal collapse); Robert Huntington, Letter, *Symptoms Following Head Injury*, 23 AM. J. FORENSIC MED. PATHOL. 105 (2002) (reporting case of 13-month-old whose “severe intracranial injury symptoms...were delayed for several hours, during which time she was under our view and review in the hospital”). More recently, it has been noted that second impact syndrome – in which a minor impact occurring weeks to months after a more significant impact results in death – produces findings virtually identical to those in SBS/AHT cases. Robert C. Cantu & Alisa D. Gean, *Second-Impact Syndrome and a Small Subdural Hematoma: An Uncommon Catastrophic Result of Repetitive Head Injury with a Characteristic Imaging Appearance*, 27 J. OF NEUROTRAUMA 1557 (2010). This raises the possibility that the original trauma in some SBS/AHT cases may have occurred weeks to months before the collapse, possibly even at birth.

When the triad findings result from a natural disease process, the concept of a “lucid interval” may be meaningless because there may be no sudden precipitating event. Like any disease process, the natural mimics of abusive head trauma – ranging from stroke to metabolic or genetic disorders – may produce sudden and disastrous results, or may have a stuttering course, with a variety of warning signs and symptoms, followed by neurologic collapse. To determine the course of the disease, it is critical to obtain comprehensive and precise caretaker reports and to examine all records, including prenatal, birth and pediatric records. This information must then be coordinated with the radiology images, neurosurgical reports and/or tissue slides, which can provide objective information on cause and timing. Often, as one explores the child’s history, it becomes apparent that multiple factors likely played a role in the collapse.

Today, there is no real dispute over whether lucid intervals can occur. Instead, the disputes about lucid intervals are more nuanced, usually arising over whether a lucid interval occurred in a particular case given the medical findings and symptoms. In a recent presentation, for example, Dr. Dias responded to the Gilliland research by noting that while children in the study experienced a period of lucidity following injury, all of the children who were seen by an independent observer “were described as *not normal*” during the interval.¹³⁰ However, the described symptoms, which included lethargy or fussiness, are signs of illness as well as head injury, and they provide little precision in timing.¹³¹ Such symptoms are not infrequently noted in children diagnosed with SBS, suggesting that some of these children may be ill rather than abused.¹³² Given these considerations, it has become increasingly difficult to time injuries or identify a perpetrator based on medical evidence alone.

3. ***Retinal hemorrhages.*** In recent years, the focus in SBS/AHT cases has shifted from subdural hemorrhages and brain swelling, which are known to have many causes, to retinal hemorrhages. For many years, ophthalmologists and pediatricians testified that in the absence of severe trauma, retinal hemorrhages were highly suggestive or even diagnostic of shaking.¹³³ This position is puzzling since retinal

¹³⁰ Dias, Presentation, *Concepts, Controversies and Conspiracy Theories in Abusive Head Trauma*, slide 12, New York City Abusive Head Trauma/Shaken Baby Syndrome Training Conference (Sept. 23, 2011) at http://www.queensda.org/SBS_Conference/SBC2011.html.

¹³¹ Gilliland, *supra* note 124, at 724. See also Robert W. Huntington III, *Symptoms Following Head Injury*, 23 AM. J. FOR. MED. PATHOL. 105 (2002).

¹³² See, e.g., *State v. Edmunds*, 746 N.W. 2d 590, 592 (2008) (during the hours before her death, the child did not feed normally and cried inconsolably).

¹³³ See, e.g., J.F. Geddes & John Plunkett, Letter, *The Evidence Base for Shaken Baby Syndrome*, 328 BRIT. MED. J. 719, 719 (2004) (many doctors consider retinal hemorrhages with specific characteristics to be pathognomonic of shaking; diagnosis is sometimes based on subdural or retinal hemorrhages alone).

hemorrhages are found in approximately one third of newborn babies¹³⁴ and in a wide range of conditions.¹³⁵ In adults, retinal hemorrhages are closely linked to intracranial hemorrhages in adults irrespective of cause, a phenomenon that is known as Terson syndrome.¹³⁶ To our knowledge, no explanation has ever been offered to explain why Terson syndrome would appear in adults but not in infants. Since infants are generally more vulnerable to illness or trauma than adults, one might suspect that, if anything, children would be *more* susceptible to retinal hemorrhage than adults.

Since it was clear by 2006 that children also develop retinal hemorrhage in a wide range of conditions,¹³⁷ supporters of the SBS/AHT hypothesis modified their claim that retinal hemorrhages are highly suggestive of abuse. Instead, they argued that certain variants – specifically, retinoschisis (separation of the layers of the retina), retinal folds (folding of the outer edges of the retina) and/or extensive retinal hemorrhages (retinal hemorrhages that affect many retinal layers and extend to the ora serrata) – are highly suggestive or even diagnostic of abuse.¹³⁸ In recent years, however, this hypothesis has also begun to unravel. Today, it appears that the size and scope of retinal hemorrhages may be largely associated with edema and time spent on life support rather than causation.¹³⁹ In addition, the severe, extensive retinal hemorrhages previously assumed to be diagnostic of SBS/AHT have also

¹³⁴ MV Emerson, *Incidence and Rate of Disappearance of Retinal Hemorrhage in Newborns*, 108 OPTHALMOLOGY 36 (2001).

¹³⁵ See, e.g., Narang, *supra* note 3, Appendices B and C; Patrick E. Lantz & Constance A. Stanton, *Postmortem Detection and Evaluation of Retinal Hemorrhages*, 12 PROC. OF THE AM. ACAD. FOR. SCI. 271 (2006) (retinal hemorrhages present at autopsy in infants who died from meningitis, asphyxia/suffocation, prematurity/congenital conditions, heart disease, in utero hemorrhage, blunt force trauma, sudden infant death syndrome/resuscitation, apnea/gastroesophageal reflux, and birth-related causes); Henry E. Aryen et al., *Retinal Hemorrhage and Pediatric Brain Injury: Etiology and Review of the Literature*, 12 J. OF CLINICAL NEUROSCIENCE 624 (2005) (retinal hemorrhages associated with an ever-expanding list of conditions). It has also, of course, long been known that retinal hemorrhages and, less commonly, cerebral edema are linked to the lack of oxygen at high altitudes. See, e.g., Sankaranarayana P. Mahesh & Jeevan R. Mathura, Jr., *Retinal Hemorrhages Associated with High Altitude*, 362 N. ENGLAND J. MED. 1521 (2010); see also Fernando A. Moraga et al., *Acute Mountain Sickness in Children and Their Parents After Rapid Ascent to 3500 M (Putre, Chile)*; 19 WILDERNESS & ENVIRONMENTAL MEDICINE 287 (2008) (children more sensitive than adults to hypoxia from high altitudes).

¹³⁶ Albert Terson, *De l'hémorragie Dans le Corps Vitre au Cours de L'hémorragie Cerebrale*, 6 CLIN. OPTHALMOL. 309 (1900).

¹³⁷ See Lantz, *supra* note 131.

¹³⁸ See, e.g., Narang, *supra* note 3, at 548-553, 557.

¹³⁹ Evan Matshes, *Retinal and Optic Nerve Sheath Hemorrhages Are Not Pathognomonic of Abusive Head Injury*, 16 PROC. OF THE AM. ACAD. FOR. SCI. 272 (2010) (retinal hemorrhages and optic nerve sheath damage may be linked to cerebral edema and advanced cardiac life support and are not limited to children who die of inflicted head injuries).

been identified in meningitis and an accidental short fall.¹⁴⁰ The Atlas of Forensic Histopathology summarizes the current state of knowledge on retinal hemorrhages as follows:

The significance of retinal hemorrhage and optic nerve sheath hemorrhage is controversial. These hemorrhages are not, in and of themselves, sufficient to determine the presence of inflicted injury. Other circumstances under which retinal and optic nerve sheath hemorrhages may be found include resuscitation and cerebral edema. A recent retrospective study (Matshes, 2010) of 123 autopsies of children up to 3 years old showed retinal hemorrhage, optic nerve sheath hemorrhage, or both, in 18 cases. Of these, two were certified as natural deaths, eight as accidents, and eight as homicides. One finding of note was hemorrhage in six of seven cases without any head injury. There is a widespread belief among clinicians that skull fractures, subdural hematomas, and retinal hemorrhages do not occur in accidental short falls. In reality, all three have been found in cases of falls from short heights.¹⁴¹

In short, it is becoming increasingly unlikely that the size, shape or location of retinal or optic nerve sheath hemorrhages will prove to be an accurate indicator of abuse.

Retinoschisis and retinal folds are similarly no longer deemed virtually diagnostic (pathognomonic) of shaking or abuse. The traditional theory was that absent an automobile accident or the like, retinoschisis or retinal folds could only be caused by the angular forces generated by the rapid acceleration and deceleration motion of shaking. However, a series of case reports has now established that retinoschisis and retinal folds also occur in accidental injuries that do not involve rapid acceleration/deceleration forces but instead involve other types of forces, such as crush forces. In one case a fourteen-month-old child suffered a skull fracture, subdural hematoma, and retinal folds when a television fell on him.¹⁴² In another, a four-month-old child suffered a

¹⁴⁰ Juan Pablo Lopez et al., *Severe Retinal Hemorrhages in Infants with Aggressive Fatal Streptococcus Pneumonia Meningitis*, 14 J. AM. ASS. PED. OPHTHAL. STRAB. 97 (2010); Lantz, *supra* note 111, at 1648, 1649.

¹⁴¹ PETER M. CUMMINGS, DARIN P. TRELKA & KIMBERLY M. SPRINGER, ATLAS OF FORENSIC HISTOPATHOLOGY 177 (2011); *see also* M. Vaughn Emerson, Elisabeth Jakobs & W. Richard Green, *Ocular Autopsy and Histopathologic Features of Child Abuse*, 114 OPHTHALMOLOGY 1384 (2007) (given our current lack of knowledge, much of what we think we know about the ocular findings of child abuse will continue to be the result of speculation rather than based on sound evidence).

¹⁴² P. E. Lantz et al., *Perimacular Retinal Folds from Childhood Head Trauma*, 328 BR. MED. J. 754, 756 (2004).

fatal skull fracture with subdural hemorrhage and retinoschisis and retinal folds when a twelve-year-old child tripped and landed with her buttocks striking the infant's head.¹⁴³ In yet another case, a ten-week-old child suffered a skull fracture with subdural and subarachnoid hemorrhages, as well as retinal hemorrhages extending to the ora serata and retinal folds, when his mother, who was carrying him in a front-holding papoose, tripped and crushed his head between her chest and a wooden barrier.¹⁴⁴ Cases such as these have led researchers to conclude that, contrary to earlier beliefs, "there may be no retinal signs seen exclusively in non-accidental head injury."¹⁴⁵

4. Bruises, fractures and other findings. In some cases, the triad is supplemented by bruises, fractures and other findings that can provide powerful confirmation of abuse. Ironically, however, such evidence may sometimes point in a different direction. While bruises are often taken as confirmation of abuse, particularly in infants, in whom bruises are unexpected,¹⁴⁶ Dr. Michael Laposata, one of the nation's leading coagulation experts, has pointed out that it is rarely possible to differentiate on external examination between bruises caused by trauma and those caused by coagulopathies (bleeding disorders).¹⁴⁷ While a child who presents with bruises, subdural hemorrhage and retinal hemorrhage may indeed be the victim of abuse and should be evaluated accordingly, it is important to be aware that these features are also consistent with genetic or acquired coagulopathies, including disseminated intravascular coagulation.¹⁴⁸

¹⁴³ Gregg T. Lueder, Jane W. Turner & Robert Paschall, *Perimacular Retinal Folds Simulating Nonaccidental Injury in an Infant*, 124 ARCH. OPHTHALMOL. 1783 (2006).

¹⁴⁴ P. Watts & E. Obi, *Retinal Folds and Retinoschisis in Accidental and Non-Accidental Head Injury*, 22 NATURE 1514 (2008), available at <http://www.nature.com/eye/journal/v22/n12/full/eye2008224a.html>.

¹⁴⁵ *Id.* at 1.

¹⁴⁶ See, e.g., Naomi F. Sugar, James A. Taylor, Kenneth W. Feldman and the Puget Sound Pediatric Research Network, *Bruises in Infants and Toddlers: Those Who Don't Cruise Rarely Bruise*, 153 ARCHIVES OF PEDIATRICS & ADOLESCENT MED. 399 (1999) ("Bruises are rare in normal infants and precruisers and become common among cruisers and walkers. Bruises in infants younger than 9 months and who are not yet beginning to ambulate should lead to consideration of abuse or illness as causative").

¹⁴⁷ Michael Laposata, Presentation, *Overdiagnosis of Child Abuse Due to Undiagnosed Underlying Disease*, Am. Assoc. of Clinical Chemistry Annual Meeting (December 2008) at http://www.aacc.org/events/expert_access/2008/december/Documents/1208EA.pdf; See also Martha E. Laposata & Michael Laposata, *Children with Signs of Abuse: When Is It Not Child Abuse?* 123 AM. J. CLIN. PATHOL., Supp. 1, S119, S120 (2005) (describing the "myriad of coagulopathies" that can mimic child abuse).

¹⁴⁸ See, e.g., *id.*; Marcel Levi & Hugo Ten Cate, *Disseminated Intravascular Coagulation*, 341 NEW ENGLAND J. OF MEDICINE 586, 586 (1999) (clinical conditions associated with disseminated intravascular association include sepsis, trauma, cancer, obstetrical complications, vascular disorders, reactions to toxins and immunological disorders).

Similar issues arise with skeletal findings. Contrary to popular belief, skull fractures may occur from birth trauma or household falls.¹⁴⁹ Other fractures or bony abnormalities may result from accidental trauma, metabolic bone disease and/or nutritional deficiencies.¹⁵⁰ In some cases, causation or vulnerability can be determined by testing and a careful medical history. In others, it may not be possible to differentiate between natural causes, accidental trauma and abuse on the basis of the medical findings alone.¹⁵¹

5. Confessions. As the differential diagnosis for the triad has expanded, the “case for shaking” as a mechanism of injury now rests largely on confessions.¹⁵² SBS supporters argue that confessions prove that (a) some children with the triad were shaken; and (b) in the absence of a proven alternative, infants or children who present with the triad were almost certainly shaken.

The overriding problem is that confessions are not scientific evidence – and are rarely used as the basis for medical diagnoses – because the researcher cannot observe the underlying event. In the past decade, moreover, we have learned that confessions are not as reliable as

¹⁴⁹ See, e.g., Brian C. Patonay & William R. Oliver, *Can Birth Trauma Be Confused for Abuse?* 55 J. OF FORENSIC SCIENCES 1123 (2010); Ross Reichard, *Birth Injury of the Cranium and Central Nervous System*, 18 BRAIN PATHOLOGY 565, 566 (2008) (incidence of skull fractures at birth is reported to be 2.9%); David S. Greenes & Sara A. Schutzman, *Occult Intracranial Injury in Infants*, 32 ANNALS OF EMERG. MED. 680, 684 (1998) (Duhaime reported that skull fractures were as likely to occur from falls of less than 4 feet as from falls of more than 4 feet, and that 18% of skull fractures in infants resulted from falls of less than 3 feet).

¹⁵⁰ See Kathy A. Keller & Patrick D. Barnes, *Rickets vs. Abuse: a National and International Epidemic*, 38 PEDIATR. RADIOL. 1210 (2008); Paul K. Kleinman, *Problems in the Diagnosis of Metaphyseal Fractures*, 38 PEDIATR. RADIOL. S388, S390-S392 (2008); Andrew Hosken, *Call For Vitamin D Infant Death Probe*, BBC RADIO 4 TODAY, Jan. 26, 2012 at <http://www.bbc.co.uk/news/health-16726841> (parents acquitted of shaking child to death “after the jury learned that his fractures, supposedly telltale signs of abuse, could have been caused by his severe rickets....Michael Turner QC, who defended Miss Al-Alas, told the BBC that he was shocked by the lack of knowledge about vitamin D deficiency of some of the expert witnesses at the trial, held at the Old Bailey”).

¹⁵¹ See Alison M. Kemp et al., *Patterns of Skeletal Fractures in Child Abuse: Systematic Review*, 337 BRIT. MED. J. 1, 7 (2008) (no fracture on its own is diagnostic of child abuse); Carole Jenny, *Clinical Report: Evaluating Infants and Young Children with Multiple Fractures*, 118 PEDIATRICS 1299 (2006) (“[B]one diseases associated with increased bone fragility can be subtle or difficult to diagnose. These children are usually preverbal and cannot give a cogent history of their experiences. If abuse has occurred, caregivers of young children may not be forthcoming with a truthful history. On the other hand, family members of a child having an undiagnosed bone disorder may not be able to explain any mechanism of injury and may be completely bewildered by the injuries. Many parents of children with genetic or metabolic bone disease report that they were initially accused of abusing their children”).

¹⁵² See, e.g., Dias, *supra* note 54, at 370 (“the consistent and repeated observation that confessed shaking results in stereotypical injuries that are so frequently encountered in AHT – and which are so extraordinarily rare following accidental/impact injuries – is the evidentiary basis for shaking”) (emphasis in original).

once thought. Indeed, approximately 25% of the DNA exonerations in Innocence Network cases involved false confessions, guilty pleas or other incriminating statements to serious offenses such as rape and murder.¹⁵³ False confessions are produced in part by the psychological techniques used in interrogation,¹⁵⁴ including, among other things, the presentation of real or fabricated proof of guilt sufficient to make a suspect feel that the situation is hopeless.¹⁵⁵ An accused who is convinced that he or she will be convicted and believes that confessing will minimize the consequences (or at least put an end to the questioning) may well make a rational choice to confess, even falsely¹⁵⁶—a type of confession recognized in the research literature as “coerced compliant false confessions.”¹⁵⁷

Confessions are particularly problematic in the child abuse area. First, there are remarkably few confessions – at least relatively few confessions that have been identified and examined in the research literature – relative to the large number of alleged shaking injuries (reportedly in the range of 1,200 to 1,500 per year in the United States).¹⁵⁸ One review of the child abuse literature from 1969 to 2001 found only 54 confessions to shaking, only 11 of which had no signs of impact.¹⁵⁹ As the author concluded, 11 cases (in this study,

¹⁵³ *False Confessions*, INNOCENCE PROJECT, <http://www.innocenceproject.org/understand/False-Confessions.php> (innocent defendants made incriminating statements, delivered outright confessions or pled guilty in about 25% of DNA exoneration cases). Indeed, in the Central Park jogger case, multiple defendants falsely confessed. See, e.g., *Anton McCray*, INNOCENCE PROJECT, http://www.innocenceproject.org/Content/Antron_McCray.php.

¹⁵⁴ See Mark Handler, Am. Assoc. of Police Polygraphists, PowerPoint Presentation, *Avoiding False Confessions and Defending Against Charges That You Obtained One* (2011) (on file with authors) (factors contributing to false confessions include investigator bias; pressure-filled interrogations; overconfidence on ability to tell truthful from deceptive subjects; certain coercive tactics; and context and subject characteristics that increase vulnerability).

¹⁵⁵ See, e.g., Richard J. Ofshe & Richard A. Leo, *The Decision to Confess Falsely: Rational Choice and Irrational Action*, 74 DENV. U. L. REV. 979, 986 (1996-1997) (“investigators elicit confessions from the innocent...by leading them to believe that their situation, though unjust, is hopeless and will only be improved by confessing”); Steven A. Drizin & Richard A. Leo, *The Problem of False Confessions in the Post-DNA World*, N. C. L. REV. 891, 915 (2004) (the most effective technique used to persuade a suspect that his situation is hopeless is to confront him with seemingly objective and incontrovertible evidence of his guilt, whether or not any actually exists).

¹⁵⁶ Standard interrogation methods include cutting off denials of guilt and making the suspect believe that his situation is hopeless, followed by minimization strategies that present a confession as in his best interest. See, e.g., Ofshe, *supra* note 151, at 998, 999.

¹⁵⁷ Ofshe, *supra* note 151, at 998.

¹⁵⁸ See, e.g., NCSBS website at <http://www.dontshake.org/sbs.php?topNavID=2&subNavID=10> (stating that an estimated 1,200 to 1,400 children are injured or killed by shaking every year in the United States); Tuerkheimer, *supra* note 37, at 10 (observing that an estimated 1,500 SBS diagnoses a year may provide “an outside parameter”).

¹⁵⁹ Jan E. Leestma, *Case Analysis of Brain-Injured Admittedly Shaken Infants: 54 Cases, 1969-2001*, 26 AM. J. FORENSIC MED. PATHOL. 199, 199 (2005).

approximately 1 every 3 years on average) does not permit valid statistical analysis or provide support for many of the commonly stated aspects of shaken baby syndrome.¹⁶⁰ Three other articles – one in the U.S. and two in France – have addressed confessions to shaking but did not identify the confessions or the circumstances in which the confessions were obtained in sufficient detail to review their validity.¹⁶¹ In two of these articles, moreover, the confessions did not reliably match the recorded medical findings, which included evidence of impact such as skull fractures, scalp swelling and bruising, underscoring the challenge with confessions.¹⁶² In such cases, the confession may have understated the actions, or the shaking may have had nothing to do with the collapse.

Second, the definitions of “shaking” used in the literature and the courtroom are broad and ill-defined, and often include admissions to conduct that no one seriously argues could cause brain injury and death. As Professor Imwinkelried points out, Dr. Caffey’s seminal 1972 article includes “burpings,” a “confession” that a mother merely said “she and her husband ‘might have shaken [the infant] when he cried at night,’” and a case in which a mother said she yanked a child to prevent him from falling off a bassinet onto the floor.¹⁶³ As Professor Imwinkelried noted, “[i]t is debatable whether such conduct should be characterized as the kind of major, violent shaking events that supposedly cause shaken baby syndrome.”¹⁶⁴ In other cases, the confessions are to mild shaking intended to revive a comatose infant.¹⁶⁵ As Judge Posner of the U.S. Court of Appeals for the Seventh Circuit pointed out recently in *Aleman v. Village of Hanover Park*, this type of shaking is the proper way to initiate infant CPR; hence, admitting to it hardly constitutes a confession to deadly criminal abuse.¹⁶⁶

Third, many of the confessions in child abuse cases involve interrogation techniques that are known to produce false confessions or plea bargains. Some interrogations include assertions that the medical

¹⁶⁰ *Id.* at 199.

¹⁶¹ Suzanne P. Starling et al., *Analysis of Perpetrator Admissions to Inflicted Traumatic Brain Injury in Children*, 158 ARCH. PEDIATR. ADOLESC. MED. 454 (2004); Catherine Adamsbaum et al., *Abusive Head Trauma: Judicial Admissions Highlight Violent and Repetitive Shaking*, 126 PEDIATRICS 546 (2010); Matthieu Vinchon et al., *Confessed Abuse Versus Witnessed Accidents in Infants: Comparison of Clinical, Radiological, and Ophthalmological Data in Corroborated Cases*, 26 CHILDS NERV. SYST. 637 (2010).

¹⁶² Starling, *supra* note 157, at 456; Adamsbaum, *supra* note 157, at 549.

¹⁶³ Imwinkelried, *supra* note 36, at 6 (quoting John Caffey, *On the Theory and Practice of Shaking Infants: Its Potential Residual Effects of Permanent Brain Damage and Mental Retardation*, 124 AMER. J. DIS. CHILD 161, 163 (1972)).

¹⁶⁴ *Id.* at 6, 7.

¹⁶⁵ See, e.g., *Aleman v. Village of Hanover Park*, 662 F.3d 897 (7th Cir. 2011) (Posner, J.) (description of gentle shaking to elicit response from collapsed infant was interpreted as confession to violent shaking).

¹⁶⁶ *Id.* at 6.

evidence proves that a child was shaken and that only the accused could have done it. In *Aleman*, Judge Posner described such a scenario:

They told him [the suspect] the only possible cause of Joshua's injuries was that he'd been shaken right before he collapsed; not being an expert in shaken-baby syndrome, Aleman could not deny the officers' false representation of medical opinion. And since he was the only person to have shaken Joshua immediately before Joshua's collapse, it was a logical necessity that he had been responsible for the child's death. Q.E.D. *A confession so induced is worthless as evidence, and as a premise for an arrest.*¹⁶⁷

Sometimes these interrogation techniques may convince innocent parents or caretakers that they have committed a crime – a type of confession known in the research literature as “persuaded false confessions.”¹⁶⁸ When confronted with “proof” of shaking or impact, parents may search their memories for what they might have done, ultimately recalling minor incidents that are then viewed as confessions or changing histories.¹⁶⁹ Some of these interrogations occur immediately after a child's death or serious injury, when distraught parents or caretakers may be particularly vulnerable to suggestion, manipulation or memory lapses.¹⁷⁰

Other “confessions” are provided as part of a plea bargain. As elegantly described by Professor Tuerkheimer, acknowledgements of guilt accompanying a plea bargain may simply represent a cost-benefit analysis, with a full and logical evaluation of the circumstances.¹⁷¹ Since innocent defendants charged with killing or severely injuring a baby confront a high likelihood that a jury will return a guilty verdict, a

¹⁶⁷ *Id.* at 16 (emphasis added); see also Emily Bazelon, *Shaken-Baby Syndrome Faces New Questions in Court*, N. Y. TIMES MAG. Feb. 2, 2011, at <http://www.nytimes.com/2011/02/06/magazine/06baby-t.html?pagewanted=all> (reporting the case of Dinesh Kumar, a Canadian father whose conviction was overturned after he had pled guilty to shaking his 5-week-old son to death; Kumar says that at the time of his guilty plea, he believed he had no hope of prevailing against the damning testimony of the state's pathologist, who has since been discredited for giving error-riddled testimony based on botched autopsies).

¹⁶⁸ *Id.* at 999 (“persuaded” false confessions “are given after a person has become convinced that it is more likely than not that he committed the crime, despite possessing no memory of having done so...[they] are elicited when an interrogator attacks and shatters a suspect's confidence in his memory”). These are known as internalized false confessions.

¹⁶⁹ See, e.g., *Aleman v. Village of Hanover Park*, *supra* note 161.

¹⁷⁰ Research confirms that emotionally challenged individuals are more susceptible to the pressures and suggestiveness of interrogations. See, e.g., Richard A. Leo & Deborah Davis, *From False Confession to Wrongful Conviction: Seven Psychological Processes*, 38 J. OF PSYCHIATRY & L. 9, 38-40 (2010).

¹⁷¹ Tuerkheimer, *supra* note 95, at 532-535.

rational defendant who is offered a “substantial discount” will accept the terms of the offer, notwithstanding factual innocence.¹⁷²

Finally, even if we assume that all shaking confessions are accurate and that shaking caused the collapse or death,¹⁷³ this still would not provide reliable evidence that the collapse or death in other cases was caused by shaking, any more than the confession of one bank robber to robbing a bank would provide reliable evidence that a defendant in another case was guilty of robbing a different bank. Today, we know that there are many alternative causes for findings previously attributed to shaking and that very few medical findings are specific for inflicted trauma. An assumption that shaking caused the collapse or death in cases with confessions would not, therefore, suggest that shaking caused the findings in cases without confessions.¹⁷⁴ At most, this would simply place shaking on the lengthy and ever increasing list of potential causes.

6. ***New hypotheses.*** In the past decade, researchers have struggled to differentiate between abuse, accidental trauma and natural causes. However, as Dr. Duhaime has pointed out, in this area, when you ask a question, you get an answer that more often than not leads to additional questions – a result that is very frustrating for those who want an answer and want it now.¹⁷⁵ Given the developments of the past decade, many more decades may pass – and many more hypotheses may be advanced and discarded – before we fully understand all of the causes of sudden infant death, with or without the triad. Today, we are still

¹⁷² *Id.* at 534.

¹⁷³ This assumption is unlikely to be valid. For example, some shaking confessions occur in cases in which there is clear evidence of impact, including skull fractures and bruising. *See, e.g.,* Starling, *supra* note 157, at 456 (observing that 12% of “shaking only” confessions showed evidence of scalp or skull injuries). In other cases, the confession is to shaking around the time of the child’s collapse, but the radiology and pathology establish that the injury was older. When the confessions do not match the injury, we do not know whether the confession was false or whether the shaking had nothing to do with the injuries, as in *Aleman*.

¹⁷⁴ Dr. Dias suggests that the “common and consistent admission by the perpetrator to shaking the infant . . . overwhelmingly suggests that shaking is an important component of infant abusive TBI and is, in fact, sufficient to cause the intracranial injuries found in AHT. To suggest otherwise (as required by the biomechanical evidence) would require that every confessed perpetrator has to have been consistently and universally lying about the same phenomenon, something that defies logic and common sense.” Dias, *supra* note 54, at 369-370. However, the same analysis applies in the opposite direction: since most caretakers do not confess to shaking or any other form of abuse even when offered plea bargains but instead describe similar patterns, including short falls and/or sick or neurologically impaired babies, one would have to assume that these parents were consistently and universally lying about what they saw, a pattern that may indeed defy logic and common sense.

¹⁷⁵ Anne-Christian Duhaime, Cindy Christian & Susan Margulies, Presentation, *The Real Science: What Research is Telling Us about SBS/AHT: From Questions to Answers: Application of the Scientific Method to Abusive Head Trauma by Interdisciplinary Research Teams*, 11th International Conference on Shaken Baby Syndrome/Abusive Head Trauma Conference, National Center on Shaken Baby Syndrome (Sept. 12, 2010) (presentation notes on file with authors).

seeking answers to the questions that we have been asking for 40 years or longer – questions such as, why do some infants or toddlers suddenly collapse or die? Why do some of these children have subdural hemorrhages while others do not? What does the presence of the triad (or some elements of the triad) tell us about the cause of the collapse or death? And are there any findings that can accurately distinguish between accidents, abuse and natural causes? For decades, we thought we had answers to some of these questions: we thought that the presence of the triad, or some of its elements, proved that the child had been shaken. Today, the correct answer to these questions is, “we don’t know.” And, until we do know, we are, in Dr. Duhaime’s words, simply “shooting in the dark.”¹⁷⁶

III. THE MEDICAL EVIDENCE: OLD AND NEW

Despite many warning signals, Dr. Narang argues that the research associating the triad, or some elements of the triad, with SBS/AHT is sufficiently reliable to form the basis for medical diagnoses and criminal convictions. While acknowledging that some of this research is marred by circularity,¹⁷⁷ he identifies a number of articles that he believes are sufficiently reliable to meet the standards of evidence-based medicine and *Daubert*. Dr. Narang further asserts that the biomechanical, neuropathological and anatomical research that casts doubt on the SBS/AHT diagnosis is unreliable and that the SBS/AHT diagnosis should rest on the judgment of clinicians, particularly child abuse pediatricians. In this section, we address each of these points.

A. Literature Supporting the AHT Diagnosis.

In the past decades, scores, if not hundreds, of medical articles have been published that examine the relationship between medical findings such as subdural and retinal hemorrhages and child abuse. Dr. Narang draws upon these studies to argue that highly significant statistical associations exist between subdural and retinal hemorrhages and child abuse, and that these associations are sufficient to support medical diagnoses of abuse and criminal convictions for assault or murder. While it is undeniable that a vast number of medical articles

¹⁷⁶ *Id.* at 14. In this remark, Dr. Duhaime was discussing the unilateral “big black brain,” *i.e.*, the one-sided brain swelling found in approximately one-third of alleged SBS cases. Since shaking would be expected to damage both sides of the brain, the unilateral big black brain has always presented a pathophysiological conundrum. Anne-Christine Duhaime et al., Presentation, *The Real Science: What Research is Telling Us about SBS/AHT, From Questions to Answers: Application of the Scientific Method to Abusive Head Trauma by Interdisciplinary Research Teams*, Eleventh International Conference on Shaken Baby Syndrome/Abusive Head Trauma (Sept. 12, 2010) (notes on files with authors).

¹⁷⁷ Narang, *supra* note 3, at 560-561.

assert that their findings support the SBS/AHT hypothesis, this literature suffers from circularity and other methodological flaws. In this section, we describe the underlying methodology and its limitations, summarize the key studies, and identify some of the methodological and interpretive flaws that frequently appear in these studies.¹⁷⁸

1. *The methodology.* The studies cited by Dr. Narang follow the same basic methodology. In each study, the authors accept the basic premises of the SBS/AHT hypothesis and adopt criteria based on those premises to classify cases that present with subdural hemorrhage or other elements of the triad as accidental, abusive or natural. While the results of this classification vary depending on the precise criteria selected, the size of the sample and the sophistication of the analysis, each study found that if one adopts the SBS/AHT hypothesis, a relatively large percentage of cases resulted from abuse rather than accident. From these studies, Dr. Narang concludes that the presence of subdural and retinal hemorrhages is a statistically powerful indicator of abuse. This methodology does not, however, confirm the hypothesis or help us determine its validity. Nor does it tell us much about the diagnostic specificity of subdural and retinal hemorrhages. Instead, all that it tells us is what the resulting breakdowns would be if the hypothesis and the resulting classifications are correct.

This type of circular classification system can be used to “confirm” any hypothesis, irrespective of its validity. For example, one might hypothesize that dogs are by nature friendly and that they bite only if they have been abused or in pain. The logical corollary is that dogs that bite must have been abused or are in pain. If one adopts these hypotheses, dogs that bite but show no signs of pain must have been abused. The given history of “no abuse” would therefore be deemed inconsistent with biting, the owners would be assumed to be lying, and the dogs would be classified as “abused”. If one further places into this category any dog who has ever bitten without evidence of pain, even as a puppy, the abuse rates for dogs might be extremely high, even approaching 100%. And the percentage of dogs for whom biting is a statistically reliable indicator of abuse would similarly be very high (theoretically 100%). This does not, however, confirm the hypothesis that biting dogs have been abused or that biting is statistically diagnostic of abuse; instead, it simply confirms what the breakdown would be *if* the hypothesis were correct. The abuse rates and correlation of biting to abuse might drop rapidly if one accepted alternative explanations, such as breed predisposition; age (very young or very old); instinctive protection of territory; poor eyesight; and/or fear of strangers.

¹⁷⁸ These studies largely address AHT as broadly defined, rather than SBS. Thus, even accepted at face value, they say nothing about the validity of shaking as the mechanism of injury and do not provide any support for the shaking hypothesis. As discussed below, because of methodological and interpretative problems, they also say relatively little about the causes and incidence of AHT.

In the SBS/AHT studies cited by Dr. Narang, the authors implicitly or explicitly accept the SBS/AHT hypothesis that subdural and retinal hemorrhages are generally traumatic in origin and require considerable force. The studies then use classification systems derived from this hypothesis to classify the findings as accidental, abusive or (in a few instances) natural. Thus, if the parent or caretaker describes a major accident, often characterized as equivalent to a motor vehicle accident or fall from a great height, the findings are classified as accidental. If the parent or caretaker cannot describe such an event – and particularly if the parent or caretaker describes a short fall or no trauma at all – the history is deemed to be inconsistent with the findings, and the case is classified as abusive. While some studies make an effort to eliminate natural causes, such as birth trauma, others do not. Overall, there is a general expectation that the parent or caretaker should be able to explain the medical findings – an expectation that is unrealistic in light of the broad range of causes.

2. The evidence. In the studies cited by Dr. Narang, the researchers typically select a cohort of children who have been diagnosed with head injury based on the presence of intracranial findings. Some studies focus on a particular element of the triad, such as subdural or retinal hemorrhage; others include evidence of impact, such as skull fractures or bruises. Using various criteria, the researchers then categorize the findings as abusive, accidental, natural or undetermined, with most studies attributing the findings to abuse if no known medical cause is found and the history is considered inadequate to explain the findings. The criteria for inadequacy vary considerably. For example, some researchers accept three-foot falls as a legitimate explanation for a subdural hemorrhage¹⁷⁹ while others accept only major motor vehicle accidents or falls from great heights.¹⁸⁰ Not surprisingly, the studies produce different breakdowns depending on the selection criteria, the sophistication of the analysis, and the inclusion of natural causes. The varying conclusions – producing abuse rates for subdural hemorrhages ranging from 28 percent¹⁸¹ to 81 percent¹⁸² in the studies discussed by Dr. Narang – are just one indication of the unreliability of “clinical

¹⁷⁹ Duhaime, *supra* note 43, at 179, 180 (intradural or subdural hemorrhages classified as neither presumptive nor suspicious for inflicted injury if the history is of a fall greater than or equal to three feet).

¹⁸⁰ Dimitra Tzioumi & R. Kim Oates, *Subdural Hematomas in Children Under 2 Years, Accidental or Inflicted? A 10-Year Experience*, 22 CHILD ABUSE & NEGLECT 1105, 1107 (1998) (motor vehicles accidents and falls from over eight feet considered sufficient to explain injuries).

¹⁸¹ Jakob Matschke et al., *Nonaccidental Head Injury is the Most Common Cause of Subdural Bleeding in Infants <1 Year of Age*, 124 PEDIATRICS 1587 (2009).

¹⁸² Duhaime, *supra* note 43, at 183. Cf. Alison M Kemp, *Abusive Head Trauma: Recognition and the Essential Investigation*, 96 ARCHIVES OF DISEASE IN CHILDHOOD EDUCATION & PRACTICE ED. 202, 205 (finding that “for a child under 3 years old with intracranial injury alone the probability of AHT was only 4%”).

judgment” across hospitals, countries and time spans – the precise problem that evidence-based medicine and *Daubert* seek to address.

There are, however, common themes. Essentially, if natural causes are excluded or ignored (as is often the case) and if the outliers are removed, most studies find that approximately half (35 percent¹⁸³ to 60 percent¹⁸⁴) of the parents or caretakers can provide an “acceptable” traumatic explanation for a subdural hemorrhage while approximately half cannot. Since the researchers generally assume that subdural hemorrhages require more force than other head injuries (including skull fractures), the “abuse” rate for subdural hemorrhages is typically much higher than the “abuse” rate for skull fractures and other head injuries.¹⁸⁵ This “abuse rate” is then used to confirm the high correlation between subdural hemorrhages and SBS/AHT.

In this section, we briefly describe the key findings in a selection of studies cited by Dr. Narang on subdural hemorrhages. We then discuss some of the methodological problems with these studies.

a. **Duhaime (1992).**¹⁸⁶ This study examined 100 consecutively admitted children 24 months of age or younger with a primary diagnosis of head injury. Subdural hemorrhages were classified as abusive if (i) they were accompanied by clinical or radiographic findings of focal impact with no history of trauma obtainable; (ii) the caregiver provided a history of a fall less than three feet when seen in association with a changing or developmentally incompatible history; *or* (iii) unexplained injuries such as healing long-bone fractures were present. Under this classification system, all of the subdural hematomas deemed accidental resulted from motor vehicle accidents; falls under three feet were categorized as trivial and constituted one prong of the test to confirm abuse.¹⁸⁷ There appears to have been no consideration of natural causes, including birth injuries. This study classified 81% of the subdural hemorrhages in the study group as abusive and 19% as accidental.

¹⁸³ Linda Ewing-Cobbs et al., *Neuroimaging, Physical, and Developmental Findings after Inflicted and Noninflicted Traumatic Brain Injury in Young Children*, 102 PEDIATRICS 300, 303 (1998).

¹⁸⁴ Kirsten Bechtel et al., *Characteristics that Distinguish Accidental from Abusive Head Trauma in Hospitalized Young Children with Head Trauma*, 114 PEDIATRICS 165, 176 (2004).

¹⁸⁵ For example, in 1992, Duhaime categorized 24% of head injuries and 81% of subdural hemorrhages as abusive. This same pattern is found in more recent studies. In 2005, for example, Vinchon classified 38% of head injuries and 64% of subdural hemorrhages as abusive. These and other studies are discussed below.

¹⁸⁶ Duhaime, *supra* note 43, at 179, 180, 181, 183.

¹⁸⁷ Consistent with Duhaime’s earlier study (Duhaime, *supra* note 41), the authors concluded that shaking “does not generate sufficient deceleration forces” to cause subdural hemorrhages and brain injuries and that impact is required. They postulated that caretakers cause subdural hemorrhages by shaking, swinging or throwing the child, with the head stopping abruptly against a surface. No biomechanical or empirical support is provided for this hypothesis (Duhaime, *supra* note 43, at 183).

b. **Ewing-Cobbs (1998).**¹⁸⁸ This study examined 40 children ages one month to six years hospitalized for inflicted or noninflicted traumatic brain injury. In determining abuse, the authors used a classification scheme similar to that of Duhaime (1992) to determine whether a caretaker's history was compatible or incompatible with the findings. Head injuries were classified as abusive if the caretakers described falls of under four feet or from arm height. Children with documented prior histories of brain injury, metabolic/neurological disorders or prematurity (gestation of less than 32 weeks) were excluded from the study. This study categorized 64% of the subdural hemorrhages in the study group as abusive and 36% as accidental (most commonly in motor vehicle accidents).

c. **Feldman (2001).**¹⁸⁹ This study examined 66 children less than three years of age with subdural hemorrhages or effusions. Histories that were considered to be incompatible with the findings included all cases with no history of trauma; all short falls; stairway falls; and an adult falling on a child. The acceptable histories included motor vehicle accidents, falls from 10 feet or more, and major accidents (kicked by horse, dresser fell on head, and hit on head by falling log). Children with previously known hemorrhagic disease, previous neurosurgical procedure, previously recognized perinatal brain injury, meningitis, brain atrophy, central nervous system infections, renal dialysis, or severe dehydration/hyponatremia or cardiopulmonary bypass were excluded. This study categorized 59% of subdural hemorrhages in the study group as likely/highly likely/definite abuse; 23% as likely/highly likely/definite unintentional; and 18% as indeterminate.¹⁹⁰

d. **Wells (2002).**¹⁹¹ This study included 293 children less than three years of age with intracranial hemorrhages that were evident on radiological examination. Intracranial hemorrhages were categorized as abusive if (i) the caretaker offered no explanation for the findings, (ii) the findings were in the authors' view incompatible with the stated mechanism; or (iii) there was a confession of abuse. Children with a

¹⁸⁸ Ewing-Cobbs, *supra* note 179, at 301, 303, 307.

¹⁸⁹ Kenneth W. Feldman et al., *The Cause of Infant and Toddler Subdural Hemorrhage: A Prospective Study*, 108 PEDIATRICS 636, 637, 638, 639, 644 (2001).

¹⁹⁰ Histories considered indeterminate included a 2-month-old who fell from a kitchen counter onto a hardwood floor while restrained in a bouncy seat (minor injuries consistent with the fall but no independent witness); a fall by a father onto a 7-month-old with the father's full weight landing on the child (indeterminate since the mother was momentarily out of sight); a 2-month-old who fell down 3 carpeted stairs with his father (witnessed by maternal grandmother; child also had chronic effusions and rib fractures that could have been perinatal); and a 4-month-old who was in a truck that was hit by a crane, throwing the infant to the floor with his mother landing on top of him (child also had chronic effusions from possible birth injury).

¹⁹¹ Robert G. Wells et al., *Intracranial Hemorrhage in Children Younger Than 3 Years*, 156 ARCH. PEDIATR. ADOLESC. MED. 252, 253, 254 (2002).

history of hemorrhage from prematurity, birth trauma, surgery or nontraumatic medical conditions were excluded. This study categorized 50.5% of intracranial hemorrhages as abusive, 37.2% as accidental, and 12.3% as undetermined.

e. **Bechtel (2004).**¹⁹² This study examined 87 children under 24 months admitted with a diagnosis of head injury and who had a CT scan. Head injuries were categorized as abusive if (i) there was no history of a traumatic event (fall, blow to head or motor vehicle crash); (ii) the history of a traumatic event was incompatible with developmental level; (iii) the inflicted injury was witnessed; (iv) there was a confession; or (v) there were other physical injuries consistent only with inflicted injuries (e.g., pattern bruises, occult rib or extremity fractures). In this study, virtually all of the cases classified as abuse had no history of significant trauma. Natural causes and birth injury were not addressed. This study categorized 40% of subdural hemorrhages in the study group as abusive and 60% as accidental.

f. **Hobbs (2005).**¹⁹³ This study included 186 children less than two years of age with subdural hemorrhages from the United Kingdom and the Republic of Ireland. Causation was determined by reporting clinicians and pathologists without predetermined criteria. This study classified 57% of subdural hemorrhages as abusive, 30% as natural (perinatal, meningitis and other medical conditions), 9% as undetermined and 4% as accidental.

g. **Vinchon (2005).**¹⁹⁴ This study examined 150 children younger than 24 months of age hospitalized for craniocerebral traumatic lesions. The authors noted that the pathophysiology of subdural hemorrhages appeared to relate to the child's age rather than a specific cause of trauma. Twenty-one cases of birth trauma and five cases with natural causes (idiopathic macrocranium, hemophilia A) were identified. A disproportionate number of abuse cases had a history of perinatal illness (prematurity, obstructed labor, hospitalization after birth), which the authors speculated might have led to poor parental bonding. The authors did not appear to consider that these children may have been suffering from birth injuries.¹⁹⁵ This study classified 64.4% of subdural hemorrhages as abusive.

¹⁹² Bechtel, *supra* note 180, at 166, 167.

¹⁹³ C Hobbs et al., *Subdural Haematoma and Effusion in Infancy: An Epidemiological Study*, 90 ARCH. DIS. CHILD. 952, 952 (2005).

¹⁹⁴ Matthieu Vinchon et al., *Accidental and Nonaccidental Head Injuries in Infants: A Prospective Study*, J. NEUROSURG: PEDIATRICS 380, 381, 383 (2005).

¹⁹⁵ Subdural hemorrhages, skull fractures, classical metaphyseal lesions (CMLs) and rib fractures may all be found at birth. *See, e.g.*, Rooks, *supra* note 91 (identifying subdural hemorrhages in nearly half of asymptomatic newborns); Rick R. van Rijn, *Birth-Related Mid Posterior Rib Fractures in Neonates: a Report of Three Cases (and a Possible Fourth Case) and a Review of the Literature*, 39 PEDIATRIC RADIOL. 30, 33 (2009) (fractures in full-term neonates are a well-known finding even after uneventful deliveries; CMLS and fractures of the clavicle, long bones, spine and skull have been

h. **Matschke (2009).**¹⁹⁶ This study looked at subdural hemorrhages in fifty autopsies of infants under one year of age. Since this study addressed children who died, it would have encompassed the most severe head injuries. At autopsy, 62% of the subdural hemorrhages were attributed to natural causes, 30% to trauma, and 8% to undetermined causes. The natural causes consisted of coagulation disorders (26%), perinatal conditions (26%), infection (8%) and metabolic disorders (2%). In a retrospective review, the authors classified the trauma cases as abusive if they resulted in a confession, criminal conviction, or at least three of the following findings: (i) subdural hemorrhage; (ii) retinal hemorrhage; (iii) an inadequate history; (iv) serious external injury, *i.e.*, hematomas or lacerations; (v) unexplained fractures of the long bones, ribs or skull; or (vi) simple or gliding contusions. Histories viewed as inadequate included sudden collapse/found lifeless; falls from a baby buggy, couch or father's arms; accidental head bumps; and, in one case, a confession of beating and shaking to stop crying. Under these criteria, all but one of the trauma cases were considered to be abusive. Thus, overall, 28% of the subdural hemorrhages were classified as abusive and 2% as accidental.

i. **Vinchon (2010).**¹⁹⁷ This study collected 412 cases of traumatic head injury in children under 24 months of age, classifying 30% of head injury cases as abusive and 70% as accidental. It did not separate subdural hemorrhage from other head injuries. Instead, it attempted to determine whether there were significant differences between confessed abuse cases and witnessed accidents. Forty-five cases of confessed inflicted head injury were compared with 39 cases of accidental trauma occurring in public places. The study found that 36.3% of the abuse cases (30 shaking, 15 beating) resulted in confessions obtained from judicial sources during or after the proceedings had been made public, as determined by a forensic pediatrician, while 13.5% of the accidents were corroborated by independent witnesses. In identifying SBS/AHT, the article endorsed the diagnostic value of what it called the "Ontario" triad, *i.e.*, subdural hemorrhage, retinal hemorrhage and no signs of impact,¹⁹⁸ rather than the classic triad of subdural hemorrhage, retinal hemorrhage and encephalopathy. In this series, clinical signs of encephalopathy were often minimal and brain

reported from birth trauma); Reichard, *supra* note 145, at 566 (incidence of skull fractures at birth is reported to be 2.9%).

¹⁹⁶ Matschke, *supra* note 177, at 1588, 1589, 1593.

¹⁹⁷ Vinchon, *supra* note 157, at 638, 639, 643, 644.

¹⁹⁸ The "Ontario" triad is based on an article by Michael Pollanen, Charles Smith and others. Charles Smith is the Ontario pathologist whose misdiagnosis of abuse in multiple cases in Ontario triggered the Goudge Inquiry. Michael S. Pollanen et al., *Fatal Child Abuse-Maltreatment Syndrome: A Retrospective Study in Ontario, Canada, 1990-1995*, 126 FORENSIC SCI. INT. 101 (2002).

ischemia was detected by CT scan in only 27% of abuse cases.¹⁹⁹ While the authors suggest that the use of confessions avoids the problem of circularity, it is difficult to assess this claim since the confessions were not spontaneous and there is no information on their content or the conditions under which they were obtained.²⁰⁰ Based on confessions, the authors conclude that the presence of subdural hemorrhage, severe retinal hemorrhage and absence of impact provides “virtual certainty of abuse.”

j. **Other studies.** Other studies cited by Dr. Narang use similar procedures to categorize cases as abusive, accidental or natural, with some considering a broader range of causes than others.²⁰¹ While fractures and bruises are often used to support findings of abuse, there is often relatively little effort to assess the age of these findings or to explore their relationship to nutritional deficiencies, coagulopathies or birth issues. Instead, most diagnoses of abuse continue to rest heavily on the inability of parents or caretakers to explain the medical findings – a process that is plagued with unknowns, even for medical professionals.

3. **The flaws.** As even a brief review of the literature suggests, the numerous studies that have concluded that SBS/AHT is a frequent cause of the triad and that subdural hematomas and retinal hemorrhages are reliable indicators of abuse have methodological flaws that range from circularity to statistical mishaps.

a. **Circularity.** The primary defect is that virtually all of the SBS/AHT literature is circular. In study after study, doctors assume that, in the absence of a known medical explanation, subdural hemorrhages are caused by major trauma. Cases are then classified as abusive if the parents cannot describe a major trauma or substantiate a natural cause. As set forth in articles by leading child abuse pediatricians, these criteria were still being used in 2008. For example, Dr. Reece proposed that when the triad was present, the diagnosis of SBS was “highly probable” when *one* of the following is present: no history of trauma; a history inconsistent with the injuries; a history that changes over time; witnessed shaking and/or impact; confession to shaking and/or impact; or additional information supplied by a multidisciplinary child-protection

¹⁹⁹ This study did not control for confounding variables, such as the evolution of the intracranial pathology in the interval between the injury and clinical assessment or scan, which was significantly different in the two groups of patients.

²⁰⁰ The authors state that they had little data on the details, perpetrator, or mechanism of abuse. Under these conditions, it is impossible to verify causality or reliability (Vinchon, *supra* note 157, at 642).

²⁰¹ For example, a small study from Spain excluded 15 babies with subdural hemorrhages from birth trauma, accidental trauma, or natural causes, including CNS infections and glutaric acidosis. In the 20 remaining cases, the study identified 3 cerebrovascular accidents (2 arteriovenous malformations and 1 sinus thrombosis) and 2 coagulation disorders. Victoria Trenchs et al., *Subdural Haematomas and Physical Abuse in the First Two Years of Life*, 43 PEDIATR. NEUROSURG. 352, 353, 354 (2007).

team.²⁰² In a review, Dr. Hymel recommended omitting the second criterion (history inconsistent with the injuries) since that “presumes that we already know which histories are ‘inconsistent’ and which are ‘consistent.’” Dr. Hymel suggested that additional research is needed to determine, with increasing precision, which histories are consistent and which are inconsistent.²⁰³

Under these standards, it is not surprising that some 50% of parents or caretakers cannot explain the findings to the satisfaction of the researchers. Contrary to Dr. Narang’s suggestion, this does not prove that 50% of subdural hemorrhages are caused by abuse. All that it proves is that the researchers *believe* that this is so. One cannot validate a hypothesis based on a classification system that assumes the association that one wishes to prove. This is no different than deciding, *a priori*, that all male teenagers with long hair are drug users, assigning all male teenagers into “drug” and “drug-free” groups based on the length of their hair, and announcing that you have established a 100% correlation between long hair and drug use (and a corresponding 100% correlation between short hair and no drug use), with no effort to determine whether the correlation reflects reality.

Since the circularity problem is well-recognized – Dr. Jenny pointed it out in 2002 and Dr. Narang agrees that “some circularity is inevitable” – Dr. Narang asserts that “numerous well-designed studies [have] set out to control circularity in their experimental design.”²⁰⁴ For instance, in 2004, Bechtel²⁰⁵ attempted to minimize circularity by using selection criteria based on “presenting history and physical examination findings.”²⁰⁶ As in other studies, however, “no history of traumatic event” was one of the criteria used to identify abuse,²⁰⁷ with 12 of the 15 reportedly abused children characterized as abused based on this criterion.²⁰⁸ Since there are many nontraumatic causes for subdural hemorrhages, this study almost certainly over-estimated the incidence of abuse.

Vinchon *et al.* later attempted to reduce circularity by examining cases of confessed abuse in France.²⁰⁹ While this might seem to be a logical improvement over earlier studies, the reliability of confessions is far from certain, as discussed above. Not surprisingly, the greatest incentive and pressure to confess may occur when the doctors, investigators and judiciary believe that the triad is strong evidence of

²⁰² Robert M. Reece, *What Are We Trying to Measure? The Problems of Case Ascertainment*, 34 AM. J. PREV. MED. S117, S118 (2008).

²⁰³ Kent P. Hymel, *Sample Review*, *Epidemiology*, QUARTERLY UPDATE at <http://www.quarterlyupdate.org/epidemiology>.

²⁰⁴ Jenny, *supra* note 76, at 51-52; Narang, *supra* note 3, at 560-561.

²⁰⁵ Bechtel, *supra* note 180.

²⁰⁶ *Id.* at 166.

²⁰⁷ *Id.*

²⁰⁸ *Id.*

²⁰⁹ Vinchon, *supra* note 157.

abuse since, in these cases, the alleged abusers will likely be told – not just by the doctors, police and prosecutor but often by their own attorneys and even their own families – that the medical evidence is conclusive and the hope for acquittal is slim to nonexistent. In such cases, the attorney may advise – and a parent or caretaker may realistically conclude – that the best option is to accept fault irrespective of guilt. In this study, the high rate of confessions (36.3%) combined with a lack of information on the cases and the fact that all confessions appear to have been obtained during judicial proceedings raises concerns with the reliability of the data.²¹⁰

Other researchers, such as Matschke, attempted to address circularity by using criminal conviction as one of the inclusion criteria.²¹¹ Since, however, such convictions are almost always based on the assumptions (and resulting medical opinions) that the research is designed to test, this criterion is entirely circular.

b. **Rule-out diagnoses.** In 1996, SBS was a “rule in” diagnosis, *i.e.*, if the triad elements were found, SBS was automatically diagnosed, at least in the absence of a known alternative cause. Today, SBS/AHT is a “rule out” diagnosis, *i.e.*, a diagnosis that can be made only if all other possible causes have been “ruled out” or excluded.²¹² “Rule out” diagnoses are also known as diagnoses of exclusion or default diagnoses. By definition, these diagnoses occur when there is no laboratory test or direct evidence that would prove the diagnosis. If there were such a test or direct evidence, we would use them rather than going through the long, complex and ever-evolving list of “rule outs.”

Because “rule out” diagnoses cannot be confirmed, they run a significant risk of being wrong. For example, doctors believed for years that stomach (gastric) ulcers were caused by stress: when they could find no other cause, the default diagnosis was that it must be the patient’s fault.²¹³ As it turned out, however, ulcers are predominantly caused by bacterial infections.²¹⁴ Such misunderstandings of causation may do relatively little harm when there is no known treatment for the findings.²¹⁵ In contrast, misdiagnoses of child abuse cause immediate

²¹⁰ *Id* at 639.

²¹¹ Matschke, *supra* note 177, at 1588.

²¹² *See e.g.*, Jenny, *supra* note 7; Narang, *supra* note 3, at 569.

²¹³ *See, e.g.*, Press Release, *The Nobel Prize in Physiology or Medicine 2005*, Barry J. Marshall, J. Robin Warren, Nobel Prize website at http://www.nobelprize.org/nobel_prizes/medicine/laureates/2005/press.html (stating that stress and lifestyle were considered the major causes of peptic ulcer disease before the discovery of *Helicobacter pylori* by Barry Marshall and J. Robin Warren, who received the Nobel Prize for their work).

²¹⁴ *Id.*, *see also* Mayo Clinic Staff, *Peptic Ulcer: Definition*, Mayo Clinic website, at <http://www.mayoclinic.com/health/peptic-ulcer/DS00242> (explaining that doctors now understand that bacterial infection or some medications, not stress or diet, cause most peptic ulcers).

²¹⁵ In the case of ulcers, one could argue that if an incorrect “rule out” diagnosis had not been propounded and widely accepted, the cause might have been discovered much

and often irrevocable harm by removing children from their homes, imprisoning innocent parents and caretakers, and destroying families. Such misdiagnoses may also result in improper or inadequate treatment for conditions that, if properly diagnosed, may have been eminently treatable.

The potential error rate of rule-out diagnoses increases as the number of alternative diagnoses expands. In SBS/AHT, there are tens or hundreds of known “rule outs,” some of which can be identified only when the child is alive and others that can be identified only after death.²¹⁶ As described by Dr. Narang, the “rule-out” procedure requires a detailed whole body physical examination and complete medical history, including a detailed history of the complaints surrounding the presenting symptoms; any history of trauma, infection and/or exposure to infection; a detailed history of prior illnesses, surgeries and hospitalizations; birth history; developmental history; a history of relevant family medical illnesses/disorders; and a comprehensive psychosocial history.²¹⁷ In addition, the clinician must review the laboratory tests and radiology images and work with multiple agencies and medical specialties.²¹⁸ These findings then form the basis for a differential diagnosis, or list of possible causes. Dr. Narang suggests that many potential disorders can be eliminated through a detailed history, physical examination, and initial laboratory and radiologic results. In so doing, the clinician must synthesize the information gathered with “the known pathophysiologic processes of the human body, the evidence-based statistical information on the injuries, and the clinician’s own experience in patient care.”²¹⁹ This is a daunting task given the paucity

more quickly. The failure to identify the true cause of ulcers also resulted in unnecessary surgery that may have increased morbidity and mortality. *See, e.g., J. R. Todd Jr., Peptic Ulcer Disease, an 11 Year Study*, 63 J. N. MED. ASS. 40, 43 (1971) (discussing morbidity and mortality rates following Billroth II procedures).

²¹⁶ For example, seizure activity and some coagulation abnormalities can only be identified when the child is alive, while slides of the brain and meninges, which may reveal congenital abnormalities or pre-existing injury, can only be obtained after death.

²¹⁷ Narang, *supra* note 3, at 569-571.

²¹⁸ *Id.* at 571; *see also* Jenny, *supra* note 7 (recommending an even more detailed “rule out” procedure which includes a complete evaluation of past history, including prenatal history; a family history going back generations, including unexpected deaths, genetic or metabolic disease; a social history; a complete systems review, including medications, allergies, immunizations and feeding history; a review of exposures, including travel, pets and toxins; a minute by minute “incredibly detailed” history of recent events; a detailed head to toe physical exam; a review of old records, including birth records, growth charts, past imaging studies, lab results and hospitalizations; extensive laboratory testing and radiology imaging, including MRI, MRA and MRV; and consults with specialists in many fields, including hematology, metabolic, genetics and infectious disease, as needed. For children who survive, the clinician should follow the child’s long-term care; for those who do not, the clinician should attend the autopsy and consult with the medical examiner, as needed.)

²¹⁹ Narang, *supra* note 3, at 572.

of knowledge on the pathophysiology of the infant brain and the lack of evidence-based statistical information on causation. It is, moreover, unlikely that individual clinicians will have experience with the broad range of alternative causes, including childhood stroke and rare genetic conditions.

Despite the wide range of alternatives, Dr. Narang suggests that at the end of this process “in the vast majority of cases, the common denominator for SDH’s and RH’s will be trauma,” in which case the clinician should distinguish between accidental and abusive head trauma by focusing on “inconsistencies.”²²⁰ Dr. Narang defines inconsistency as (i) the absence of a history; (ii) a history that substantially changes or evolves; (iii) a history that is inconsistent with the child’s developmental capabilities; (iv) a history that is inconsistent with the pathophysiology of the injuries; or (v) a history that is inconsistent with the SBS/AHT literature. Dr. Narang concludes that in the presence of such inconsistencies, “the clinician can diagnose ‘AHT/non-accidental trauma’ with a reasonable degree of medical certainty.”²²¹

This process presents considerable challenges. For example, to determine if a particular injury is consistent with an accidental fall, the clinician must have a solid understanding of biomechanics and the unique characteristics of the fall; the unique characteristics and vulnerabilities of the child, including any genetic, nutritional or birth-related predisposing factors; the secondary metabolic response to injury; the anatomy of the developing brain; and the time course of the injury, including the impact of medical interventions.²²² Since there is strong evidence that an infant’s response to a given injury is much worse than an adult’s response to a similar injury,²²³ what might appear to be minor or even trivial trauma in an adult may produce serious consequences in an infant, particularly one with predisposing conditions.²²⁴ In looking at

²²⁰ *Id.* at 572.

²²¹ *Id.*

²²² See, e.g., Wilkins, *supra* note 108, at 393 (determinants of injury severity for a fall may include the distance fallen, the nature of the surface on to which the child falls, forwards or sideways protective reflexes, whether a fall is in some way “broken,” whether the child propelled himself, the mass of the body and of the head, what proportion of the total kinetic energy is absorbed in compressing the ground and/or deforming the skull, brain or the rest of the body, whether the kinetic energy is dissipated in causing fractures, whether the contact with the ground is focal or diffuse, and the role of secondary brain injury such as hypoxic encephalopathy from an unprotected airway or ischemia from cerebral edema.)

²²³ See Jenny, *supra* note 7 (there is overwhelming evidence that the response to a given injury in an infant is much worse than that of an adult to a similar injury).

²²⁴ See, e.g., Joseph H. Piatt, *A Pitfall in the Diagnosis of Child Abuse: External Hydrocephalus, Subdural Hematoma, and Retinal Hemorrhages*, 7 NEUROSURG. FOCUS 4 (1999) (infants with external hydrocephalus may develop retinal and subdural hemorrhages spontaneously or from minor trauma); P.D. McNeely et al., *Subdural Hematomas in Infants with Benign Enlargement of the Subarachnoid Spaces Are Not Pathognomonic for Child Abuse*, 27 AM. J. NEURORADIOL. 1725 (2006) (subdural hematomas

the absence of a history or a history that substantially changes or evolves, moreover, the clinician must assess the possibility that the parent or caretaker truly does not know what happened to the child and that “changes” in the story may reflect improper interviewing techniques or the efforts of parents and caretakers to search their memories to help the doctors and investigators determine what happened to the child. To examine these factors, clinicians must evaluate the conditions under which the information was obtained, as well as the psychological condition of the caretakers.

Given the consequences of an abuse diagnosis, doctors must be just as careful – and just as knowledgeable – in weighing these considerations as in ordering major surgery or terminating life support, for in each and every case, they hold the future of a family in their hands. If, at the end of the analysis, the answer to whether particular injuries are accidental, natural or abusive is “we don’t know,” that is what needs to be said, and no more.

c. **Clinical judgment.** As Dr. Narang points out, it is not possible to conduct prospective randomized controlled studies in SBS/AHT research since it is not possible to violently shake babies for purposes of experimentation. Dr. Narang further points out that other medical diagnoses have not been validated by randomized controlled trials yet are widely accepted and uncontroversial.²²⁵ For example, a doctor may listen to a patient describe symptoms that have been described as “migraine” and prescribe migraine treatment.²²⁶ If the description of the symptoms accords with that of other migraine patients and the treatment works, the doctor may reasonably diagnose migraine based on clinical experience.

Doctors do not, however, have this type of clinical experience with SBS/AHT. In exercising clinical judgment, doctors generally correlate the patient’s description of the symptoms and their onset (the patient history) with objective medical data (such as lab results) and response to treatment. Unlike a diagnosis of migraine, however, the SBS/AHT diagnosis is typically made in the context of patients who cannot talk, medical findings that lack definitive research, and a legal arena that demands near certainty (proof beyond a reasonable doubt). Since the parents or caretakers typically deny abuse, no one has seen it, and the infant obviously cannot verify it, there is no history to correlate with the findings.²²⁷ There is similarly no course of treatment that would

may occur either spontaneously or as result of minor or unrecognized trauma in infants with benign enlargement of the subarachnoid spaces); Sirotnak, *supra* note 10, at 203 (“spontaneous or trauma-induced intracranial hemorrhages can occur in various common inherited coagulation disorders and those induced by another disease process or medical therapy”).

²²⁵ Narang, *supra* note 3, at 531-532.

²²⁶ *Id.*

²²⁷ One of the more unusual aspects of the SBS/AHT diagnosis is that clinicians typically reject the history provided by the caretakers and substitute their own

confirm or disprove SBS or AHT. Unlike a diagnosis of migraine, a diagnosis of intentional injury cannot be verified by response to a specific treatment or medication. With no history to correlate with the findings and no treatment that would confirm the diagnosis, the SBS/AHT diagnosis lacks the safeguards that gird most clinical diagnoses, including migraine.²²⁸

d. **Observer bias.** Observer bias refers to the innate cognitive biases that lead us to interpret data in ways that are consistent with what we expect to find.²²⁹ Considerable research confirms that police investigators,²³⁰ scientists,²³¹ and physicians²³² are all subject to cognitive errors that lead us to seek, recall, and interpret data in ways that support our initial judgments or hypotheses, and to disregard or minimize information that is inconsistent.

As reflected in the studies cited by Dr. Narang, cognitive biases are unavoidable when physicians use “clinical judgment” to determine which cases are abuse and which are accidental or natural. In *Hobbs*, for example, the authors acknowledged that “there is no absolute or gold standard by which to define NAHI [nonaccidental head injury]”²³³ and declined to provide criteria for determining the causation of subdural bleeding. Instead, the authors deferred to the opinions of the treating physicians, who had been taught for decades that subdural hemorrhages in children were generally caused by abuse. Unsurprisingly, the treating physicians ascribed 57% of subdural hemorrhages and effusions to abuse. Even so, 57% is far from an overwhelming majority – far less

description of the events preceding admission, in effect creating a new patient history that then becomes the lynchpin of the diagnosis.

²²⁸ As this suggests, SBS/AHT is not really a medical diagnosis but a legal conclusion. Doctors may reliably diagnose subdural hemorrhage, retinal hemorrhage and encephalopathy from radiology images and eye examinations. However, determining timing, causation and state of mind goes into areas that are more commonly reserved for pathologists, detectives, psychologists and juries.

²²⁹ See, e.g., D. Michael Risinger et al., *The Daubert/Kumho Implications of Observer Effects in Forensic Science: Hidden Problems of Expectation and Suggestion*, 90 CAL. L. REV. 3 (2002).

²³⁰ Karl Ask & Pär Anders Granhag, *Motivational Bias in Criminal Investigators’ Judgments of Witness Reliability*, 37 J. APPLIED SOC. PSYCH. 561 (2007); Karl Ask et al., *The “Elasticity” of Criminal Evidence: A Moderator of Investigator Bias*, 22 APP. COG. PSYCH. 1245 (2008); Keith A. Findley & Michael S. Scott, *The Multiple Dimensions of Tunnel Vision in Criminal Cases*, 2006 WIS. L. REV. 291.

²³¹ Andrea Follmer Greenhoot et al., *Prior Beliefs and Methodological Concepts in Scientific Reasoning*, 18 APPLIED COGNITIVE PSYCH. 203 (2004); Itiel E. Dror & David Charlton, *Why Experts Make Errors*, 56 J. OF FORENSIC IDENTIFICATION 600 (2006).

²³² Thomas S. Wallsten, *Physician and Medical Student Bias in Evaluating Diagnostic Information*, 1 MED. DECISION MAKING 145 (1981); Vicki R. LeBlanc et al., *Believing is Seeing: The Influence of a Diagnostic Hypothesis on the Interpretation of Clinical Features*, 77 ACADEMIC MED. S67 (Oct. Supplement 2002); Jesse M. Pines, *Profiles in Patient Safety: Confirmation Bias in Emergency Medicine*, 13 ACADEMIC EMERGENCY MED. 90 (2006); Mark L. Graber et al., *Diagnostic Error in Internal Medicine*, 165 ARCHIVES OF INTERNAL MED. 1493 (2005).

²³³ *Hobbs*, *supra* note 189, at 954.

than the 81% identified by Duhaime and far below the criminal standard for proof beyond a reasonable doubt – making it difficult to apply these “statistics” in any given case.²³⁴

Similar disparities arose in a study in which 570 doctors (primarily pathologists and pediatricians) estimated the likelihood of abuse in 16 scenarios involving head injury.²³⁵ In this study, the doctors were asked to classify the head injuries as unintentional, inflicted or undetermined.²³⁶ While no case produced complete agreement, a majority opinion was considered achieved if more than 50% of all survey respondents and more than 50% of experienced respondents²³⁷ rated the injury as either unintentional or inflicted. Using these standards, a majority opinion was achieved in only 8 of the 16 scenarios, 5 of which were classified as inflicted and 3 of which were classified as unintentional. In general, pediatricians were more likely than pathologists to classify cases as inflicted. As the authors noted, the inability to achieve consensus in 50% of the cases may be an appropriate recognition of the uncertainties that persist in this challenging arena.

Finally, observer bias influences the way in which we conduct research. To determine whether subdural or retinal hemorrhages are correlated with abuse, it is critical to determine whether and under what conditions these findings occur in children (or adults) who are not abused. Not surprisingly, the major scientific breakthroughs in SBS/AHT research have come through the examination of groups in which abuse is impossible or unlikely. Thus, from Geddes we learned that the swollen brains and thin subdural hemorrhages previously believed to be diagnostic of abuse are also found in infants who died from respiratory tract infection, perinatal asphyxia, gastroenteritis or sudden infant death syndrome (SIDS);²³⁸ from Rooks we learned that thin subdural hemorrhages are present in 46% of asymptomatic newborns;²³⁹ from Lantz, Matshes and Lopez we learned that retinal

²³⁴ *Id.* at 952.

²³⁵ Antoinette L. Laskey, Michael J. Sheridan & Kent P. Hymel, *Physicians' Initial Forensic Impressions of Hypothetical Cases of Pediatric Traumatic Brain Injury*, 31 CHILD ABUSE & NEGLECT 329 (2007).

²³⁶ *Id.* at 332. Respondents classified the hypothetical cases into seven categories ranging from definitive unintentional to definitive inflicted, which were then collapsed into the three broad categories of unintentional, inflicted or undetermined by the study authors. (“In an effort to identify case examples of widely acceptable criteria for research definitions of unintentional and inflicted pediatric TBI, the participants’ responses were collapsed from seven forensic categories into three, according to the following conservative schema: definitive or probable unintentional TBI were labeled unintentional; possible unintentional, undetermined, or possible inflicted TBI were labeled undetermined; and probable or definitive inflicted TBI were labeled inflicted”).

²³⁷ The study classified as experienced those physicians who indicated they had devoted 50% or more of their professional time to activities directly related to child abuse for at least 15 years. *Id.* at 332.

²³⁸ Geddes, *supra* note 53, at 1304.

²³⁹ Rooks, *supra* note 91.

hemorrhages are found in many types of deaths;²⁴⁰ and from Holmes-Morton we learned that these findings may be associated with genetic abnormalities.²⁴¹ As this suggests, if we want to determine the full range of causes associated with the triad, we must go outside the child abuse arena and conduct studies that are free from observer bias and that look for the findings associated with abuse in children who collapse or die from natural causes.²⁴²

e. **Reversing the burden of proof.** Through a strange alchemy of legitimate confusion and flawed methodology, the burden of proof is reversed in SBS/AHT cases. The 2001 AAP Technical Report made the burden-shifting presumption explicit, stating that “data regarding the nature and frequency of head trauma consistently support the need for a presumption of child abuse when a child younger than 1 year has suffered an intracranial injury.”²⁴³ Once this presumption is in place, the burden is on the parents to “prove” an alternative explanation.

In so doing, Dr. Narang states that “[a] clear, biomechanically plausible account for how the injuries occurred should be available. When the history is absent, minimal, changing, or mechanistically implausible, suspicion of abusive injury is raised.”²⁴⁴ This standard raises two concerns. First, it assumes that the medical findings are traumatic and that doctors are able to accurately assess the biomechanical plausibility of the event. Second, in explaining the findings, parents are at a considerable disadvantage since they typically lack medical expertise and do not know what elements of the history might be important. Unlike doctors, moreover, who are encouraged to change their diagnoses as they acquire new information, parents are not

²⁴⁰ Lantz, *supra* note 131; Lopez, *supra* note 136.

²⁴¹ See, e.g., D. Morton Holmes et al., *Glutaric Aciduria Type I: A Common Cause of Episodic Encephalopathy and Spastic Paralysis in the Amish of Lancaster County, Pennsylvania*, 41 AMERICAN JOURNAL OF MEDICAL GENETICS 89 (1991); D. Holmes Morton, *Through My Window – Remarks at the 125th Year Celebration of Children’s Hospital of Boston*, 94 PEDIATRICS 785 (1994); D. Holmes Morton et al., *Pediatric Medicine and the Genetic Disorders of the Amish and Mennonite People of Pennsylvania*, 121 AMERICAN J. OF MEDICAL GENETICS Part C 5 (2003).

²⁴² Since children who are asymptomatic or who are diagnosed with medical conditions do not routinely receive CT scans or eye examinations, we do not know the prevalence or characteristics of retinal and subdural hemorrhages in the general population or in specific medical conditions. We do know, however, that the more we look, the more we find. See, e.g., Lantz, *supra* note 131; Matshes, *supra* note 135 (finding retinal hemorrhages in natural, accidental and abusive deaths); Lopez, *supra* note 136 (finding severe retinal hemorrhages in *Streptococcus pneumoniae* meningitis); Rooks, *supra* note 91 (finding subdural hemorrhages in 46% of asymptomatic newborns); Laura Rooms et al., *Hemophagocytic Lymphohistiocytosis Masquerading as Child Abuse: Presentation of Three Cases and Review of Central Nervous System Findings in Hemophagocytic Lymphohistiocytosis*, 111 PEDIATRICS e636 (2003) (reporting three cases of hemophagocytic lymphohistiocytosis initially misdiagnosed as suspected child abuse).

²⁴³ Comm. on Child Abuse and Neglect, *supra* note 64, at 206.

²⁴⁴ Narang, *supra* note 3, at 559.

permitted to add to the history as they learn more about the findings since this is viewed as a “changing story” and confirmation of abuse. This is especially problematic since the medical personnel and police often insist that the initial history cannot account for the injuries and pressure the caretaker to search his or her memories for additional details or other possible explanations. When the caretaker attempts to comply, however, any new details or possible explanations are viewed as a “changing story” and confirmation of abuse. Often, this is a circle from which there is no escape.

f. **Interpretive error: statistical misunderstandings.**

Even if the studies cited by Dr. Narang and others did not suffer from circularity and other methodological flaws, they still would not provide a reliable statistical basis for diagnosing SBS/AHT. The statistical errors fall into two categories: misperceiving the significance of the *P-value*, and failing to avoid what is known as the Prosecutor’s Fallacy.

(i) *P-value*. Dr. Narang claims that the studies he cites have tremendous statistical power because they achieve *P-values* of .05 or better. While that does indeed sound overwhelming, reliance on the *P-value* can be misleading. The *P-value* means that a finding is statistically significant based on the improbability that the conclusion attributed to a specific variable was caused by chance, using the standard threshold criterion of .05 (*i.e.*, the chance of a random rather than significant correlation is only 5%). The articles cited by Narang conclude that there is only a very small chance that the higher rates of subdural and retinal hemorrhage seen in cases involving abuse (as opposed to accidents or natural causes) are due to chance, indicating that the correlation is real rather than artificial (*i.e.*, produced by chance). Even if the causes were accurately classified, however, this measure provides no indication of the *strength* of the correlation for it does not distinguish between weak correlations (*e.g.*, subdural and/or retinal hemorrhages are 3% more likely in abuse cases than non-abuse) and strong ones (*e.g.*, such findings are 80% more likely in abuse cases). Yet the strength of the correlation is precisely what is needed to satisfy fact finding requirements in criminal cases, which requires proof beyond a reasonable doubt. Statistical significance is necessary but not sufficient to support this evidentiary standard.

(ii) *The Prosecutor’s Fallacy*. Dr. Narang’s article makes a fundamental logical error that is so common that it has its own name: the Prosecutor’s Fallacy.²⁴⁵ It is the same mistake as saying: “Because

²⁴⁵ See McDaniel v. Brown, 130 S. Ct. 665, 670 (2010); William C. Thompson & Edward L. Schumann, *Interpretation of Statistical Evidence in Criminal Trials: The Prosecutor’s Fallacy and the Defense Attorney’s Fallacy*, 11 LAW & HUM. BEHAV. 167 (1987); Michael I. Meyerson & William Meyerson, *Significant Statistics: The Unwitting Policy Making of Mathematically Ignorant Judges*, 37 PEPP. L. REV. 771, 778 (2010) (the “‘prosecutor’s fallacy’ ... incorrectly reverses events in a conditional probability to create a direct statement about the defendant’s probability of guilt that is

lawyers tend to be literate people, literate people tend to be lawyers.”²⁴⁶ For example, Dr. Narang cites several studies for the proposition that AHT is more likely to cause subdural hematomas in infants than accidental trauma.²⁴⁷ Even if these studies accurately assess causation, it would be an improper application of statistics to conclude that an infant who presents with a subdural hematoma is likely to have been abused.

Bayesian statistics teach that to determine the predictive value of an association – in this case, the likelihood that the presence of subdural or retinal hematomas indicates abuse – one must know not only the correlation between subdural hematoma and abuse but also the prior probability, or base rate, of abuse.²⁴⁸ If the base rate of abuse is much smaller than the base rate of non-abuse, even an extraordinarily high correlation between subdural hematomas and abuse would not make abuse more likely than non-abuse when a child presents with a subdural hematoma.²⁴⁹ Professor James Wood puts it this way: “Exactly the same evidence may lead to quite different conclusions, depending on the rate of abuse in the group being evaluated.”²⁵⁰

A simple illustration makes this point. Suppose that an airport machine that checks for explosives hidden in checked bags is 99% accurate in detecting explosives. This means that the machine will sound an alarm 99 times if 100 bags with explosives are fed through the machine, and will sound an alarm only once if 100 bags without explosives are fed through the machine. In other words, bags containing explosives are 99 times as likely to make the alarm sound as bags not containing explosives. If the alarm sounds, how likely is it that the bag contains explosives? Probably not very likely at all. If one million bags are checked by machine, one of which contains explosives (a number that is almost certainly too high), there would be approximately 10,000 *false* alarms for every *true* alarm. By the same token, if the number of children with subdural hematomas from accidental or natural causes is significantly greater than the number with subdural hematomas from abuse, then Dr. Narang is wrong to assume from the studies he cites that subdural hematomas most likely indicate abuse.

The studies in Dr. Narang’s article illustrate this point. In these studies, the correlation of subdural hematoma to abuse is very high but

not implied by the evidence. In logical reasoning, such an error is called “transposing the conditional” (footnotes omitted).

²⁴⁶ Myerson, *supra* note 241, at 778.

²⁴⁷ See above, pages 40-44.

²⁴⁸ For a general overview of Bayesian statistics, see J. ARTHUR WOODWARD ET AL., INTRODUCTION TO LINEAR MODELS AND EXPERIMENTAL DESIGN 13-15 (1990).

²⁴⁹ For a discussion of base rates, see James M. Wood, *Weighing Evidence in Sexual Abuse Evaluations: An Introduction to Bayes’s Theorem*, 1 CHILD MALTREATMENT 25 (1996); Michael J. Saks & D. Michael Risinger, *Base rates, the Presumption of Guilt, Admissibility Rulings, and Erroneous Convictions*, 2003 MICH. ST. L. REV. 1051 (2003).

²⁵⁰ Wood, *supra* note 245, at 26.

the base rate of abuse compared to non-abuse – to the extent it is revealed in the studies – is sometimes relatively modest, suggesting that subdural hematomas are at best only weakly diagnostic of abuse. Bechtel et al., for example, studied 82 children admitted for head trauma and concluded that 15 (18%) of the injuries were inflicted and 67 (82%) were “accidental.”²⁵¹ Bechtel then reported that 80% (12/15) of the “inflicted” group had subdural hematomas while only 27% (18/67) in the “accidental” group had subdural hematomas.²⁵² From this, Dr. Narang concludes that, with a *P-value* of .001, “the association of SDH’s with inflicted injury was highly statistically significant.”²⁵³ But that is only part of the story. When one factors in the low base rate of abuse, the conclusion is quite different. To compute the posterior probability of abuse, which more accurately reflects the diagnostic significance of subdural hematoma, one has to multiply the base rate by the likelihood ratio, which represents “the relative probability of coming across a particular piece of evidence in one group rather than in another.”²⁵⁴ Here, since 80% of purported inflicted cases have subdural hematomas and 27% of accidental cases have subdural hematomas, the likelihood ratio is 80:27, or 2.96:1. But because the base rate of abuse is only 18%, the true likelihood of abuse given subdural hematoma is only 35%.²⁵⁵ One can make the same calculation in a different manner: since 18 of the subdural hematomas identified by Bechtel were accidental and 12 were inflicted, subdural hematomas were 50% more common in accident cases than in abuse cases. Either way, subdural hematoma is not diagnostic of abuse since most cases with this finding are non-abusive.²⁵⁶

A similar analysis applies to other studies. In the Matschke study, for example, the authors looked at 715 infant deaths, finding subdural hematomas in 50 of them.²⁵⁷ Unlike the Bechtel study, the Matschke study attempted to identify all causes of the subdural hematomas, not just those attributed to trauma. Of the 50 cases with subdural hemorrhage, 15 (30%) were identified as traumatic and 35

²⁵¹ Bechtel, *supra* note 180, at 165.

²⁵² *Id.* at 167.

²⁵³ Narang, *supra* note 3, at 544.

²⁵⁴ Wood, *supra* note 245, at 26.

²⁵⁵ The formula for computing the probability of abuse, also known as the posterior odds, using Bayes’s theorem, is: Prior Odds (here, the base rate) x the Likelihood Ratio = Posterior Odds. See Wood, *supra* note 245, at 29. With prior odds (the base rate) of abuse of 1:5.56 (18%), and a likelihood ratio of 2.96:1, the posterior odds are: 1/1.56 x 2.96/1 = 2.96/1.56. That computes to a probability of abuse of about 35%, because converting odds into probability is accomplished by adding the numerator and the denominator of the odds together (2.96 plus 1.56 = 8.52) and dividing the numerator (2.96) by that total: 2.96/8.52 = .35 (35%). See Wood, *supra* note 245, at 28-29.

²⁵⁶ The Bechtel study had only two classifications: inflicted or accidental. If some of the abuse cases were natural in origin, the base rate of inflicted abuse would have been even smaller.

²⁵⁷ Matschke, *supra* note 177, at 1587.

(70%) were attributed to other causes.²⁵⁸ Of the 35 cases that were not identified as traumatic, the subdural hemorrhages were attributed to bleeding/clotting disorders, perinatal events, infections, metabolic diseases, or (in 8% of the cases) undetermined causes.²⁵⁹ A simple counting reveals that the study does not support the conclusion of its authors, which Dr. Narang quotes for the proposition that “most SDH’s are attributable to trauma.”²⁶⁰ To the contrary, the data show that most SDH’s are attributable to non-traumatic events, by a ratio of 70% to 30%.²⁶¹ As this suggests, while Dr. Narang is undoubtedly correct that some children who have been abused will have subdural hemorrhages, he commits the Prosecutor’s Fallacy when he claims that children who have subdural hemorrhages are likely to have been abused. Instead, this is just one of many possible causes.

(iii) *Improper classifications.* These statistical misunderstandings assume even greater importance when superimposed on statistics that likely misclassify a significant number of medical findings as abusive. At present, we have no reliable statistics on the incidence of abusive head injuries. Instead, what we have are estimates of what the incidence would be if various hypotheses prove to be correct. Without some method of properly and accurately classifying the medical findings previously associated with shaking, there is no valid statistical basis for estimating the incidence of abusive head trauma in general, let alone the likelihood that abusive head trauma has occurred in specific cases.

B. The Skeptics: New Research, Old Anatomy

Two types of study cast doubt on the old SBS hypothesis: (1) studies that point out the lack of support for the traditional hypothesis, and (2) studies that identify specific problems with the hypothesis and/or suggest alternative causes. Dr. Narang dismisses both types of studies, suggesting that they were improperly conducted or are unsupported by the evidence.

1. *Studies that identify the lack of support for the traditional SBS hypothesis.* Dr. Narang focuses on Dr. Donohoe’s 2003 study, “Evidence-Based Medicine and Shaken Baby Syndrome Part 1:

²⁵⁸ *Id.* at 1587.

²⁵⁹ *Id.* at 1589.

²⁶⁰ Narang, *supra* note 3, at 542 (citing Matschke, *supra* note 177, at 1594).

²⁶¹ The Matschke study goes on claim that over 90% of the trauma cases were attributable to abuse. Matschke, *supra* note 177, at 1593. However, the study uses criteria that likely lead to an overestimation of the rate of abuse. *See* note 161, Matschke *supra* 177, at 1588, and related text. In any event, the study’s conclusion that abuse is the most common cause of subdural bleeding in infants depends on dividing the natural causes into separate categories. If combined, they constitute 36% of cases, a greater proportion than that of alleged abuse.

Literature Review, 1966-1998,”²⁶² which he dismisses as poor scholarship.²⁶³ Specifically, he claims that Dr. Donohoe failed to capture the breadth of SBS/AHT medical research by using only the search term “shaken baby syndrome” in the Medline database and internet search.²⁶⁴ Since, however, Dr. Donohoe was examining the evidence base for SBS, not for all types of traumatic brain injury, it was appropriate to search for articles using the phrase “shaken baby syndrome.”²⁶⁵ It was not until after Dr. Donohoe’s analysis – and may have been partly as a result of his analysis – that the medical community began moving away from shaking as a mechanism and adopting more expansive terminology. Dr. Narang does not identify any research on shaking that Dr. Donohoe (or for that matter the participants in the 2002 NIH conference) missed. Without identifying the missing literature, Dr. Narang’s criticism appears to be semantic rather than substantive.

Dr. Narang further criticizes Dr. Donohoe’s observation that none of the SBS research achieved the “best evidence” standards of “Level 1,” which includes randomized controlled trials.²⁶⁶ We all agree that such studies are not possible since one cannot violently shake a child – let alone a large sample of children – to see what happens. Dr. Narang thus notes that “even the most ardent [evidence based medicine] advocate would admit that the best quality of evidence that can be expected in diagnostic studies is ‘Level 2.’”²⁶⁷ While Dr. Narang is correct that Level 1 evidence cannot be achieved in SBS research, this does not mean that Dr. Donohoe was incorrect to note that none of the SBS literature achieved Level 1 status and that none exceeded Level 3.²⁶⁸ Instead, the lack of high quality evidence requires that clinicians and researchers exercise considerable caution in endorsing particular diagnoses or hypotheses, particularly when the adverse consequences are high. Rather than urging greater caution, however, Dr. Narang urges the courts to substitute the clinical judgment of pediatricians and others, which is by nature subjective, for the objective medical evidence envisioned by evidence-based medicine and *Daubert*. This suggestion

²⁶² Donohoe, *supra* note 82.

²⁶³ Narang, *supra* note 3, at 533.

²⁶⁴ *Id.* Dr. Narang contends that Dr. Donohoe should have searched for terms such as “Inflicted Neurotrauma,” “Non-Accidental Trauma,” “Whiplash Shaken Infant/Baby Syndrome,” or even more general terminology such as “Subdural Hemorrhage/Hematoma” or “Retinal Hemorrhage.”” *Id.* at 533-534. Such expanded searches would have dramatically altered Dr. Donohoe’s inquiry, broadening its scope far beyond his objective of identifying the research basis for shaken baby syndrome.

²⁶⁵ Dr. Donohoe examined SBS research through 1998, a period in which SBS was an increasingly popular foundation for criminal convictions. As Dr. Donohoe observed, 1998/1999 is also regarded as “the turning point in acceptance of the tenets and practice of EBM [evidence based medicine].” Donohoe, *supra* note 82, at 239.

²⁶⁶ Narang, *supra* note 3, at 534.

²⁶⁷ *Id.*

²⁶⁸ Donohoe, *supra* note 82, at 241 (by the end of 1998, no evidence on the subject of SBS exceeded QER III-2).

would lower the level of proof in child abuse cases and almost certainly result in mistaken diagnoses and false convictions – the very problems that evidence-based medicine and *Daubert* were attempting to address.

2. ***Studies that identify problems with the SBS/AHT hypothesis.*** Dr. Narang also criticizes studies that identify errors in the SBS literature, including the neuropathological studies conducted by Dr. Geddes and the more recent work on infant anatomy by Dr. Squier (a pediatric neuropathologist and a co-author), Dr. Mack (a pediatric radiologist) and Dr. Eastman (a clinical pathologist), claiming that this work is unsupported by the evidence. However, this research is extensively referenced to the medical literature. Once again, Dr. Narang does not identify any errors in the articles or the supporting literature.

In criticizing the work of Dr. Geddes, Dr. Narang selects his targets curiously. Dr. Narang does not discuss, or even mention, the groundbreaking research of Dr. Geddes and her colleagues in which they found that the brain swelling in alleged SBS/AHT cases was in most cases hypoxic-ischemic rather than traumatic, and that the subdural hemorrhages were typically thin, bilateral, and quite different in appearance from the traumatic hemorrhages found in older children and adults.²⁶⁹ These observations, which are now generally accepted, called into question the traumatic origins of two of the three components of the SBS triad. Instead, Dr. Narang attacks Geddes III,²⁷⁰ in which Dr. Geddes and her co-authors suggested a “Unified Hypothesis” to explain the mechanism of subdural hemorrhage and brain damage in allegedly abused infants. In Geddes III, the authors examined 50 non-traumatic infant deaths from infection, hypoxia and sudden infant death syndrome as well as three “shaken baby” deaths. Since all of the SBS deaths and most of the natural deaths showed intradural rather than subdural bleeding, the paper suggested that the mechanism might be vascular leakage from veins within the dura rather than the traumatic rupture of bridging veins. The paper further suggested that the intradural bleeding might result from a cascade of events combined with immaturity and hypoxia-induced vascular fragility.²⁷¹ Contrary to Dr. Narang’s

²⁶⁹ Geddes, *supra* note 53, at 1304 (observing that “axonal damage occurs in the brains of both head-injured subjects and in controls in much the same distribution...this is not ‘DAI’ [diffuse axonal injury]; but diffuse vascular or hypoxic-ischaemic injury, attributable to brain swelling and raised intracranial pressure”); Geddes, *supra* note 52, at 1297 (subdural hemorrhages found in cases of alleged non-accidental trauma are “materially different from those seen in adults, and are rarely ‘massive’...They are almost invariably bilateral thin films of blood over the cerebral hemispheres, which do not require neurosurgical intervention”).

²⁷⁰ Geddes, *supra* note 89.

²⁷¹ *Id.* at 19 (“our observations in the present series indicate that, in the immature brain, hypoxia both alone and in combination with infection is sufficient to activate the pathophysiological cascade which culminates in altered vascular permeability and extravasation of blood within and under the dura. In the presence of brain swelling and raised intracranial pressure, vascular fragility and bleeding would be exacerbated by

assertion, Dr. Geddes did not recant this suggestion in her courtroom testimony but simply made clear that it was a hypothesis, akin to the SBS hypothesis, albeit more closely aligned with the anatomy of the infant brain.²⁷²

Like the Geddes studies, Squier and Mack's description of the "immature vascular plexus" is firmly rooted in anatomical research.²⁷³ Indeed, this is an observational study of the kind described by Dr. Narang as "not just the norm but the cornerstone of medical diagnoses."²⁷⁴ As Professor Goldsmith pointed out in 2001 and Dr. Reece pointed out in 2002, research on the physiology and pathophysiology of the central nervous system is essential to understanding the issues associated with SBS/AHT.²⁷⁵ While Dr. Narang suggests that the existence of a highly vascularized immature dural plexus is simply a hypothesis, this description of the anatomy is based on microscopic examinations and resin casts, which are illustrated in the Squier and Mack articles.²⁷⁶ Their descriptions are further confirmed by decades of anatomical research on the dura.²⁷⁷

additional haemodynamic forces, such as venous hypertension, and the effects of both sustained systemic arterial hypertension and episodic surges in blood pressure").

²⁷² In her testimony, Dr. Geddes stated that "[the 'unified hypothesis'] is not fact; it is hypothesis but, as I have already said, so is the traditional explanation.... [W]e do use the word "hypothesis" throughout [the paper]." *R v Lorraine Harris, Raymond Charles Rock, Alan Barry Joseph Cherry, Michael Ian Faulder*, 1 Cr App R 5, [2005] EWCA Crim 1980, Case Nos: 200403277, 200406902,200405573,200302848, at <http://www.bailii.org/ew/cases/EWCA/Crim/2005/1980.html>.

²⁷³ Waney Squier & Julie Mack, *The Neuropathology of Infant Subdural Haemorrhage*, 187 FORENSIC SCI. INT. 6 (2009); Julie Mack, Waney Squier & James T. Eastman, *Anatomy and Development of the Meninges: Implications for Subdural Collections and CSF Circulation*, 39 PEDIATR RADIOL. 200 (2009).

²⁷⁴ Narang, *supra* note 3, at 531-532.

²⁷⁵ Goldsmith, *supra* note 55 ("Intimate collaboration is urged between biological specialists, medical professionals and biomechanicians to investigate crucial unsolved problems related to head injury, such as the rate of blood absorption from broken vessels by the body as a function of age, and the rate of effusion from ruptured vessels"); *Inflicted Childhood Neurotrauma*, *supra* note 66, at VIII ("[T]he contributions of basic scientists doing bench research related to the physiology and pathophysiology of the central nervous system are welcome and essential to the generation of understanding about these phenomena").

²⁷⁶ Squier, *supra* note 269, at 8; Mack, *supra* note 269, at 203-205.

²⁷⁷ See, e.g., Erna Christensen, *Studies on Chronic Subdural Hematoma*, 19 ACTA PSYCHIATRICA ET NEUROLOGICA 69, 74 (1944) ("[t]he outermost fibrillary layer of the dura contains arteries as well as veins; the arteries are running in looping streaks, accompanied by two veins which open into the superior sagittal sinus. The arteries as well as the veins form anastomoses, the vessels branching dichotomically. Fine capillaries and arteries run obliquely through the dural tissue to the inner side where a nicely arranged, long-meshed capillary net is found, the junctions of which form ampullary blood-filled dilatations; and these ampullary dilatations constitute the connecting link between the capillary and venous systems. On the outer aspect a more wide-meshed capillary network is seen; and at the transition between the two capillary layers a few tiny vessels are seen"); J.A. Hannah, *The Aetiology of Subdural Hematoma: An Anatomical and Pathological Study*, 84 J. NERV. MENT. DIS. 169, 171

Squier and Mack further pointed out that the thin “subdural” bleeds traditionally associated with SBS/AHT in infants are unlikely to be caused by bridging vein rupture since the quantity of blood is too small given the volume of blood carried within these veins.²⁷⁸ They also noted that there is no “subdural space”, as hypothesized in traditional SBS theory; instead, the arachnoid and the dura are contiguous. Based on the anatomy, Squier and Mack observed that the blood-rich network of vessels in the inner layer of the immature dura may be the source of thin film bleeds found in infants, which are quite distinct from the thick, space-occupying subdural hemorrhages found in older children and adults. Dr. Narang does not identify any errors in these descriptions of the anatomy, which have been presented without objection at conferences on both sides of the debate.²⁷⁹

3. *A shifting paradigm.* Broadly speaking, the research dynamic between supporters and skeptics of the SBS/AHT hypothesis can be characterized as follows – supporters publish great quantities of research, in which selection criteria and clinical judgment based on the SBS/AHT hypothesis are used to differentiate abuse from accidents and natural causes. By failing to consider the wide range of known alternative causes or the unique pathophysiology of the infant brain, the

(1936) (“[c]ontrary to the usual conception, that the dura is a comparatively avascular structure, its blood supply is richer and much more complicated than would appear necessary to supply a structure, the functions of which are merely to support the brain and to act as an endosteum to the skull bones); C. W. Kerber & T.H. Newton, *The Macro and Microvasculature of the Dura Mater*, 6 NEURORADIO. 175, 179 (1973) (the dura contains “a vascular network which is complex and far in excess of the expected metabolic needs of a membrane furnishing only mechanical support); Hui Han et al., *The Dural Entrance of Cerebral Bridging Veins into the Superior Sagittal Sinus: an Anatomical Comparison between Cadavers and Digital Subtraction Angiography*, 49 NEURORADIO. 169 (2007).

²⁷⁸ Squier, *supra* note 269, at 7-8 (rupture of the large caliber veins carrying large volumes of blood from the brain to the dural sinuses would be unlikely to produce the thin film haemorrhages characteristic of the young infant). The infant brain receives a large proportion of the cardiac output, creating substantial regional blood flow (averaging 40 ml/100 g per minute in a 6-month-old). The parasagittal bridging veins, which are strong and few in number, are responsible for draining a large proportion of the blood that flows through the supratentorial cortex. *Bilateral* subdural hemorrhages would require the rupture of multiple bridging veins, all of which would bleed at a relatively rapid rate. Since the bilateral thin film subdural hemorrhages in infants are typically small, sometimes no more than 5 cc, bridging vein rupture is an implausible explanation for these hemorrhages. *See also* Max Wintermark et al., *Brain Perfusion in Children: Evolution with Age Assessed by Quantitative Perfusion Computed Tomography*, 113 PEDIATRICS 1624 (2004).

²⁷⁹ *See* Julie Mack, *Alternatives to Bridging Vein Rupture: Embryology and Function of the Infant Dura*, Presentation, EBMS Symposium (February 21, 2009) (brochure on file with authors); Waney Squier, Presentation, *The Pathology of Infant Subdural Hemorrhage and Brain Swelling*, EBMS Symposium (February 22, 2009) (brochure on file with authors); Julie Mack, Keynote Presentation, *The Dural Venous Plexus: Implications of Subdural Collections*, Second International Conference on Pediatric Abusive Head Trauma (June 26, 2009) brochure at <http://www.childdeathreview.org/Reports/2009PedAHTConference.pdf>.

studies almost certainly overestimate the incidence of abuse. Dr. Narang aggregates this data and presents it as persuasive statistical evidence that subdural and retinal hemorrhages are reliable indicators of abuse. In making these claims, Dr. Narang also fails to consider the base rates of abuse and non-abuse when making statistical claims about the diagnostic power of subdural and retinal hemorrhages. Nonetheless, irrespective of its evidentiary basis and statistical validity, the sheer volume of this research serves to intimidate those who are not familiar with its methodological shortcomings.

At the same time, researchers and clinicians who question the SBS/AHT hypothesis or suggest alternatives based on biomechanical studies or the anatomy of the infant brain routinely confront personal and professional attacks on their motivation, competence and integrity.²⁸⁰ These attacks have slowed the research and deterred others from addressing these important issues.²⁸¹ What Dr. Narang and other supporters of the SBS/AHT hypothesis fail to mention, however, is that despite these vociferous attacks, most of the work that they have attacked in the past has been absorbed into the mainstream, slowly but certainly shifting the paradigm. As this suggests, the recent changes in terminology are not semantic but instead reflect the slow process of discarding previous “truths” about SBS.

At present, the new paradigm includes general agreement on the following points:

- Subdural hemorrhages in infants are not caused exclusively or almost exclusively by shaking or inflicted trauma.
- The dura is far more complex than previously understood, with some hemorrhages previously identified as subdural arising within the dura.
- Thin subdural hemorrhages are found in nearly half of asymptomatic newborns, confirming that they are not always symptomatic and can occur without brain damage.
- Rebleeds of chronic subdural hematomas can and do occur.

²⁸⁰ These attacks appear to be largely coordinated by the NCSBS. *See, e.g.*, Holmgren, *supra* note 39 (Pinocchio slides and sing-along); Colin Welsh, Presentation, *A National Co-ordinated Approach to Cases of Non-Accidental Head Injury in the UK*, 11th International Conference on Shaken Baby Syndrome, sponsored by the National Center on Shaken Baby Syndrome (Sept. 2010) (describing efforts of New Scotland Yard and child abuse prosecutors to silence experts who question the diagnosis) (notes on file with authors); Brian K. Holmgren, *Irresponsible Expert Testimony*, NCSBS website at http://dontshake.org/sbs.php?topNavID=3&subNavID=28&subnav_1=96&navID=115.

²⁸¹ In a recent discussion of an SBS case on the Fifth Estate, a Canadian investigative program, a defense attorney said that he had talked to 50-60 experts who questioned SBS theory, but that only two were willing to testify for fear of being blackballed. Television Program, *Diagnosis Murder*, THE FIFTH ESTATE (January 13, 2012) available at <http://www.cbc.ca/fifth/2011-2012/diagnosismurder/>.

- Retinal hemorrhages are not caused exclusively or almost exclusively by shaking or other forms of trauma.
- Retinal folds and retinoschisis are not diagnostic of abuse.
- The brain swelling in alleged SBS/AHT cases is hypoxic-ischemic rather than traumatic.
- Impact, even on a padded surface, generates more force than shaking.
- Short falls can present with the triad and result in death.
- Lucid intervals can occur in trauma cases.
- The concept of a lucid interval does not apply when the triad arises from natural causes.
- There is a long list of alternative causes for the triad, ranging from birth trauma to genetic abnormalities, infection and childhood stroke.

As the new paradigm emerges, new cases must be evaluated – and old cases re-evaluated – with the same commitment to meticulous diagnosis found in any other complex area of medicine. Our understanding of the medicine and the biomechanics of injury must be combined with a recognition that many fundamental questions remain unanswered. In the meantime, we must strive to make the best possible decisions under conditions of uncertainty—conditions that require us to balance the unthinkable harm of child abuse against the equally unthinkable harm of destroying families and imprisoning innocent parents and caretakers based on a flawed hypothesis.

To this end, in 2011 two of our co-authors – Dr. Barnes and Dr. Squier – published invited reviews of the literature in their own areas of expertise, pediatric neuroradiology and pediatric neuropathology. These reviews describe our current state of knowledge on the medical findings previously attributed to shaking as well as the ever-expanding list of alternative diagnoses.²⁸²

IV. MEDICAL AND LEGAL STANDARDS OF RELIABILITY

While we now have a better understanding of potential causes for subdural hemorrhage, retinal hemorrhage and encephalopathy, the issue has become: how much of this evidence is sufficiently reliable for medical diagnosis and courtroom testimony?

A. Medical Diagnosis: Art or Science?

As Dr. Narang recognizes, there has been a shift in medicine towards the objective examination of the quality of the evidence supporting established theories. The movement known as evidence based

²⁸² Barnes, *supra* note 12; Squier, *supra* note 12.

medicine represents an effort to examine the reliability of the evidence on which doctors make diagnoses and order treatment.²⁸³

Under the standards of evidence-based medicine, clinicians formulate questions, conduct literature searches to identify the best available evidence, and critically assess the reliability of that evidence.²⁸⁴ In so doing, clinicians need to distinguish high from low quality primary studies, identify knowledge gaps and frame questions to fill those gaps, and apply the research evidence to the particular patient.²⁸⁵ Evidence-based medicine guidelines assist in this process by providing a hierarchy of evidence, ranging from randomized controlled trials to unsystematic clinical observations.²⁸⁶

While randomized controlled trials of child abuse are not possible, a review of the literature indicates that the problem goes much deeper: the real problem is that the literature cited in support of the SBS/AHT hypothesis falls at the bottom of the hierarchy of evidence and rests almost entirely on assumptions and hypotheses, combined with emotionally compelling demonstrations and anecdotal evidence, largely in the form of confessions. Recent research has made clear that many of the underlying assumptions are inconsistent with the anatomy and physiology of the infant brain.

To address the lack of an objective evidence base for the SBS/AHT hypothesis, Dr. Narang recommends that the clinical judgment of child abuse pediatricians be substituted for evidence-based medicine. This proposal circles back, however, to the original problem: even the most popular clinical judgments can be wrong, as evidenced by a long list of misguided clinical judgments, ranging from lobotomies to ulcers to hormone replacement therapy.²⁸⁷ Organizational acceptance of clinical judgments is not, moreover, persuasive. As Daniel Kahneman, the Nobel Prize winning Professor of Psychology and Public Affairs at Princeton University, points out, this problem is not unique to medicine:

²⁸³ See, e.g., David L. Sackett et al., *Evidence Based Medicine: What It Is and What It Isn't*, 312 BRIT. MED. J. 71, 71 (1996) (“[e]vidence based medicine is the conscientious, explicit, and judicious use of current best evidence in making decisions about the care of individual patients”); Frank Davidoff et al., *Evidence Based Medicine*, 310 BRIT. MED. J. 1085, 1085 (1995) (“clinical decisions [in evidence based medicine] should be based on the best available scientific evidence...and the clinical problem – rather than habits or protocols – should determine the type of evidence to be sought”).

²⁸⁴ *Id.*; see also Robert C. Hawkins, *The Evidence Based Medicine Approach to Diagnostic Testing: Practicalities and Limitations*, 26 CLIN. BIOCHEM. REV. 7 (2005); Guyatt, *supra* note 1, at 1290-1296.

²⁸⁵ See Guyatt, *supra* note 1, at 1290, 1293 (clinicians should seek evidence from as high in the appropriate hierarchy of evidence as possible and apply it to the particular circumstances of the patient); Hawkins, *supra* note 280, at 8 (clinicians must determine whether the research used independent reference standards and was applied to a population of patients comparable to the patient in question).

²⁸⁶ Guyatt, *supra* note 1, at 1292; see also Phillips, *supra* note 74.

²⁸⁷ See, e.g., Guyatt, *supra* note 1, at 1293 (hormone replacement therapy does not help prevent coronary artery disease despite several observational studies that had shown “dramatically positive results”).

history has shown that “people can maintain an unshakeable faith in any proposition, however absurd, when they are sustained by a community of like-minded individuals.”²⁸⁸ In this case, the reluctance to apply the standards of evidence-based medicine to SBS/AHT has been exacerbated by the efforts of advocacy groups dedicated to the promulgation of the SBS/AHT hypothesis and the criminal prosecution of SBS/AHT cases.²⁸⁹ While we support their commitment to the prevention of child abuse, this commitment should not substitute subjective beliefs for objective scientific evidence. Instead, the commitment must be to getting it right.

Given the current state of knowledge, what is it reasonable for medical personnel to suggest? Is this simply one of the areas in which “the evidence is so sparse, that EBM simply cannot be instructive either for Medicine or Law”?²⁹⁰ The answer to this question depends on the facts of the case and the proposed solutions. SBS/AHT cases range from cases with obvious head trauma (facial bruising, skull fracture and/or soft tissue swelling) to cases in which seemingly healthy children have suddenly and inexplicably collapsed. Sometimes the history and a meticulous review of the medical records provide a likely answer; other times, it is not possible to determine causation based solely on the medical evidence.

In the face of such uncertainty, we must look closely at the costs and benefits of the proposed solutions. The answers are simplest when we are dealing with prevention. Because violent shaking is dangerous and has no known benefits, there are few costs and many potential benefits associated with educating parents that they should never shake a child. Because short falls can be fatal, parents should also be warned that children should not be placed on counters or couches, or in other places from which they might fall or where other children or adults might fall on them.

Similar principles apply to treatment. Because the body cannot always distinguish between trauma and illness, we need to constantly examine and re-examine our treatment protocols to ensure that we are providing the best possible care to children who present with the triad or one of its components. If the head findings are primary, we need to be able to quickly and accurately distinguish between the various possibilities (e.g., injury, infection or stroke) so that we can provide appropriate treatment. If the head findings are secondary, we need to promptly identify and treat the underlying illness or condition if the child is to survive.

²⁸⁸ DANIEL KAHNEMAN, THINKING, FAST AND SLOW 217 (2011).

²⁸⁹ Of these, the most prominent is the NCSBS, which since the 1990s has taken a lead role in training prosecutors, doctors and social workers. Active participants in the NCSBS have been involved in the NAME and AAP policy statements and the more recent certification of child abuse pediatricians.

²⁹⁰ Narang, *supra* note 3, at 521-522.

The burden shifts when the solution is to destroy families and imprison parents. Based on what we now know, it is inappropriate for medical professionals to diagnose shaking or abusive head trauma based solely or primarily on the presence of subdural hemorrhage, retinal hemorrhage and/or encephalopathy. When a child abuse referral or diagnosis is made based on these findings, it should be clearly disclosed that there are many possible causes for these findings; that the issues are complex and poorly understood; and that an SBS/AHT diagnosis based exclusively or primarily on these findings rests on good-faith beliefs and hypotheses, rather than science.

B. Daubert: Is SBS/AHT Ready for the Courtroom?

As Dr. Narang states, in determining reliability for admissibility purposes under *Daubert*, courts may consider: (1) whether a theory or technique can be (and has been) tested (also known as falsifiability or testability); (2) whether the theory or technique has been subject to peer review and publication; (3) whether there is a known or potential error rate; and (4) whether there is general acceptance in the relevant scientific community.²⁹¹ In addition, the courts must consider whether the theory is “tied sufficiently to the facts of the case.”²⁹²

Dr. Narang does not argue that the medical literature on SBS/AHT meets the technical standards of *Daubert* (particularly factors 1 and 3) but argues that the courts should instead accept the “clinical judgment” of doctors, particularly child abuse pediatricians, that abuse has occurred. According to Dr. Narang, this interpretation is supported by *Kumho Tire v. Carmichael*,²⁹³ which according to Dr. Narang “tethered” the admissibility standard of expert testimony to the standards of medical practice, including the SBS/AHT studies on which he relies. This analysis is, however, incomplete.

To begin, *Daubert* governs only the general *admissibility* of scientific or expert testimony about the causes of injury or death in SBS/AHT cases. Increasingly, the legal issues do not focus on admissibility but focus instead on the case-specific significance of the evidence once it is admitted. These issues include whether medical opinions based on disputed medical issues are legally or factually sufficient to support convictions under the “beyond a reasonable doubt” standard²⁹⁴ and whether previously obtained convictions should be re-examined given the new scientific understanding of the limitations of the triad as a diagnostic tool and the very real possibility of alternative explanations for a child’s injuries or death. As a legal matter, in *Cavazos v. Smith*, six of the nine Supreme Court justices acknowledged flaws in

²⁹¹ *Daubert*, *supra* note 2.

²⁹² *Id.*

²⁹³ *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999).

²⁹⁴ *See Tuerkheimer*, *supra* note 37.

the evidence but held that the disputed SBS science presented at trial met the minimal due process standards for sufficiency of the evidence, at least as of the trial date.²⁹⁵ Today, given the many challenges to the old SBS theory, the factual sufficiency of the evidence has become an increasingly significant question, as has the question of how to handle old convictions – a question not addressed by the majority in *Smith* beyond the narrow holding that the old expert opinions constituted sufficient evidence to convict as of the trial date and the suggestion that Ms. Smith seek clemency, which has since been granted. Given the changes in the science, old SBS/AHT convictions are now being challenged based on newly discovered evidence, actual innocence, ineffective assistance of counsel and other similar claims.²⁹⁶

In arguing admissibility under *Daubert*, moreover, it is unclear what Dr. Narang believes should be admitted. Evidence that some brain injuries in children are of traumatic origin, sometimes even intentionally inflicted? Evidence that subdural hematomas and retinal hemorrhages are seen in cases of inflicted abuse? Evidence that shaking can cause the triad and can lead to injury or death? Evidence that subdural hematomas and retinal hemorrhages are diagnostic of shaking or abuse in the absence of a major motor vehicle accident, fall from a multistory building or other proven alternative? Some of these questions are not controversial, and the evidence clearly satisfies the *Daubert* standard. Others are undermined by the research.

Dr. Narang’s analysis of admissibility under *Daubert* further attempts to assess admissibility without limiting the evidence to be introduced or the purpose for which it is proffered. Under *Daubert*, however, any determination of admissibility must include an assessment of the significance of the evidence as it applies “to the task at hand.”²⁹⁷

²⁹⁵ *Smith* did not address the quality of the science, and admissibility was not an issue. Instead, the Court merely purported to apply, in a very straightforward manner, the deferential and forgiving constitutional standard for assessing sufficiency of the evidence under *Jackson v. Virginia*. Cavazos v. Smith, *supra* note 20, at 6. Under that standard, evidence will be deemed sufficient if, taking the evidence in the light most favorable to the prosecution, a reasonable jury could have found guilt beyond a reasonable doubt. Because the State offered experts who opined that the child died of SBS, the Court held that the jury could have found guilt if it credited those expert opinions, which the jury was free to do. The three dissenters – Justices Ginsburg, Sotomayor and Breyer – disagreed, suggesting that the changes in the literature and the fact-intensive character of the case called for a full briefing and consideration of the issues. Cavazos v. Smith, dissent, *supra* note 20, at 8, 9.

²⁹⁶ *State v. Edmunds*, 746 N.W. 2d 590, 596 ¶ 15 (2008) (granting a new trial based on newly discovered evidence because “a significant and legitimate debate in the medical community has developed in the past ten years over whether infants can be fatally injured through shaking alone, whether an infant may suffer head trauma and yet experience a significant lucid interval prior to death, and whether other causes may mimic the symptoms traditionally viewed as indicating shaken baby or shaken impact syndrome”); *State v. Louis*, 332 Wis.2d 803 (Wis. Court of Appeals) (unpublished disposition).

²⁹⁷ See Kumho, *supra* note 289 (quoting *Daubert*, *supra* note 2).

As Professor Michael Risinger explains, under *Daubert* and *Kumho*, “reliability cannot be judged globally, ‘as drafted,’ but only specifically, ‘as applied.’ *The emphasis on the judgment of reliability as it applies to the individual case, to the ‘task at hand,’ runs through the opinion like a river.*”²⁹⁸ Because Dr. Narang’s global analysis does not identify the specific propositions he wishes introduced or their application to the “task at hand,” it tells us little about the admissibility of particular evidence in particular cases.

In determining these issues, clinical judgment cannot trump scientific research. To the contrary, under *Daubert*, the role of judgment or experience is limited:

When a witness is called to ... make conclusions or inferences about adjudicative facts in the case at hand, the testimony is based in part on experience, but in part on some translation scheme to mediate between previous experiences and a particular conclusion in this case. In those circumstances, reliability is dependent on both sufficient experience and a reliable translation system. Perhaps where there are real-world, practice-based, empirically unambiguous indices of success or failure in coming to one’s conclusions, we might rationally rely upon experience not only to provide the expert’s data base, but also to authenticate the reliability of the conclusory skills involved. . . .

*[But], in circumstances when experience alone does not resolve the main doubts about reliability, it would be irrational, and therefore an abuse of discretion to rely upon it.*²⁹⁹

It is also insufficient to rely on the fact that some professional groups accept or endorse the diagnosis of SBS/AHT. As Professor Risinger points out:

[A]dherence to such standards cannot establish reliability [for admissibility purposes] when, as is often the case, it is the very reliability of the standard practice that is in issue. The guild test does at least claim to deal with reliability of the process beyond individual experience, but the reliability judgment is delegated to a group that, by definition, already believes in the process. The guild

²⁹⁸ D. Michael Risinger, *Defining the “Task at Hand”: Non-Science Forensic Science after Kumho Tire Co. v. Carmichael*, 57 WASH. & LEE L. REV. 767, 773 (2000) (footnote omitted; emphasis added).

²⁹⁹ *Id.* at 775-76 (emphasis added).

test trades the ipse dixit of the individual for the ipse dixit of the group.³⁰⁰

For this reason, *Kumho Tire* recognizes the inadequacy of general acceptance by a community when the issue is the reliability of the discipline and/or its application to the case at hand.³⁰¹

In this response we do not take a position on the appropriate application of *Daubert* or other legal standards to particular hypotheses. We note, however, that there are essentially two possibilities. One could exclude both sides of the debate from the courtroom because there is inadequate information to make a conclusive diagnosis. Or, as is presently the case, experts with differing perspectives can argue it out in the courtroom, leaving it to judges and juries to sort out the intricacies of the infant brain and the complexities of biomechanics, as advocated by some prominent legal scholars, including Professor Edward Imwinkelried.³⁰² This approach presents two problems. First, trying and retrying undecided scientific issues on a weekly basis is extraordinarily expensive and inevitably results in inconsistent and “fluky” justice.³⁰³ Second, and perhaps more important, if doctors cannot agree on these complex and unresolved issues, it is unlikely that jurors or judges can do any better.

What cannot be allowed is for supporters of the SBS/AHT hypothesis to present their hypotheses in the courtroom without making clear the limits of their knowledge and without the provision of competing presentations that are equally well-grounded and are often more consistent with the anatomy and physiology of the infant brain. Given the deference that judges and juries often give to expert opinion – a topic that is well-covered by Dr. Narang – the failure to present evidence from critics of the SBS/AHT hypothesis would almost certainly increase the number of false convictions in an area that is likely already riddled with false convictions.³⁰⁴

³⁰⁰ *Id.* at 777.

³⁰¹ *Id.* at 778.

³⁰² See Imwinkelried, *supra* note 36.

³⁰³ Tuerkheimer, *supra* note 95, at 523.

³⁰⁴ While Dr. Narang dismisses the Goudge Inquiry in Ontario, Canada as consisting of “a few recent case reports of wrongful convictions” (Narang, *supra* note 3, at 515), the inquiry identified significant shortcomings in the field of pediatric forensic pathology and the diagnosis of shaken baby syndrome in particular. See Inquiry into Pediatric Forensic Pathology in Ontario (Sept. 2008) at <http://www.attorneygeneral.jus.gov.on.ca/inquiries/goudge/index.html>. The final report recommended a review of shaken baby and pediatric head injury convictions given the changes in SBS knowledge over the past two decades. See Consolidated Recommendations, Inquiry into Pediatric Forensic Pathology in Ontario 86 at http://www.attorneygeneral.jus.gov.on.ca/inquiries/goudge/report/v1_en_pdf/Vol_1_En_g_CR.pdf. Given the composition of the reviewing panel, it is unclear whether this review will lead to meaningful reform.

C. The Costs of Misdiagnosis.

The costs of misdiagnosing child abuse are obvious. If we under-diagnose child abuse, abusive parents will go unpunished and children will be left in unsafe homes. If we over-diagnose abuse, we destroy families and imprison innocent parents and caretakers. But there is a third often under-recognized cost of misdiagnosis: if we identify the wrong problem, we will inevitably apply the wrong solution. For example, when infection or stroke is misdiagnosed as abuse, the focus almost inevitably shifts from appropriate treatment to interrogations and arrests. If the misdiagnosis becomes systemic, this may be accompanied by a broader failure to identify medical problems that may ultimately prove to be preventable or treatable.

V. THE PATH FORWARD

As we work towards a new paradigm, we must bear in mind that the misdiagnosis of SBS/AHT is extraordinarily harmful, and that there is no self-corrective mechanism. Typically, any suggestion of SBS/AHT results in the automatic removal of the child and/or the child's siblings from the home. In addition to the emotional anguish, families often lose their savings and homes in frantic attempts to reclaim their children while facing prison sentences up to and including the death penalty. While these costs may be justified if a child has been abused or murdered, one should be quite certain that the abuse did indeed occur before imposing these costs, particularly given a legal system that is ill-equipped to correct past mistakes.³⁰⁵

In this case, the suggestion that shaking may harm vulnerable infants – a suggestion originally made by Dr. Guthkelch – was eminently sensible and holds true today. The SBS corollary – that shaking can be presumed from specific medical findings, including subdural hemorrhage – was plausible and widely accepted, including by Dr. Barnes and Dr. Squier, two of the co-authors of this article. Research conducted over the past decades has, however, established that the SBS hypothesis was based on a misunderstanding of biomechanics and the infant brain, and that there are many alternative causes. The shift in terminology from SBS to AHT has not solved this problem since it is *harder* – not easier – to defend against mechanisms that are not specified and that therefore cannot be tested or even debated.

³⁰⁵ See, e.g., Tuerkheimer, *supra* note 95, at 544 (“While not always expressly articulated, commitment to the finality of criminal convictions is deeply embedded in our criminal law structures and jurisprudence”); Cavazos v. Smith, *supra* note 20, at 7 (upholding conviction in Shirley Smith case despite acknowledging that “[d]oubts about whether Smith is in fact guilty are understandable”).

We suggest four paths forward: research, collaboration, acknowledgment of the complexities, and learning to work under conditions of uncertainty.

A. Research

While we may never reach the levels of certainty demanded by evidence-based medicine or *Daubert*, we can certainly do better than we have done in the past. The research that Professor Goldsmith suggested in his NIH presentation in 2001 is as applicable today as it was then, and many of his suggestions align with those of Dr. Narang. Promising avenues include:

1. Studies on the anatomy and physiology of the infant brain, including the tolerance and failure limits of bridging veins, the role of cerebral spinal fluid, the mechanisms of retinal hemorrhage, and the role of biochemical cascades.
2. Analysis of other diseases and medical conditions that “mimic” SBS/AHT. While children are not little adults, they are subject to many of the same illnesses and medical conditions, including stroke, infection and nutritional deficiencies. We need to prevent, diagnose and treat these conditions rather than automatically ascribing them to abuse.
3. Careful, complete and nonjudgmental interviews of parents and caretakers, who often hold the clues to the correct diagnosis.
4. The development of protocols for investigating known alternative causes and identifying new causes.
5. Maintenance of a national registry on SBS/AHT cases, with retention of medical records, radiology images, blood samples and tissue samples. Videotaped autopsies would also be helpful. This would allow us to obtain accurate numbers and would provide a basis for ongoing evidence-based medical scrutiny and judicial review.

B. Working Together

To date, the child abuse community has been divided into hostile camps. If the medical issues are to be addressed, however, we need to work together. To do this, we endorse Dr. Guthkelch’s recommendation that we adopt descriptive medical terminology that does not attempt to answer the question that is being asked. It is very difficult to have professional discussions on the cause of medical findings that are named “shaken baby syndrome” or “abusive head trauma” since these terms assume the causation.

Second, we need to continue to have less antagonistic professional discussions. The biannual conferences conducted by Penn

State Hershey are a good start: at these conferences, the organizers invite one or more presenters with diametrically opposed viewpoints to debate important issues. Often, the opposing camps are not as far apart as one might think. At the joint conference in Jackson Hole in 2009, for example, Dr. Plunkett and Dr. Dias quickly reached agreement that short falls can indeed be fatal, albeit rarely.³⁰⁶

Another constructive conversation occurred at a conference sponsored by the Queens District Attorney's Office in New York in September 2011. While the presenters and audience consisted largely of supporters of the SBS/AHT hypothesis, a panel composed of representatives from both sides of the debate discussed the key issues in a professional manner, sometimes reaching the same conclusions. For example, all of the panelists agreed that violent shaking may cause serious injury or death; that the triad is not diagnostic of abuse; and that each case requires an extended inquiry into the child's medical history and findings.

Third, personal and professional attacks on those with opposing views must stop. New ideas and a willingness to question traditional understandings are a precondition to scientific progress. If we are to ensure the wellbeing of children and families, our commitment to "getting it right" requires that we put aside our preconceptions and consider new ideas, including those contrary to our most cherished beliefs. While there is always resistance to new ideas, every mistake – and every delay in correcting our mistakes – imposes heavy costs on children and families. Debate and disagreement are essential, but there is no room for ad hominem attacks or efforts to prevent the dissemination of new research.

Finally, this debate needs to be taken to the broader legal, medical and scientific communities. Since we now know that our initial understanding of SBS/AHT was flawed, we need the advice and support of other specialties, including scientists and doctors who are not so closely involved in the debate. An independent review of the validity and basis for the SBS/AHT diagnosis by the National Academy of Sciences would be a good start. Discussions at major Children's Hospitals and other teaching hospitals would also be useful. In the legal arena, it is important to keep lawyers and the judiciary abreast of the advancing medical science and for prosecutors, judges and child protection agencies to consider the facts of each case rather than relying exclusively on medical hypotheses.

C. Acknowledging the Complexities

For decades, the SBS hypothesis provided a clear and simple explanation for the collapse or death of children who presented with

³⁰⁶ Plunkett, *supra* note 111.

subdural hemorrhage, retinal hemorrhage and brain swelling. We now know, however, that its premises were wrong. The SBS hypothesis was based on a three-component model that did not reflect or recognize the complexities of the infant brain. In its original form, SBS taught that subdural hemorrhages were caused by the traumatic rupture of bridging veins in the “subdural space.” However, the small thin subdurals typically found in infants are too small to represent the rupture of bridging veins, there is no subdural space between the dural and arachnoid membranes, and the “sub”dural hemorrhages in infants more likely originate in the venous dural plexus. The SBS hypothesis also taught that retinal hemorrhages in children were caused by the traumatic rupture of retinal veins. However, retinal hemorrhages in children are also seen in natural diseases and appear to reflect the same causes as retinal hemorrhages in adults, including lack of oxygen, thrombosis, increased intracranial pressure and time spent on life support. Finally, the SBS hypothesis taught that brain swelling was caused by the traumatic rupture of axons (nerve fibers) throughout the brain. However, we have known for more than a decade that the brain swelling is due to lack of oxygenated blood from any cause. All of this knowledge was neglected because it did not fit the model.

As our analyses become more anatomically correct, we are finding that there is no single model. Instead, the cases vary widely. A few cases present with large space-occupying subdural hemorrhages, as one would expect from ruptured bridging veins, but most present with thin intradural/subdural hemorrhages or thrombosed (clotted) veins with surrounding leakage. The ocular findings range from small unilateral retinal hemorrhages to bilateral multilayered retinal hemorrhages with retinoblastoma. The brain findings range from no brain damage at all to swollen hypoxic-ischemic brains with no hope of recovery. In some cases, all of the findings are acute (new) while in others, some or most of the findings are weeks to months old, or even older. The clinical histories are equally diverse: some children were healthy until their collapse; others had seizures, feeding difficulties or neurological impairments from birth; and yet others were symptomatic for days or weeks before collapse. In some cases, the collapse occurred when the child and a caretaker were alone; in others, the child and the caretaker were alone for minutes, if at all.

Given the heterogeneity of the medical findings and factual settings, one should be skeptical of a “one size fits all” diagnosis. One should also be skeptical of diagnoses that rest on three isolated findings without considering the characteristics of the developing brain and the relationship between the brain and the rest of the body. In so doing, one should remember that:

If one were to name the universal factor in all death,
whether cellular or planetary, it would certainly be loss of

oxygen. Dr. Milton Helpem, who was for twenty years the Chief Medical Examiner of New York City, is said to have stated it quite clearly in a single sentence: “Death may be due to a wide variety of diseases and disorders, but in every case the underlying physiological cause is a breakdown in the body’s oxygen cycle.” Simplistic though it may sound to a sophisticated biochemist, this pronouncement is all-encompassing.³⁰⁷

In infant deaths, like all other deaths, the medical question is “what caused the lack of oxygen?” – not “who did it?” In our effort to determine why the child lacked oxygen – a question that has hundreds of possible answers and may sometimes prove unanswerable – we must treat each case the same way as we treat any other complex diagnosis: we must consider the lab results, the history, and all of the medical findings, bearing in mind the complexities of the human body and the physiological cascades that occur when this tightly regulated system goes awry. We must also carefully sort out, to the best of our ability, which findings help determine the cause of injury or death and which are secondary to an ongoing process and/or medical intervention. To do anything less is a disservice to children, families and our system of justice.

Today, everyone agrees that the “triad” of findings previously attributed to shaking may reflect abuse, accident or natural causes. What we don’t know is how many cases – or sometimes which cases – fall into each of these categories. More than a decade ago, the Five Percenters suggested that 5% of SBS cases were misdiagnosed as child abuse³⁰⁸ -- a figure that many thought was high. Based on the changes in the literature over the past decade, however, this figure may be even higher. But is it 10%, 25%, 50% or even 95%? The answer to this question is: we don’t know. And until we do know, we cannot use statistics to address the issues, let alone to diagnose individual cases.

D. Working Under Conditions of Uncertainty

While we would all like a “gold standard” that distinguishes quickly and accurately between abuse, accident and natural causes, the medicine is uncertain and evolving, and the cases are complex. As we continue to search for answers, we need to make the best possible

³⁰⁷ SHERWIN B. NULAND, *HOW WE DIE: REFLECTIONS ON LIFE’S FINAL CHAPTER* 67 (1994). Professor Nuland teaches surgery and the history of medicine at Yale University.

³⁰⁸ Beth Hale, *Falsely Branded a Baby Batterer – Now Rioch Edwards-Brown’s a Fighter for Justice*, DAILY MAIL, Nov. 24, 2011, at <http://www.dailymail.co.uk/femail/article-2065430/INSPIRATIONAL-WOMEN-OF-THE-YEAR-Falsely-branded-baby-batterer--Rioch-Edwards-Browns-fighter-justice.html>.

decisions under conditions of uncertainty. Dr. Narang suggests that we do this by emphasizing clinical judgment, leaving the resolution of the disputed medical issues to judges and juries. We suggest that the costs of this approach are too high and that we instead need to make clear the limits of our knowledge while expanding our knowledge base. In essence, this is what doctors and lawyers do when we treat patients or advise clients. It should be no different in the courtroom, where the safety of children and the futures of entire families hang in the balance.