The Shaken Baby Syndrome

Ronald Uscinski, M.D.

In 1971, Guthkelch hypothesized that subdural hematomas could be caused by manually shaking an infant, without the head impacting any surface.[1] One year later, Caffey alluded, in a paper describing "parent-infant traumatic stress syndrome" (PITS), to manual shaking causing intracranial injury in the form of subdural hematoma and cerebral contusions in infants.[2] Two further papers by Caffey over the next two years emphasized shaking as a means of inflicting intracranial bleeding in children.[3,4]

After publication of these papers, shaken baby syndrome became widely accepted as a clinical diagnosis for inflicted head injury in infants. However, in 1987 and again in 2003, careful laboratory investigations based on the known biomechanics of head injuries showed that human beings cannot achieve the necessary accelerations for causing intracranial injury in infants by manual shaking alone, but that impact is required.[5,6] Moreover, after more than 33 years, despite numerous reports of series of case studies, an actual witnessed incident in which an infant sustained an intracranial injury as a result of shaking alone has yet to be documented.

As is true in other scientific disciplines, knowledge of medicine should, and generally does, advance in two distinct ways. The first is clinical observation of various physical and physiologic manifestations of disease processes, with an attempt to verify underlying etiologic, anatomic, and physiologic principles. The second is laboratory investigation of both normal and abnormal (or disease) processes, in an attempt to arrive at underlying mechanisms. Ideally, both should aim to discover treatment principles.

Biomechanical Considerations

Our understanding of trauma to living tissue is derived from both clinical observation and laboratory experimentation. While there is a physiologic response to trauma, the initiating event of necessity must involve mechanical disruption of living tissue. Hence, force is applied to living tissue in such amount and manner as to result in disruption. In the physical universe, as described by classical Newtonian physics, force is the product of mass and acceleration. Insofar as living tissue has mass and undergoes motion, these laws apply. The study of the principles of disruption of tissue is referred to as biomechanics, and an understanding of trauma to the nervous system or any other body system necessitates some understanding of this discipline.

It is significant that in all four previously cited original papers regarding the hypothesis of shaking, both Guthkelch and Caffey refer to a single paper by Ommaya published in 1968[7] as a biomechanical justification for this concept. Therefore, it is important to understand what was attempted and accomplished by Ommaya .

Carrying forward work by physicist A.H. Holbourn,[8,9] Ommaya had formulated and demonstrated the concept of an injury threshold for neural tissue. If achieving this threshold required force, it is understood that this force must be the product of mass and acceleration, and specifically, rotational acceleration, or acceleration involving the head moving through an arc.

Moreover, previous work had demonstrated that this threshold force represented a constant factor and was related to the inverse of the mass of the individual brain raised to two-thirds power.[10] Scaling of injury thresholds to individual brains was theoretically possible and, to an extent, experimentally verified. It is important to understand that mass is a physical property, and other factors, such as age, gender, and even species, are irrelevant. Building upon this work, Ommaya had recognized that for a given mass of brain, the critical factor in determining injury would be rotational acceleration.

As Ommaya and other clinical neurosurgeons observed, people who sustained whiplash injuries to the neck in motor vehicle accidents sometimes also exhibited symptoms referable to altered brain function such as altered sensorium, diplopia, and even occasional intracranial bleeding.[11]

The Threshold of Injury

Working with the U.S. Department of Transportation, Ommaya devised an experiment to measure more precisely the amount of rotational acceleration necessary to reach the threshold of injury. A contoured fiberglass chair was built, mounted on wheels, and placed on tracks with a piston behind it. Rhesus monkeys were strapped into the chair with their heads free to rotate. The piston then impacted the chair, simulating a rear-end motor vehicle collision.

The experiment was photographed with a high-speed camera, enabling calculations of generated rotational accelerations. Measuring the arc of the head rotating and accelerating around the neck, Ommaya was able to demonstrate that a rotational acceleration of 40,000 radians/sec^2 was sufficient to cause concussion in the animal subjects. Ommaya was able to produce intracranial injury in 19 of the animals, with 11 of them also demonstrating neck injury. Then, using the scaling parameters, he estimated that less rotational acceleration would be required to produce concussion in the larger human brain, perhaps on the order of 6,000 to 7,000 radians/sec^2.

It is significant to note that whereas this experiment showed, qualitatively, that rotation alone could indeed produce intracranial

injury, it was not shown quantitatively that human beings could generate the required rotational acceleration by manual shaking. Nonetheless, this critical omission was not addressed until 19 years later. At that time it was shown quantitatively that impact was required to generate adequate force. Guthkelch, Caffey, and others either were not aware of, or disregarded, this critical missing piece of information. In the intervening years, and even up to the present, numerous references are made to infants sustaining inflicted brain injury by manual shaking. Yet no laboratory proof of this possibility has ever been put forth. In fact, the available experimental evidence, beginning as far back as 1943, addressed directly in 1987 and reproduced in 2003, seems to indicate the contrary.

Conclusions

Clinical observation and scientific experimentation and verification should complement one another. More than 30 years after the original hypothesis of shaken baby syndrome, this does not appear to have happened.

With regard to treatment of cranio-cerebral trauma, the differentiation between accidental and inflicted injury is of limited practical importance: injuries are injuries. For social purposes, however, the distinction is critical.

While the desire to protect children is laudable, it must be balanced against the effects of seriously harming those who are accused of child abuse solely on the basis of what is, at best, unsettled science.

Ronald Uscinski, M.D., F.A.C.S., is a neurosurgeon practicing in the Washington, D.C., area. He has consulted and testified as an expert witness for the defense in cases involving alleged child abuse, both pro bono and for time compensation. He has never consulted or testified for the prosecution, because no prosecuting entity has ever contacted him. Address correspondence to: 18111 Prince Philip Drive, Olney, MD 20832, ruscinski@juno.com.

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