# What Does Science Tell Us About Abusive Head Injuries in Infants and Young Children?

**Mary E. Case, MD**

What Is The Shaken Baby Syndrome? Abusive head injury refers to the traumatic brain injury inflicted on an infant or young child and is used in this discussion to encompass all mechanisms of inflicted traumatic brain injury. Because the investigation into whether an injury is intentional or unintentional is often complicated by caretakers providing a false history or no history at all to explain a child's injury, understanding mechanisms of head injury as revealed by the pathological findings may assist in determination of how the injury was caused. Abusive head injuries are the most common cause of death in child abuse. These injuries are most common in infants under one year old but the same injuries can be seen in children as old as age 4 or 5 years. Shaken Baby Syndrome is one form of abusive head injury in which a child is submitted to severe repetitive acceleration-deceleration forces with or without blunt impact to the head that result in a characteristic pattern of injuries which may include retinal hemorrhages, certain fractures (in particular ribs and the ends of long bones) and recognizable patterns of brain injury.

## Is A Child's Head And Brain Different Than An Adult's?

In evaluating the head injuries of young children, it is important to appreciate that the trauma affects a brain and skull that are in the process of maturing and developing so that head injuries in young children differ in certain respects from head injuries seen later in life. The skull of a young child is thin and pliable because the bone is not yet ossified, the sutures are not yet fused, and the fontanelles are open. The head of a young child is proportionately much larger and heavier than later in life because the brain grows very rapidly and attains 75% of its full weight by age two years although it is far from mature in development. The newborn child's head is about 10 to 15% of its body weight compared to 2 to 3% for the adult head. Within the skull, the dura is a thick membrane covering the surface of the brain and attached to the inner surface of the skull. Beneath the dura are the leptomeninges consisting of the two thin layers of the arachnoid and the pia separated by the subarachnoid space. Although the young child's brain has a relatively large subarachnoid space it is very shallow in depth so that the brain is closely positioned next to the skull. The subarachnoid space contains the spinal fluid and serves as some protection to dampen impact. The neck musculature of the young child is immature and unable to adequately support the weight of the head. One of the greatest protections against common forms of head injury is the ability to keep the head stationary in response to impact to the head or to movement of the body. Maintaining a stationary head requires neck strength which lacking in young children. The brain of the young child is very soft and easily deformable by inertial head motion. Brain tissue has a soft consistency at all ages somewhat like set gelatin. Its consistency depends upon myelination which is the development of a sheath of myelin around the axonal processes, the development of the network of glial cells which are the supporting network of cells of the nervous system, and the amount of water content in the brain. In young children, the consistency of the brain is very soft somewhat like unset gelatin.

## How Do We Know When a Child Has A Head Injury?

To understand head injuries requires an appreciation of the mechanisms of head injury. Forces which act on the head may cause movement of the head in a variety of ways. The brain does not necessarily move in perfect synchronicity with the skull due to the softer consistency of the

brain compared to the more rigid skull. Similar to water in a glass which can be jostled about by moving the glass due to the forces of inertia, movements of the head may cause the brain to move about within the cranial cavity somewhat separately from the movement of the skull. Because of these mechanics, traumatic head injury results in certain patterns of brain injuries that are recognizable either clinically when the child is alive or when the brain is examined after death.

**Can A Child Die From Falling Off A Couch Or Out Of Bed?**

Forces acting on the head that result in movement of the brain in a straight line in relation to its center of gravity (translational movement) have minimal effect on the brain except for those resulting from focal contact. Contact forces may result in scalp bruises, skull fractures, epidural hemorrhage, and focal subdural hemorrhage. In very rare incidences of trivial home falls from short distances, contact forces may produce a fatal head injury in a young child by producing a space occupying lesion from an epidural hemorrhage or subdural hemorrhage. In these rare cases, the child may not immediately rendered unconscious but gradually becomes symptomatic from increasing intracranial pressure. Because the brain is confined within the skull, only a limited amount of space is available for the brain plus the blood and the spinal fluid to occupy. Traumatically created bleeding in the epidural or subdural spaces encroaches upon the space occupied by the brain and its fluids and devastating consequences result and these are due to increased intracranial pressure. Epidural hemorrhage is blood that lies between the bone and the dura and most result from fractures of the skull although not all. Surgical or medical intervention may prevent a fatal outcome by removal of the hematoma. Subdural hemorrhage, which is discussed more thoroughly below as a diffuse injury, may on rare occasions be a contact injury where the bleeding arises in a focal area in the subdural space. It is estimated that the incidence of death from a short fall (<4 feet) is probably at most 1 in a million. When this does occur, the brain injuries tend to be recognizable as contact injuries and different from those seen in fatal abusive head trauma.

A much more common serious or fatal head injury in young children is caused by events that produce rotational movement of the brain about its center of gravity. Rotation of the brain's center of gravity is caused by acceleration-deceleration movement of the head which may be initiated by either impact or non-impact mechanisms. The majority of cases of abusive head trauma are related to direct impact to the head causing forceful angular acceleration-deceleration of the head. Shaking is a nonimpact inertial mechanism which may also produce angular acceleration-deceleration of the head. Inertial movement refers to the disparity between movement of the brain and movement of the skull. Acceleration-deceleration movement of the head is damaging when it is forceful enough to cause rotational movement of the brain within the cranial cavity causing the brain to turn abruptly on its axis. Rotational movement of the brain within the confines of the skull creates shearing or tearing of the blood vessels or bridging veins on the surface of the brain as well as the axonal processes within the brain.

**How Much Force Is Necessary To Hurt A Baby's Brain?**

Because the young child's brain and skull as noted above are developmentally immature, they are particularly vulnerable to shearing injuries of the brain when significant forces are applied to the head. Impact to the head of the young child is much more likely to produce shearing injury of the vessels and axons rather than brain contusions as might be seen in older ages. The supporting structures of myelin and the glial framework are both lacking to a great degree and

which facilitates shearing injury . The soft consistency of the brain and the pliability of the bone facilitate brain deformation on head impact. The large heavy head supported on the weak neck allows greater movements of the head and brain in response to acceleration-deceleration forces.

In the early 1970s, shaking as a mechanism of injury was described in young children who demonstrated a syndrome of subdural and subarachnoid hemorrhages, retinal hemorrhages, and metaphyseal fractures. Some have questioned whether shaking alone as a mechanism of injury generates enough force to seriously or fatally injure a young child through rotational acceleration - deceleration. In a 1987 study, Duhaime (The Shaken baby syndrome. J Neurosurgery 66;409-415, 1987) measured the angular acceleration caused by either shaking or impact of the head of a doll model and found that shaking alone did not be reach the thresholds for concussion, subdural hemorrhage, or diffuse axonal injury. The thresholds used in that study, however, had been derived from studies on adult primates which do not necessarily truly resemble the immature human infant skull and brain. A more current model for the study of inertial brain injuries uses the miniature pig to study the effects of rotational acceleration on a human infant. The brain of a young pig is believed to closely resemble a 3 to 4 month old human infant brain based on anatomical and developmental similarities. These studies demonstrate that the young pig's brain is more vulnerable to rotational acceleration than the adult whereas the data from the primate model had suggested the infant would be less vulnerable. This newer data thus indicates that the thresholds for concussion, subdural hemorrhage, and DAI used in the 1987 Duhaime study were not appropriate for human infants. In addition, the confessions by perpetrators, the absence of similar injuries even in severe accidental injury such as motor vehicle accidents, and work with other mechanical, animal, and computer models informs us that shaking alone can be fatal.