C10 Motor Vehicle Pediatric Brain Injury

Richard W. McLay, PhD, STARK rxp, 1231 Hamilton Court, Iowa City, IA 52245; and Janice J. Ophoven, MD, 6494 Crackleberry Trail, Woodbury, MN 55129*

After attending this presentation, attendees will be able to recognize good science in biomechanics of brain injury in a child.

This presentation will impact the forensic community by showing methods that are good science in the study of pediatric brain injury. The methods provide a fairness in the presentation of evidence in both civil and criminal cases, particularly in the area of auto collision injuries.

Pediatric brain injuries in auto collisions are varied and serious. The mechanisms of trauma to the head for a child in an auto collision can number literally in the hundreds. One common mechanism is illustrated by the dummy in FIG. 1*: Subdural hematoma* and *diffuse axonal injury* caused by impact from either the vehicle interior or an air bag strike.

FIG. 1: Impact of child's head by air bag

There are three common effects from this mechanism that causes injury: 1) the increase in pressure in the cerebral spinal fluid (CSF) under the point of impact on the skull, 2) cavitation in the CSF caused by the decrease in pressure on the opposite side of the skull cavity, and 3) cavi- tation in the brain tissue and CSF caused by the shearing action from a high angular acceleration of the head-neck system. These are illustrated schematically in FIG. 2.

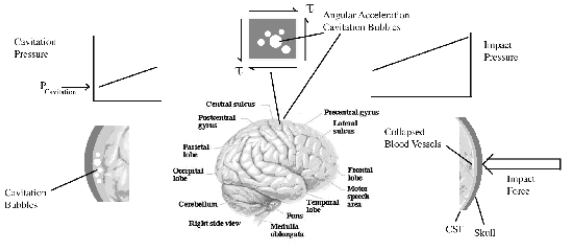

FIG. 2: Three effects from head impact acceleration

The increase in pressure in the CSF under the point of impact is illus- trated on the right side of FIG. 2. The true mechanism for the formation of a subdural hematoma is subtle: The higher pressure in the CSF surrounding a blood vessel acts against only the blood pressure inside. Because the induced impact pressures can be an order of magnitude greater than the blood pressure, the blood vessel collapses and the bending action forms a lesion at the outer surface. This lesion can be large or quite small, the latter result yielding a very slow bleed of several days. Thus, the child can be injured and the event nearly forgotten when the child becomes comatose from pressure on the brain.

The cavitation in the CSF caused by a decrease of pressure on the opposite side of the skull cavity causes a contre coup injury to the brain. The schematic of this is on the left-side of FIG. 2. The true mechanism can be one of several forms, but *diffuse axonal injury* can occur. The basic equation for this is:

$$\mathbf{K}\, d^2\mathbf{u}/dx^2 = \rho\, \mathbf{a},$$

where **K** is the *bulk modulus* of the CSF, **u** is the displacement of the fluid in the direction of the decreasing pressure gradient, ρ is the mass density of the CSF, and **a** is the acceleration of the head in impact. For a child,

 ** Presenting Author*

this equation yields accelerations on the order of 180 gs to cavitate the CSF on the opposite side of the skull cavity. This agrees with the literature for brain injury of children from infants to 3 years of age.

The third mechanism of brain injury in children that presented here is cavitation produced by an angular acceleration of the head-neck system, illustrated schematically at the top of FIG. 2. The mechanism for this injury is the shear stress generated by the acceleration of an element in the brain at the greatest throw distance from the point of rotation in the neck. The basic equation for this stress comes from a modification of the elasticity equation and results in:

$\tau = \rho \alpha r^2/4$,

where ρ is the mass density of the brain material, α is the angular acceler- ation in radians/sec^2, and **r** is the distance from the point of rotation of the head neck system to the element studied. Values of α that generate *diffuse axonal injury* in a child are generally in excess of 16,000 rads/sec^2, which this equation predicts within a few percent.

This paper gathers together the literature on pediatric brain injury and shows the basic mechanics for several of the mechanisms of injury in vehicle collisions. The application of these analyses can be very broad, from auto and other vehicle collision injuries to falls and child abuse.

Pediatric, Trauma, Brain

 ** Presenting Author*