## H33 Cranial Fracture Patterns in Pediatric "Crushing" Injuries and Preliminary Biomechanical Modeling Using a Simple Finite Element Model

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The goal of this presentation is to inform attendees about the characteristic fracture patterns that result from bilateral "crushing" (quasi-static loading) injuries of the subadult cranium by presenting several case studies of such insults and a simple biomechanical model that replicates and helps explain these patterns.

This presentation will impact the forensic community by demonstrating the type of fractures that can be expected in cases of bilateral crushing in subadults and attribute these characteristic patterns to the stresses developed in the cranium.

Bone fracture analysis is an integral component of some forensic casework. In terms of determining cause and manner of death, the forensic professional must possess a working knowledge of not only the forces involved in fracture production and propagation, but also the effects of geometry and stress concentrations. Most often blunt cranial injuries involve dynamic forces characterized by large energy changes generally due to rapid changes in velocity over the loading duration. Conversely, crushing injuries involve quasi-static forces that are applied slowly across broad aspects of the skull. The understanding of typical fracture patterns based on common scenarios and biomechanical modeling may be pertinent to the evaluation of cranial injuries sustained by subadults and attempts to determine circumstances of the injury (accident vs. abuse). If a fracture pattern is found which does not correspond to the adult's account, there may be need to inquire further to ascertain the true nature of the injury.

For this study, four cases are presented in which young children of various ages (from 1.5 to 6 years of age) have sustained fatal cranial crushing injuries from the tire of a slow moving motor vehicle or a heavy, non-motorized farm trailer. In each case the cranium was entrapped between the ground and the tire. In all four cases, the major bone fractures occurred in the basilar region of the cranium that bridges and links the loading sites (the tire and the ground) and traverses the middle cranial fossa in the area of the sella turcicum. Biomechanical engineering was then utilized in efforts to explain the mechanism of this fracture pattern using a mathematical model.

A model of a simplified cranium was constructed with symmetry about the sagittal plane, but not about the coronal or transverse planes. The base of the cranium was modeled as a flat surface with the same thickness as the dome and the primary landmarks in the basal region. A hole was added to simulate the foramen magnum, two dense spheres were placed anterior to the foramen magnum to represent the petrous portion, and the thickness in a section of the cranium between the petrous portions was hollowed out to represent the region of the spheno-occipital synchondrosis.

Finite Element Analysis (FEA) was conducted on the model by applying quasi-static, bilateral pressures. The pressures were applied to the model in such a way as to simulate the crushing forces reported in the four cases. The stress pattern developed in the simplified model revealed significant stresses on the base of the skull with areas of lower stresses on the cranial vault. The stress pattern corresponded well with the fracture pattern documented in the four cases. Further analysis revealed that tensile stresses were generated in the region of high stress that correlated with and explained the observed fracture pattern. This suggested that the quasi-static (slow) loading of the cranium leads to fracture in predictable ways.

The computational model suggests that the reason crania fracture through the basicranium is largely due to the concentration of tensile stresses due to the geometry of the cranium. Based on these pilot studies, it would appear that a simplified cranial model of a slow, "crushing" force could be used to help explain fracture patterns seen in typical case situations.

**Pediatric Fracture Patterns, Bilateral Crush Injuries, Finite Element Modeling (FEM)**