Cerebral Mechanics during traumatic brain injury

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Introduction

Traumatic Brain injury (TBI) is a leading cause of death and disability among children and young adults in United States, with an estimated 1.5 million Americans sustaining TBI per year [1]. Pressure variations with respect to space and time cause brain tissue to deform beyond the level of recovery which is the elastic limit. The Cranio-Cerebral Complex is subjected to frontal impact. The shock wave propagating through the skull-brain complex as result of the external impact, causing coup and contrecoup lesions on the brain, are investigated in greater detail.

Modeling Methodology

The three dimensional model of the Cranio-cerebral complex is developed using MRI and CT data of a 20 year old male. The contours representing the individual slices of the skull, brain and Cerebro Spinal Fluid (CSF) are stacked together to form three-dimensional volumes, using packages MIMICS from Materialise, Geomagic from Raindrop and IDEAS from EDS. These surfaces are exported as International Graphics Exchange Standard (IGES) format to the mesh generation software, TRUEGRID, to build hexahedral meshes. The concept used for creating hexahedral meshes is to project simple block structures onto surfaces of interest such that the projected blocks conform to the shape of the actual geometry [2]. The final mesh of the brain generated from the basic block structure is shown in Figure 1.

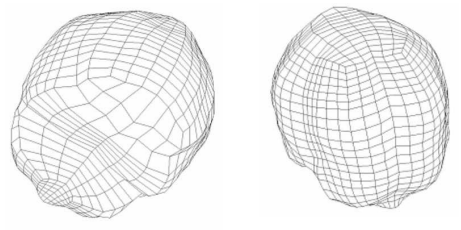

Fig. 1. Different views of the final mesh for the brain.

Boundary Conditions

The cranio-cerebral complex is subjected to impacts from the frontal direction as shown in Figure 2.

Tied and sliding contact conditions are used to define the skull - CSF interface and the CSF - brain in-

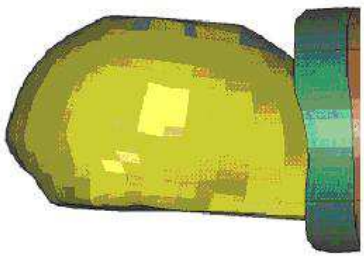

Fig. 2. Cranio-Cerebral complex subjected to frontal impact.

terface. A value of 0.2 is used to define the coefficient of friction between the sliding interfaces [3]. The velocity of 5.5 m/sec is imparted to the cranio-cerebral complex which impacts the stationary padded material.

Results and Discussion

The skull-brain complex is subjected to frontal impact and the simulated results compared with existing experimental results [4]. Figure 3 shows the coup stress contours at 6 mSec during the frontal impact.

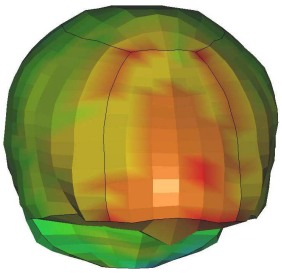

Fig. 3. Cranio-Cerebral complex subjected to frontal impact.

The contre coup stresses are concentrated on the occipital lobe of the cerebrum. This result is in accordance with the clinical studies, which shows the major portions of damage to the brain during a frontal impact to be the frontal and occipital regions of the cerebrum.

Conclusions

A hexahedral finite element model of the cranio-cerebral complex was developed. The intracranial pressure variations during frontal impact were analyzed the using explicit non-linear finite element code, LS-DYNA. The coup and contre-coup pressure responses during the impacts were concentrated over a small region of the brain tissue which confirmed the clinical studies about the presence of focal lesions that were present on the brain tissue over a small region. It was also concluded that the location of maximum shear strain was always at the inferior portion of the brain stem. The developed finite element model of the cranio-cerebral complex can be used to understand the cerebral mechanics during various degenerative diseases such as hydrocephalus, edema etc. affecting brain.

References

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