Validation of the GHBMC Small Female Head Model and Development of Crash Induced Injury Tolerance for Head Injury Prediction

Runzhou Zhou[1], Tushar Arora[2], Varun Pathak[2], Liying Zhang[1]

[1]Department of Biomedical Engineering, Wayne State University, Detroit, MI
[2]Department of Mechanical Engineering, Wayne State University, Detroit, MI

Objectives

Finite element (FE) modeming can serve as a powerful tool to study human head and brain injuries that is difficult to investigate experimentally. Recently, a detailed human head model, GHBMC M50 (Global Human Body Modelling Consortium), representing a 50th percentile male adult head has been developed and validated. A number of Crash induced injury (CII) criteria were also developed for predicting head injury risk. The objective of this study was to develop the GHBMC 5th percentile female (F05) head model which accounts for gender related size, geometrical and anatomical differences in order to properly predict injury risk sustained by this population.

Problem to be solved

This study focuses on conducting rigorous validation of the GHBMC F05 head model and the determination of the CII values for various head injuries to the skull, face, and brain of various regions.

Methodology

The FE mesh of the GHBMC F05 was carefully evaluated and the refinement was made to accurately represent all essential anatomical structures for the skull, brain, face and surrounding tissues. Five sets of contact interfaces were defined between various anatomical structures for proper connectivity and simulation of biomechanical interaction. Thirty-one sets of published cadaveric head impact experimental data were simulated to validate the biomechanical response of the head model in terms of force-deflection for various facial and cranial bones, intracranial pressure and brain/skull relative displacement for brain of various regions. Then, Forty-four sets of head impact experiments with injury and noninjury conditions were simulated to develop CII values for various types of head injuries including skull fracture, facial fracture, acute subdural hematoma (ASDH), cerebral contusion, and diffuse axonal injury (DAI) of various region and severities.

Results and Discussion

The model predicted time histories of the force-deflection, intracranial pressure and brain/skull relative displacement responses were correlated to the experimentally measured results using CORA objective rating method. Parametric studies on the effects of material properties, damping, and contact parameters improved overall CORA rating from 0.5 to >0.65. The CII values for cortical and cancellous bones were determined for predicting skull and facial fracture in various regions/bones. The injury probability curves for cerebral contusion and acute subdural hematoma were developed respectively, based on intracranial pressure in coup-contrecoup and strain measurement in the bridging veins. The CIIs values of maximum principal strain and strained volume in the white matter, corpus corpus callosum and brainstem were developed for predicting diffuse axonal injury.

Conclusion

The GHBMC F05 head model has been rigorously validated against all exiting data in response to head impact. The current model is capable of predicting 4 different head injury types affecting 9 regions/locations with reasonable predictive capability (Category 0) and 2 injury types at Category 1 which requires additional test data. With further improvement, the human head model can enable assessment of possible real-world injury scenarios to allow for engineering improvements to help prevent potential head injury.