Prediction of Diffuse Axonal Injury with a Strain Measure from an Analytical Model of Head Impacts

Hong Zou[1], James Schmiedeler[1]

[1]The Ohio State University

ABSTRACT

Diffuse axonal injury (DAI) is one of the most devastating types of traumatic brain injury and frequently occurs from automobile crashes. Strain deformation induced by shear force from sudden acceleration of the human head during impact has been recognized as a major cause of DAI. Recent mathematical studies on strain damage of brain tissue are dominated by finite element (FE) modeling work. Although offering detailed modeling of anatomical structures, FE models have not been fully validated due to the lack of complete knowledge of the material properties of brain tissue. Based on a well-established analytical brain injury model, which was validated against the most advanced experimental brain motion data and compared with high-fidelity FE results under low-severity impacts, a measure of strain for DAI prediction is presented. Increasing with higher accelerations under more severe impact, the maximum shear strain was selected as the injury indicator of DAI because DAI most likely results from shear force. This strain measure was applied to the frontal crash tests using the acceleration data collected with dummies through the New Car Assessment Program (NCAP) conducted by the National Highway Traffic Safety Administration (NHTSA). The results were compared with the Head Injury Criterion (HIC) and the Cumulative Strain Damage Measure (CSDM) in the SIMon FE head model developed by NHTSA. It shows that the maximum shear strain from the analytical model can be used as a critical element to predict DAI from automobile crashes. It also suggests that brain injuries can be better predicted when the maximum shear strain is used together with HIC and CSDM. Including both linear and angular accelerations, this analytical model tends to fill the gap between HIC and the more complex SIMon, where HIC predicts injuries based only on linear accelerations while the SIMon prediction is dominated by angular accelerations.