Characterization of Head Kinematics in a Rodent Closed Head Injury Model

Alex Reiff [1], Soroush Assari [1], Melanie Elliot [2], Kurosh Darvish [1]

[1]Biomechanics Laboratory, Department of Mechanical Engineering, Temple University
[2]Department of Neuroscience, Thomas Jefferson University

Abstract

Traumatic Brain Injury (TBI) is a leading cause of death and disability worldwide. In order to investigate into the diagnosis and treatment of injury, and improve the protective equipment, different rodent injury models have already been developed and utilized. One of the closed head injury (CHI) models widely used in such studies uses a linear impactor to directly hit the rat head. While the kinematic aspects of head trauma, including the head linear and angular velocities and accelerations have been shown to correlate with the severity of the injury, in the CHI models only test input parameters such as impactor speed, depth of penetration, angle of impact, and impactor tip diameter and material are provided. In order to compare the result of one study with others, or to scale the results from animal head to human head, knowing the kinematics of the head is essential. Understanding how the test parameters affect the kinematics of the head during the impact will allow researchers to more reliably replicate controlled brain injuries. In the current study, the kinematics of the rat head in a CHI model is characterized for different impactor angles, depths.

In the experiments, three photo targets are attached to the rat's skull, and the rat is placed in front of a mirror so that it can be viewed from two angles simultaneously using one high-speed camera. The rat's head is struck with an impactor device at angles of 20° and 40° on the transverse plane, with depths of 2, 3, and 5mm, at a constant impactor velocity of 5 m/s. After image processing of the recorded high-speed video of the impact, the positions of the photo targets on the head in three dimensions are calculated during the head motion. The centroid of the skull is then found in relation to the three photo targets, and its velocity and acceleration are determined over time. The Head Injury Criterion (HIC) value is calculated based on the magnitude of the head acceleration.

For hit angles of 20° and 40° and different penetration depths, the average peak velocity of the head are found to be 0.9-2.5 m/s and 0.9-2.7 m/s; the average peak acceleration 100-220 g and 90-240 g and the average HIC 70-530 and 50-730 respectively. It is determined that head peak velocity, peak acceleration, and HIC increased linearly with the depth of penetration ($R^2 = 0.95$). On average, impacts at 40° angle cause 8% increase in peak velocity, 9% increase in peak acceleration, and 30% increase in HIC value. However, these changes were not statistically significant. The kinematics measures found in this study can be used as basis to compare different rodent TBI data.