Numerical investigations of factors affecting neck injuries during rollover crashes and a new concept for rollover neck protection

Jingwen Hu[1], Clifford C. Chou[1], King H. Yang[1], Albert I. King[1]

[1]Wayne State University

ABSTRACT

The neck is the third most commonly injured body region during rollover crashes. The objective of this study was to analyze systematically neck responses and associated injury predictors under complex loading conditions using an updated finite element (FE) human head-neck model.

A previously validated human head-neck model was further validated against near-axial impacts onto two different inclined surfaces. Active muscles were added to the model and then validated against frontal and lateral impact test data obtained from volunteers. The effect of changing the coefficient of friction (COF), padding material stiffness and muscle force was analyzed along 10 different impact orientations. Because most of the neck injuries during rollovers were vertebra fractures, the maximum force and moment at each vertebral level and the maximum principal strain in the vertebrae were considered as injury predictors to evaluate the injury risk.

Impact of the head against a frictionless surface generally resulted in a lower injury risk than a surface with friction. Increasing the COF from 0 to 0.5 caused all injury predictors to increase significantly. However, only minimal increases were observed in injury predictors when the COF was increased from 0.5 to 1.0. For frictionless head contact onto a rigid surface, the maximum injury risk occurred when the impact surface was approximately perpendicular to the longitudinal axis of the cervical spine. When the COF was 0.5, lateral contacts generated much higher injury risks than those without a lateral component due to the asymmetric loading distribution in the vertebrae. Muscles, especially the active muscles, increased the risk of neck injury significantly. Interestingly, a layer of padding with a proper stiffness and reduced COF between the padding and head could slightly decrease the neck injury risk. This was in contrast to some experimental data which showed that all padding could increase the risk of neck injury. More simulations further demonstrated that if padding material was installed onto the roof with a frictionless sliding interface, the risk of neck injury could be reduced significantly.

In real-world rollovers, it is likely that both COF and lateral forces are present. Results from this series of simulations suggest that a careful selection of proper padding stiffness along with a very low COF between the padding and its supporting structure may decrease head and neck injuries simultaneously. This new design concept should be further validated before it is implemented.