ABSTRACT
ANIMAL TO HUMAN SCALING OF CERVICAL SPINE INJURY TOLERANCE IN FRONTAL IMPACT

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Cervical spine (c-spine) injury tolerance is not well understood during severe frontal impacts. While these c-spine injuries are rare, they are disproportionally debilitating to the individual in the long-term. To study the dynamics of c-spine injury during frontal impact, this dissertation repurposed historical kinematic data from frontal impact experiments using a modern statistical and modeling approach. Frontal impact data was obtained from two historic sources: non-human primate (NHP) experiments from the Naval Biodynamics Laboratory and human research volunteer (HRV) experiments from the Air Force Research Laboratory.

First, injury probability curves were calculated from published NHP peak head kinematics and injury outcomes. The risk curves established c-spine injury as a risk of head specific metrics (50% injury risk of head Z acceleration = -101 G). Next, the mean head kinematic responses from the non-injurious HRV frontal impact experiments were validated against a previously developed human head-neck (HN) computational model. The measured ligament strains from the human HN model were used to verify an optimal muscle activation scheme to replicate the live HRV response, with extensors activated at 40% of maximum activation. Lastly, a NHP HN model was constructed and used to simulate experimental accelerations applied to NHP. Mean peak head kinematic measures were used to validate the NHP HN model across non-injurious and injurious levels. Additional simulations were completed with the human HN model under the same acceleration conditions as the NHP. Ligament strains were compared between both models, and the NHP-to-human responses were mass-scaled to derive human injury risk curves.

The NHP HN model confirmed injury mechanisms seen in experimental outcomes from severe frontal impact. Additionally, the scaled injury risk curves, detailing potential severe human c-spine injury risk as a function of head acceleration, compared well with the ligament strains in the re-validated GHBMC HN model. A 50% severe injury risk of head Z acceleration of -58 G was established for adult males in frontal impact. The results of this project utilized historical kinematic data from frontal impact experiments, which will likely never be replicated, to establish a potential human c-spine injury tolerance during severe frontal impacts.