Development of Finite Element Mouse Model for Primary Blast Simulations

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Abstract

Incidence of exposure to explosive threats has increased in recent military conflicts, leading to more frequent blast-induced traumatic brain injuries. In vivo animal research models are commonly used as surrogates to investigate the effects of primary blast on humans. Coupling experimental models with numerical tools such as finite element (FE) modeling allows tight control of boundary conditions and observation of transient response during the blast event. FE models are a powerful tool for calculating physical response to blast impact that might be difficult, if not impossible, to measure experimentally. However, many FE models currently employed for blast simulation use the human head, which lacks in vivo human blast data, making them difficult to validate. This necessitates the use of animal FE models, which are more easily validated by in vivo experimental data. The purpose of the current study is to develop a FE model of a mouse head for blast impact simulations. Improved understanding of human dose responses to primary blast impact as predicted by in vivo models will contribute to creation of accurate injury criterion, optimization of protective technologies, and potential improvement of clinical treatments.

A cadaveric mouse was scanned using X-ray micro-computed tomography and imported into visualization and analysis software (Avizo 8.0). Tissues including the brain, bone, and soft tissue were segmented into regions based on linear attenuation. A surface was extracted from the innermost brain layer. Internal smoothing functions in Avizo were used to refine and correct voxel artifacts on the extracted surface. The smoothed surface was imported into automatic meshing programs (TrueGrid and Altair Hypermesh 11.0). A multi-block structured hexahedron mesh composed of 8-node hexahedral elements was projected onto the tissue layer surface. Hexahedral elements were used to avoid shear and volumetric locking often observed in tetrahedral-element simulations. Equipotential relaxation and uniform smoothing functions were used to improve mesh metrics including Jacobian, aspect ratio, and orthogonality of individual elements. This process was repeated for multiple tissue layers while optimizing element quality to create the full head model. Standard tissue specific material properties were integrated into the model including stress-strain data from indentation tests on an in vitro mouse brain. The testing parameters were then specified and the model was run in LS-DYNA R7.1.1.

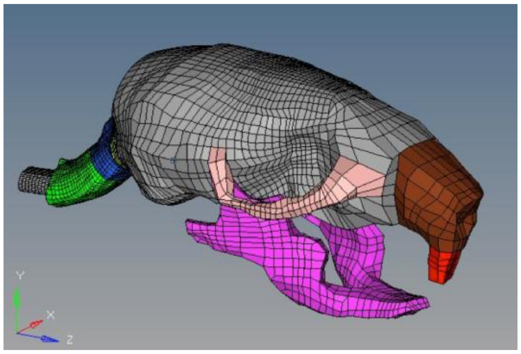

Figure 1: Hexahedral FE mouse model displayed in Altair Hypermesh 11.0

Element quality parameters will be assessed and reported. There are a total of 58474 elements in the current model with an average element length of 11 microns. 770 (1%) elements have Jacobians below 0.5 and 2397 (4%) have aspect ratios about 5. Results will include optimized element quality assessment and physical dimensions for all parts, from bone to soft tissues. A convergence study will be run. The simulation results will be reported including spatial locations and magnitudes of peak pressures and deformation which could potentially correlated with deficits during post-blast behavioral and functional testing. In silico results will be compared to existing blast data on in vivo mice specimen and to a previously created FE ferret model.