Planar Analysis of Visceral Response to Thoraco-Abdominal Impacts

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ABSTRACT

*Post-mortem human specimen (PMHS) experiments have correlated torso biomechanics (e.g., compression and V*C) to injury risk. Experiments have employed the "chestband," an instrumented steel belt from which contours are derived representing torso cross-sectional shape. Although injury outcomes are correlated to chestband-derived uniaxial metrics, it is desirable to establish a relationship between deformation behaviors and tissue response throughout the impact event. Using 2D chestband contours from PMHS experiments, visceral (spleen) strain and strain energy density responses were examined using a planar viscoelastic finite element model. A plane strain model was developed for LS-DYNA. Geometry, from NLM Visible Human Project images at the T11 level, was meshed with 11,438 shell elements and consisted of vertebra, chest wall, liver, spleen, omentum/hollow viscera, and external tissue. Material properties were obtained from literature. Validation compared model to published PMHS pendulum and force-deflection response. The model was exercised by applying normalized subject-specific chestband deformations to the model periphery; material responses in the spleen were determined. Chestband contour data from 21 published PMHS experiments were obtained in four impact boundary conditions: (i) flat rigid lateral (n=7), (ii) anterolateral oblique rigid (n=4), (iii) close-proximity torso airbag lateral (n=4), and (iv) stationary close-proximity torso airbag loading (n=3x2 aspects). Mean peak localized spleen strain responses for boundary conditions i-iv were: (i) 1.24, (ii) 0.83, (iii) 2.26, and (iv) 0.68. Mean peak strain energy density responses were (i) 17.4, (ii) 5.6, (iii) 38.2, and (iv) 6.0 kJ/m3. Using matched-pair experiment comparisons, 50% risk of splenic trauma corresponded to localized strain and strain energy density of 1.55 and 33.0 kJ/m3 ($p < 0.1$). Although strains were large, model response demonstrated sensitivity to impact boundary conditions and observed trauma during matched-pair PMHS autopsy. This model formulation is useful for examining visceral injury risk from torso deformations measured experimentally using the chestband device.*