

Material Properties of the Post-Mortem Small Intestine in High-Rate Equibiaxial Elongation

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ABSTRACT

Motor vehicle collisions (MVCs) are the most common cause of small intestine injuries and the associated mesenteric injuries that occur due to blunt trauma. Crash-induced injuries of the small intestine include partial or complete lacerations, serosal tears, over-pressurization injuries, and de-vascularization or ischemic bowel injuries. Little biomechanical data exist identifying the material properties of the small intestine. To characterize the biomechanical response of the small intestine associated with failure modes occurring in MVCs, the multidirectional failure properties of cruciate tissue samples are investigated with high-rate equibiaxial stretch. Tissue testing is conducted on samples harvested from four post-mortem human surrogates. The small intestine is excised intact and opened along the mesenteric border. Cruciate samples are stamped from the tissue with the material and stretching axes aligned with the visible longitudinal fiber direction or offset by 22 degrees. Sample arms are gripped in four low-mass tissue clamps and simultaneous motion of four carriages applies equibiaxial stretch in four orthogonal directions. Tests are conducted at a target strain rate of $100^{s^{-1}}$ to investigate tissue failure properties at rates expected to be experienced in MVCs. Load and acceleration are measured at each carriage. Laser displacement sensors are used to obtain changing sample thickness. All data are captured at 20ksps. True stress and 2nd Piola Kirchhoff stress are computed in both directions and transformed to align with the material axes. Overhead high-speed video captured at 2500fps provides optical marker displacement data in a central region of interest of the sample at a resolution of 7pixels/mm. Marker positions are tracked using motion analysis software employing a regional correlation method. Displacement data are input into LS-DYNA as boundary prescribed motion for nodes corresponding to each marker, and average Green-Lagrange strain in the region of interest is calculated at 0.05ms time intervals. All data are truncated at tear initiation determined from high-speed video analysis. Preliminary results from 27 small intestine tests indicate an average maximum principal strain rate of $86.8 \pm 26.4^{s^{-1}}$. Average maximum principal failure strain is 0.270 ± 0.084 . Average Green-Lagrange failure strain is 0.168 ± 0.061 and 0.167 ± 0.068 in the circumferential and longitudinal directions, respectively. Based on the subset of data analyzed, the average failure strain is nearly identical in both anatomical directions for tests conducted throughout the length of the small intestine. Preliminary stress data suggest failure stresses ranging from 1 to 5MPa with a general trend toward a stiffer response in the longitudinal direction. Overall, tests conducted in this study identify the failure thresholds for the small intestine loaded in equibiaxial stretch at rates expected to be experienced in MVCs. Material property data acquired in this study contribute to the biomechanical dataset useful for the prediction of abdominal soft tissue injury in automobile collisions.