Material and Failure Modeling of Human Kidney under Tensile Loading

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Abstract

The accuracy of finite element (FE) human models depends not only on geometrical characteristics, but also on assigned material and failure properties. While various tissue tests of abdominal organs have been reported in the literature, FE material and failure models are still unknown. Therefore, the main objective of this study was to propose new material and failure FE models for renal parenchyma and to report the ranges of their parameters identified using the specimen-specific models.

Uniaxial-tensile tests were performed on twenty-one kidney specimens. The PMHS specimens were divided into 3 groups and tested until failure at strain rates of 0.01, 0.1 and 1.0 s-1 respectively. The mesh of each specimen was developed based on its surface obtained in Rhino 5.0 from the point clouds recorded by a FARO Laser Scanner. Several hyper-elastic material and failure models were assigned to the specimens and the tension tests were simulated in LS-DYNA 971. The square root error between the time histories of force recorded in testing and simulations was defined as objective function and heuristic optimization algorithms were used to identify the values of material and failure parameters.

With the increase of the tensile strain rate, the average values of failure Green- Lagrangian strain and 2nd Piola-Kirchhoff stress decreased from 88% to 25% and increased from 57kPa to 110kPa respectively. The pre-failure tensile behavior of the renal parenchyma was well replicated by an Ogden material model. A better approximation of the post-failure behavior of the tissue was obtained using a Cohesive Zone Layer (CZL) approach than the traditional element elimination approach. Finally, a material model which uses a tabulated formulation of hyper-elasticity with rate effects was proposed for the human renal parenchyma. We hypothesize that the data reported in this study may help in improving the bio-fidelity of human FE model.