An Experimental and Finite Element Model for Traumatic Injury in Aorta

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Abstract

Traumatic Aortic Rupture (TAR) is a leading cause of fatality in motor vehicle accidents. About 20 percent of fatalities in motor vehicle crashes are caused by aortic injuries. The biomechanical mechanism of TAR is yet unknown since laboratory tests to reproduce repeatable TAR in crash tests using cadavers have been unsuccessful. A better understanding of the mechanism of TAR is essential for evaluation of the effect of the existing injury mitigation devices and predication of the likelihood or risk of TAR which can lead to choosing better treatment strategies.

An experimental model of porcine aorta was developed to simulate the pinching phenomenon, e.g. contact with the anterior or posterior bony structures, which is considered to be one of the mechanisms of TAR. Approximately 200-mm long segments of thoracic descending aorta, incased in a clear urethane box were pressurized to 80 mmHg. The specimen was fixed at the two ends and was allowed to bend in the middle upon impact. A 5-mm flat indenter was placed in front of the specimen approximately at the mid-point and the setup was decelerated at 55-G to cause pinching.

A finite element model was developed in LS-Dyna (LSTC, CA) using the Arbitrary Eulerian Lagrangian (ALE) formulation for the fluids and a hyperelasticviscoelastic Lagrangian aorta material. The Eulerian/Lagrangian coupling algorithm was used for the interface between the fluid and the aorta wall and a soft contact algorithm for the interface between the aorta wall and the indenter.

Significant W-shaped deformations were observed in the specimens upon impact and dissected sections of aorta near the indenter showed laceration in inner media. The FE model successfully simulated the experiments in terms of global kinematics and internal pressure and the effective strain predicted by the FE model near the indenter was about 30% which agreed with the expected threshold of failure for a young human aorta.

In this study a repeatable in vitro model of TAR with pinching as the cause of injury was developed. Since puncture and partial failure was observed, it can be concluded that pinching can not be the only cause of total rupture of aorta. For next step, models for shearing and tethering need to be developed.