HYPERELASTIC BEHAVIOR OF PORCINE AORTA UNDER SUB-Failure Inflation Loading

Mobin Rastgar Agah, Kaveh Laksari, Kurosh Darvish

INTRODUCTION

Traumatic Aortic Rupture (TAR) is a major cause of fatal injury in motor vehicle accidents. The loading conditions that lead to TAR are complex and involve multi-axial stresses and large deformations and therefore require using finite element analysis (FEA). The material model for aorta that is needed for FEA is the focus of this study. Since obtaining healthy samples of fresh human aorta is difficult, porcine aorta were used as the surrogate material. The available constitutive models for porcine aorta are primarily derived around the physiological state and it is not known if these models are capable of predicting the mechanical behavior up to sub-failure loadings. In this study, the sub-failure mechanical behavior of porcine aorta was studied in quasi-static and impulse pressurization tests.

METHODS

Inflation test setup

- Thoracic descending aorta samples were obtained from 4 month-old pigs, transported in ice-cold PBS solution to the lab where they were cleaned from surrounding tissues.
- After insertion of pressure sensors, intercostal arteries were ligated and photo targets were attached on the external surface of the samples.
- Samples were installed in an inflation setup filled with PBS at room temperature (Fig. 1).

Internal pressure was recorded with two fiber optic pressure sensors. Another pressure sensor was used to measure the inlet pressure.
- 3D deformation of the sample was recorded with two high speed cameras in combination with a front face mirror.
- Coordinates of photo targets were calculated using a MATLAB code.

RESULTS

- Material behavior in quasi-static and impulse loading were not significantly different, so the hyperelastic model was fitted to the results of both test protocols and listed in Table 1.

DISCUSSION

As in the isotropic case, the maximum stress occurs in the circumferential direction (Fig. 4). However in most cases of TAR, aortic tear occurs in the transverse direction [1]. It can be concluded that either the structure of artery (e.g. orientation of SMC’s) creates a higher failure threshold for the circumferential direction or that other mechanisms of failure (such as stresses due to contact with internal or external objects) significantly increase the longitudinal stresses. It should be noted that the model used in this study does not include the heterogeneity that has been reported in the mechanical properties of aorta [3] which can affect the magnitude of the predicted stresses. The strain energy at impulse loading was slightly lower than in quasi-static loading. Although this difference was not significant but requires more investigation.

CONCLUSION

Porcine descending aorta under loading up to 70 kPa internal pressure was modeled using a Fung-type hyperelastic strain energy function. The sensitivity of the model to the loading rate was not statistically significant.

REFERENCES