20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

Inelastic mechanical properties of porcine coronary arteries

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Paper ID: 80
Symposium S11: Mechanics of biological materials & biomechanics

Abstract

Coronary artery disease is the leading cause of death worldwide. The prevalence of atherosclerosis varies between the three main coronary arteries, with the highest occurrence in the proximal segments of the left anterior descending artery, followed by the right coronary artery, and the circumflex artery [1]. Although their constitutive behavior has been studied for decades, simplifications have often been made. In particular, only elastic properties have been investigated, while tissue inelasticity has received comparatively little attention [2]. To limit inelastic effects, mechanical tests in experimental practice are often performed applying multiple loading and unloading cycles, referred as to preconditioning, at a low deformation rate, i.e., under quasi-static conditions. However, this assumption has recently proven inadequate for vascular studies [3]. Stress softening and viscous effects may, however, play a role in the development of pathological conditions. Therefore, we propose the use of different testing protocols, such as step-wise stress relaxation, to differentiate the various constitutive phenomena and to characterize the inelastic properties of the coronary arteries. After harvesting the three coronary arteries from ten porcine hearts, two strips, one oriented along the circumferential and one along the longitudinal direction, were cut from each proximal segment of each coronary artery and tested under uniaxial extension. Two loading-unloading

cycles were performed stepwise. Each specimen was deformed to a stretch of 1.5, with stretch increments of 0.1 and a strain rate of 2.5 per minute. The mechanical results confirmed the inelasticity of the tissue. In particular, an interplay between viscosity and stress softening was observed. To better discuss the aforementioned phenomena, the equilibrium relationship was approximated using the terminal points of each relaxation process, and the corresponding thermodynamic quantities were calculated following the framework presented in Bogoni et al. [3]. Using the proposed methodology, various material constitutive properties were investigated, evaluated separately, and compared for both test directions as well as the different coronary arteries. These experimental data provide a complete mechanical characterization of the coronary arteries and can subsequently be used to calibrate material models of varying complexity.

Keywords:

Mechanical testing Experimental biomechanics Porcine coronary arteries Inelastic effects Viscoelasticity Stress softening

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