Comparison of Mechanical Response of Intact Artery and Isolated Arterial Elastin

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Statement of Purpose: The mechanical response of arteries is governed primarily by the structural proteins collagen and elastin. It is generally accepted that the nonlinear response of arteries can be separated into two distinct regions of response: an initial, low stiffness mechanical response dominated by elastin and a subsequent high stiffness response dominated by collagen (1). It is important to understand the material properties of elastin due to its role in the mechanical response of natural biomaterials, such as arteries and other soft tissues, and also for its potential use as a scaffold for engineering new biomaterials. In this study, the stiffness of elastin isolated from arteries is compared to the stiffness of intact arteries. Through this comparison, we are able to investigate the role of elastin in the overall mechanical response of arteries and consider the effect of the isolation process on the material properties of the elastin.

Methods: Porcine aortas were obtained from a local butcher immediately following slaughter and transported to the lab on ice. Arterial samples are prepared by removing adjoining tissue from the aorta, and creating dog-bone shaped specimens (10mm x 30mm overall dimensions) using a custom die. For isolated elastin samples, arterial samples were further prepared using the method of Lu et al. (2). This method removes collagen and cellular material, but does not affect elastin. Mechanical testing was completed on the intact arterial samples and the isolated elastin samples using a custom-built material testing system. All samples were preconditioned and then tested to failure at a strain rate of 0.05mm/sec. Stress (σ = load/initial cross-sectional area) and stretch ratio (λ = current length/initial length) were calculated for each specimen from load and displacement values collected during mechanical testing. Linear regression analysis was used to calculate a best-fit line for each sample to model the response. For the arterial samples, only the initial, low stiffness response of the arterial mechanical response was modeled, since this portion of the response is fairly linear and is attributed to elastin. For the isolated elastin samples, the line represents the entire response of the material, since the response is approximately linear and is solely due to elastin. In each case, the slope of the linear regression model represents the stiffness of the material. Maximum stress (σ_{max}) and stretch ratio at maximum stress ($\lambda_{max\text{-}stress}$) were also calculated and compared.

Results: Experimental results for the intact arterial samples and isolated elastin samples are plotted together in Figure 1. The average slope was 0.120 ± 0.026 MPa for the initial response of the arteries and 0.120 ± 0.031 MPa for the isolated elastin. Average σ_{max} was 0.756 ± 0.258 MPa for the arteries and 0.117 ± 0.054 MPa for the elastin. Average $\lambda_{max\text{-}stress}$ was 2.23 ± 1.24 mm/mm for arteries and 1.98 ± 0.354 mm/mm for elastin.

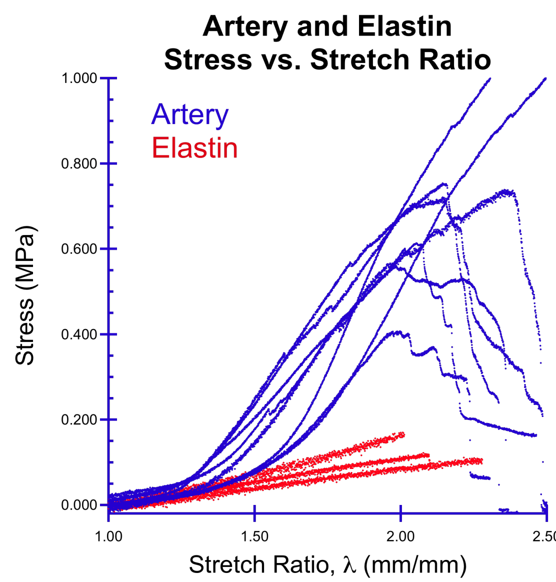

Figure 1. Plot of stress vs. stretch ratio for intact arteries (blue) and isolated elastin (red).

Conclusions: The stiffness of the initial response region of the intact arteries and the stiffness of the isolated elastin were both 0.120 MPa. This supports the theory that elastin dominates the initial arterial response. It also supports the modeling of this initial response region of arterial mechanical response using a linear model. Additionally, it suggests that the mechanical response of elastin remains relatively unchanged by the isolation process. Therefore, this isolation process provides a means to study the properties of elastin separate from the overall arterial response. Average σ_{max} was six times higher for the intact arteries compared to the elastin. This is expected since the high stiffness response of arteries is attributed to collagen, a much stiffer material believed to prevent over-extension of the elastin fibers. Average $\lambda_{max\text{-}stress}$ was not significantly different for elastin vs. arteries. The results of this study help characterize the role of elastin in the mechanical response of arteries and present a method of isolated elastin for further study. Future work will continue to use the Lu isolation method to study the effect of different treatments on the elastin structure and mechanical response.

References:

(1) Roach MR and Burton AC. Can J Biochem Physiol. 1957. 35(8): 681-690.
(2) Lu, Q, Ganesan, K, Simionescu, DT, Vyavahare, NR. Biomaterials. 2004. 25: 5227-5237.