Biomechanical properties of acellular myocardial scaffolds

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Introduction

- Cardiovascular diseases are the leading cause of mortality in the world
- Myocardium consist of discrete muscle fibers, collagen fiber network, elastin, proteoglycans, and Glycosaminoglycans
- Myocardial extracellular matrix (ECM) provides important functions in maintaining structural integrity
- Understanding of the functional and structural changes in the diseased heart
- Tissue engineering strategies have potential to restore cardiac function using viable tissue constructs
- Acellular scaffolds derived from native tissues

Objectives

- There are significant differences in cells, the composition of ECM of atria and ventricles
- The left ventricular myocardium has thicker walls as the ventricle has to generate significant pressure to pump blood into the aorta and throughout the systemic circulation

I. The biomechanical properties of the Left Ventricle (LV) and Right Ventricle (RV)

II. Impact of decellularization on the biomechanical properties of the myocardium

Material and methods

- Fresh caprine heart (n=6)
- Uniaxial compression testing
- Hyperelastic Ogden model

Constitutive modeling: Strain energy density function W for the *Ogden model* is given as:

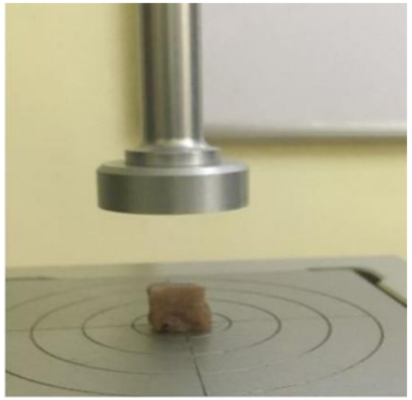
$$W = \sum_{i=1}^{N} \frac{\mu_i}{\alpha_i} \left(\lambda_1^{\alpha_i} + \lambda_2^{\alpha_i} + \lambda_3^{\alpha_i}\right)$$

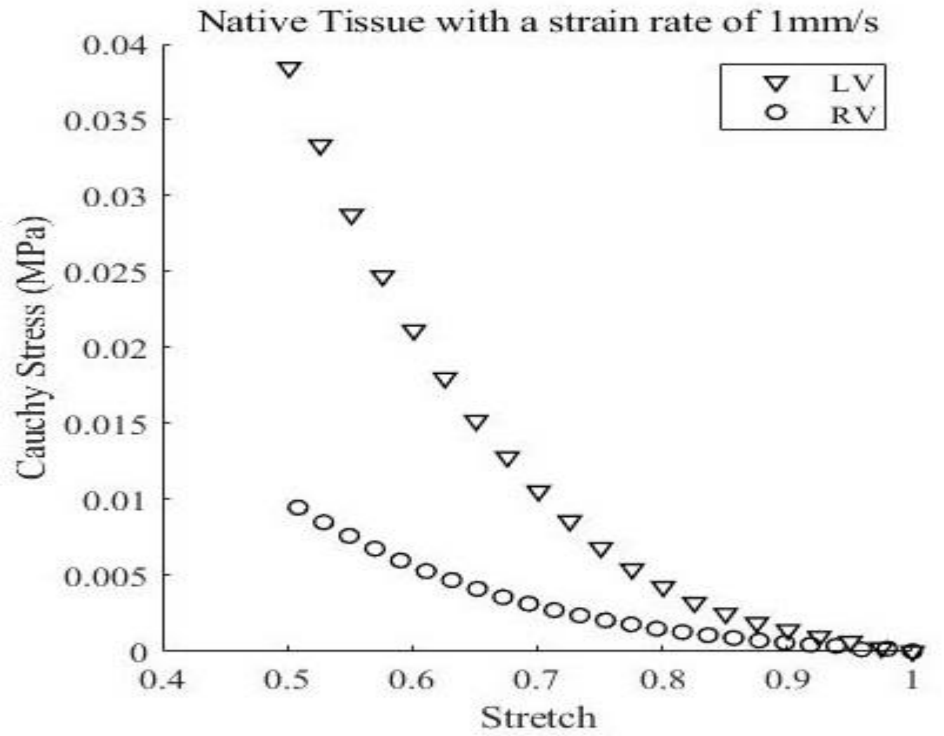
where μ and α are the material parameters and λ_i, (i=1, 2, 3) are principal stretches.

$$\text{Cauchy Stress } (\sigma_1), = \sum_{i=1}^{N} \mu_i\left(\lambda_1^{\alpha} - \lambda_1^{-\frac{\alpha_i}{2}}\right)$$

Uniaxial compression test

- Samples were preconditioned with 5% strain for 5cycles
- 5-gram preload was applied to the myocardia samples
- Compressed up to 50% strain at a strain rate of 1mm/s

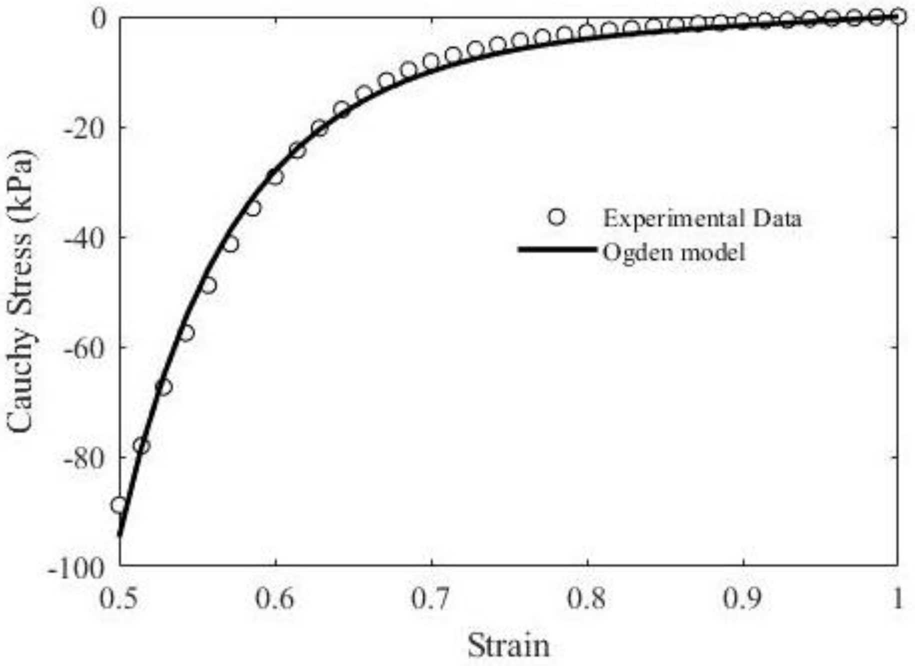




Compressive Cauchy Stress vs Stretch response of the myocardium (LV and RV).

Constitutive modeling

Experimental data was fitted with Ogden model, and best fitted material parameter and corresponding r^2 values were reported.



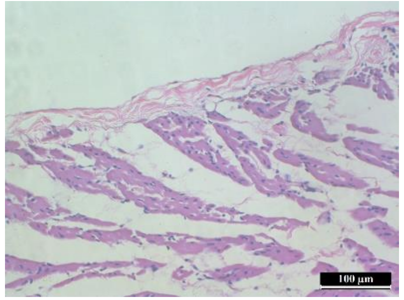
	LV			RV		
	μ(kPa)	α	r^2	μ(kPa)	α	r^2
Native	**4.93±1.19**	**2.82±1.85**	**0.994-0.999**	**3.49±0.94**	**1.18±0.39**	**0.996-0.999**

Significant difference in model parameters between the RV and LV native tissues ($p<0.05$)

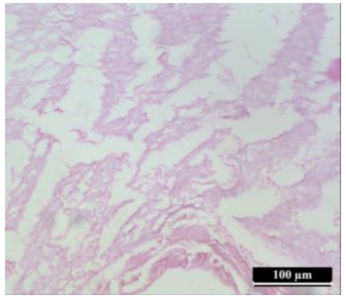
Decellularization of myocardium

- For decellularization, the LV and the RV myocardial tissues were treated with 1% (wt/vol) of sodium dodecyl sulfate (SDS) at 6°C for 7 days and 3 days, respectively
- SDS solution was replaced every 24hrs

Native

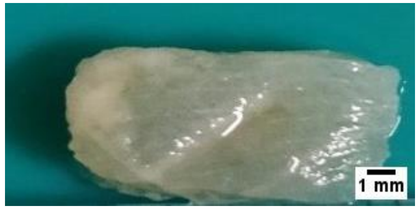


Decellularised

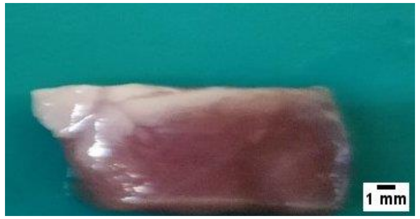


Hematoxylin, and eosin (H&E) staining -To identify the presence of cell nuclei in decellularized myocardium

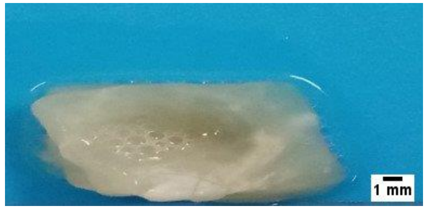
Right Ventricle



Decellularized Right Ventricle

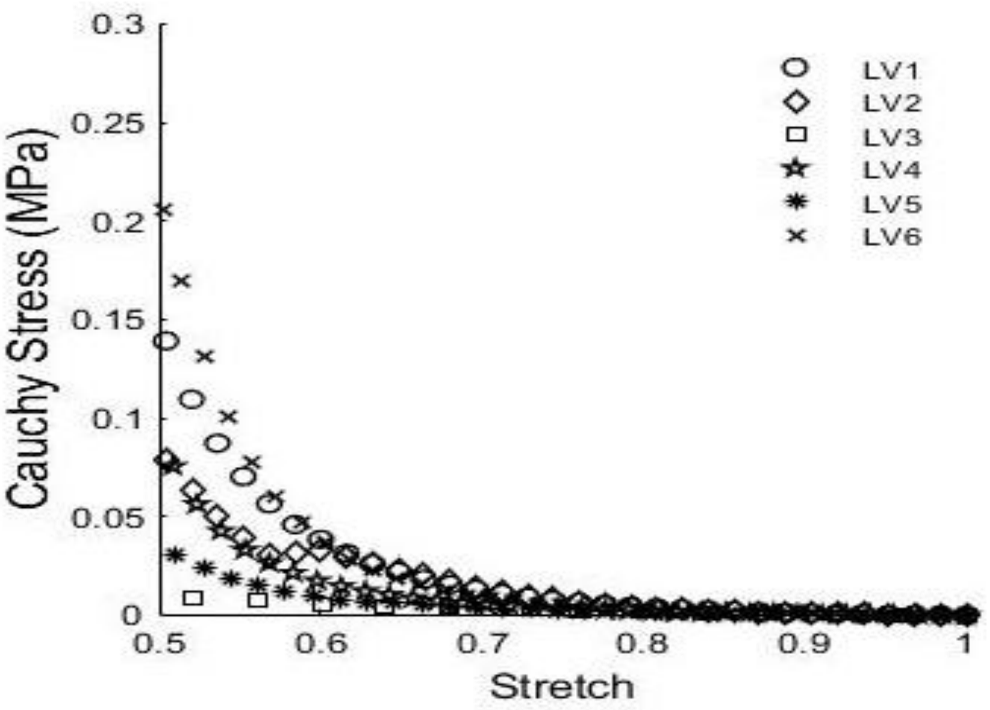


Left Ventricle



Decellularized Left Ventricle

Impact of decellularization on the biomechanical properties

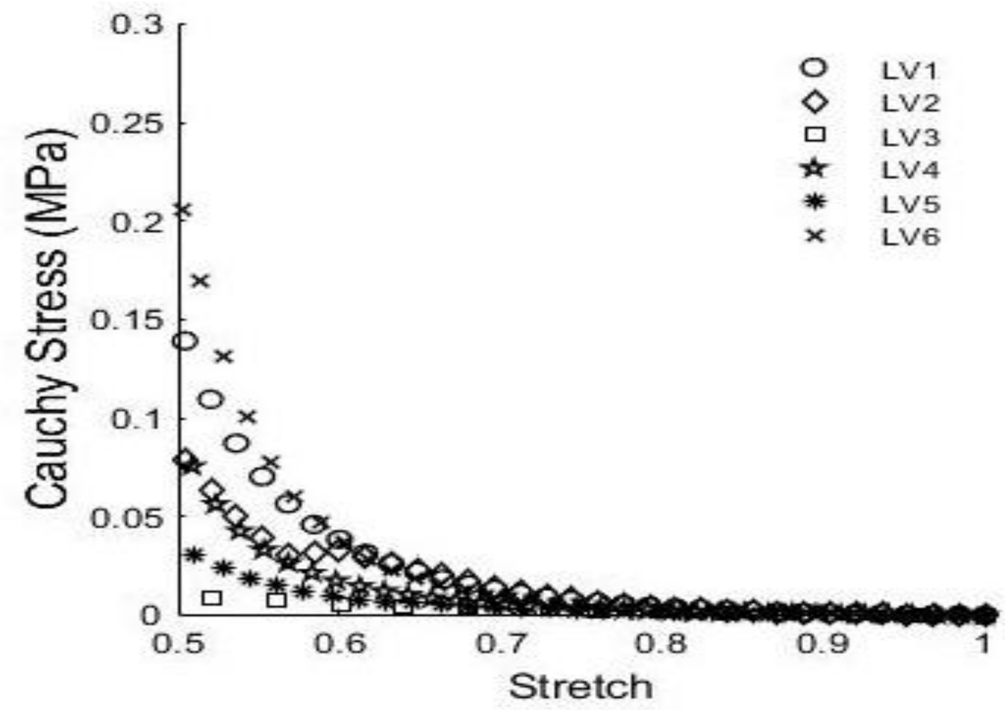


Cauchy stress vs Stretch responses of the decellularized myocardium (LV)

Modulus calculated at the low (**E_L**) strain linear region

	LV	RV
Native	8.79±2.93	6.12±1.99
Decellularized	9.26±2.56	7.54±1.88

Impact of decellularization on the biomechanical properties



Cauchy stress vs Stretch responses of the decellularized myocardium (LV)

	LV			**RV**		
	μ(kPa)	α	r^2	μ(kPa)	α	r^2
Native	4.93±1.19	2.82±1.85	0.994-0.999	3.49±0.94	1.18±0.39	0.996-0.999
Decellularized	6.83±2.52	0.90±0.80	0.989-0.999	6.05±1.51	0.88±0.4	0.998-0.999

Summary

- Nonlinear biomechanical response behavior of caprine native and decellularized myocardium
- No significant difference in the modulus value between the decellularized and native tissues
- Significant difference in Ogden model parameters between the RV and LV native myocardium ($p<0.05$)
- Significant difference in the material parameter, μ, between decellularized and native RV
- There was no significant difference ($p>0.05$), in Ogden material parameters between native and decellularized LV myocardium

Thank you !