University of Houston - Biomedical Engineering Seminar
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On Cardiac Elastin and Its Biomechanical Functions

Abstract

Collagen and elastin are major structural extracellular matrices (ECM) in heart muscles and play crucial functional roles in cardiac biomechanics. The role of elastin in cardiac mechanics, however, is poorly understood. In this seminar, we focus our discussion on (1) the spatial distribution and microstructural morphologies of cardiac elastin, and (2) one of its unique functional contributions as an epicardial protective mechanical interface. In Study 1, we demonstrated that the epicardial elastin network had location- and depth-dependency, and the overall epicardial elastin fiber mapping showed certain correlation with the helical heart muscle fiber architecture. When compared to the epicardial layer, the endocardial layer was thicker and has a higher elastin-collagen ratio and a denser elastin fiber network; moreover, the endocardial elastin fibers were finer and more wavy than the epicardial elastin fibers, all suggesting various interface mechanics. The myocardial interstitial elastin fibers co-exist with the perimysial collagen to bind the cardiomyocyte bundles. We also discovered that cardiac elastin fibers, along with collagen network, closely associated with the Purkinje cells, indicating that this ECM association could be essential in organizing cardiac Purkinje cells into “fibrous” and “branching” morphologies and serving as a protective feature when Purkinje fibers experience large deformations in vivo. In Study 2, during our tissue dissection from the surface of fresh porcine hearts, we discovered an interesting phenomenon: the bi-layered heart surface strip (myocardial layer + epicardial layer) always curled towards the epicardial side, revealing the existence of prestrain and residual stress in the epicardial layer. In the curled surface strip, the histological image demonstrated that the elastin pre-tensioned morphology disappears, and the elastin network demonstrates a recoiled, higher degree of waviness, indicating the release of tension. Moreover, if only the epicardial layer was dissected off the heart, the epicardial layer contracted. In other words, the epicardial layer, rich in elastin, acts like a prestrained “balloon” wrapping around a healthy heart. Our finite element analysis demonstrates that the ventricle gains additional resistance against ventricular diastolic expansion and ventricular wall protection by reducing myocardial stress, and such resistance and protection mainly derives from the prestraining instead of the epicardium alone. In short, our observations revealed novel microstructural characteristics of cardiac elastin and its critical roles in cardiac interface mechanics.

Biosketch

Dr. Jun Liao is a Professor of Biomedical Engineering in the Department of Bioengineering at the University of Texas at Arlington (UTA). He is a Fellow of AIMBE, ASME, and AHA. He received his Ph.D. in Biomedical Engineering from the Cleveland Clinic Foundation/Cleveland State University and his postdoctoral training from the University of Pittsburgh. Dr. Liao's research is far-reaching, covering tissue biomechanics, tissue engineering and regeneration, and computational modeling and simulation. Dr. Liao has published 110 peer-reviewed journal articles, 195 conference presentations/posters, 10 book chapters, and 3 books. His laboratory has a strong funding track record from NIH, AHA, and DOD. He is currently an Associate Editor for BMES Annals of Biomedical Engineering, ASME Journal of Medical Devices, and the Frontiers in Bioengineering and Biotechnology. He is an Editorial Board Member for the Engineered Regeneration Journal and Bioengineering Journal. He also serves as the Co-Leader of the Cardiovascular Theme in the ASME Bioengineering Division. As the team Faculty Mentor, Dr. Liao guided four UTA seniors to win the BMES Coulter College Design Competition Best Overall Award in 2023.