First Realistic Finite Element Model of Regional Biventricular Mechanics in a Patient with Tetrology of Fallot

Jonathan F. Wenk, PhD[1,2,6]
Christopher Nguyen, MS[3]
Mehrdad Soleimani, MD[1,6]
Zhihong Zhang, MS[1,6]
Mike Burger, MS[7]
Kathy Gleason, MS[3]
Alistair J. Martin, PhD[3]
Philip C. Ursell, MD[5]
Roland G. Henry, PhD[3]
Alison K. Meadows, MD, PhD[2,3,4]
Liang Ge, PhD[1,2,6]
Julius M. Guccione, PhD[1,2,6]

Departments of Surgery[1], Bioengineering[2], Radiology[3], Pediatrics[4], Clinical Pathology[5], UCSF
San Francisco VA Medical Center[6]
Livermore Software Technology Corporation[7], Livermore, CA

The number of adults with Congenital Heart Disease (CHD) in the United States is rising exponentially, and now exceeds 1,000,000. Although this number is not large compared to the number of adults with acquired heart disease, this population of patients consumes a disproportionate portion of health care dollars. Tetralogy of Fallot (TOF) is the most common cyanotic congenital heart lesion and represents approximately 4-9% of all children born with CHD. Despite the good long-term prognosis for patients with TOF, life expectancy is less than that of the normal age-matched population. Our current goal is to adapt state-of-the-art mathematical (finite element) models, already developed and validated for applications in acquired heart disease (primarily myocardial infarction-induced heart failure), to the study of regional biventricular myofiber orientation and myocardial contractility in TOF patients. To date we have used diffusion MRI to measure ex-vivo regional biventricular myofiber orientation in a cadaveric heart specimen with TOF. Additionally, using the World's first imaging suite to combine MRI with a cath lab, we performed delayed enhancement MRI and CSPAMM on a patient with TOF. The nonlinear stress-strain relationship for the diastolic myocardium in our finite element software (LS-DYNA) was anisotropic with respect to the local muscle fiber direction. An elastance model for active fiber stress was incorporated in an LS-DYNA model of the biventricular unit of a patient with TOF. Our patient-specific model results suggest further RV remodeling due to an end-diastolic myofiber stress concentration. Our ultimate goal is to automatically optimize patient-specific therapeutic intervention for CHD.