NON-INVASIVE DETERMINATION OF HUMAN MYOCARDIAL WALL STRESS WITH *in vivo* PHYSIOLOGICAL PARAMETERS

Aichi Chien [1] Ajit Mal [2], and Carlo Montemagno [3],

[1] Dept. of Biomedical Engineering
University of California
Los Angeles, CA 90095, USA
aichi@ucla.edu

[2] Dept. of Mechanical and
Aerospace Engineering
University of California
Los Angeles, CA 90095, USA

[3] Dept. of Biomedical Engineering
University of California
Los Angeles, CA 90095, USA

To gain insight into ventricular dysfunction from the perspective of cardiac mechanics, a quantitative method to describe regional myocardial mechanics is needed. It has been reported that impaired myocardium regions have a long term effect on the deterioration of global cardiac function such as ventricular dilation and ventricular remodeling [1, 2]. Therefore, noninvasive assessments of ventricular stress provide essential information not only to understand the ventricular dysfunction but to predict areas which may have higher risks to change elasticity and tissue geometry.

We developed a method to calculate cardiac motion and forces based on real human cardiac movement, ventricular geometry, and ventricular chamber pressure. With this approach, the three dimensional stress distributions on the ventricular wall can be quantified throughout the entire cardiac cycle. This methodology is aimed to provide information for further cardiac functional assessment in addition to individualized calculation parameters. We achieved noninvasive determination by analyzing tagged magnetic resonance (MR) cine images with recorded blood pressure and heart rate. In this paper, two human subjects who had normal cardiac function were investigated. We used MR imaging techniques to acquire geometrical changes of the heart in a cardiac cycle. Incorporating the blood pressure, myocardial material properties were derived to address the variation in myocardial contractility among individuals. The derivation was based on the large deformation theory and Mooney-Rivilin incompressible material functions. Then, the geometrical structure of ventricles was reconstructed using the same MR images. Combining derived material properties and ventricular geometry, nonlinear finite element analysis was finally used to calculate the wall stress changes throughout the cardiac cycle.

Results showed that myocardial material properties changed in a cardiac cycle. A distinct difference was noticed when comparing the myocardial material stress-strain curve for two subjects. We found that through the cardiac phases, the stress in the myocardium is the same but the strain differs between subjects. The finite element calculation for ventricular wall stress (Von Mises stress) showed that both subjects had higher inner wall stress in the left ventricle than other areas through the cardiac cycle. However, a detailed comparison of the stress distribution between the two individuals showed that there were different high stress patterns which may have been caused by differences in geometry or in inner ventricular chamber pressures.

References

[1] R.L. Quarterman, S. Moonly, A.W. Wallace, J. Guccione, and M.B. Ratcliffe, "A Finite Element Model of Left Ventricular Cellular Transplantation in Dilated Cardiomyopathy." *ASAIO J.* **48**, 508-513, 2002.

[2] D.K. Bogenm, A. Needleman, and T.A. McMahon, "An Analysis of Myocardial Infarction The effect of Regional Changes in Contractility." *Circ. Res.* **55**, 805-815, 1984.

Keywords: myocardial material properties, ventricular wall stress, *in vivo* determination