**Annual Report- Slezak Super Center**

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**Full Human Heart Computer Model: Coupled Electrical-Structural-Hemodynamic Models with and without Aortic Valve Pathology**Rami Haj-Ali, Ashraf Hamdan and Ehud Raanani

***Brief Summary:***

This study deals with integrating a new parametric aortic valve (AV) structural model with the electro-mechanical Living Heart Human Model © (LHHM). The LHHM is a finite element robust and integrative model simulating human heart function capable of realistic electro-mechanical simulations. A novel biomechanical model was developed presenting an integrated parametric AV within a full heart model and was used as a platform for examining the effect of the electro-mechanical boundary conditions of the LV on the AV structural response investigating its geometrical parameters variation during the cardiac cycle.

The proposed FE simulations indicate a strong correlation to the literature. It was found that the AV max/min diameter and ellipticity index values correspond adequately to the clinical data where the AV perimeter matches the same trend. Thus, the kinematic behaviors as the leaflets coaptation and metrics like the stresses over the leaflets and the root are directly influenced and well founded.

The current model significance is dramatic from the clinical point of view, where it can be a platform for a pre transcatheter aortic valve replacement procedure calculations and a preoperative tool in the assessment of valve geometry before AV repair. In addition, the proposed modeling provides a general computational framework for fully coupled FSI model of the heart which includes multi-physics effects, such as electro-structural-fluid that affect the flow patterns during the cardiac cycle through the AV and consequently recognizes the hemodynamic metrics.

Pathology in the form of calcific aortic valve disease (CAVD) involves calcium and bone-like deposits embedded inside the leaflets of the AV, which rapidly leads to aortic stenosis (AS). This study was able to include several biomechanical aspects of this pathology. For example, simulations were performed with AV that includes patient specific calcified cusps. Deployments of the Evolut R and PRO transcatheter aortic valve replacement (TAVR) devices inside the calcified bicuspid aortic valve (BAV) were also simulated. The paravalvular leakage (PVL) was also calculated by computational fluid dynamics (CFD) simulations. The hypothesis of asymmetric and elliptic stent deployment was confirmed. Positioning the bioprosthesis commissures aligned with the native commissures was found to yield the lowest PVL. The Evolut PRO reduced the PVL in half compared with the Evolut R. The proposed biomechanical computational model could help assess the functionality of TAVR in BAV patients.

***Publications as a result of full or partial Shlezak grant****:*

1. Halevi R, Hamdan A, Marom G, Lavon K, Ben Zekry S, Raanani E and Haj-Ali R. “A New Mechano-biology Model for Aortic Valve Calcification Growth”. ASME. J Biomech Eng. 2018;():. doi:10.1115/1.4040338
2. Paper submitted: Lavon K, Marom G, Bianchi M, Halevi R, Hamdan A, Morany A, Raanani E, Bluestein D, Haj-Ali R. “Biomechanical Modeling of Transcatheter Aortic Valve Replacement in a Stenotic Bicuspid Aortic Valve: Deployments and Paravalvular Leakage”.

***Poster & oral presentations at conferences as a result of full or partial Shlezak grant****:*

1. Morany A, Lavon K, Haj-Ali R. “Integrated Parametric Aortic Valve Models with the LHHM including Pathology and FSI Co-Simulations”. Living Heart Human Model (LHHM) annual users meeting, Paris, France April 2018.
2. Morany A, Lavon K, Haj-Ali R. **Webinar**: “Numerical Analysis of Healthy, Diseased, and Prosthetic Aortic Valve within the LHHM. Part 1 - Integrated parametric aortic valve model including pathology and FSI simulations”. Living Heart Human Model (LHHM) community, August 2018.
3. Lavon K, Marom G, Bianchi M, Halevi R, Hamdan A, Morany A, Raanani E, Bluestein D, Haj-Ali R. “Biomechanical Modeling of Transcatheter Aortic Valve Replacement in a Stenotic Bicuspid Aortic Valve: Deployments and Paravalvular Leakage”. The 8th World Congress of Biomechanics (WCB), Dublin, Ireland, July 8-12, 2018.
4. Lavon K, Marom G, Bianchi M, Halevi R, Hamdan A, Morany A, Raanani E, Bluestein D, Haj-Ali R. “Biomechanical Modeling of Transcatheter Aortic Valve Replacement in a Stenotic Bicuspid Aortic Valve: Deployments and Paravalvular Leakage”. Biomedical Engineering Society (BMES) Annual Meeting, Atlanta, Georgia USA, October 17-20, 2018.