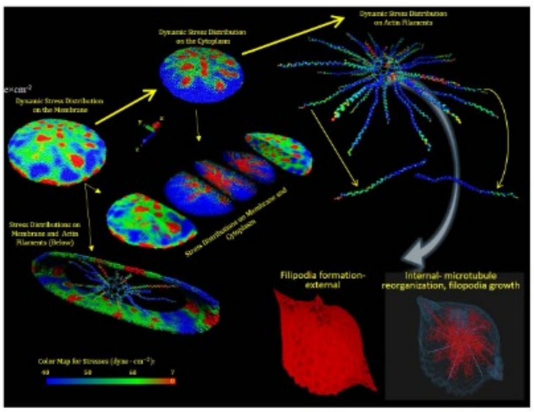
DEPARTMENT OF BIOMEDICAL ENGINEERING & INSTITUTE FOR ENGINEERING-DRIVEN MEDICINE

2020 – 2021 Seminar Series

Optimization of prosthetic devices and procedures for treating cardiovascular diseases, and biomechanics of thrombosis across the scales



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Mechanical circulatory support (MCS) devices provide hemodynamic support for advanced heart failure patients. Unfortunately, these devices remain plagued by thrombosis and thromboembolic complications – mandating complex, lifelong anticoagulation therapy. A universal predictive methodology: Device Thrombogenicity Emulation (DTE) was developed for optimizing their performance – ideally to a level that may obviate the need for anticoagulation. DTE combines in silico numerical simulations with in vitro measurements of coagulation markers – before and after iterative design optimization. DTE was applied for optimizing Ventricular Assist Devices, prosthetic heart valves, and the only FDA approved Total Artificial Heart. The efficacy of the device optimization was compared to that achieved by typical anticoagulation regimen, showing in VADs for example that the anticoagulation achieves less than 30% platelet activity reduction of that achieved by the optimization. The robustness of this predictive technology in attaining safe and cost-effective pre-clinical MCS thrombo-optimization, indicates its potential for reducing device thrombogenicity to a level that may liberate their recipients from mandatory anticoagulation.

Cardiovascular disease diagnostics and treatment by prosthetic cardiovascular devices can be enhanced using numerical simulations and biomechanical analysis approach, by utilizing patient specific Fluid Structure Interaction (FSI) simulations. A polymeric valve appears as better alternative to bioprosthetic tissue valves initially adapted for TAVR procedures, as those may get damaged during the stenting process of the valve and have reduced durability, yielding poor clinical outcomes. Recently the DTE methodology was used for developing and optimizing the performance of a novel polymeric heart valve for Transcatheter Aortic Valve Replacement (TAVR) - a life-saving solution for high risk and inoperable patients with advanced calcific aortic valve disease (CAVD). Advanced biomechanical studies of the stenting procedure that involves the crimping, deployment and the anchoring of both tissue and the polymer TAVR valves were conducted in patient based model geometries reconstructed from CT images.

The coagulation cascade leading to thrombosis may be initiated by flow-induced platelet activation; platelets undergo complex morphological changes: filopodia formation, aggregation and deposition and attachment to surfaces. An innovative multiscale modeling approach was developed to describe the mechanotransduction processes involved in flow-induced platelet activation, combining dissipative particle dynamics (DPD) to describe the viscous blood fluid flows and coarse-grained molecular dynamics (CGMD) to describe the platelet membrane, cytoplasm and its cytoskeleton. Departing from traditional continuum approach, it is aimed at bridging the gap in spatiotemporal scales between macroscopic transport and the mesoscopic scales of blood clotting. The model predictions were further validated by in vitro microchannel experiments.

Zoom

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Wednesday, March 3rd @ 11:45AM