The Nidus for Possible Thrombus Formation: Insight from the Micro-Environment of Bioabsorbable Vascular

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An Absorb bioresorbable vascular scaffold (Absorb BVS, Abbott Vascular, Santa Clara, California; 3.0x18mm) was implanted in the mid-segment of the left anterior descending(LAD) coronary artery of a patient with stable angina pectoris. Optical coherence tomography(OCT) was performed following scaffold implantation(Pull-back speed 18mm/s acquisition rate 180 frames/s).OCT images demonstrated well-expanded and apposed scaffold. Patient-specific 3D-geometry of scaffolded lumen was generated using OCT and coronary angiography. Computational fluid dynamics (CFD) techniques were used to simulate pulsatile blood flow through 3D patient-specific finite volume mesh by solving Navier–Stokes equations. Blood was considered non-Newtonian fluid and pulsatile flow profile was imposed in the inflow of the model. Shear-thinning blood rheology was simulated using Quemada constitutive equation that takes hematocrit and shear rate into account (1).Endothelial shear stress (ESS) at the lumen and scaffold surfaces was calculated as the product of local blood viscosity and near-wall velocity gradient(2).

Increased ESS was noted at strut surface and outer curve of the bend; low ESS (<0.5 Pa) was noted between successive stent hoops and inner curve of the bend (Figure, Panel-I,-II and-III). An internal view of the scaffold segment, across grey line in Figure, panel-I reveals micro-recirculations (red arrows in Figure, panel-IV) between stent hoops. Arterial curvature created a spiral velocity component (streamlines flowing from top-to-bottom of the vessel in Figure, panel-IV), also termed secondary flow (3).

As a result of skewed velocity profile along the bend (Figure, panel-III), micro-recirculations are less pronounced at outer curve but relatively larger at the inner curve of the bend. It is hypothesized that such micro-recirculations in the vicinity of struts are associated with lower shear rate zones that may become nidus for thrombus formation (4). *In vivo* 3D OCT-based CFD modeling can be used to evaluate the implications of scaffold implantation on the local hemodynamics that may shed light on possible pathophysiological responses such as thrombus formation and neointimal hyperplasia.

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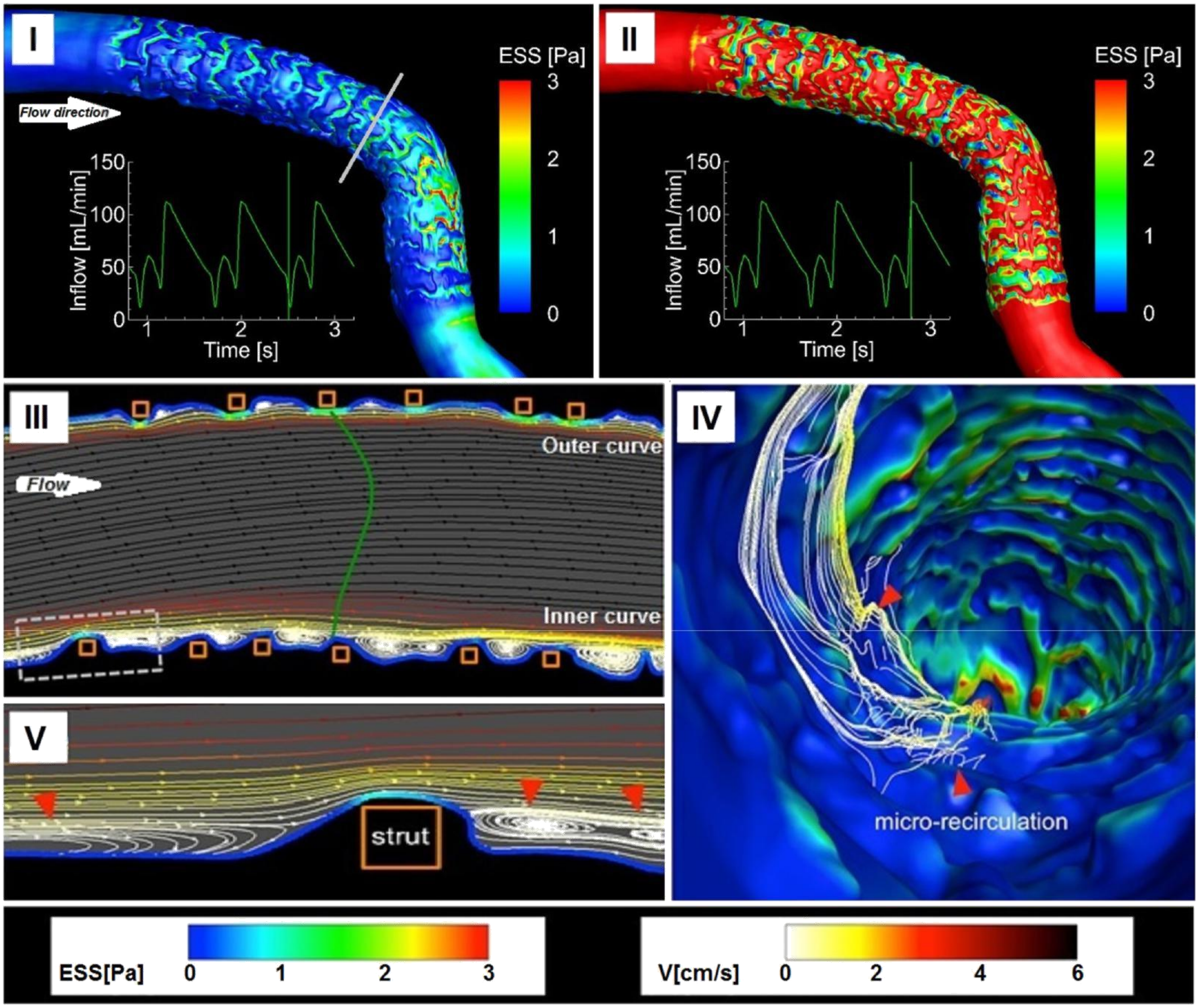

Figure: Shear stress distribution in scaffolded segment in systole and diastole.

Panel-I represents flow at peak systole and ESS, panel-II represents the flow at peak diastole and related SS. Panel-III demonstrates the longitudinal view of the 3D patient specific geometry. The corresponding surface integrated streamlines clearly indicate that the longitudinal velocity component is skewed towards the outer curve of the bend (green velocity profile in panel-III) in the presence of the secondary flow. Panel-IV reveals the streamlines exhibit a spiral velocity component, termed as secondary flow. The micro-recirculations (red arrows in panel-IV and -V) are responsible for the reduction in local shear rate and thus lower local ESS distribution. Conversely, the smaller micro-recirculation zones at the outer curve of the artery correlate with higher local ESS.