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IMAGES IN INTERVENTION

The Nidus for Possible Thrombus Formation

Insight From the Microenvironment of Bioresorbable Vascular Scaffold

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A 3.0 × 18 mm Absorb bioresorbable vascular scaffold (Abbott Vascular, Santa Clara, California) was implanted in the midsegment of the left anterior descending coronary artery of a patient with stable angina pectoris. Optical coherence tomography was performed following scaffold implantation (pullback speed 18 mm/s, acquisition rate 180 frames/s). Optical coherence tomographic images demonstrated a well-expanded and apposed scaffold. Patient-specific 3-dimensional geometry of the scaffolded lumen was generated using optical coherence tomography and coronary angiography. Computational fluid dynamics techniques were used to simulate pulsatile blood flow through 3-dimensional patient-specific finite volume mesh by solving Navier-Stokes equations. Blood was considered a non-Newtonian fluid, and a pulsatile flow profile was imposed in the inflow of the model. Shear-thinning blood rheology was simulated using the Quemada constitutive equation, which 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 the strut surface and outer curve of the bend; low ESS (<0.5 Pa) was noted between successive stent hoops and the inner curve of the bend (**Figures 1A to 1C**). An internal view of the scaffold segment, across the gray line in **Figure 1A**, reveals microrecirculations (red arrows in **Figure 1D**) between stent hoops. Arterial curvature created a spiral velocity component (streamlines flowing from top to bottom of the vessel in **Figure 1D**), also called secondary flow (3).

As a result of skewed velocity profile along the bend (**Figure 1C**), microrecirculations were less pronounced at the outer curve but relatively larger at the inner curve of the bend (**Figure 1E**, Online Video 1). It has been hypothesized that such microrecirculations in the vicinity of struts are associated with lower shear rate zones that may become the nidus for thrombus formation (4). In vivo 3-dimensional optical coherence tomographic computational fluid dynamics modeling can be used to evaluate the implications of scaffold implantation on the local hemodynamic parameters, which may shed light on possible

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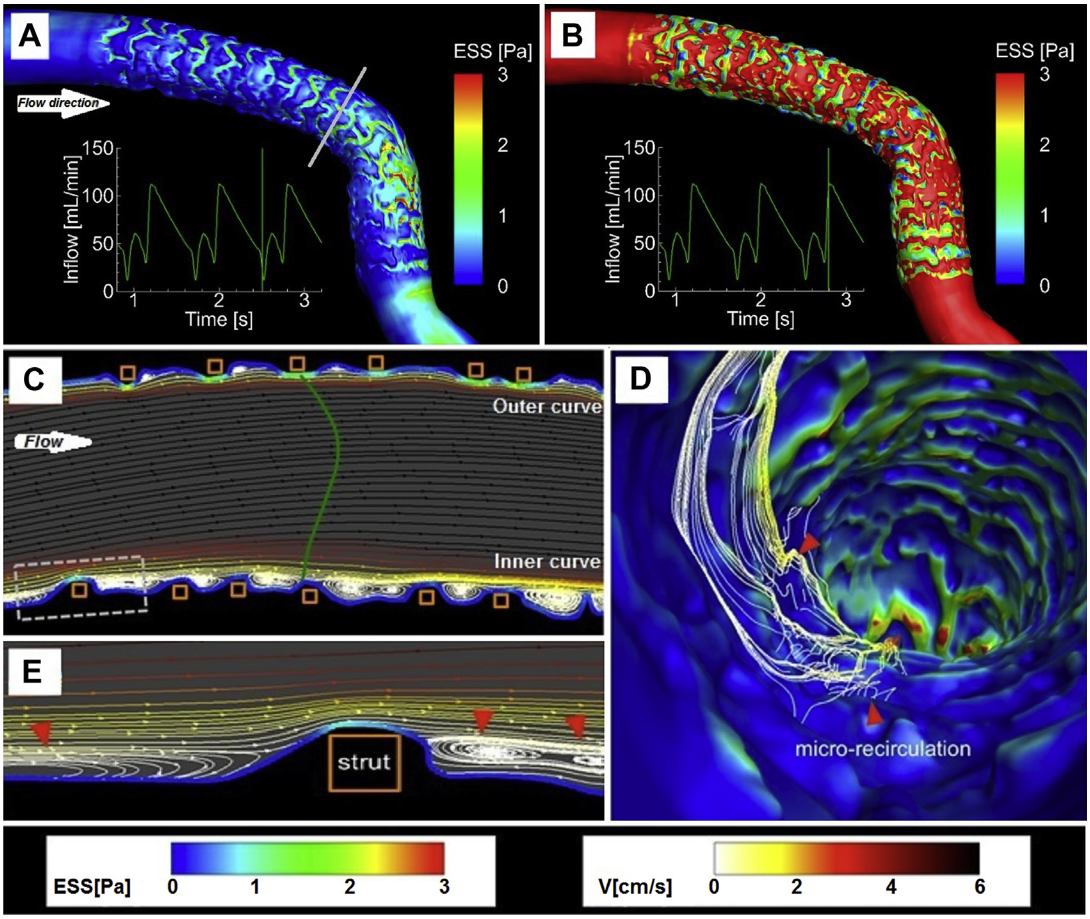
FIGURE 1 Shear Stress Distribution in Scaffolded Segment in Systole and Diastole



(A) Flow at peak systole and endothelial shear stress (ESS). **(B)** Flow at peak diastole and related ESS. **(C)** Longitudinal view of 3-dimensional patient-specific geometry. The corresponding surface-integrated streamlines clearly indicate that the longitudinal velocity component is skewed toward the outer curve of the bend (green velocity profile in **C**) in the presence of the secondary flow. **(D)** The streamlines exhibit a spiral velocity component, called secondary flow. The microrecirculations **(red arrows in D and E)** are responsible for the reduction in local shear rate and thus lower local ESS distribution. Conversely, the smaller microrecirculation zones at the outer curve of the artery correlate with higher local ESS (Online Video 1).

pathophysiological responses, such as thrombus formation and neointimal hyperplasia.

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APPENDIX For a supplemental video and legend, please see the online version of this article.