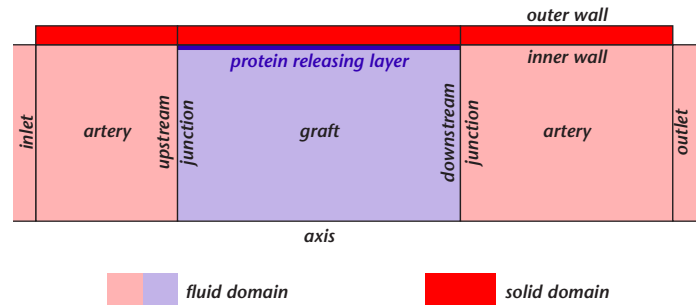


Exploring Graft-Artery Mismatch

By Sandy F.C. Stewart, Center for Devices & Radiological Health, Food & Drug Administration, Rockville MD; and Donald J. Lyman, Department of Materials Science & Engineering and Department of Bioengineering, University of Utah, Salt Lake City, UT

Replacing diseased arteries with synthetic grafts, especially in large vessels (to repair an aortic aneurysm, for example), has shown fairly good success for almost fifty years. In small vessels (3.0 mm radius or less) however, arterial grafts still have a much lower success rate, with failure often due to tissue overgrowth (intimal hyperplasia) and clotting (thrombosis), which block the vessel. Such failures are often seen primarily at the downstream end of the graft. This asymmetry suggests that a flow mechanism of some sort is responsible. Most commercially available synthetic grafts are less compliant than natural arteries, so that the pulsating blood must flow from the stiff graft region into the compliant artery. The mismatch in compliance causes a pulsatile tubular expansion effect at the downstream junction that can cause flow disturbances. A mismatch in graft/artery radius (synthetic grafts only come in fixed radii) may also cause a disruption in flow. It has been hypothesized that these flow disturbances somehow trigger the intimal hyperplasia seen clinically, with thrombosis following due to low or stagnating flow. Previous experimental and numerical studies have shown that lower than normal wall shear stresses (WSSs), trapping of particles (such as cells and other blood elements), and high particle residence times are observed at junctions between a stiff graft and compliant artery. Low WSS and the trapping of cells are known to be deleterious to vessel walls and blood elements. Intimal hyperplasia may also be triggered by the transport of chemicals in the blood, such as proteins, but much less is known about this relationship.

A numerical study was undertaken to examine the effects of compliance and radius mismatch on the distribution of a representative protein released into the blood at the graft/fluid interface. The protein chosen was platelet-derived growth factor (PDGF), which has been shown to be released from smooth muscle cells growing on the inner walls of vascular grafts, and has been linked to intimal hyperplasia. FIDAP was used to simulate pulsatile blood flow in an axisymmetric model of a synthetic graft implanted into a natural artery. Fluid-structure coupling was employed to give physiologic displacements of the vessel walls. PDGF was transported



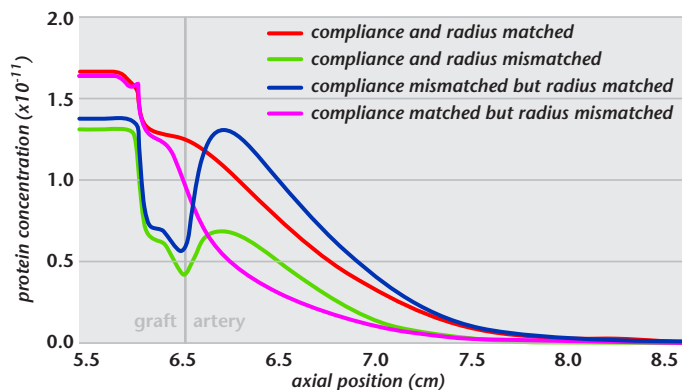
Schematic of graft/artery model; the radial dimension (r) is scaled by a factor of ten; the overall model is 0.24 cm radius x 9.5 cm long (reprinted with permission)

(by diffusion and convection) from a thin layer lining the inner wall of the graft, using a diffusion constant calculated from its molecular weight. The results are representative of similarly-sized molecules being transported by the blood.

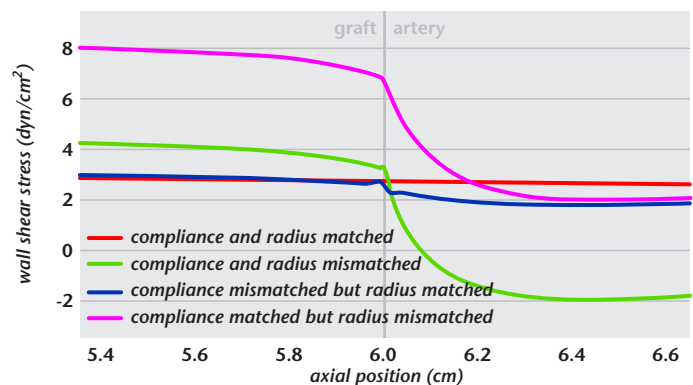
Results showed that protein released from the graft is convected smoothly downstream in a uniform compliant tube. A compliance mismatch disturbs the protein transport, causing positive and negative gradients in the concentration profile at the downstream junction. This was seen whether or not the graft and artery radii were matched, but the disruption was unexpectedly worse when the radii were matched. Disruptions in WSSs were only observed when the radii were mismatched. Thus the downstream intimal hyperplasia seen in noncompliant grafts may be caused partly by decreased WSS, and partly by disruption of the concentration gradients of dissolved chemicals, which can affect the movement of cells (chemotaxis) in the blood. ■

reference:

S.F.C. Stewart and D.J. Lyman, Effects of an Artery/Vascular Graft Compliance Mismatch on Protein Transport: A Numerical Study, *Ann. Biomed. Engr.* **32**, p. 991-1006, 2004.



Protein concentration along the vessel inner wall at the end of the third cardiac cycle (time = 2.5 s), at the downstream junction between the graft and artery (reprinted with permission)



Minimum wall shear stress during the third cardiac cycle (time = 1.90 s), at the downstream junction between the graft and artery (reprinted with permission)