

Drug Delivery from Coronary Stents

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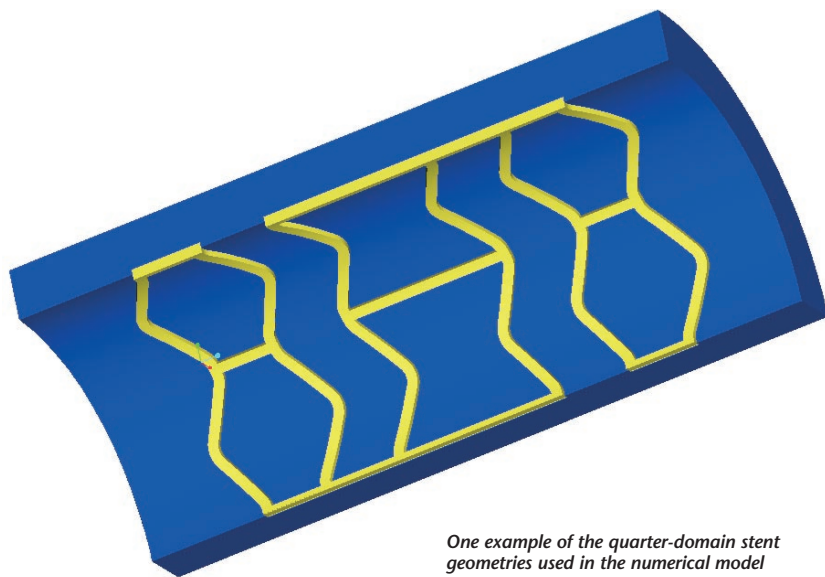
Minimally invasive catheter-based interventions have revolutionized the world of heart surgery. Lengthy recovery times associated with open-heart surgeries are routinely avoided through the use of balloon angioplasty and coronary stenting. Stenting is a process involving the deployment of a metal scaffolding inside a blocked artery to maintain blood flow to the heart muscle. Though these techniques have achieved a high degree of success, they are not by any means perfect. In a large percentage of cases, the patient's body responds to the implantation of a stent by growing many layers of smooth muscle cells over the implant. This response can often lead to blockage of the coronary artery – the exact problem that the stent is intended to solve initially.

One promising solution to this problem is the deployment of drug-loaded stents in diseased arteries. By coating the stent structure with a chemical-infused polymer, drugs that limit smooth muscle cell growth can be delivered directly to the area responsible. Over a critical therapeutic period of about one month, uniform drug distribution can effectively eliminate the proliferation of smooth muscle cells. The challenge is to achieve a uniform drug distribution in the region of the stent, and to verify that an appropriate dose is provided.

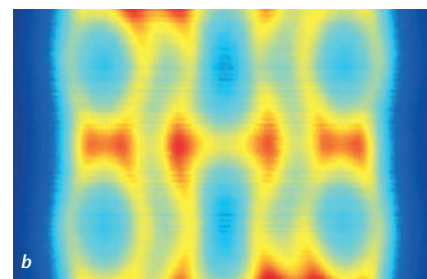
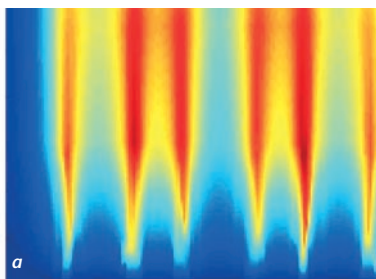
Animal trials investigating drug-loaded stents can give a general indication of an implant's success, but do not provide accurate dose distributions in the arterial tissue. One practical, inexpensive and efficient means of studying these dose distributions is through numerical modeling. Although real tissues are complex, irregular, and widely varied among patients, appropriate simplifications to the coronary artery tissues can yield meaningful general dose distribution results.

In a study carried out at McGill University in Montréal, Canada, FIDAP was used to model the pharmacokinetics of drug-eluting stents. The goal of the study was to develop a tool for evaluating the dose delivery characteristics of real 3D stent geometries. Such a tool could then be used by stent designers to modify geometries in order to ensure optimal dose delivery outcomes.

Three common stent geometries were modeled, and a simulation was carried out in a quarter-artery domain. By examining mass concentration over time at field points throughout the arterial wall, an estimate for how the drug moves through the solution domain was obtained. Dose homogeneity, final concentration, and stent contact area values were combined into a single parameter, the "Local Delivery Effectiveness Score" (LDES). This score, out of ten, combines key factors that may contribute to the success of partic-



One example of the quarter-domain stent geometries used in the numerical model



(a) Longitudinal (constant θ) and (b) cylindrical (constant radius) sections of the therapeutic region after 7 days; the flow travels from bottom to top in (a), and the thickness of the vessel wall is exaggerated to illustrate the spread of the drug

ular stent designs, and provides a simple, one-step evaluation criterion.

In order to increase the accuracy and realism of this basic model, work is now underway to use actual patient-specific artery geometries in a numerical model. Images obtained using Intravascular Ultrasound (IVUS) can be reconstructed from individual transverse "slices" to build a 3D model. Such models incorporate arterial tissues as well as calcified deposits and other inclusions known to be present in diseased coronary arteries. These geometries, along with accurate diffusion information for the tissues represented in them, could serve as the basis for FIDAP simulations which would allow the optimization of stent

and drug loading parameters tailored to each patient's specific needs. ■

references:

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