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3D Computational Modelling of Drug Elution from Angioplasty Stents

Yousefi, Azizeh-Mitra; Laroche, Denis; DiRaddo, Robert
Industrial Materials Institute-NRC, Boucherville, QC, Canada

PURPOSE/INTRODUCTION:

In treatment of coronary artery disease, the risk of restenosis after stent implantation can be controlled by using drug-eluting stents. For the drug-eluting stent to be effective, the stent design and the drug-loaded coating should ideally be optimized.[1] This presentation will focus on identification of the key parameters affecting the drug elution rate, including stent geometry, coating thickness, and drug diffusion coefficient for simplified 3D stent/artery geometries. The modelling of drug delivery for a stent deployed inside a real artery will also be presented.

METHODS:

The release of the drug from stent into the artery is governed by the following set of mathematical equations:[2]

$$\frac{\partial c}{\partial t} = D\left(\frac{\partial^2 c}{\partial x_i^2}\right) \qquad i = 1,2,3 \quad \text{for a 3D case}$$

$$c = c_i(x_i) \qquad \text{at} \quad t = 0 \quad \text{for } \Omega \quad \text{(Initial condition for the entire domain } \Omega\text{)}$$

$$\frac{\partial c}{\partial x_i} = 0 \qquad \text{at} \quad t > 0 \quad \text{for } \Gamma_1 \quad \text{(Boundary condition at the metal-coating interface } \Gamma_1\text{)}$$

$$-D\frac{\partial c}{\partial x_i}\bigg|_{\Gamma_2} = h(c_s - c_\infty) \qquad \text{at} \quad t > 0 \quad \text{for } \Gamma_2 \quad \text{(Boundary condition at the coating outer boundary } \Gamma_2\text{)}$$

where $c_i(x_i)$ is the initial drug distribution, c_s is the drug concentration at the boundary, D is the diffusion coefficient, h is the mass transfer coefficient in the boundary layer, and c_∞ is the drug concentration in the surrounding medium. The stents were meshed with 8-node hexahedral elements. The artery mesh was created after reconstructing the artery model from intravascular ultrasound (IVUS) images obtained during a percutaneous coronary intervention (PCI).

RESULTS/DISCUSSION:

Typical transient drug release profile for a stent after contacting arterial walls is shown in Fig. 1. Figure 2 shows the example application of modelling the drug release after stent deployment for a reconstructed artery model.

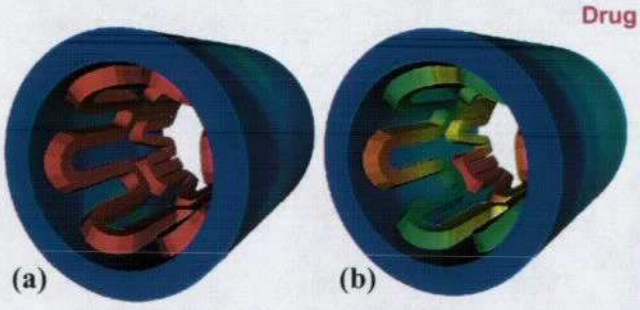

Fig. 1. Drug distribution for (a) day 0, and (b) day 1

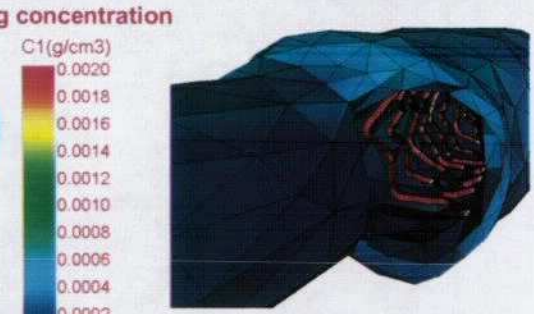

Fig. 2. Drug release for artery model

REFERENCES:

1) Prabhu, S., Medical Device Manufacturing & Technology, 41, 2004.

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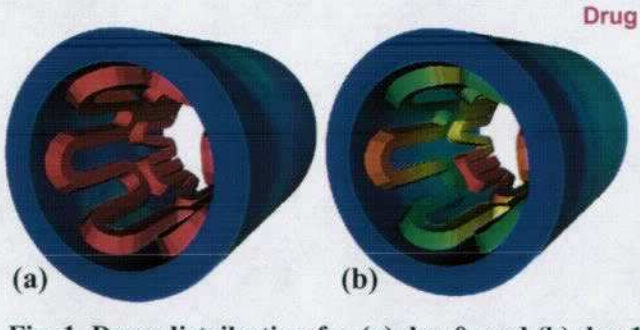

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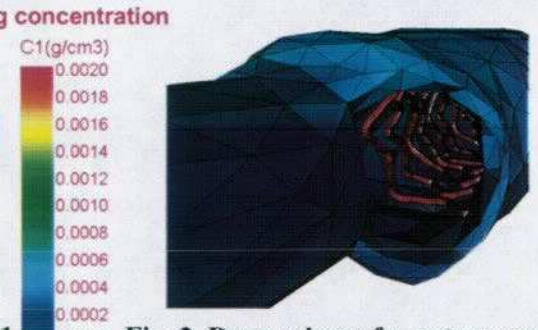

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