Simulation of Coronary Stent Implantation: Towards a Biomechanical Model of Restenosis

Delorme, Sébastien; Laroche, Denis; El-Ayoubi, Rouwayda; Anderson, Todd; DiRaddo, Robert

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Towards a Biomechanical Model of Restenosis

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Delorme, Sebastien PhD[1]; Laroche, Denis ~~PhD~~[1]; El-Ayoubi, Rouwayda PhD[1]; Anderson, Todd MD[2]; DiRaddo, Robert PhD[1]
[1]*Industrial Materials Institute, Boucherville, QC, Canada*
[2]*University of Calgary, AB, Canada*

PURPOSE/INTRODUCTION:

The most frequent post-procedural complication of angioplasty, restenosis, is an excessive repair reaction of the arterial wall, related to two types mechanical damage that occur during the intervention: 1) overstretch injury of the arterial wall and 2) denudation of the endothelium due to friction with the balloon and stent. To our knowledge, friction damage to the endothelium has never been considered in computer simulations of angioplasty, possibly because of the difficulty of implementing a robust contact/slip algorithm for deforming bodies.
This work presents improvements to numerical technique for predicting the balloon/stent/artery behavior during angioplasty and assessing the risk of restenosis. The goal of this numerical tool is to assist clinician in the selection of appropriate intervention strategy for a specific patient by using IVUS imaging data to simulate the intervention.

METHODS:

A finite element modeling software developed at IMI for the analysis of large deformations of soft materials was used to solve angioplasty mechanics [1][2]. The model computes the large deformations and the friction slip that occurs during balloon/stent insertion and deployment into the diseased artery. It predicts the resulting artery lumen reopening, including stress and strain distribution in the arterial wall, for a specific device and inflation pressure.
Friction experiments were conducted on porcine aortas explants. A mathematical model, based on those experiments, was developed and implemented in the finite element software. It predicts the percentage of endothelium denudation based on the friction mechanics.

RESULTS/DISCUSSION:

A proof-of -concept test was performed using IVUS images of one patient who underwent balloon angioplasty. A 3-D model of a 68 mm LAD segment was produced from IVUS images acquired 7 minutes before stent implantation. The deployment of a 3 by 12 mm Taxus stent was simulated by applying an 18 atm pressure inside a folded balloon (Figure 1). The immediate predicted artery deformation was compared with IVUS images of the same patients obtained 8 minutes after stenting.

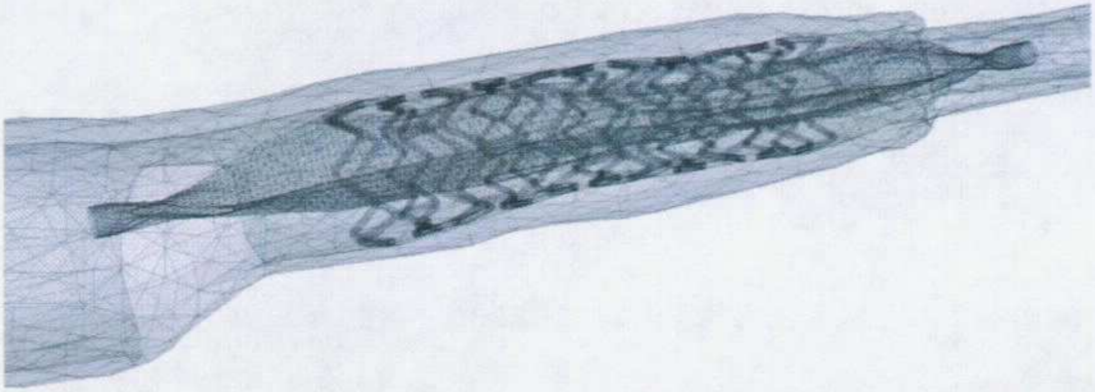

Figure 1: Simulation results of device deployment into the artery, showing predicted deformation at after balloon deflation

REFERENCES:

[1] Delorme, S. et al (2004) Annual Technical Conference (ANTEC) of the Society of Plastic Engineers, Chicago, IL.

[2] Laroche, D. et al (2003) ASM Materials & Processes for Medical Devices Conference, Anaheim, CA.