COUPLED MODELING OF DRUG-COATED BALLOON TREATMENT OF PERIPHERAL ARTERY DISEASE

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Introduction

Peripheral artery disease (PAD) affects more than 200 million people in the world above 25 years of age [1]. The most common method of mitigating the effects of plaque buildup that causes PAD is balloon angioplasty which involves inserting a catheter into the narrowed part of the artery followed by balloon expansion and pushing the plaque on one side of the artery [2]. This sudden expansion damages the arterial wall and the body's tissue repair mechanisms react, causing inflammation and restenosis by extensive tissue proliferation at the site of the procedure. Hence, drug-coated balloons were developed to deliver antiproliferative agents, such as paclitaxel, directly to the arterial tissue to prevent restenosis [2]. Computational models have provided insight into paclitaxel absorption and release with high precision; but the research was focused on drug-eluting stents [3]. Drug release and kinetics research on DCBs has been limited to extensively simplified 2D models which are intrinsically very constrained [1]. This abstract presents a 2D solid-fluid interaction model which is a novel method for solving the problem of drug absorption after the balloon has been deployed.

Methods

The computational procedure is implemented in PAK finite element (FE) solver [4]. The DCB is modeled as a linear elastic material with Young modulus of 920 MPa, Poisson's ratio of 0.4, and material density of 1100 kg/m^3. The flow of drug from the DCB is modeled using the Navier-Stokes equation while the artery is modeled using a hyperplastic Ogden model. Finally, the calcified arterial plaque is modeled using a modified Mooney-Rivlin model.

Results

The interface of the module designed in CAD Fields and Solid specifically for DCB treatment of PAD is shown in Figure 1. The model consists of a plate that mimics the expandable balloon and the pressure used for balloon inflation is approximated using prescribed displacements for each balloon. The balloon area is depicted by the marked zone of elliptical shape, and it is idealized with no fluid flow and no random drug diffusion. The mechanics described by the model are balloon inflation, plaque and arterial wall compression, and drug diffusion in steps depicted in Figure 2.

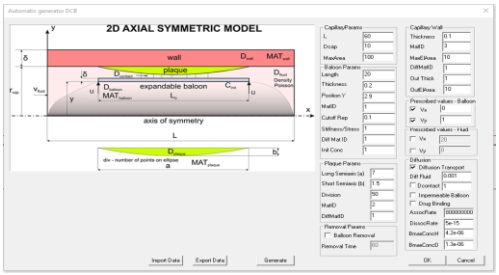

Figure 1. Parameter adjustment in CAD Fields and Solid

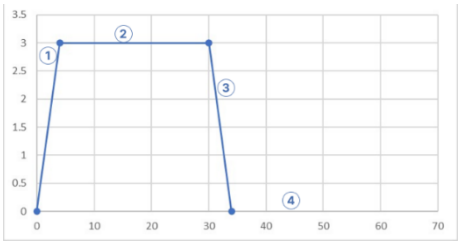

Figure 2. DCB mechanics - (1) balloon inflation (2 s), (2) drug application (60-180 s), (3) balloon deflation (2 s), (4) post-application period (adjustable)

Discussion

The model can be used for the evaluation of the impact of DCB inflation time on angioplasty procedure, sequential application of multiple DCBs, inflation pressure on the timing of drug transport, and the amount of drug washed out of the system due to circulatory blood flow. This and prospective tissue-rupture and restenosis models are intended for *in silico* optimization of DCB angioplasty and maximization of drug effects.

References

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4. PAK software, accessible at: http://www.bioirc.ac.rs/index.php/software/5-pak

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