Mathematical Methods for Next Generation Stent Design

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Real-life problems often times give rise to problems whose understanding requires development of sophisticated mathematical methods. In particular, mathematical methods for next generation stent design require novel results in nonlinear analysis of partial differential equations, moving boundary problems, and numerical methods for multi-physics, multi-scale problems defined on moving domains. In this talk we will review the state-of-the-art in mathematical methods for next generation stent design. Stents are mesh-like devices used in the treatment of various cardiovascular diseases. Currently used stents include bare metal stents, biodegradable stents, Despite the beneficial effects of stenting, persistent high rates of complications such as in-stent restenosis and late stent thrombosis call for novel approaches to stent design. Recent ideas based on nanoengineered stents seem to be particularly promising. They include: (1) nano-engineered, drug-free stents, which are stents covered with nano-engineered surfaces that promote accelerated restoration of functional endothelium and provide a drug- free approach to keeping stents patent long-term; and (2) ferromagnetic stents with magnet-enhanced nano-particle drug delivery of anti-thrombogenic drugs, or viable endothelium, for improved arterial wall healing and drug-eluting stents.

We will show how the following mathematical results have and will continue to influence further development of these bioengineering inventions: existence results in nonlinear fluid-structure interaction (FSI), FSI with novel multi-layered poroelastic structures, an extension of the Lions-Aubin-Simon compactness theorem to problems on moving domains, development of loosely-coupled partitioned schemes for FSI problem, theory of 1D hyperbolic nets obtained using dimension-reduction to model stents' mechanical properties, and Smoothed Particle Hydrodynamics approaches to study emergent behaviors of active ferromagnetic nano-particles.

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