The pathological complications of atherosclerosis, namely heart attacks and strokes, are the leading cause of mortality in the world. The most common treatment for atherosclerosis is the implantation of a stent, a wiremesh structure that is deployed on a balloon catheter and expanded at the location of arterial obstruction to restore blood flow. Most stents deployed in coronary arteries today are drug-eluting stents (DES) that release a drug into the arterial wall in a controlled manner in order to prevent the occurrence of certain complications. However, despite the widespread use of DES, there is a persistent risk of serious complications including instant restenosis (vessel re-blockage), late stent thrombosis (blood clot formation), and stent fracture. Minimizing the incidence of these complications requires devising optimal DES designs that strike a fine balance among a myriad of competing considerations including drug release dynamics, stent strut dimensions, and stent surface characteristics that accelerate device cellular coverage. In this talk, I will describe a multivariable optimization approach to optimize DES design. I will also present a stentable coronary artery mimic that we have developed in order to experimentally test the predictions of the computational optimization. This arterial mimic contains the relevant cells of the arterial wall and allows cellular monitoring as well as detailed characterization of arterial flow fields using particle image velocimetry. Finally, I will describe two novel approaches for radically improving stent performance: 1) patterning stent surfaces to accelerate device cellular coverage, and 2) developing smart and communicating stents that can detect the onset of stent restenosis or thrombosis and communicate the information wirelessly to the outside world.

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