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FLUID AND SOLID MECHANICS IN STENTED ARTERIES

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ABSTRACT

Vascular stents are being used in increasing numbers to correct arterial flow limiting disorders. Although data exist on the in vivo performance of these devices, comparatively little is known about how these devices affect the arterial mechanical environment. The long-term success of stenting is very likely affected by the blood flow patterns and artery wall stresses that follow stent placement.

This study was undertaken to identify the mechanical environment in stented arteries and to propose a stent design that minimizes the "mechanical trauma" of stent implantation. A series of pulsatile flow visualization experiments were performed with a Johnson & Johnson Palmaz/Schatz stent inserted in a straight compliant tube. A flow loop was constructed that was capable of applying a physiologic pulsatile flow indicative of conditions in the femoral or coronary arteries. The results showed that this stent design creates complex flow patterns including large-scale vortices, and that these patterns are caused by the compliance mismatch between the stented vessel and adjacent unstented vessel.

The compliance mismatch also would be expected to create abnormal stress concentrations in the artery wall near the ends of the stent. A simplified model of an artery was constructed to estimate the stress in the artery wall. The stent/artery structure was assumed to be an axisymmetric thin shell made of a linear elastic, orthotropic material that undergoes small deformations. The stent diameter was assumed to be equal to the artery systolic diameter. The stresses were estimated under diastolic pressure, when the deflection of the artery due to the presence of the stent is greatest. It was found that the circumferential and axial stresses at the ends of the stent were 2 to 3 times higher than the stress far from the stent.

Based on these mechanical studies, a new stent design was proposed that provides a smooth transition in compliance at the proximal and distal ends of the tube. Flow visualization studies with this new stent indicate that the flow disturbances are greatly reduced with this new design. The transition zone was incorporated into the shell model to estimate the artery wall stresses induced by this new model. It was found that the stress concentration was reduced by as much as 36% from the rigid stent value. These studies demonstrate the potential complexity of flow in stented arteries and provide some recommendations for optimizing stent design from a biomechanical point of view.

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