INCREASING ATHEROSCLEROTIC PLAQUE ECCENTRICITY INCREASES ARTERIAL WALL STRESS

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Introduction

More than half of all atherosclerotic coronary lesions are reported as eccentric [Mintz, 1996], yet the relationship between eccentricity and arterial wall stress has not been systematically investigated. We hypothesise that arterial wall stress post-stenting will be significantly higher as the eccentricity of the plaque increases.

We tested this hypothesis using finite element models to examine the effect of altering plaque geometry on arterial wall stress in an idealised stenosed coronary artery.

Methods

Arterial tissue was represented by a sixth-order reduced polynomial isotropic hyperelastic model [Gastaldi, 2010; Holzapfel 2005]. The cellular plaque type described by Loree et al [1994] was used combining an isotropic hyperelastic model, with a plasticity model to account for plaque failure [Gastaldi, 2010]. Bi-linear elasto-plasticity with properties of stainless steel was used for the stent.

The lumen was expanded via pressurized balloon expansion of a stent similar in design to a Palmaz-Schatz stent using Abaqus/Standard (Simulia Inc). An idealized artery was modelled with a stenosis comprising 50% of its transverse cross-sectional area. Four degrees of eccentricity were created: 0% (concentric), 5%, 10% and 20%. Eccentricity percentage was calculated as offset of lumen centre from artery centre (*a*) divided by the artery radius (*R*) x 100 (see Fig. 1).

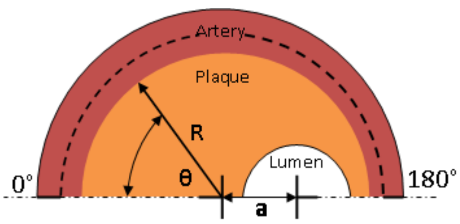

Fig. 1: Artery cross-section. a is offset of lumen centre from artery centre, R is artery radius. Stress is calculated along the dashed line, i.e. mid-artery.

Results

Higher artery wall stresses are associated with the degree of lesion eccentricity (see Fig. 2). The range of stresses also increases with eccentricity e.g. for a/R=0.2 the range is 10 to 80 kPa.

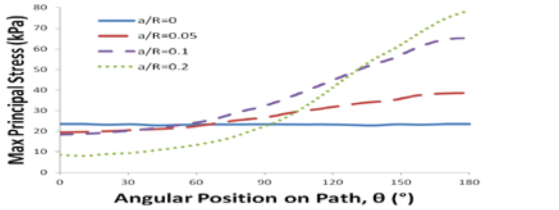

Fig. 2: Plot of stress along a circumferential central path (see Fig. 1) through the artery wall for a/R=0 (i.e. concentric model) and eccentric models.

Discussion

Eccentric plaques exhibit substantial stress variations compared to their concentric equivalents. In a transverse cross-section of an eccentric plaque, relatively thicker plaque "shields" the underlying tissue from stress, yet as the thickness decreases arterial tissue rapidly comes under increasingly high levels of stress. The relationship between eccentricity and arterial stress, therefore suggests that idealized concentric plaques offer limited predictive value of the arterial stress state.

While some FE studies of coronary stenting include eccentric plaques [Conway, 2012], no study at present to the authors' knowledge, has focused on assessing the impact of eccentricity. In conclusion the hypothesis forms an essential consideration for determining stent-induced arterial injury.

References

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