QUANTIFICATION OF ARTERIAL DEFORMATIONS DURING LEG FLEXION IN SUBJECTS WITH PERIPHERAL ARTERIAL DISEASE

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Introduction

In-stent restenosis occurring in lower limb arteries has been associated with stent fractures. It has been suggested that the mechanical environment which is produced through knee flexion not only causes the failures of these endovascular devices but also inflicts damage to the arterial walls. To improve current device designs and ensure higher success rates following stent deployment, the aim of this study was to accurately characterize the in-vivo deformations of the femoropopliteal artery (FP), caused by physiological movements during knee flexion, in subjects with clinically relevant peripheral arterial disease (PAD).

Methods

3D rotational angiography was performed (Siemens, AXIOM-Artis) on 5 patients (mean age 71 ± 9), with varying levels of calcification, ranging from mild to severe. The images were taken with the patients' lower limbs straight and with a knee flexion of 90º. Following the segmentations of each image, the 3D reconstructions of the arterial trees for both positions were obtained (Fig. 1). Using the method proposed by Choi [Choi, 2008], the axial contraction, twisting and curvature changes in the arteries were calculated. In addition, the relation between the severity of calcifications and the amount of deformation was analysed.

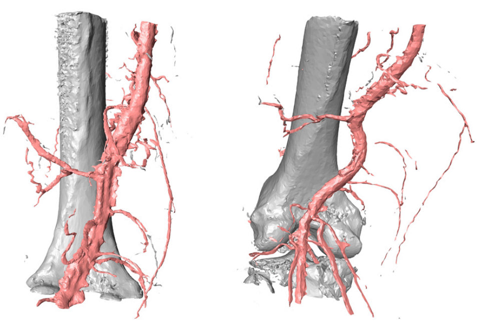

Figure 1: Threshold-based segmentation of the bone and artery for patient #1 with the leg in a straight position (180°) (left) and flexed at (90°) (right)

Results

The axial length of all FP arteries decreased during leg flexion with an average shortening of 5.8% (Tab. 1). The average twist rate was calculated as 4.8°/cm and an increase in the maximum curvature was observed from 0.11 cm^{-1} in the straight position to 0.22 cm^{-1} in the flexed configuration. The results also suggest a relation between the calcification levels and the values of curvature and twist rate. As the severity of the calcification increased, maximum curvature increased, while the twist rate decreased. No relation between axial shortening and level of calcification was observed.

	Axial (%)	**Twist rate (°/cm)**	**Max. Curvature (cm^{-1})**	
			Straight	**Flexed**
P1	-4.5	4.2	0.17	0.39
P2	-7.6	9.00	0.08	0.17
P3	-6.3	2.4	0.10	0.09
P4	-8.4	4.9	0.13	0.22
P5	-2.4	6.3	0.08	0.21
Mean	5.8±2.4	5.4±2.4	0.11±0.04	0.22±0.11

Table 1: FP arterial deformations in 5 patients undergoing endovascular therapy; axial compression, twist rate and curvature

Discussion

The 3D imaging technique allowed us to fully characterize arterial deformations. Significant changes were measured for the axial length, twist rate and curvature during flexion of the leg. The higher curvature observed for increased calcification can result from a concentration of the deformations in the flexible segments next to the stiffer calcified section. These measurements provide important information to define realistic boundary conditions to calculate stresses in stents using the finite element technique and will help defining virtual and physical test environments to improve stent designs and decrease the restenosis in lower limb arteries.

References

Choi *et al*, Ann Biomed Eng, 37:14-33, 2008.