PREDICTION OF RESTENOSIS BASED ON THE HEMODYNAMICS OF REVASCULARIZED FEMORAL ARTERIES DURING LEG FLEXION

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Introduction

The long-term outcomes of endovascular therapy in patients with Peripheral Arterial Disease (PAD) show high rates of restenosis, which may be explained by the demanding mechanical environment during leg movements. Although the presence of these extreme arterial deformations has been qualitatively linked with restenosis, their effects on the hemodynamics of femoro-popliteal (FP) arteries remain unknown [1].

This study aimed to quantify the flow behaviors of the FP arteries following endovascular revascularization and correlate the numerical results with restenosis rates reported on clinical cases at 6 months follow-up. Our hypothesis is that personalized simulations of patients' hemodynamic behaviors can provide clinical markers that are able to predict the risk of restenosis.

Methods

25 patients with varying degrees of PAD were recruited for this study [1]. 13 patients underwent Percutaneous Transluminal Anigoplasty (PTA); while the remaining patients were implanted with Nitinol stents after PTA. Following treatment, images were acquired with the leg in supine and flexed positions. These images were, then, used to construct the 3D geometries of the arterial lumens using a custom-built reconstruction software [1]. The transient flow condition within the artery was simulated with ANSYS CFX 18.0. The blood was modeled as a Newtonian fluid and the flow was considered to be laminar. A volumetric flow profile obtained from an MRA measurement was applied at the inlet of the artery [2], while the outlet was set as a zero-pressure opening. The artery wall was prescribed to have a no-slip condition. Three cardiac cycles were simulated and various Wall Shear Stress (WSS) descriptors – low time-averaged WSS (TAWSS) (< 0.5 Pa), high TAWSS (> 7 Pa), and high Oscillatory Shear Index (OSI) (> 0.3) – were evaluated only for the final cycle. Based on restenosis rates reported at 6 months, logistic regression analyses were performed to predict the risk of restenosis from hemodynamical parameters.

Results

For stented arteries, leg flexion caused a statistically significant difference in the areas affected by low TAWSS ($p = 0.04$); whereas no difference was observed for the patients that only underwent PTA ($p = 0.80$). For patients grouped according to the presence/absence of restenosis, there were clear trends related to the changes in the flow behavior due to leg flexion (Fig. 1). Most importantly, the areas affected by low TAWSS increased with leg flexion and were higher for restenosed arteries. A logistic regression analysis based solely on hemodynamical markers had a prediction accuracy of 75% (restenosis vs. no-restenosis: $p = 0.03$).

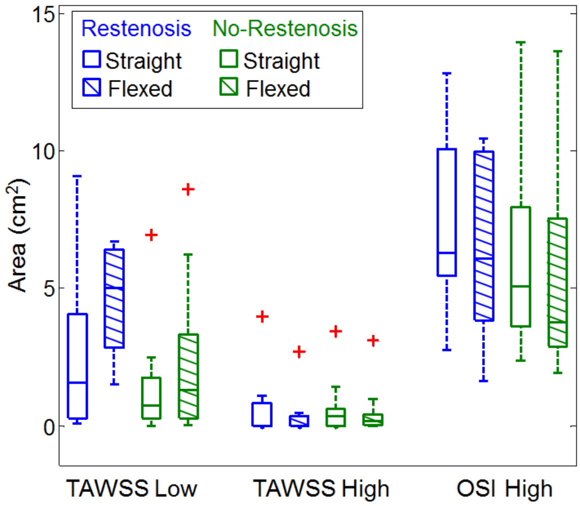

Figure 1: The areas of the artery (cm2) affected by adverse hemodynamics for the groups of patients with (n = 7) and without (n = 18) restenosis.

Discussion

Unphysiological arterial deformations (i.e. kinking, pinching) induced postoperatively by the flexion of the leg led to adverse hemodynamic conditions that may trigger restenosis. Although regression analyses showed that flow parameters are sufficient to predict restenosis, better predictions were achieved by adding the treatment method in the model (Acc. = 80%; $p = 0.005$). This suggests that a more accurate image acquisition technique is required to capture the localized modifications of blood flow following intervention. This approach, based on the immediate post-operative configuration of the artery, has the potential to identify patients at increased risk for restenosis. Based on this information, clinicians could take preventive measures and closely follow these patients to avoid complications.

References

1. Gökgöl et al, J Endovasc Ther, 24:27-34, 2017.
2. Mohajer et al, J Magn Reson Imaging, 23:355-360, 2006.

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