IMPACT OF DIFFERENT PATIENT-SPECIFIC BOUNDARY CONDITIONS ON HAEMODYNAMIC MARKERS IN PERIPHERAL ARTERIAL DISEASE

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Introduction

Peripheral arterial disease (PAD) is the third cause of cardiovascular morbidity [1]. Surgical (i.e. bypass) and/or endovascular approaches (i.e. stenting) are employed to restore impaired blood flow resulting from the pathology. Restenosis, i.e. an abnormal re-narrowing of the treated blood vessels, is a common negative outcome of these procedures. Altered haemodynamics plays a role in its progression. The integration of haemodynamic variables, arising from computational fluid dynamic (CFD) simulations, and routinely collected information has the potential to predict when re-occlusion occurs. However, the accuracy of such predictive tools relies on the quality of the clinical data. Data availability (i.e. computed tomography (CT) scans and Doppler ultrasound (DUS) images) tends to be fragmented, as the timings of DUS and CT imaging may differ. In this work, we assess the impact of applying different (in time) patient-specific boundary conditions (BCs) - obtained from the DUS images - on haemodynamic indices and hence ascertain that reliable information is obtained to predict restenosis occurrence.

Methods

CT scans and DUS images of three patients suffering from PAD who underwent bypass or stenting were obtained from VA Connecticut Healthcare Systems, West Haven, USA. DUS images acquired at the same time and at heterogeneous time points with respect to CT scans acquisition were considered as inlet BCs. Patients' vessels were reconstructed and patient-specific CFD analyses were performed following Colombo et al. workflow [2]. Haemodynamic indices related to restenosis (i.e. Time-Averaged Wall Shear Stress (TAWSS), Oscillatory Shear Index (OSI), Relative Residence Time (RRT) and Topological Shear Variation Index (TSVI)) were computed. The differences in the haemodynamic indices with respect to those obtained when CT scans and DUS match in time were quantified, and the ability to capture regions subjected to altered haemodynamic values was assessed.

Results

Fig.1(a) shows the % differences in spatially averaged TAWSS index along the bypass length with respect to the reference case for one patient. Fig.1(b) shows the regions subjected to low TAWSS (restenosis marker). These were identified by imposing as critical threshold the 1st tertile of the TAWSS distributions for every applied BC. The TAWSS index may be underestimated or overestimated along the bypass length. However, no significant differences were observed in the depicted critical regions for restenosis [3].

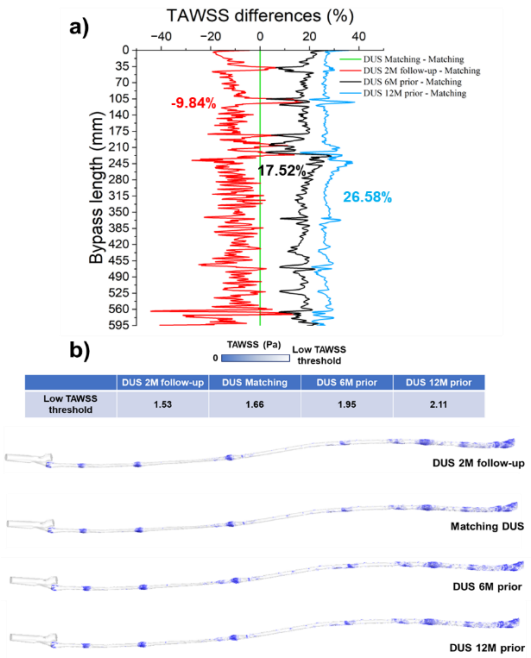

Figure 1: a) Differences (median value in bold) in TAWSS indices with respect to the reference case along the bypass length when 2-months (2M) follow-up, 6- and 12-months (6M,12M) prior DUS to CT scan acquisition are applied; b) luminal regions subjected to low TAWSS for examined inlet BCs.

Discussion

In summary, potential critical areas for restenosis can be identified even from fragmented data if critical thresholds are computed based on single distributions. Although the haemodynamic values along the bypass may be incorrectly estimated when DUS images do not match CT scans in time, critical areas for restenosis are still reliably identified. Further analysis of the entire dataset is currently in progress to support these findings.

References

1. Fowkes et al., The Lancet, 2013.
2. Colombo et al., Med Eng Phys, 2020.
3. Colombo et al., Ann Biomed Eng, 2021.

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