THE IMPACT OF A LIMITED FIELD-OF-VIEW ON COMPUTED HEMODYNAMICS IN ABDOMINAL AORTIC ANEURYSMS

Judith Fonken (1,2), Esther Maas (1,2), Arjet Nievergeld (1,2), Marc van Sambeek (1,2), Frans van de Vosse (1), Richard Lopata (1)

1. Eindhoven University of Technology, Netherlands; 2. Catharina Hospital Eindhoven, Netherlands

Introduction

To improve abdominal aortic aneurysm (AAA) rupture risk assessment, a large, longitudinal study on AAA hemodynamics and biomechanics is necessary, using patient-specific (PS) fluid-structure interaction (FSI) modeling [1]. 3-dimensional, time-resolved ultrasound (3D+t US) is the preferred image modality to obtain the PS AAA geometry for such a study, since it is safe, affordable and contains temporal information. However, the 3D+t US field-of-view (FOV) is limited compared to that of computed tomography (CT), and often fails to capture the inlet and aorto-iliac bifurcation geometry (Fig. 1). The limited FOV and the absence of the bifurcation does not significantly influence the numerical assessment of wall mechanics in the AAA region [2]. In this study, the impact of this limited FOV on the hemodynamics in the AAA was evaluated.

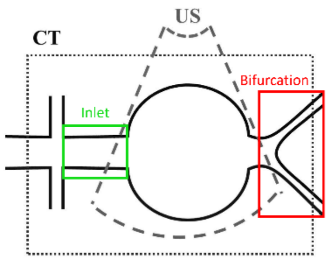

Figure 1: Illustration of an abdominal aortic aneurysm (AAA) with typical field-of-view of CT and 3D+t US imaging. Figure from [2].

Methods

A framework was developed to add parametric inlet and bifurcation geometries to the aneurysm geometry by employing dataset statistics and parameters of the AAA geometry. The impact of replacing the PS inlet and bifurcation geometries, acquired by CT scans, by parametric geometries was evaluated by examining the differences in CFD-derived systolic and time-averaged wall shear stress (WSS_{sys} and TAWSS, respectively) and oscillatory shear index (OSI) in the aneurysm region [3].

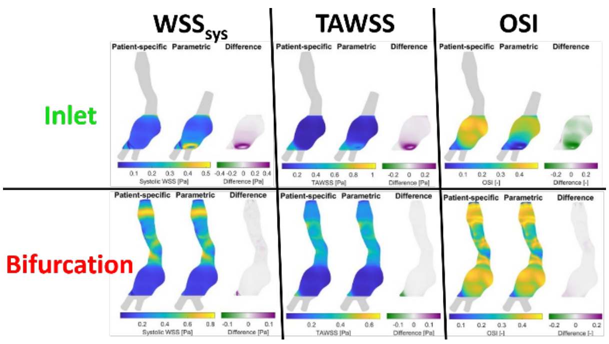

Figure 2: CFD-derived WSS_{sys}, TAWSS and OSI values for the PS and parametric inlet and bifurcation geometries, and the differences in the AAA region.

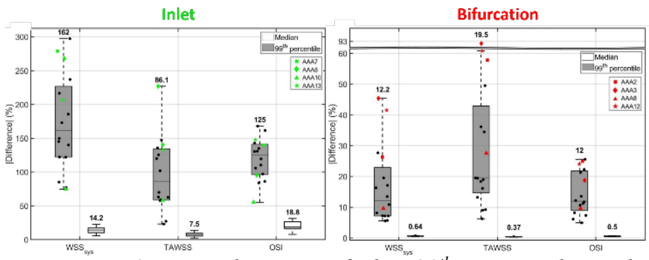

Figure 3: Visualization of the 99th percentile and median absolute percentual point-wise differences in WSS_{sys}, TAWSS and OSI between the PS and parametric inlet (left) and bifurcation (right) geometries.

Results

Considerable differences in hemodynamics in the aneurysm region were observed when the PS inlet geometry was replaced by a parametric one (Fig. 2). Median 99th percentile differences up to 162% and median differences between 7.5-18.8% were observed (Fig. 3). For the bifurcation geometry, the largest differences were observed in the distal part of the AAA region (Fig. 2). In the remainder of the aneurysm, the differences were small. All medians of the 99th percentile difference values were below 20% (Fig. 3). For all hemodynamic quantities and all patients, the median absolute difference was below 1%.

Discussion

These results indicate that it is not feasible to replace the PS inlet geometry by a parametric one, since this causes significant differences in hemodynamics in the AAA region. Future studies should focus on extending the proximal FOV by registering multiple (3D+t) US acquisitions. For the bifurcation, the obtained results illustrate the feasibility of adding a parametric bifurcation geometry to the aneurysm geometry, with median differences all below 1%. After extending the proximal FOV, the obtained framework can be used to extract AAA geometries from 3D+t US for FSI simulations, despite the absence of the bifurcation geometry.

References

1. Fonken et al., Front. Physiol., 1255, 2021.
2. Disseldorp et al., J. Biomech., 2405-2412, 2016.
3. Fonken et al., Ann. Biomed. Eng., 2023.

Acknowledgements

This work was supported by the Dutch Research Council (NWO) and received funding from the NWO talent program VIDI. This work was carried out on the Dutch national e-infrastructure with the support of SURF Cooperative.