11º CONGRESSO NACIONAL DE BIOMECÂNICA
A. P. G. Castro, C. Pina, P. R. Fernandes, C. Santos, J. Folgado & A. Amaro (Eds)
Sesimbra, Portugal, 21-22 de Fevereiro, 2025

PATIENT-SPECIFIC WALL MOTION AND AORTIC ROOT DYNAMICS OF ASCENDING THORACIC AORTA ANEURYSMS

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KEYWORDS: Ascending Thoracic Aorta Aneurysm (ATAA); Cine Computed Tomography Angiography (CTA); Patient-specific wall motion; Deformation analysis

1 INTRODUCTION

Ascending Thoracic Aorta Aneurysm (ATAA) is a permanent deformation caused by age, genetic conditions, or environmental/behavioural factors. Nowadays, clinicians characterise this deformation by measuring the maximum diameter with a threshold to determine the approach for clinical intervention [1,2]. Some improvements in the clinical protocol have been made by using advanced computational tools such as Computational Fluid Dynamics (CFD) or Fluid-Structure Interaction (FSI) [2]. While these models are accurate in terms of aortic hemodynamics, the annulus mechanical behaviour remains poorly understood. Furthermore, such models often overlook the unique in-vivo wall motion of each patient, neglecting important dynamic behaviour. In this article, we discuss a new analysis regarding the patient-specific dynamic behaviour of the ATAA. The analysis is based on deformation data obtained from Cine Computed Tomography Angiography (CTA) images, which were examined in 53 patients with ATAA

2 METHODS

A cine CTA is a sequence of 21 CTA taken over one cardiac cycle. This imaging method can be used to extract patient-specific ATAA motion. To interpolate and extract this motion, we first developed a semi-automatic segmentation tool in Python using the skimage library [3] to translate the CTA images into 3D Point Clouds. This semi-automatic program only required 2 points inside the Region of Interest (ROI) and a defined colour threshold with a visual guide. Subsequently, we developed a python program that calculates the deformation of the ATAA using feature-based point selection and a Radial Basis Function (RBF) interpolation. This process produces a mesh with a time-dependent displacement vector for each node. The nodal deformation is important to analyse the motion across multiple sections. We assessed the patient-specific deformation in all the ATAA using metrics recommended in clinical guidelines and other more recent approaches that may provide insights into the development of the aneurysm.

3 RESULTS

To analyse the results of the semi-automatic segmentation Python code, we use the Dice coefficient, with resulted in an accuracy of 0.964 (SD=0.024), and the Relative volume error within 5% (SD=3.5%). One significant result obtains from the patient specific motion analysis is motion of the aortic root centre-of-mass. We observed a maximum distance of 5.35 mm (SD=2.03) travelled by the centre of mass between systole and diastole. Figure 1 displays the deformation in the aortic root.

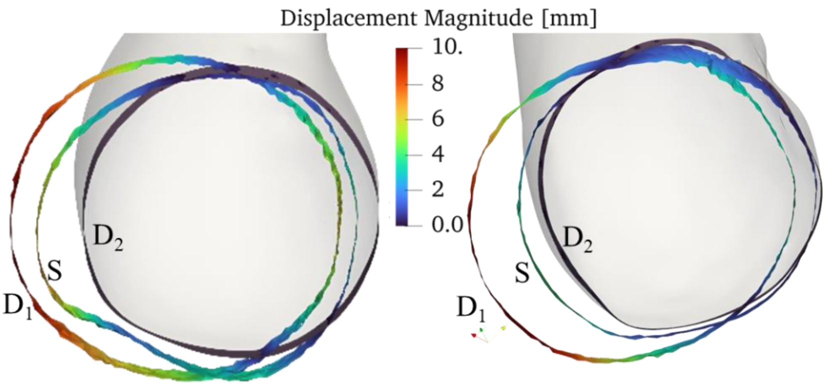

Figure 1: Deformation of the aortic root extracted from two in vivo patients: Systolic peak (S), Beginning of Diastole (D1) and end of Diastole (D2).

Another important result of this analysis focuses on the centreline length variation during the cardiac cycle. We reported that the centreline length difference was 1.09 (SD=0.045) between systole and diastole.

4 CONCLUSIONS AND DISCUSSIONS

In this article, we successfully calculated the patient-specific ATAA deformation throughout the cardiac cycle and analysed multiple metrics. We report the significant non-rigid deformation arising from other sources other than the inside haemodynamic pressure. The centreline motion and the centre of mass in the aortic root show a significant motion in this section. Standard numerical methods do not currently account for this motion, but it appears to be significant.

Currently, we are now implementing the patient-specific ATAA motion in CFD models using mesh morphing and plan to develop a FSI model that incorporates aortic root dynamics in the future. The objective is to understand the implication of this motion in the aortic haemodynamics and structural integrity of the aorta.

ACKNOWLEDGMENTS

This research was funded by the Portuguese Foundation for Science and Technology (FCT,IP) under the projects: “Fluid-structure interaction for functional assessment of ascending aortic aneurysms: a biomechanical-based approach toward clinical practice” (AneurysmTool) DOI: 10.54499/PTDC/EMD-EMD/1230/2021; UNIDEMI: UIDB/00667/2020 and R. Valente Ph. D grant 2022.12223.BD UIDP/00667/2020; A. Mourato Ph.D. grant DOI:10.54499/UI/BD/151212/2021.

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