FABRICATION OF A PATIENT-SPECIFIC COMPLIANT AND TRANSPARENT PHANTOM FOR IN-VITRO AORTIC DISSECTION HAEMODYNAMICS

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Introduction

Aortic Dissection (AD) is a life-threatening and highly patient specific vascular condition in which the vessel wall splits creating a false lumen. In-vitro studies of AD are vital to understand its complex hemodynamics, provide reliable and quantitative data for numerical model validation and test intervention scenarios. The fabrication of patient-specific compliant and transparent phantoms of AD has been a main challenge for in-vitro haemodynamic studies using optical measurement techniques. A patient-specific compliant and transparent phantom of a type-B aortic dissection was fabricated for PIV measurements in our mock circulatory loop [1]. The overall vessel compliance was quantified and spatio-temporal measurements of wall displacement over the cardiac cycle were also obtained.

Methods

The geometry of the model was obtained from CT scans of a 77-year-old male subject to a chronic Type-B AD, which has been studied in [1] using a rigid phantom. In this study, we fabricated a patient-specific compliant and transparent phantom by a casting technique employing 3D printed PVA molds -dissolved in water and Sylgard^{TM} 184 Polydimethylsiloxane (PDMS) (Dow Chemical, USA) material for the vessel wall. The Young's modulus was measured using a uniaxial testing rig (BT1-FR5.0TN, Zwick Roell Group, Ulm, Germany). The phantom was connected into a pulsatile circulatory loop described in [1] and its overall compliance -defined as C=$\Delta V/\Delta P = (\Delta V_{in} - \Delta V_{out})/\Delta P$-was determined. This was done by monitoring the volume change (ΔV) between the inlet and outlets for a given pressure change ΔP over the cardiac cycle. The flow rate was measured using an ultrasound flow meter (Sonotec, Germany) and the pressure by pressure transducers (Omega Engineering, UK). Fluorescent markers were placed on the vessel wall surface, illuminated using a laser light sheet (Diode-Pumped Solid-State Laser, Laserglow Technologies, Canada) and imaged by a high speed camera (Phantom VEO710, AMETEK, US) to enable wall displacement measurements. The latter were compared with values obtained by the moving boundary method in compliant CFD simulations of the same AD case [3].

Results

The Young's modulus of the phantom material was 0.7±0.03 MPa, and lies within the range of reported Young's modulus values for the aorta (0.2-0.8 MPa, [2]). The measured overall compliance was 0.33 ml/mmHg, comparable to the value reported in the simulations of Bonfanti et al. [3] for the same patient specific geometry.

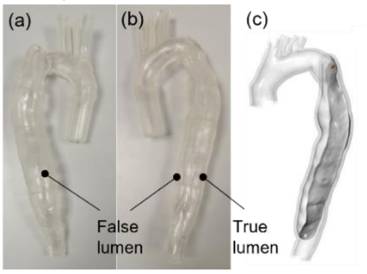

Figure 1: (a)(b)Two side views of the phantom. (c)semi-transparent sketch where the entrance tear is denoted by a red circle.

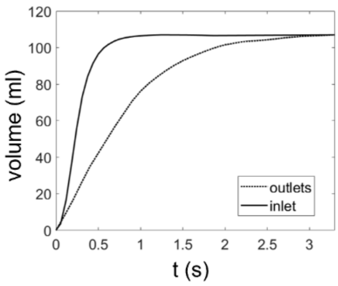

Figure 2: Plots showing the integration of the flow waveforms at the inlet and outlets, used to estimate compliance.

Discussion

A patient-specific compliant and transparent AD phantom was fabricated enabling fluid structure interaction studies of AD by optical measurements such as PIV or PTV. This will allow highly resolved quantitative data to be obtained for the validation of numerical models. Further work is under way to fabricate phantoms with variable compliance to enable in-vitro testing of AD intervention scenarios.

References

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3. M. Bonfanti et al, J. R. Soc. Interface, 14(136), 2017.

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