IN-VITRO HAEMODYNAMICS IN A PATIENT-SPECIFIC COMPLIANT DISSECTED AORTA

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Introduction

Aortic dissection (AD) is a vascular condition in which a tear forms on the aortic wall, which allows the blood to flow in and form a false lumen [1]. It is a complex, patient specific condition with high morbidity and mortality rate. Patient specific numerical modeling has shed light in the hemodynamics of the condition [2]; coupled with in-vitro studies can provide a powerful tool to personalize interventions for AD as was illustrated in our previous work [3]. Recent numerical studies of AD make use of compliant AD simulations to capture the wall motion (see [2] for example); these need to be rigorously validated in order to be translated to the clinic and such validation procedures are currently lacking. We report an in vitro, fluid structure interaction study of AD, aiming to aid understanding of the disease and the development of CFD approaches. A patient specific compliant phantom of a type-B dissected aorta is fabricated and the flow field and wall displacement are simultaneously resolved using a mock circulatory loop and high speed imaging and Particle Image Velocimetry (PIV).

Methods

A patient specific, compliant phantom of aortic dissection B was fabricated by Polydimethylsiloxane (PDMS) (Young's modulus: 0.7MPa, refractive index (RI): 1.41); it is based on the patient/ geometry studied previously using rigid phantoms [3]. The phantom was connected into a pulsatile flow mock circulatory loop described in [3] (see figure 1). A patient specific flow wave obtained from PC-MRI data was imposed at the inlet and dynamic boundary conditions at the outlets as described in [3]. The working liquid was water-glycerol-urea solution (45.64%:28.77%:25.58% by weight, RI=1.4118, viscosity:3.5 $mPa \cdot s$, density:1130 kg/m^3). The flow was seeded with Rhodamine B fluorescent polymer particles (20–50 μm, Dantec Dynamics, Denmark) and illuminated by a continuous wave laser light sheet (Diode-Pumped Solid-State Laser, Laserglow Technologies, Canada). A high-speed CMOS camera (Phantom VEO710, AMETEK, US) equipped with a 550 nm cutoff filter was employed to acquire images for time-resolved PIV (TR-PIV) measurements. The cross correlation algorithm was applied for successive PIV images to obtain the velocity vectors in selected planes. Pressure and flow data were acquired at inlets and outlets using pressure transducers (Omega, UK) and an ultrasound flowmeter (Sonotec, Germany) respectively. The wall displacement was simultaneously measured by means of fluorescent markers attached on the phantom wall.

Results

The outlet boundary conditions were tuned by adjusting parameters of the three element windkessel model to reproduce patient-specific systolic and diastolic pressure values and correct cardiac output flow rate distribution (see figure 2a for the flow rate measured at the outlets). Velocity fields and vessel wall displacement are obtained in different sections and planes of the vessel simultaneously (see figure 2b for a typical raw PIV image).

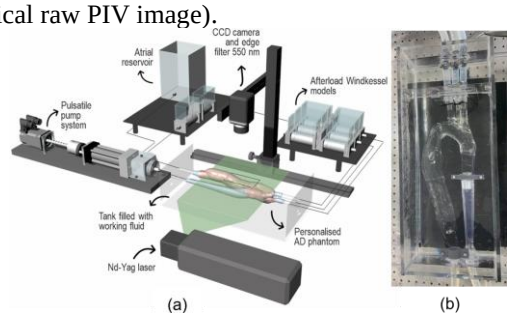

Figure 1: (a)Schematic illustration of the experimental platform [3]; (b) top view of the test section.

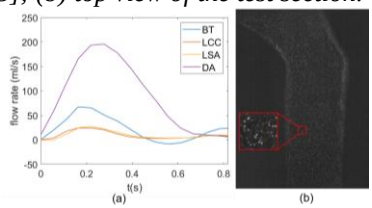

Figure 2: (a)Plots of flow rate measured at brachiocephalic trunk (BT), left common carotid (LCC), left subclavian artery (LSA), and descending aorta (DA); (b) a raw PIV image at the ascending aorta with a zoom-in view.

Discussion

This is the first attempt to characterize the hemodynamics of type-B aortic dissection in a patient-specific compliant phantom in vitro using high resolution TR-PIV measurements.

References

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