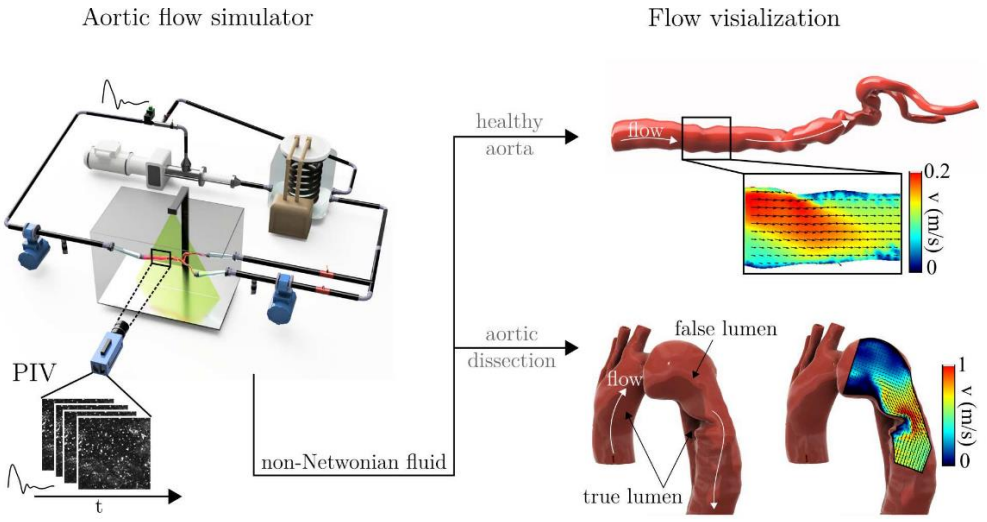
IN VITRO CIRCULATORY MOCK LOOP STUDY OF NON-NEWTONAIN HEMODYNAMICS IN AORTA PHANTOMS: APPLICATION TO AORTIC DISSECTION

ABSTRACT

Cardiovascular diseases (CVDs) including diseases of the heart and circulatory system are the leading cause of death in the European Union and accounted for about 37% of all deaths in 2017 (OECD, 2020). Among CVDs, aortic dissection (AD) is a life-threatening condition in which a tear occurs in the inner layer of the aortic wall. Blood surges into the tear, causing aorta layers separation (dissection) and the formation of a blood channel in between the layers. AD is a complex pathology, difficult to treat, and strongly related to hemodynamics and vessel geometrical features (Nienaber et al., 2016). Fluid dynamics and biomechanics have contributed to AD understanding and pointed out some culprits such as alteration in stress patterns, flow distribution, and vortical flows. However, one of the main limitations in analyzing and understanding this disease mechanism is flow visualization. *In vivo,* routine traditional imaging that gives access to fluid velocities such as 4D-MRI or US-doppler suffers from low time and space resolutions. This is one reason why alternative techniques are developed with artificial circulation emulations to overcome human body observation limitations.

The present work proposes an in *vitro* blood flow investigation. An aortic flow simulator was designed to emulate blood flow in aorta models (healthy and pathological) with biofidelic properties. The objective is to implement a high-resolution flow visualization device to explore aorta hemodynamics and address the limitations encountered with *in vivo* traditional imaging as a complementary tool. We have implemented Particle Image Velocimetry to accurately measure fluid velocities and compute quantities of interests in the context of disease mechanism understanding (shear rate, shear stress, vorticity, etc). The bench accommodates healthy and pathological aorta models – also called phantoms – and a panel of inflow conditions as a versatile tool. Phantoms with specific optical and mechanical features were manufactured to approach human aorta behavior. In addition, a non-Newtonian blood mimicking fluid was designed to represent the shear-thinning behavior of blood which is often neglected in aortic flow simulators. Finally, the experimental bench was developed in close connection with numerical simulation from a parallel thesis that focused on aided surgery for AD (Pan et al. 2020). It allowed confrontation and inter-validation of both model approaches.



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