CFD VIRTUAL ANGIOGRAM FOR AVM PRE-INTERVENTIONAL TREATMENT PLANNING

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Introduction

Congenital arteriovenous malformation (AVM) is a disorder in which arteries and veins are communicated directly without a normal capillary system. In AVMs, capillaries are bypassed by larger channels creating a low resistant shunt termed nidus, that causes a rise in the blood flow and pressure in the venous side [1]. The gold-standard technique to visualise the angioarchitecture of AVMs is intra-arterial digital subtraction angiography (DSA) [2], which is unfortunately, highly invasive. This work combines medical images and computational modelling to generate pre-intervention personalised CFD virtual angiograms with the aim to minimise invasive diagnostic procedures. An experimental campaign involving 3D printed phantoms and laser based diagnostics (Figure 2) is also employed to determine concentration and velocity fields for validation purposes.

Methods

A patient-specific geometry from an extracranial Yakes Type III AVM was extracted by segmenting head and neck CT scans from a 47yo male patient pre intervention (PreOp) obtained as part of an ethically approved protocol (NHS Health Research Authority, ref:19/SC/0090). The feeding artery (Ø ~3.7mm) was used as the inlet and the arterial outflow branch (Ø ~1.4mm), and two draining veins (Ø ~1.5-1.8mm) as the outlets. CFD simulations were performed considering an inlet periodic waveform obtained from the literature [4] and scaled based on DSA-based flow estimations. The nidus structure (vol: 1100mm^3) was modelled as a homogenous porous medium and the DSA contrast agent (CA) simulated as a passive scalar whose transport is described by a convection-diffusion equation as in [3].

Results

Figure 1 shows a qualitative and quantitative comparison between the *in vivo* DSA images and the *in silico* blood flow CA transport under steady and unsteady flow conditions. Quantitative comparison averages pixel intensity within vessel diameter bands located in selected region of interest (ROI) perpendicular to the flow direction.

Discussion

We present a computational approach that can generate patient-specific virtual angiograms in complex AVM geometries. Good qualitative agreement between patient DSA images and simulations is found. The quantitative analysis illustrates how the CFD results capture the trend of CA distribution for 4 of the 6 selected ROI of the geometry. An experimental platform has been developed to generate in vitro angiograms in the same patient geometry and quantify scalar transport using Laser Induced Fluorescence methods. We are also working towards implementing an heterogenous porous medium and an equivalent microfluidic network to better characterize the AVM nidus.

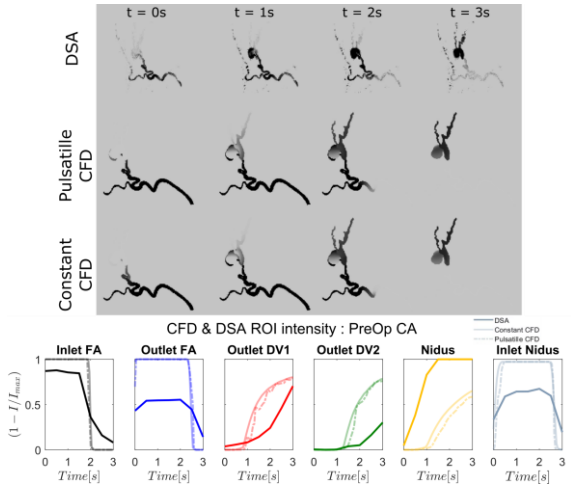

Figure 1: DSA and CFD CA distribution qualitative (top) and quantitative (bottom) comparison in selected ROI at critical points for the pre intervention (PreOp) scenario.

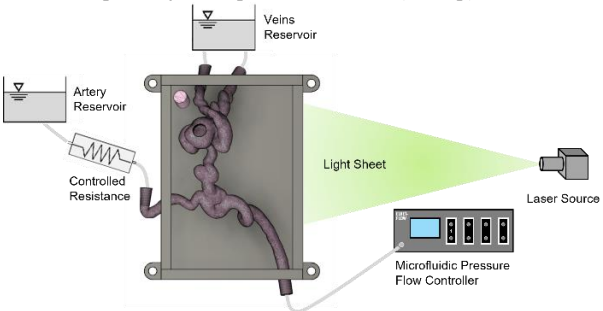

Figure 2: Experimental set up to acquire LIF measurements.

References

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