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Vascular Stress Analysis During *in Vivo* Intravascular Optical Coherence Tomography Imaging

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Abstract: Intravascular optical coherence tomography (IVOCT) has been employed to clinical coronary imaging for several years. But the influence of flushing and OCT catheter to the blood vessel biomechanical properties have not been studied. In this paper, IVOCT imaging is integrated with the fluid-structure interaction (FSI) simulation to study the blood flow velocity and the stress distribution of a porcine carotid artery during IVOCT imaging. 3D geometric model is built based on the *in vivo* OCT images, and a hyperelastic model is employed for the material properties of the vascular wall. The blood flow profile and wall stress distributions under various imaging condition are obtained. This study is helpful for the biomechanical property studies of blood vessels and the clinical treatment of vascular diseases.

Keywords: IVOCT, fluid-structure interaction, stress analysis, flush speed.

1 Introduction

Blood flow and biomechanical properties of vascular wall play a significant role in inducing and modulating physiological responses of endothelial cells (ECs) [Ajami, Gupta, Maurya et al. (2017)]. During intravascular optical coherence tomography (IVOCT) imaging, a catheter is inserted into the blood vessel along a guide wire, then contrast was injected to optically clear the blood while imaging [Sun, Nolte, Cheng et al. (2012)]. This procedure may distort the intravascular flow profile from physiological states. Subtle changes in geometry of blood vessels can affect the flow field significantly [Perktold and Resch (1990)]. During most catheter based interventional procedures, the multiple devices inside the vessel (e.g., guide catheter, imaging catheter, guide wires, etc.) will have already significantly altered the flow profile. Directly imaging changes during different stages of interventional treatment, such as those before and after angioplasty or stenting, will provide insights to clinical applications. In this study, the velocity distribution of flushing and structures of vascular wall are simultaneously imaged by OCT, based on which, the stress status of the blood vessel is analyzed.

2 Methods and results

A porcine carotid artery was imaged with an intravascular OCT system (C7-XR, St. Jude Medical Inc. St. Paul, Minnesota, USA) *in vivo* and the 3D structural image was

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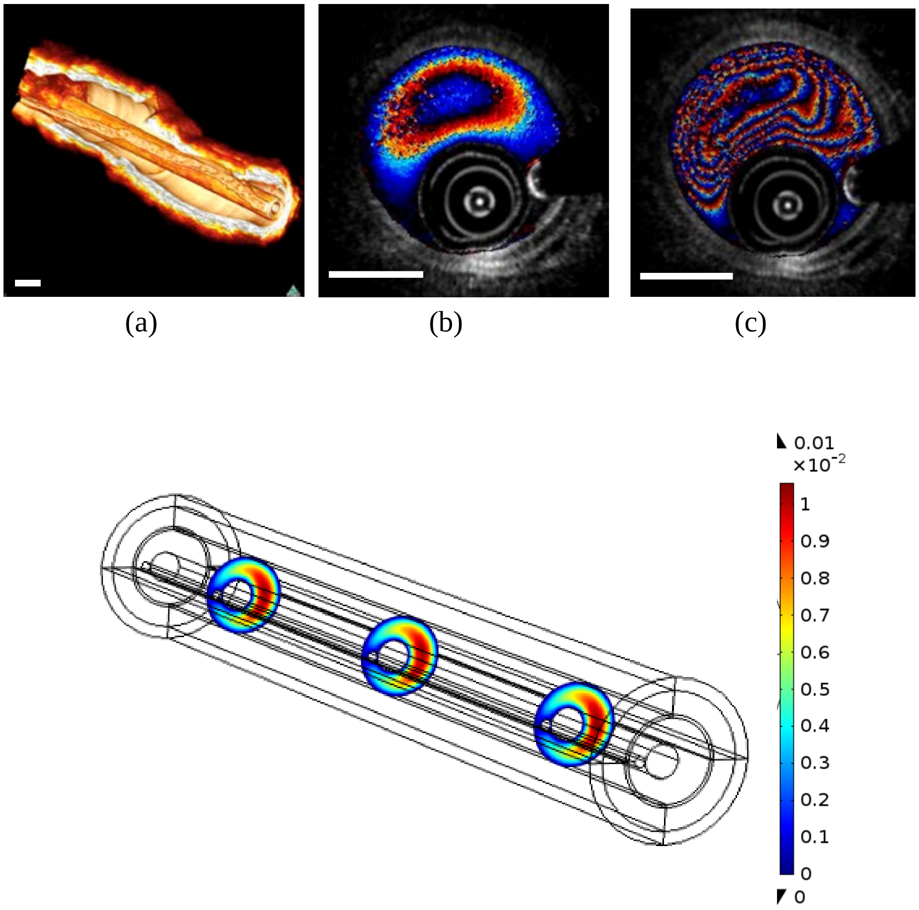
reconstructed in Osirix by inputting a hundred frames of pull back OCT images as shown in Fig. 1a. Then one cross-section of the blood vessel was imaged for 6 s, without pulling back the catheter, while a mixture of saline and blood was injected. The OCT structural images overlapped with the Doppler phase changes at two different times were shown in Figs. 1b and 1c. 3D simplified structure was then created in COMSOL (Comsol 5.3, Sweden) based on Fig. 1a. The saline and blood mixture was modelled as an incompressible Newtonian fluid. The carotid vascular model was modelled as Neo-Hookean hyperelastic material. The distribution of flow velocity and von Mises stress are shown in Fig. 1e.



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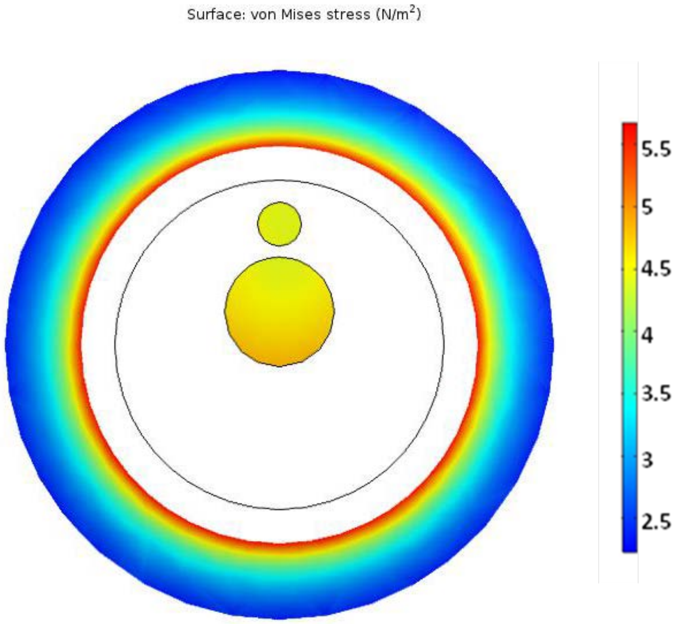

(e)

Figure 1: OCT imaging of porcine carotid artery: a) OCT 3D image of the artery; b) and c) blood flow profiles at two different times during flush. Scale bars represent 1 mm; d) velocity wave form of point A; e) von Mises stress distribution of a cross section

3 Discussion and conclusion

The velocity profile obtained from IVOCT imaging is integrated with numerical simulation. The velocity distribution shown in Fig. 1c does not show the umbilicate contour lines as shown in Fig. 1b, possibly because the geometric model is greatly simplified. Flow velocity at various flushing rate causes changes of the wall shear stress. In conclusion, the influence of imaging catheter to the flow and the vascular wall stress are studied by both experiment and simulation. The results will be beneficial for the biomechanical property studies of blood vessels and intravascular imaging guidance.

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