TOWARDS PERSONALIZED SIMULATIONS AS PRE-PLANNING TOOL FOR CARDIOVASCULAR PROCEDURES

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Background

Currently, computer modeling and simulation are increasingly mentioned as technology to represent and predict well-defined quantitative clinical endpoints. In cardiovascular applications, transcatheter aortic valve implantation (TAVI) and thoracic endovascular aortic repair (TEVAR) are examples of planned interventions to treat aortic valve and aorta disease respectively, while intra-arterial thrombectomy (IAT) is an emergency intervention to treat acute ischemic stroke. Despite their widespread clinical use, they still show some short- and long-term complications that require further investigation.

Recent Advances

Recently an inverse elastostatics method with exact linearization to obtain the zero-pressure configuration of the reconstructed-from-images vessels (Fig. 1a-2a) has been developed to obtain accurate results in terms of stress and strain field on the patient-specific domain.
TAVI (Fig. 1b) – Starting from the developed patient-specific fluid-structure interaction (FSI) methodology [1], recent studies concern the inclusion of the coronary arteries, the fluid domain validation within MRI scans, the TAVI in patients with bicuspid aortic valve [2].
TEVAR (Fig. 1c) – The same verification and validation analysis we proposed in [3] has been recently applied to different stent grafts in order to have a library of the most used devices available to perform FSI simulations. The in silico TEVARs have been recently used prior to the real interventions to help clinicians in the pre-operative decisions.

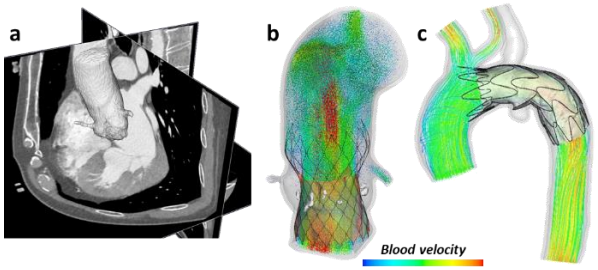

Figure 1: (a) reconstructed aorta for FSI (b) TAVI and (c) TEVAR patient-specific simulations.

IAT – The developed high-fidelity simulation to virtually reproduce the IAT has been validated with in vitro experiments [4-5] and used to model a patient-specific procedure [6]. Recently, we have investigated surrogate modeling techniques to have a real-time prediction of IAT outcomes [7].

Dr. Luraghi is currently Assistant Professor at Politecnico di Milano (Italy) from 2022 where she is the leader of the Computational Biomechanics Laboratory – Cardiovascular division. She is also Affiliated Research fellow at the Department of Biomechanical Engineering, Delft University of Technology (Netherlands) since 2020. She is a member of the ESB and ESB-Italian chapter since 2017 and of the VPH society since 2020. She is author of 30 publications in peer- reviewed journals and more than 50 contributions to International and National Conferences. She won the best Thematic Presentation for an in silico model (ESB-ITA 2019) and the best VPHi Student Award for the oral presentation (VPH 2018).

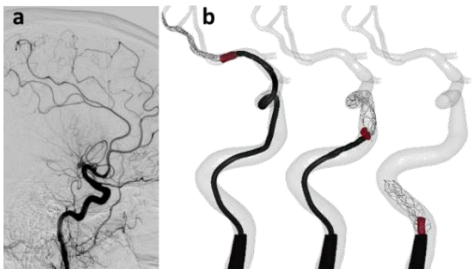

Figure 2: (a) angiography of a stroke patient and (b) simulated IAT to extract the thrombus.

Future directions

How these in silico technologies can be used, in which context, and at what point in time need to be always clarified when dealing with computational modeling. Personalized simulations as a pre-planning tool will be improved in the context of use of the single considered procedure: high-fidelity FSI models for the planned TAVI and TEVAR, surrogate models for the emergency IAT.

References

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Acknowledgements

The author thanks all the Computational Biomechanics Laboratory – Cardiovascular group members and collaborators who contributed to this work, in particular Sara Bridio and Anna Ramella.