A numerical and 3D printing framework for the *in vivo* mechanical assessment of patient-specific cardiovascular structures

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ABSTRACT

Computational simulations represent a powerful tool for the pre-procedural clinical assessment of minimally invasive cardiovascular interventions [1]. Patient-specific simulations rely on the accurate numerical implementation of both geometrical and mechanical features. While current imaging techniques are able to depict accurately patient-specific anatomies, at date, a similar image-based tool capable to retrieve subject-specific material properties is missing.

The scope of this study is to present a framework, involving *in silico* tools and 3D printing, for the refinement of an image-based technique [2] capable to retrieve *in vivo* patient-specific mechanical information from functional and morphological magnetic resonance imaging (MRI) data. The workflow consists in three main steps: (i) selection and mechanical testing of 3D commercially available deformable 3D printed materials; (ii) fluid-structure interaction (FSI) simulation of a vessel model under pulsatile regime; (iii) 3D printing of the model and experimental replica in MRI environment. Finally, the image-based technique is applied to both numerical (ii) and MRI data (iii) to retrieve material information to compare to reference (i).

The described workflow strategy was successfully implemented by our group. The deformable material TangBlackPlus FLX980 was selected and mechanically tested, resulting in an elastic module (E) of 0.50±0.02 MPa. A vessel model was designed for FSI simulations (E=0.50 MPa) as well as 3D printed with an Objet500 Connex machine (Stratasys, Minnesota, USA) to acquire MRI data. The image-based technique was used to retrieve the E value from numerical and experimental data. *In silico*, the indirect material evaluation resulted in E=0.49 MPa, while *in vitro* we found E=0.51±0.04 MPa. Moreover, other values of E (up to 32 MPa) were tested *in silico*, leading to matching results as well. Other deformable materials will be investigated, i.e. Agilus30 (Stratasys, Minnesota, USA) and Elastic and Flexible resins (Formlabs, Massachusetts, USA), by using the described framework. With further refinements, this strategy would lead to an indirect and image-based tool for the *in vivo* assessment of patient-specific material properties, thus enhancing the confidence of patient-specific computational models.

REFERENCES

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