HOW TO SHOW CREDIBILITY OF IN SILICO CLINICAL PROCEDURES: APPLICABILITY ANALYSES

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Introduction

In silico technologies are used to investigate aspects of prevention, diagnosis, follow-up, treatment and outcome of diseases. In particular, cardiovascular and neurovascular clinical procedures can be simulated using detailed -high-fidelity- computational models, but their credibility needs to be assessed. Model credibility is intended as the capability of a computational model to address a given question of interest (QOI) in a specific context of use (COU), through the collection of evidence [1].

The aim of this work is to show an in silico applicability analysis to (i) the thrombectomy and (ii) the Thoracic Endovascular Aortic Repair (TEVAR) procedure in order to deem them credible for use within the frame of in silico medicine.

First, the real environment setting (R-COU) and the physical experimental setting (R-VAL), and the corresponding computational models (M-COU and M-VAL) are described (figure 1 for the thrombectomy case). Then, the central body of the applicability analysis includes equalities and differences between all the described ingredients (R-COU, R-VAL, M-COU and M-VAL). The analysis ends with the conclusion of the credibility assessment.

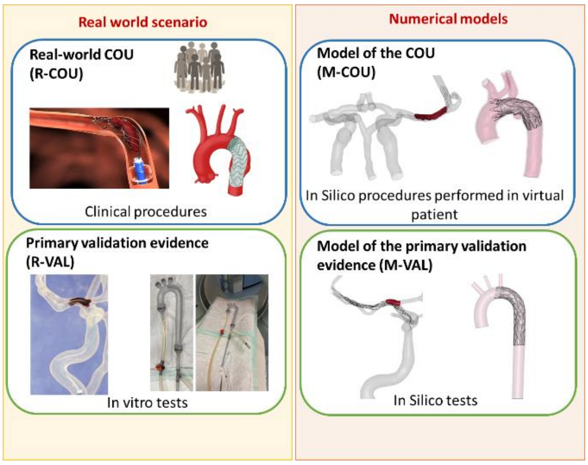

Figure 1: In silico thrombectomy and TEVAR procedures credibility: on the left, the real-world scenario of the context of use and validation evidence. On the right, numerical models of the context of use and validation evidence.

Credibility of the virtual thrombectomy procedure

Intra-arterial thrombectomy is a minimally invasive procedure for acute ischemic stroke in which the obstructing thrombus (clot) is removed using a minimally invasive device (stent-retriever). The stent-retriever is inserted from the femoral artery access to the thrombus location in the brain. After the deployment of the stent-retriever, the thrombus is removed by the retraction of the stent-retriever. The virtual procedure can be used as a tool to predict procedure outcome: positive if the clot removal is successful, or negative if the clot remains inside the vessel. In this view, the QOI is: "Is the thrombectomy procedure with a given stent-retriever capable of successfully removing a clot of a given composition, a given volume, from a given location?" [2]. The main validation evidence to demonstrate the applicability of the model is an in vitro thrombectomy performed in a silicone 3D-printed patient-like branch with a specific device and a specific clot analogue.

Credibility of the virtual TEVAR procedure

TEVAR procedure is a minimally invasive technique for treating aortic pathologies in which a self-expandable stent-graft is inserted and deployed in the pathological region to treat the patient and recreate a more physiological situation. The numerical model is able to simulate the stent-graft deployment and its interaction with the aortic wall. It can be used to predict the TEVAR outcome in a virtual population. In this view, the QOI is: "Will a given stent-graft model be successfully deployed in a given patient-specific aorta in a given position with respect to the location of the pathology (e.g. aneurysm, dissection, PAU)" [3]. As validation evidence, a rigid 3D printed idealized aorta is used to experimentally implant a stent-graft under a CT scan. The stent configuration obtained with the experiment is adopted to validate the simulation results.

Conclusion

Validation evidence sources are here identified for the specific context of use and adopted to demonstrate the applicability of the numerical procedures replicating thrombectomy and TEVAR procedures, thereby answering the specific questions of interest.

The discussed applicability analyses demonstrated that the developed in-silico models are trustworthy for replicating the clinical procedures in virtual patients.

References

1. Pathmanathan et al, J Verif Valid Uncert, 2(2), 2017.
2. Luraghi et al, J Biomech, 126, 110631, 2022.
3. Ramella et al, J Biomech, 146, 111423, 2023.