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MRI strain-based validation of patient-specific computational models of human hearts—building a target for *in silico* studies of surgical procedures

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ABSTRACT

Computational modeling is an integral part of the design and analysis in many engineering fields (*e.g.*, mechanical, civil, *etc.*) for the past several decades. However, it is only very recently that computational modeling is applied to biomedical areas, one of which is cardiology. Compared to other biomedical areas, computational cardiac modeling is still at its infancy primarily due to (*i*) the complexity of the system itself (multi-scale, multi-physics) and (*ii*) the difficulty in performing precise experiments to investigate mechanisms and validate models. To address the former issue, the model is typically constructed so that the validity of its prediction is balanced against its simplicity. On the other hand, the latter issue is continually addressed by new evolving experimental technologies, such as modern imaging tools (*e.g.*, MRI) that can measure deformation *in vivo* and most importantly, non-invasively.

In this presentation, we propose to review our generic cardiac computational modeling process applied to normal humans. Specifically, we show 1) how computational models can be directly constructed from MRI, 2) how inverse FE modeling was used to personalize each model, and 3) how each model was validated using MRI-based measurements. Following [1]□ and [2,3]□, we use an incompressible transversely isotropic Fung's law for the passive behavior (with 1/3 stiffness in cross-fiber direction compared to fiber direction), and a time-varying elastance law for active contraction (also with 1/3 contractility in cross-fiber direction compared to fiber direction). After the patient-specific anatomy has been extracted from MRI data, we optimize the scaling parameters of the passive and active constitutive laws for every normal ventricular pressure to match the volumes measured through MRI. We then validate the calibrated models by comparing FE-predicted and MRI-measured strains—the error in circumferential strain is typically *ca.* 10%. Finally, we compute the range of normal fiber stresses associated to normal ventricular pressures. The data presented here are derived from five normal human models. We

believe this data will serve as a target for any computational study of a cardiac surgical procedure.

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