FUNDAMENTAL INSIGHTS INTO STENT-VESSEL INTERACTIONS THROUGH A NOVEL CONSTITUTIVE LAW AND IN-SILICO FRAMEWORK.

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This study presents a subject-specific *in-silico* framework in which we uncover the structure-function relationship between the spatially varying constituents of the aorta and the non-linear compliance of the vessel during the cardiac cycle uncovered through our MRI investigations. We then proceed to uncover a fundamental insight into stent-vessel interactions, and describe the mechanism by which Nitinol stents affect local vessel compliance. First, a microstructurally motivated constitutive model is developed, and simulations reveal that internal vessel contractility, due to pre-stretched elastin and actively generated smooth muscle cell stress, must be incorporated, along with collagen strain stiffening, in order to accurately predict the non-linear pressure-area relationship observed *in-vivo*. Simulations reveal that collagen and smooth muscle volume fractions increase distally, while elastin volume fraction decreases distally, consistent with reported histological data [1]. The study then presents a computational analysis of the influence of Nitinol-based devices on the biomechanical performance of a healthy patient-specific human aorta. Simulations reveal that Nitinol stent-grafts stretch the artery wall so that collagen is stretched to a straightened high-stiffness configuration. The high-compliance regime (HCR) associated with low diastolic lumen pressure is eliminated, and the artery operates in a low-compliance regime (LCR) throughout the entire cardiac cycle. The slope of the lumen pressure–area curve for the LCR post-implantation is almost identical to that of the native vessel during systole. This negligible change from the native LCR slope occurs because the stent-graft increases its diameter from the crimped configuration during deployment so that it reaches a low-stiffness unloading plateau. The effective radial stiffness of the implant along this unloading plateau is negligible compared to the stiffness of the artery wall. Provided the Nitinol device unloads sufficiently during deployment to the unloading plateau, the degree of oversizing has a negligible effect on the pressure–area response of the vessel, as each device exerts approximately the same radial force, the slope of which is negligible compared to the LCR slope of the native artery. We show that 10% oversizing based on the observed diastolic diameter in the mid descending thoracic aorta results in a complete loss of contact between the device and the wall during systole, which could lead to an endoleak and stent migration. 20% oversizing reaches the Dacron enforced area limit (DEAL) during the pulse pressure and results in an effective zero-compliance in the later portion of systole [2].

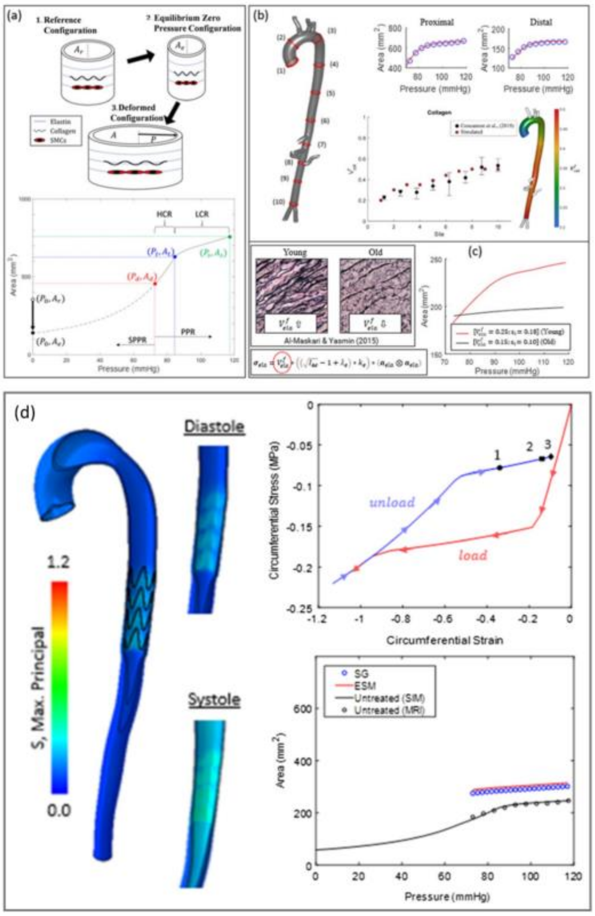

Figure 1: *(a) Microstructurally based constitutive law; (b) Patient-specific FE model fit to MRI data, and predictions of wall constituent volume fractions; (c) simulations of the effect of ageing on Pressure-Area curves; (d) Stent deployment in patient specific model resulting in loss of high-compliance regime of aorta.*

References

1. Concannon & McGarry (2021); Acta Biomaterialia, 125:154–171
2. Concannon et al., (2021); Biomechanics and Modeling in Mechanobiology, 20:2373–2392.

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