RISK ASSESSMENT OF ASCENDING AORTIC ANEURYSMS USING PROBABILISTIC MATERIAL PARAMETERS AND IN VIVO THICKNESS

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Introduction

Rupture and dissection are feared possible consequences of an ascending thoracic aortic aneurysm, associated with mechanical failure of the arterial wall. The failure risk of the aneurysm wall can be quantified as the difference between the *in vivo* wall stress and the wall strength. Estimating these values requires knowledge of material parameters, loading conditions and geometry of the aneurysm, all of which are affected by a high degree of uncertainty.

As a way to deal with this uncertainty, the concept of a probabilistic failure risk has been introduced, albeit for abdominal aortic aneurysms, by [1]. In this study, we have extended this approach by including the uncertainty related to the material parameters and *in vivo* thickness.

Materials & Methods

From 30 ATAA patients, 142 planar biaxial samples were tested to characterize the material behavior of the aneurysmatic tissue. Experimental stress-stretch curves were fitted according to [2], resulting in an estimation of a deterministic *in vivo* thickness at diastole H_{dias} and five material parameters of the Gasser-Ogden-Holzapfel model $(C_{10}, k_1, k_2, \kappa, \alpha)$ [3]. Based on all tested samples, probability density functions were generated for H_{dias}, C_{10} and k_1. The value for k_2 is treated as a constant, physiological value for now.

To estimate a patient-specific peak wall stress (PWS), the aneurysm was modeled as an axisymmetric thick-walled cylinder with a known inner diameter at diastole D_{dias}, and was prestressed based on the condition of static equilibrium of the diastolic configuration with a known blood pressure p_{dias}. The transmural distribution of the collagen fibers (κ, α) was determined according to [4]. The maximal stress was calculated by inflating the ATAA with a known systolic blood pressure p_{sys} and axially stretching with λ_{ax}, while the material parameters and *in vivo* thickness were obtained through random sampling from the generated probability distributions.

A lognormal probability distribution was assumed for the wall strength (Y) which was derived from literature [1]. The probabilistic failure risk (PFI) is defined as [1]:

$$\mathrm{PFI} = \int_0^\infty \left(\rho_{\mathrm{PWS}}(\mathrm{pws}) \int_0^{\mathrm{pws}} \rho_{\mathrm{Y}}(\mathrm{y})\, \mathrm{dy}\right) \mathrm{dpws},$$

with ρ_i the probability density function of the respective variable $\mathrm{i} = \mathrm{PWS}, \mathrm{Y}$.

Results

H_{dias} and C_{10} were fitted with a lognormal distribution, k_1 was fitted with a Weibull distribution. Figure 1 shows the probability distribution of the wall strength ρ_Y and the circumferential peak wall (Cauchy) stress ρ_{PWS} ($D_{dias} = 50$mm; $p_{dias} = 100$mmHg; $p_{sys} = 149$mmHg, $\lambda_{ax} = 1, k_2 = 3$), fitted over the histogram of PWS, resulting in a PFI of 12.48%.

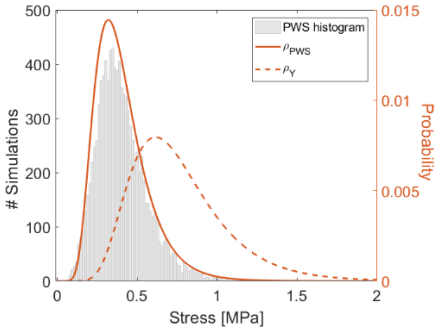

Figure 1: Histogram of PWS (gray), with fitted ρ_{PWS} (solid line) and ρ_Y (dotted line). For this patient, the PFI is 12,48%.

Discussion & Conclusion

Material parameters and *in vivo* wall thickness are inaccessible *in vivo* and reported values from *in vitro* experiments are varying drastically. Therefore, a probabilistic view on material parameters and thickness is highly encouraged and will enhance the trustworthiness of biomechanical-motivated failure risk assessment methods. In this study, stochastic distributions were fitted to a large database of estimated material parameters and *in vivo* wall thicknesses. This led to a patient-specific probabilistic *in vivo* wall stress and failure risk assessment.

Until now, the loading conditions and diameters were determined in a deterministic way. As a next step, the presented framework needs to be generalized by including the stochastic nature of the blood pressure and the uncertainty related to the diameter measurements.

References

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