Introduction

AAA rupture risk prediction using FEM

- Computational rupture risk indicators are superior to the diameter criterion [1]
- Most "patient-specific" models use population averaged model parameters

Existing uncertainties

- Computational geometries (e.g. wall thickness, stress free configuration)
- Boundary conditions (e.g. intra luminal pressure)
- Physical parameters (e.g. constitutive parameters)

Towards more reliable rupture risk prediction

- In absence of truly patient-specific parameters: Include uncertainties in the FEM analysis
- As a first step in this direction uncertain constitutive parameters are considered

Experimental research

Incorporation of approximate models [3]

Monte Carlo

- Tensile tests reveal significant inter- and intra-patient variations
- Random field approach to model fluctuations in the parameter $\beta$

Material behavior

- Stochastic extension of Raghavan and Vorp’s hyperelastic constitutive model for aneurysmal arterial wall [2]
- The parameter $\beta(x, \xi)$ is modeled as a three dimensional random field [4]:
  - Marginal probability density:
  - Autocorrelation function:

Stochastic Constitutive Law

Distribution of von Mises stress evaluated at the center of the dorsal surface of the aneurysm sac:

Propagation of Uncertainties

Monte Carlo

- Estimate the distribution of the quantity of interest $p_{\text{MC}}(y)$ directly using:
  - Minimal implementationl overhead
  - Extremely expensive, verification only

Incorporation of approximate models [3]

- Do sampling on cheap approximate model
- Establish a probabilistic link between high fidelity and approximate model with Bayesian regression
- Bayesian regression model $f(x, \theta)$
- Determination of posterior of the model parameters using Bayes’ rule and advanced SMC scheme with few selected training samples of high fidelity model

Distribution of von Mises stress evaluated at the center of the ventral surface of the aneurysm sac:

Efficiency

- Tremendous reduction in computational costs
- Up to factor 40 cheaper than direct MC on high fidelity model
- Additional potential through numerical continuation schemes

Conclusion and Outlook

- Population mean values are not good enough for patient-specific assessment of AAA rupture risk
- Strains exhibits large variations whereas stresses are only mildly affected
- Advanced UQ methods cut down the cost to acceptable level
- Include more sources of uncertainty and apply method to a larger patient cohort

References