

**Different AAA
biomechanical rupture risk
assessment approaches.
Model fidelity versus
diagnostic predictability**

T.Christian Gasser

KTH Royal Institute of Technology, Stockholm, Sweden

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on Aortic Diseases

New insights into an old problem

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Disclaimer

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Background

Based on a large number of interventions, a maximum transverse diameter of, on average, 55 mm appears to be the best indicator for elective AAA repair.

The UK Small Aneurysm Trial, Lancet 1998

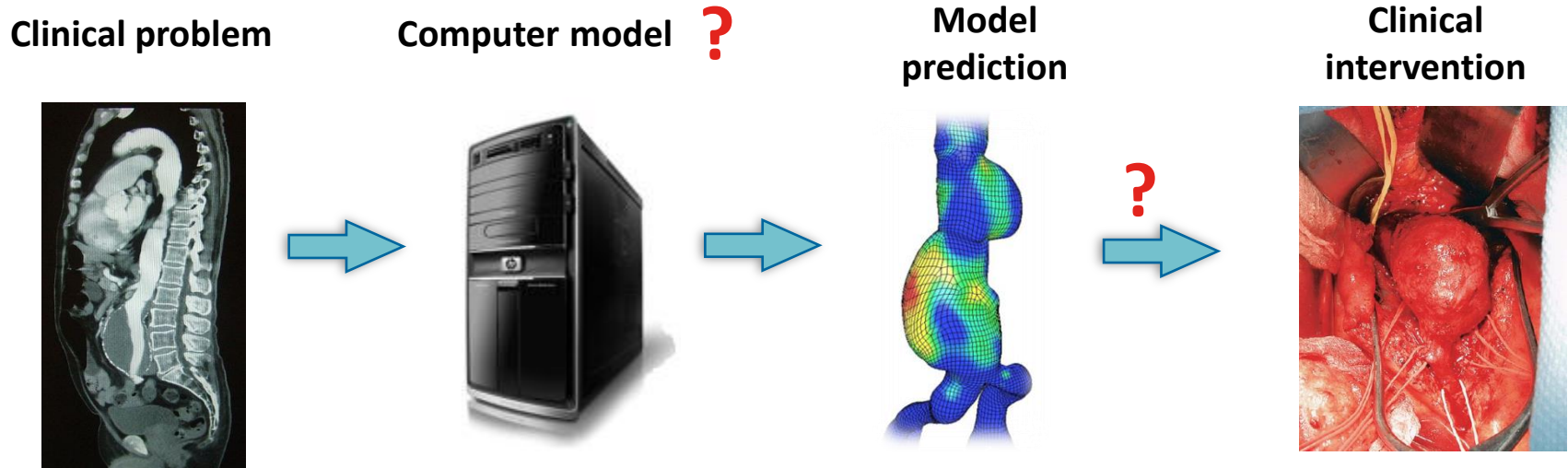
... but not for the individual patient!

Poor specificity and sensitivity

Nine out of ten operations are unnecessary

Biomechanical risk assessment

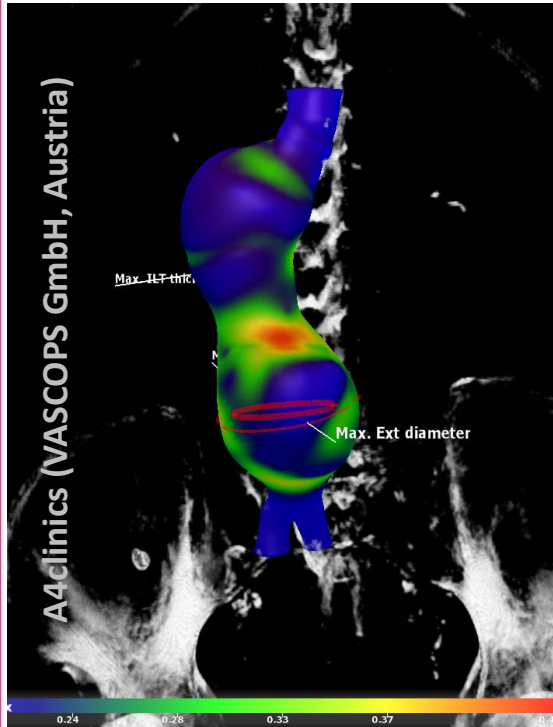
FE simulation integrated in clinical workflow



Biomechanical model fidelity? Which rupture risk index?



Peak Wall Rupture Risk (PWRI)



$$PWRI = \max \left[\frac{\text{Wall stress}}{\text{Wall strength}} \right]$$

Vande Geest, et al, ANABIOENG, 2006

Gasser et al, EJVES 2010



Validation

PWRI explains why....

... AAA rupture (retrospectively)

Fillinger et al, JVS 2002; Venkatas. et al, EJVES 2004; Heng et al, JVS 2008;
Maier et al, ABME 2010; Gasser et al, EJVES 2010/2014, ...

... AAA rupture (quasi-prospectively)

Erhart et al, JEVT 2016, Siika et al (submitted)

Biomechanical risk collocates with ...

... wall patho-histology

Hyhlik-Dürr et al, JEVT 2014

... FDG-uptake

Reeps et al, JVS 2008, Nchimi et al. Circ CVasclmag 2013

... site of rupture

Erhart et al, JEVT, 2016, Siika et al (submitted)

Biomechanical stress influences growth rates

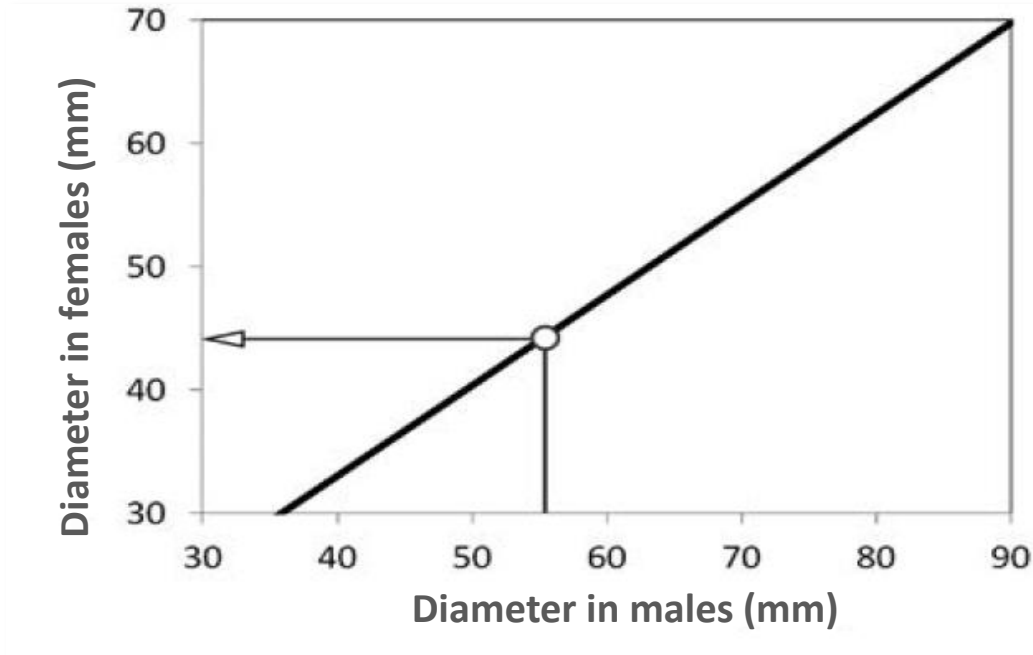
Martufi et al, JEVT 2016; Lindquist Liljeqvist et al, JVS 2016



Validation

PWRI explains why AAA in **females rupture at smaller diameters**

Larsson, et al, JVS 2011; Gasser et al, EJVES 2014





AORTA

State-of-the-Art Review

AORTA, [Month] [Year], [Volume], [Issue]: [Page range]
DOI: <http://dx.doi.org/10.12945/j.aorta.2015.15.030>

Received: October 7, 2015
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Published online: [Month] [Year]

Biomechanical Rupture Risk Assessment

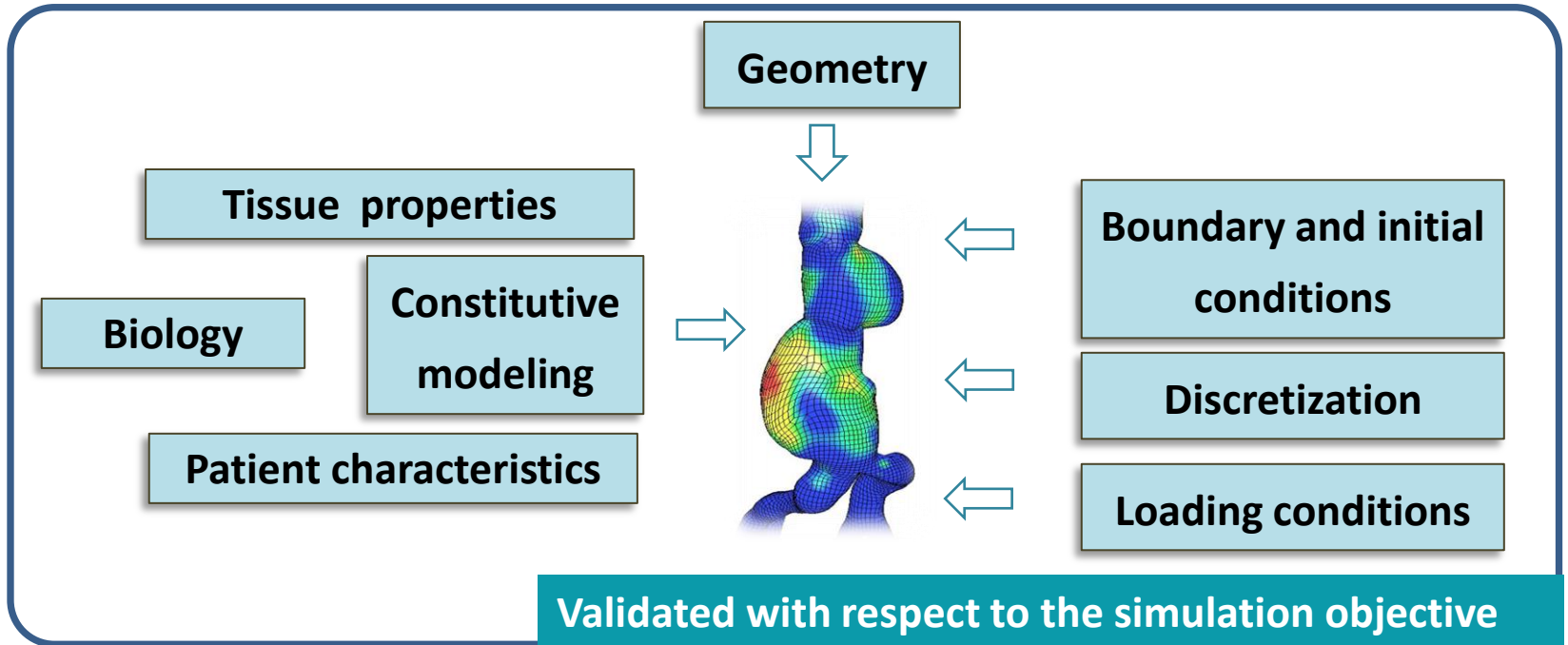
A Consistent and Objective Decision-Making Tool for Abdominal Aortic Aneurysm Patients

T. Christian Gasser, PhD

KTH Royal Institute of Technology, KTH Solid Mechanics, Stockholm, Sweden

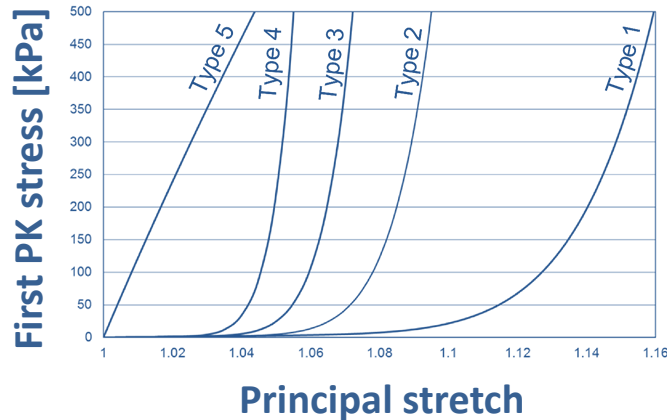
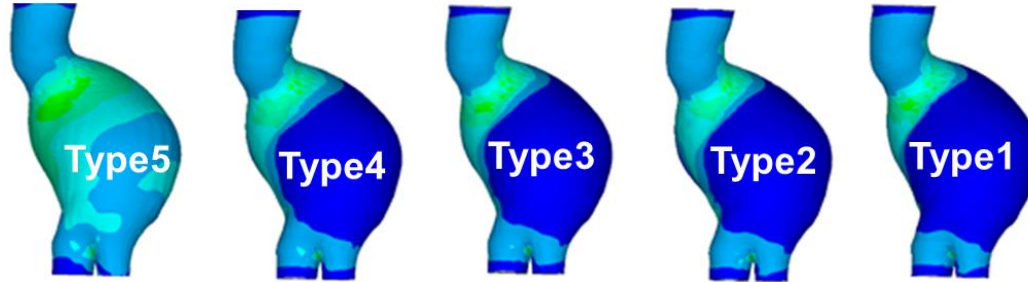
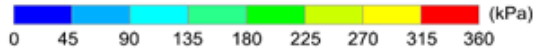


Input information





How complex should the wall model be?



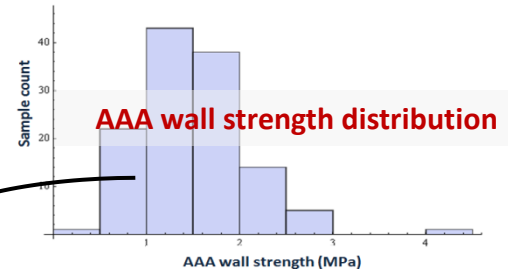
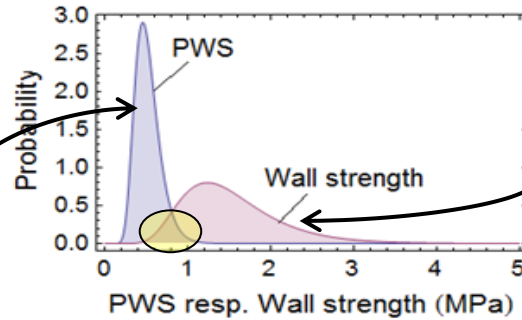
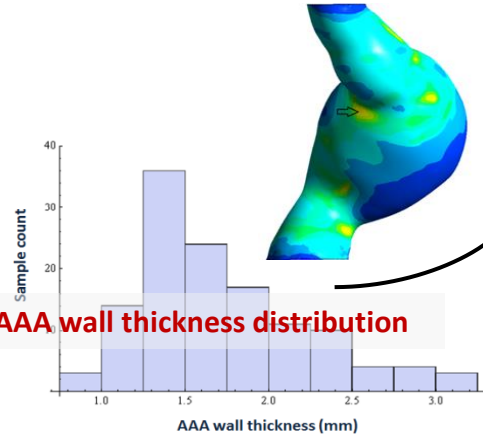
Man et al Med Engrg & Phys, 2018
Polzer et al Med Engrg & Phys, 2013



Probabilistic Rupture Risk Index (PRRI)

Polzer et. al, Med. Engrg & Physics 2013.

Polzer, et al. Ann. Biomed. Eng. 2012.



Reeps, et al. Biomech Model Mechanobiol, 2013

Reeps, et al. Biomech Model Mechanobiol, 2013

$$PRRI = \int_0^{\infty} \left(\rho_{PWS} \int_0^{\overline{\rho_{PWS}}} \rho_Y d\rho_Y \right) d\overline{\rho_{PWS}}$$

Polzer & Gasser, Royal Soc. Interface, 2016



Study design

48 cases from Saint Ann Faculty Hospital Brno, and General Faculty Hospital Prague, Czech Republic

In 2009 to 2016 a CT-A scans showed an intact AAA

No repair has been carried out (patient noncompliance or comorbidities)

16/48 cases ruptured at a later time point



Method/Analysis

Risk indices

Maximum diameter

Peak Wall Rupture Index (PWRI)

Probabilistic Rupture Risk Index (PRRI)

Sensitivity analysis

Receiver Operator Characteristics (ROC)

Predict rupture in 3/6/9/12/18/24/more month



Six month predictability

Receiver Operator Characteristics (ROC)



Conclusions

Biomechanics-based risk indices have **higher predictability** than the diameter

PRRI slightly better than PWRI

Predictability decreases with the time to the event

Integration of additional risk factors might further improve PRRI and PWRI

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