The biomechanical AAA rupture risk

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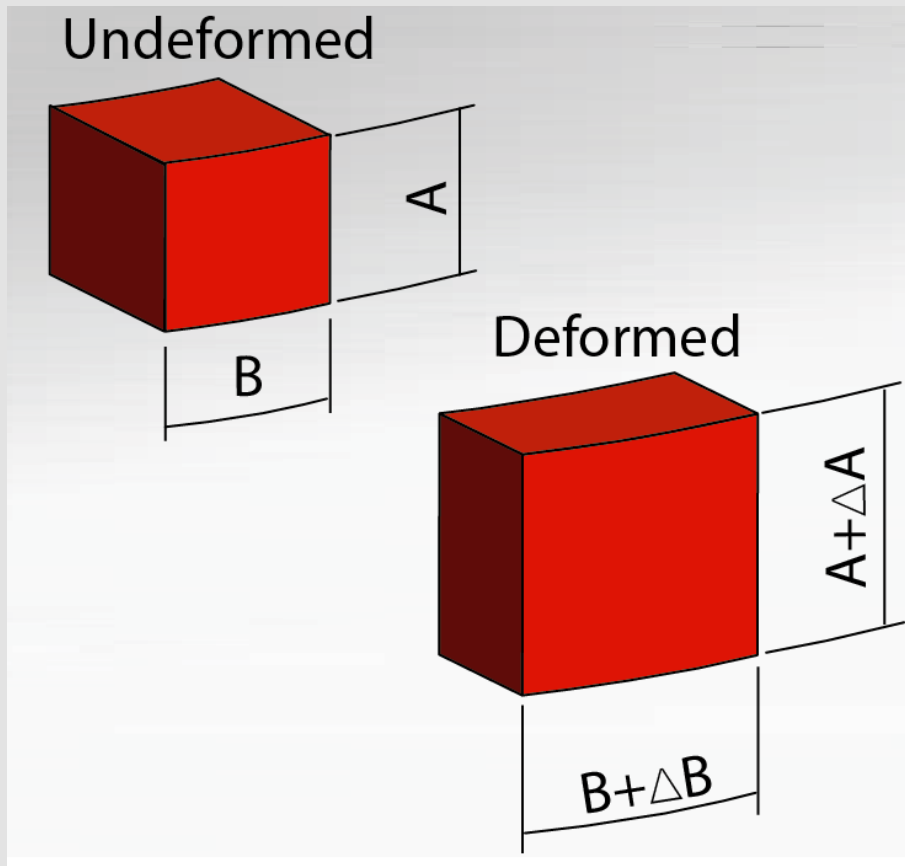**What's tissue biomechanics?**

How does biomechanics help?

What can we realistically dream of?

Mechanical strain
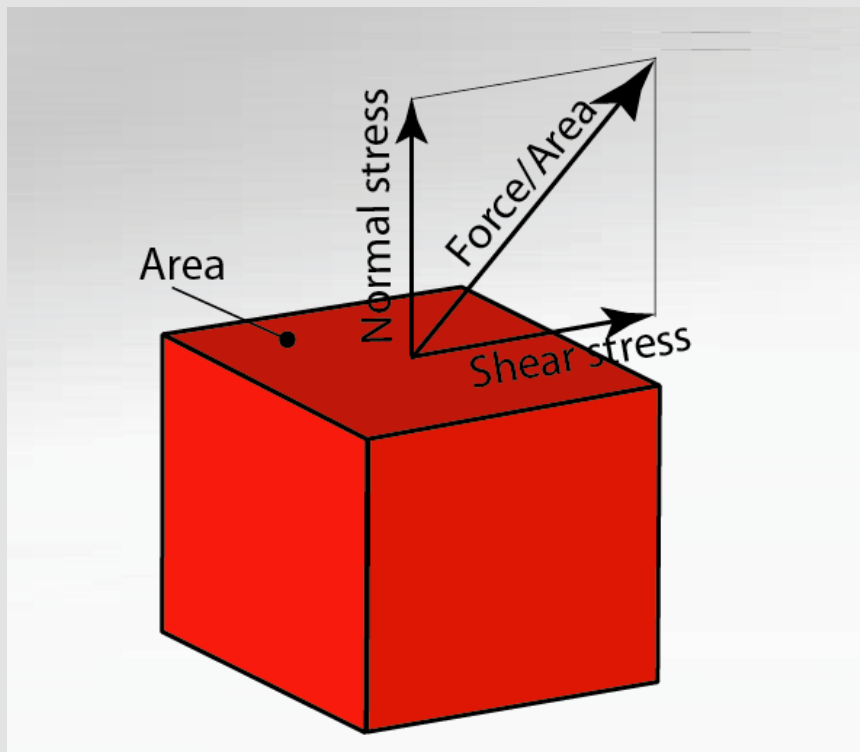

$$\epsilon_A = \frac{\Delta A}{A}$$

$$\epsilon_B = \frac{\Delta B}{A}$$

Mechanical stress
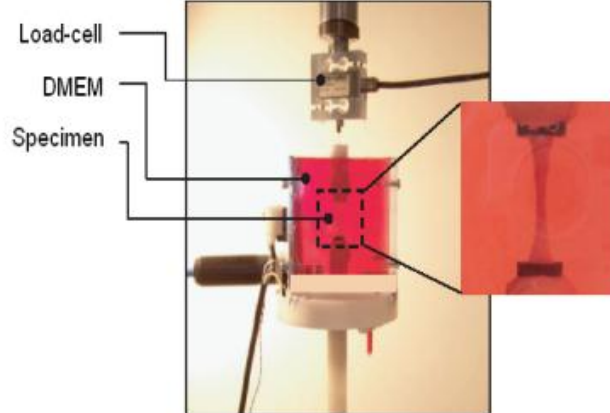
$$\text{stress} = \frac{\text{Force}}{\text{Area}}$$

Normal stress

Shear stress

Constitutive model

Strain

Mechanical Testing

Load-cell
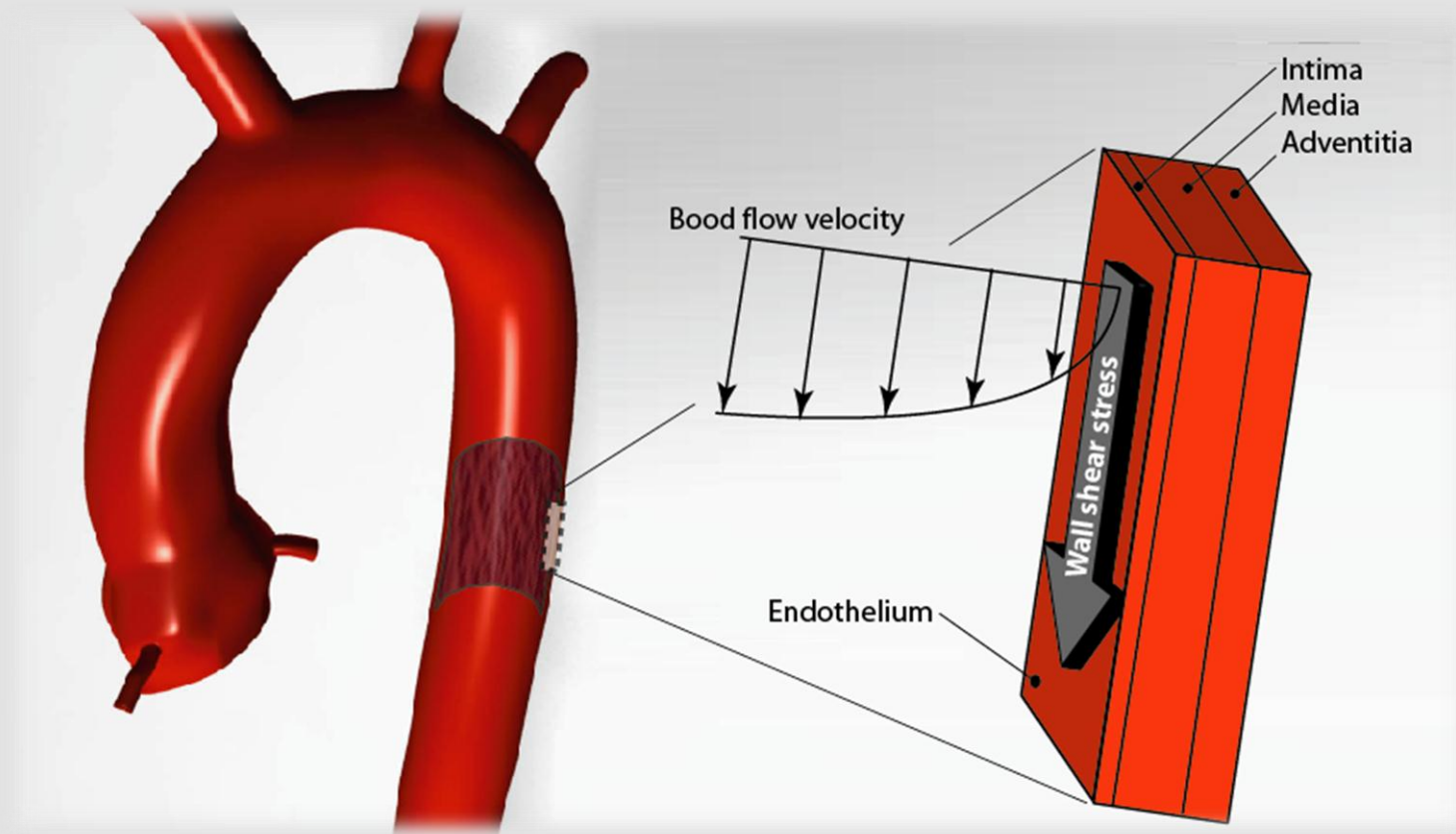DMEM
Specimen

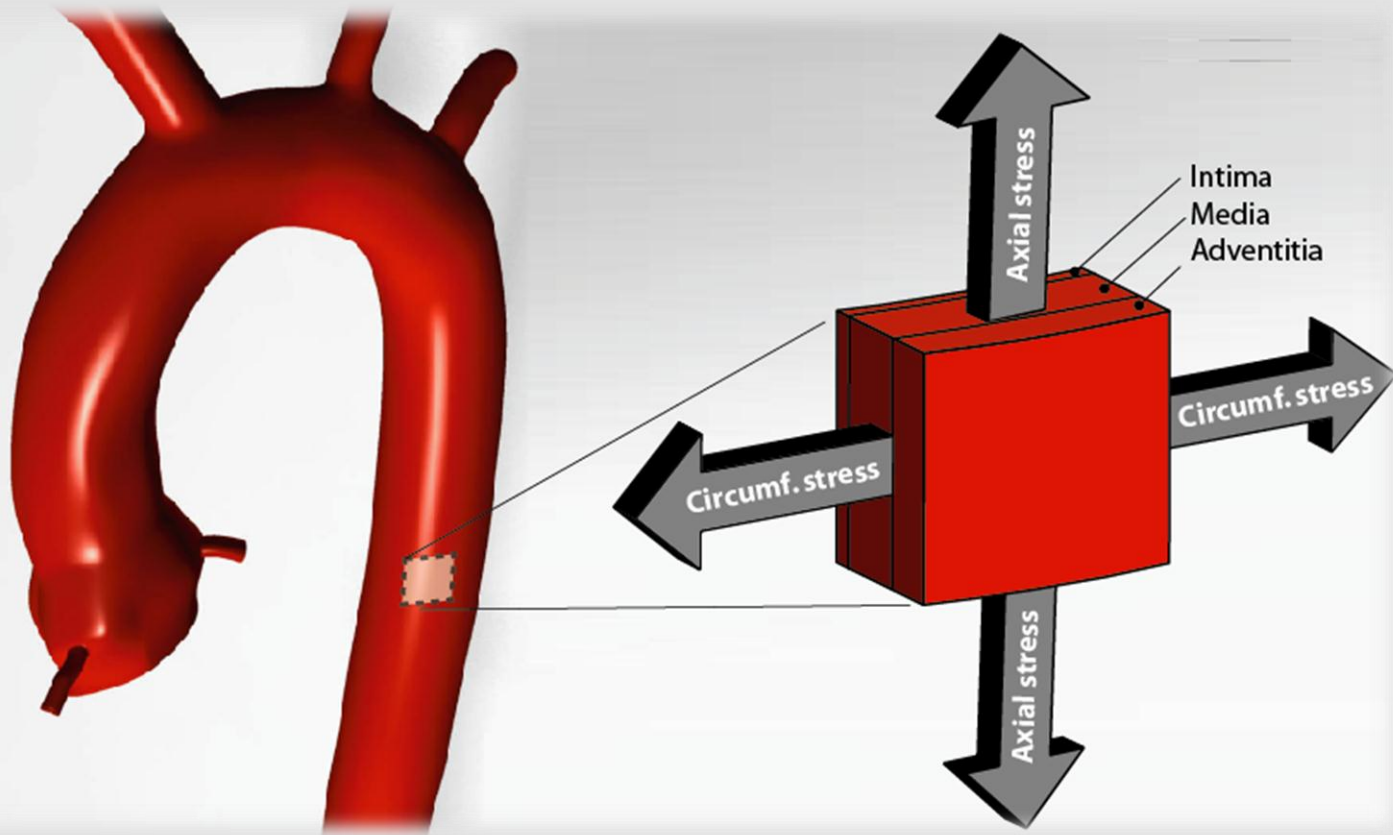Stress

Length scale
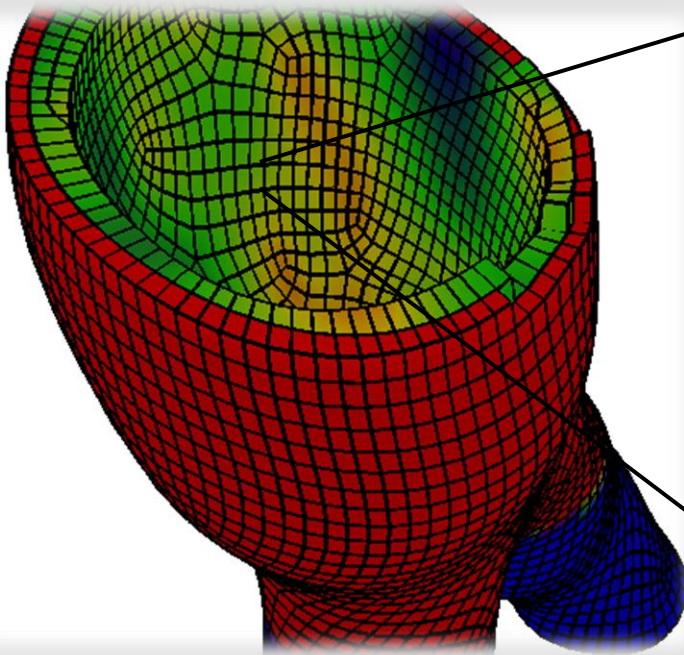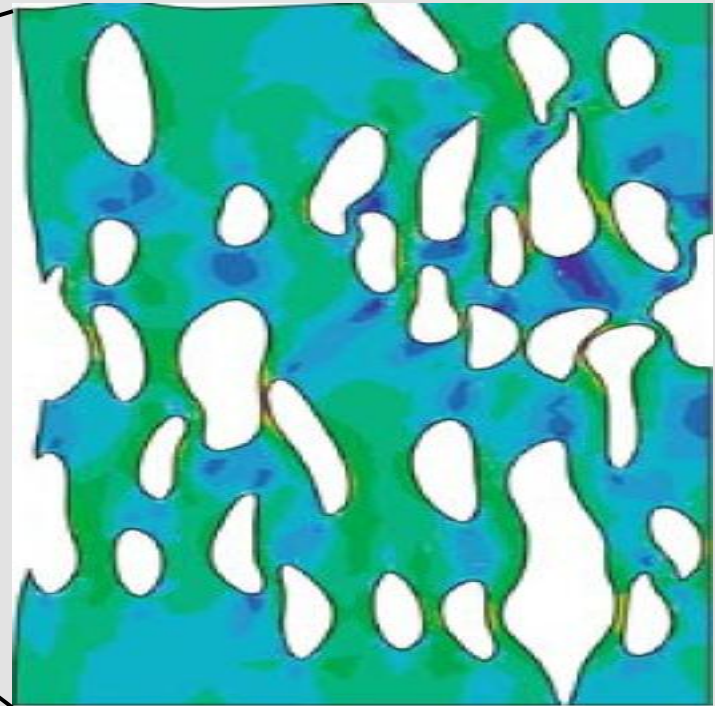
| ▬▬▬ 1 cm | ▬▬▬ 0.1 mm |

Wall shear stress – Blood flow

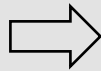# Wall stress – Blood pressure

What's tissue biomechanics?

How does biomechanics help?

What can we realistically dream of?

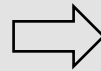# Biomech. rupture risk assesment

Workflow

Clinical Problem   **Comp. Model**   **Model Prediction**   **Treatment**
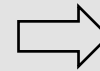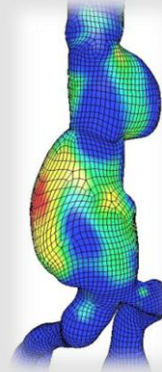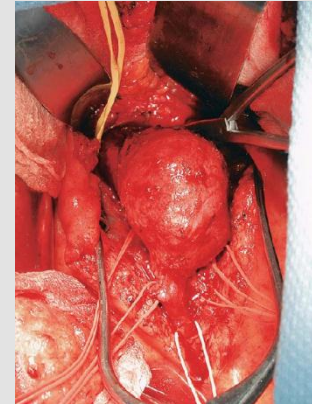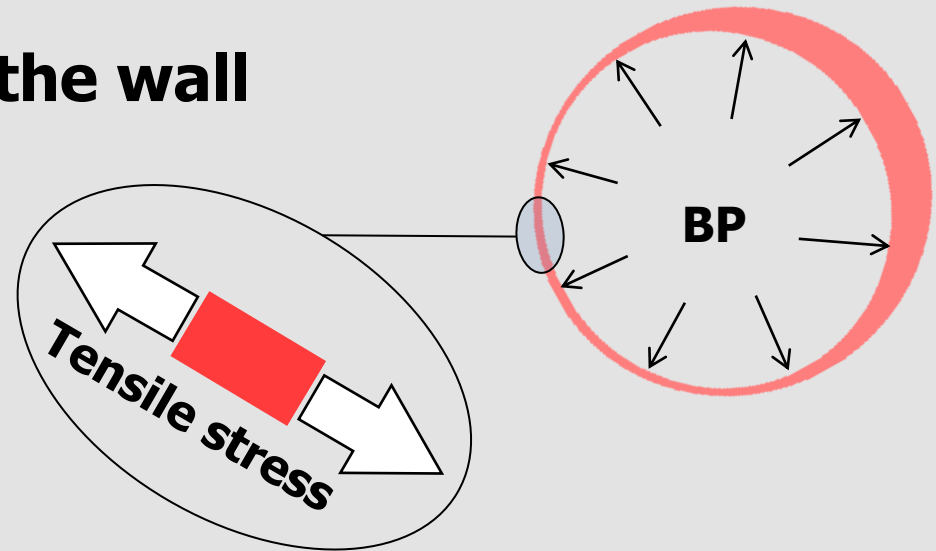

Predictions are computed through Finite Element (FE) Models using the A4clinics (VASCOPS GmbH, Austria) software

Biomech. rupture risk indicators

Mechanical loading of the wall

Peak Wall Stress (PWS)

...identifies the maximum tensile stress in the wall

Peak Wall Rupture Risk (PWRR)

...relates the tensile stress to wall strength

Biomech. rupture risk indicators

Quantitative integration of risk factors

	diamter	shape	gender	BP	ILT	fam. history	rel. diamter
PWS	X	X		X			
PWRR	X	X	X	X	X	X	X

Peak Wall Stress (PWS)
Peak Wall Rupture Risk (PWRR)

Inter- and Intra-observer variation

Hyhlik–Dürr et al, JVET 2011.

Arno Teutelink et al, JVS 2012.

Retrospective study: Do biomechanical indices discriminate between ruptured and intact AAAs?

Fillinger et al, JVS 2002.
Venkatasubramaniam et al, EJVES 2004.
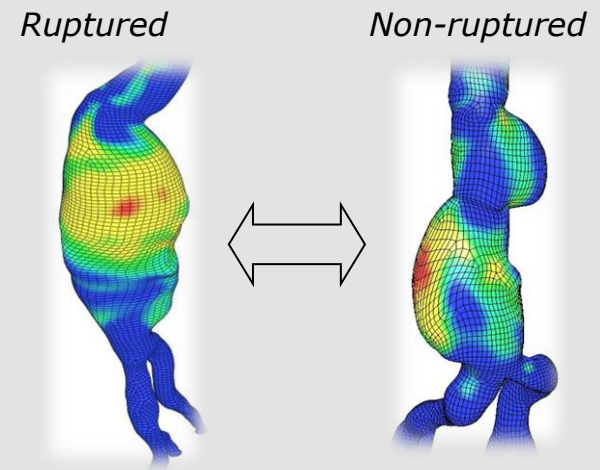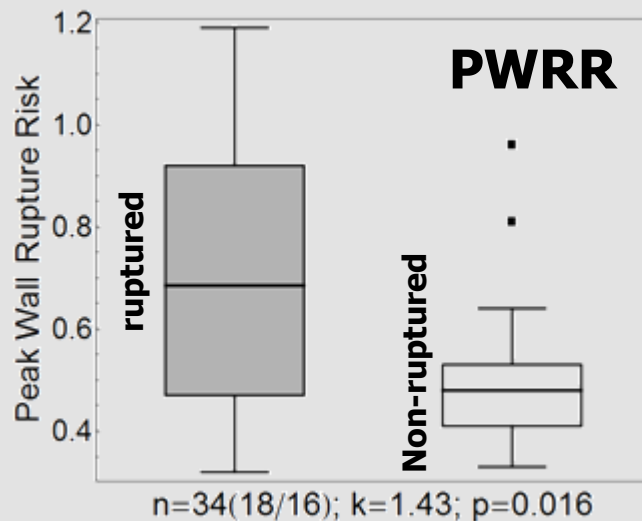Heng et al, JVS 2008.
Maier et al, ABE 2010.
…

Department of Vascular Surgery, Karolinska University Hospital and Institute, Stockholm, Sweden

Gasser et al, EJVES 2010.

Retrospective study: Do biomechanical indices discriminate between ruptured and intact AAAs?

PWRR index is superior to the diameter

How to translate the message?

Multicenter study including 200 AAAs to define PWRR of the average AAA patient

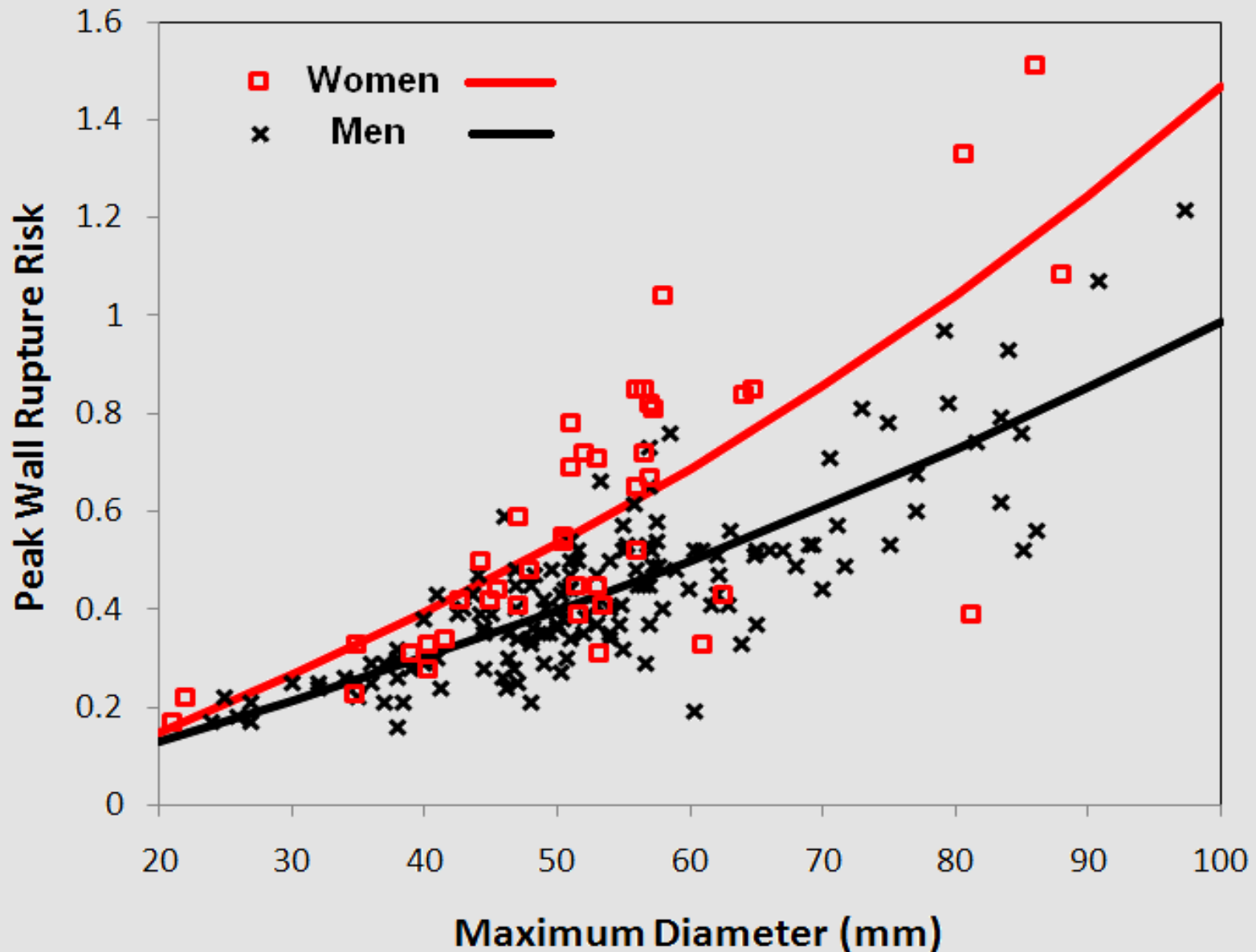Karolinska University Hospital and Institute, Stockholm, Sweden

St. Göran Hospital, Stockholm, Sweden
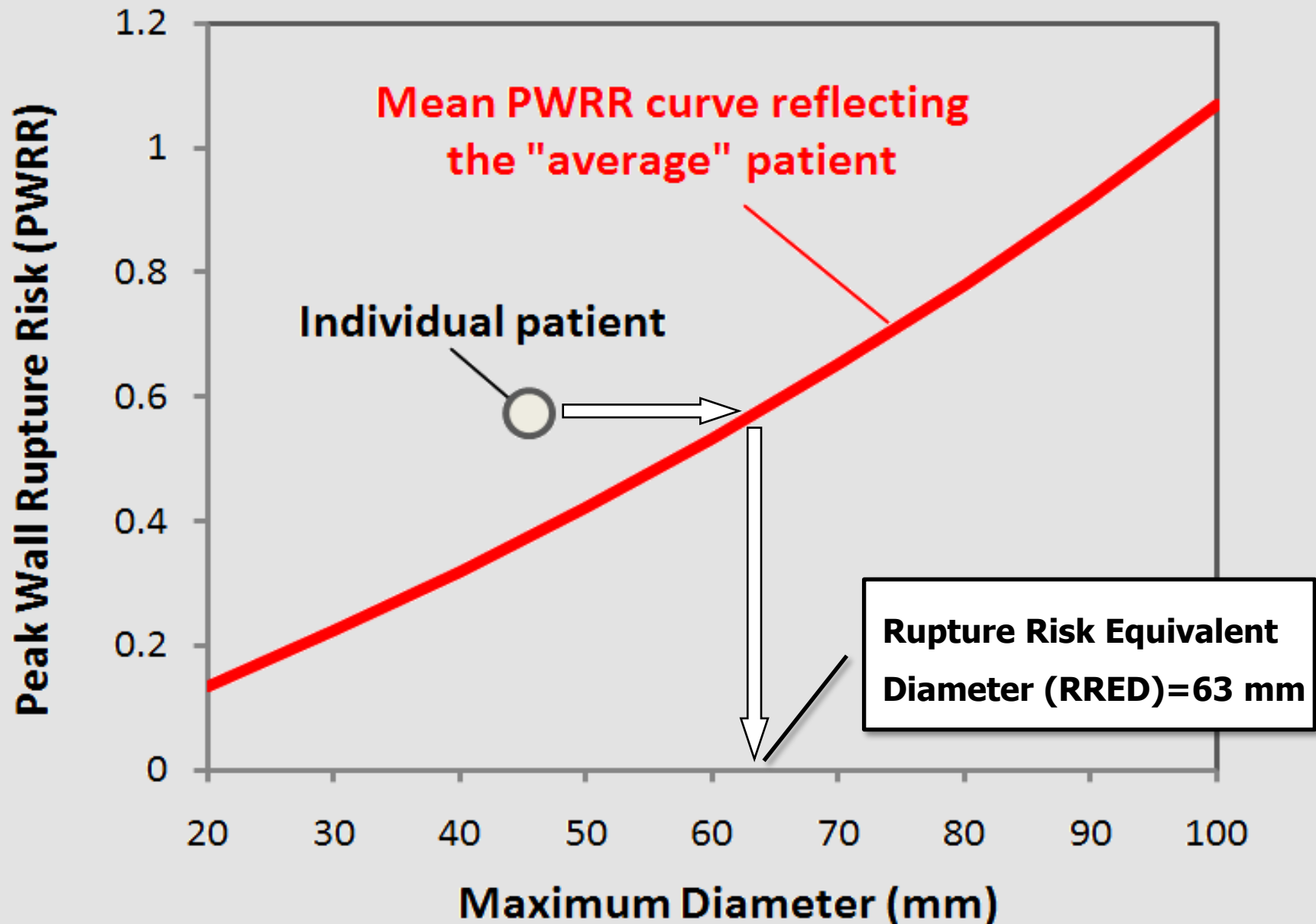
University Hospital of Liege, Belgium

St. Joseph Hospital of Liege, Belgium

Ruprecht - Karls University Heidelberg, Germany

The average AAA patient

The average AAA patient

Mean PWRR curve reflecting the "average" patient

Individual patient

Peak Wall Rupture Risk (PWRR)

Maximum Diameter (mm)

Rupture Risk Equivalent Diameter (RRED)=63 mm

Objectives

What's tissue biomechanics?
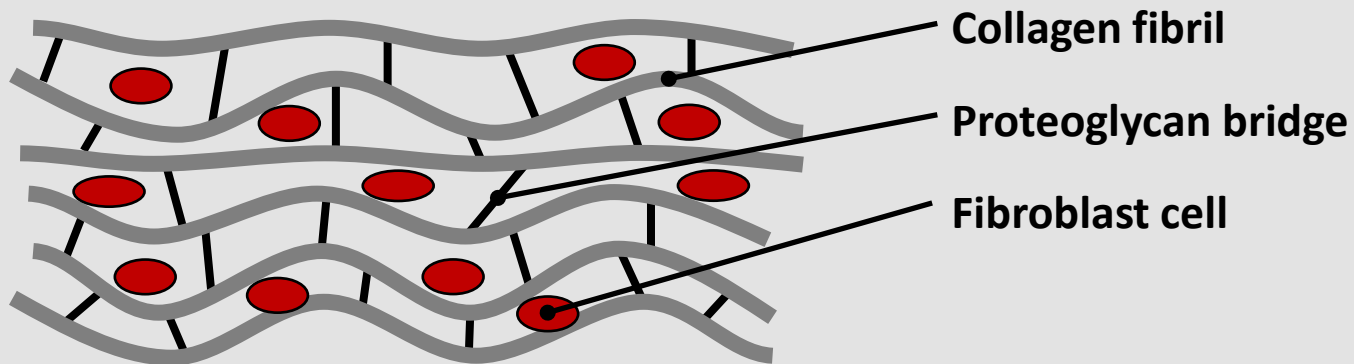
How can biomechanics help?

What can we realistically dream of?

Improve the stress predictions

Remodeling of the AAA wall

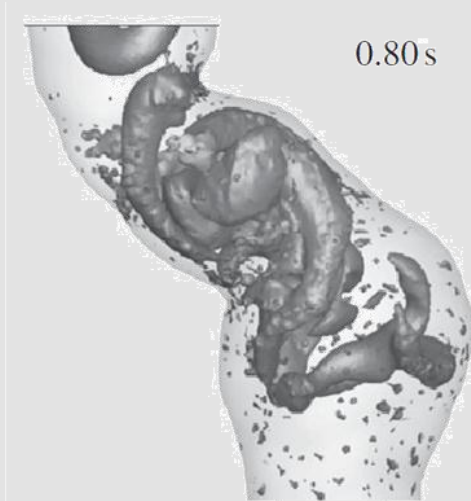Collagen fibril

Proteoglycan bridge

Fibroblast cell

Martufi & Gasser, Royal Soc Interface (2012)

Further improvements
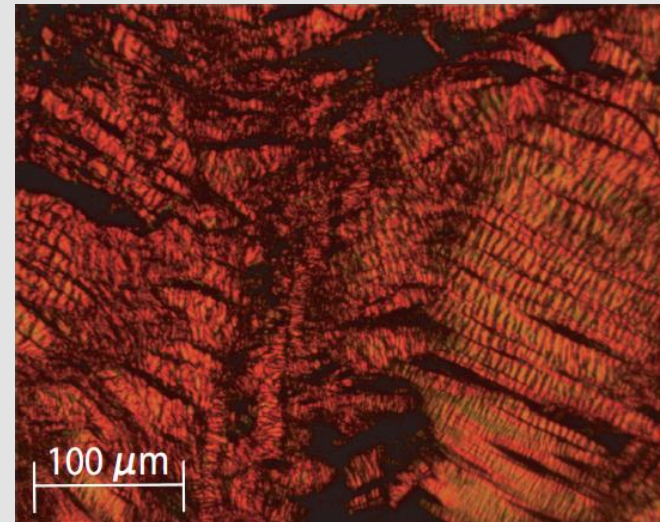
Better understanding of AAA wall strength

Patient characteristics (gender, diabetes, COPD …)

Local heterogeneity (ILT, expansion rate, PET, WSS, …)

0.80 s

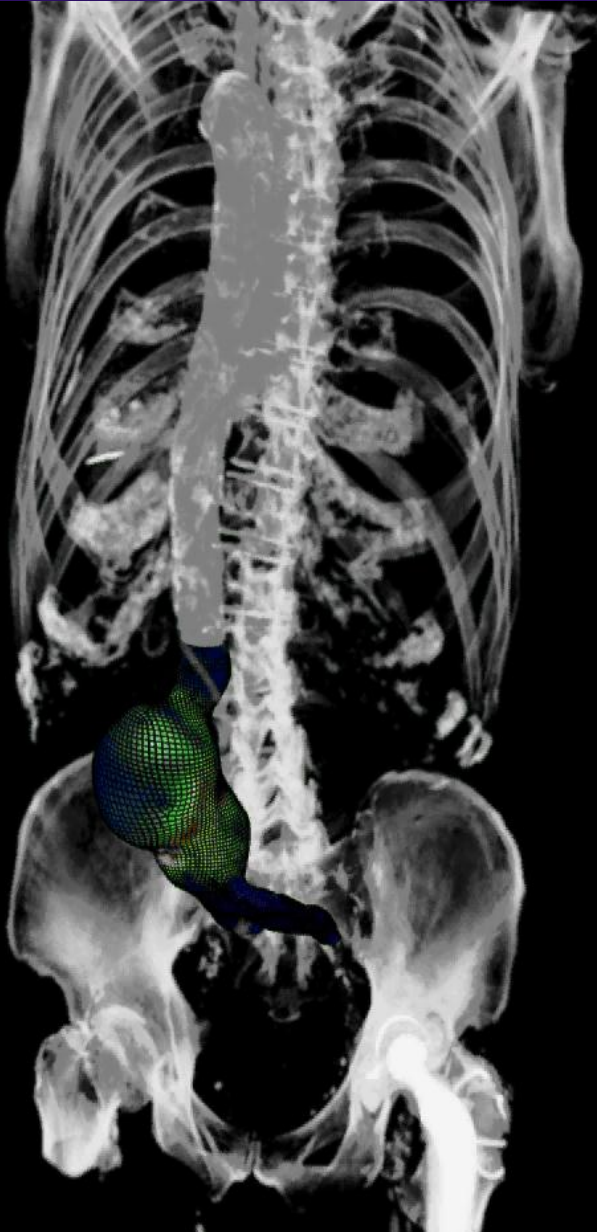**Vortical Structure (VS) dynamics**

Biasetti et al, Royal Soc Interface (2012)
Biasetti et al, Front. Physio (2012)

100 μm

Collagen in AAA wall of COPD patient

Gasser et.al, Acta Biomat., 2012
Forsell et al, in revision

Conclusions

➢ **Biomechanics analysis enriches the AAA rupture risk assessment**

➢ **Peak Wall Rupture Risk (PWRR) index quantitatively integrates risk factors**

➢ **PWRR was translated to the Rupture Risk Equivalent Diameter (RRED)**

➢ **Computer models are approximations to the real world** (Remodeling, cause for diversity in wall strength, …)