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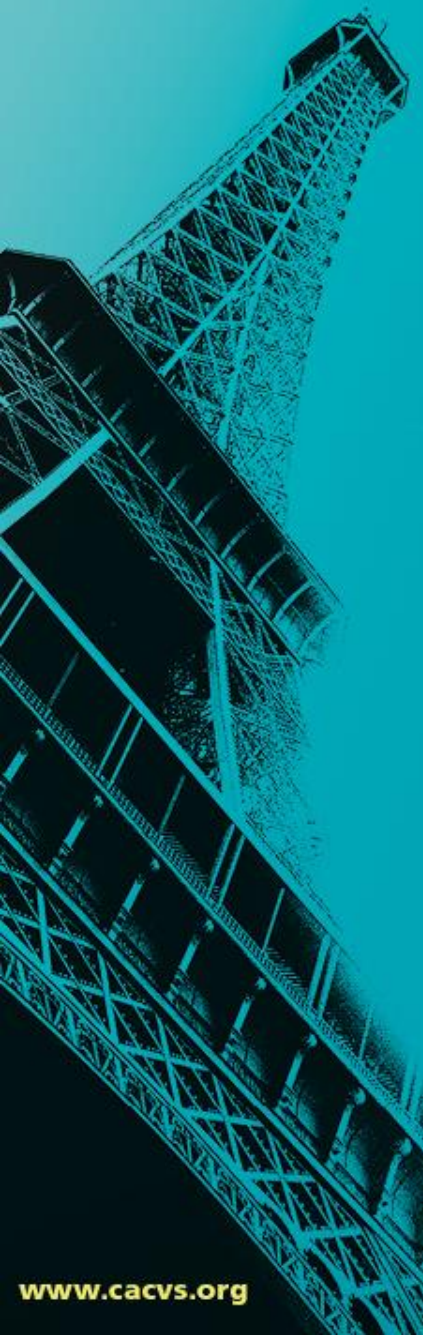

Can rupture be predicted by 4D US wall stress analysis

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Disclosure

Marc RHM van Sambeek

I have the following potential conflicts of interest to report:

Consulting and speakersfee

- W.L Gore & Associates
- Medtronic

Unrestricted research grants

- Medtronic
- W.L Gore & Associates
- Philips Healthcare

From a biomechanical point of view, aneurysms will rupture if the mechanical stress exceeds the local strength of the vessel wall.

Therefore,

the state of the aortic wall
the mechanical properties of the wall and
stresses in the wall combined

could be a better predictor for rupture risk than AAA diameter.

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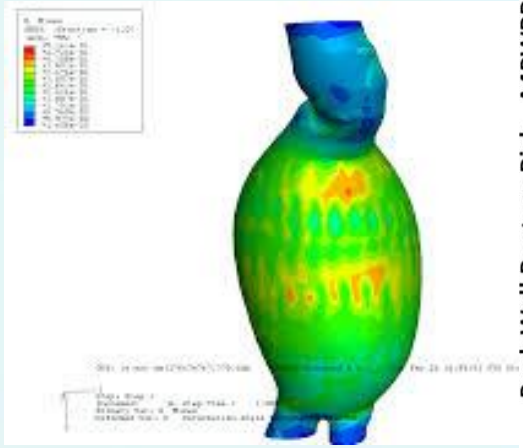
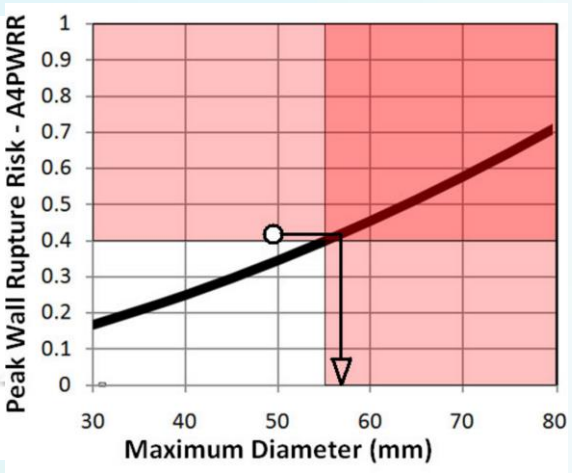
Finite Element Analysis

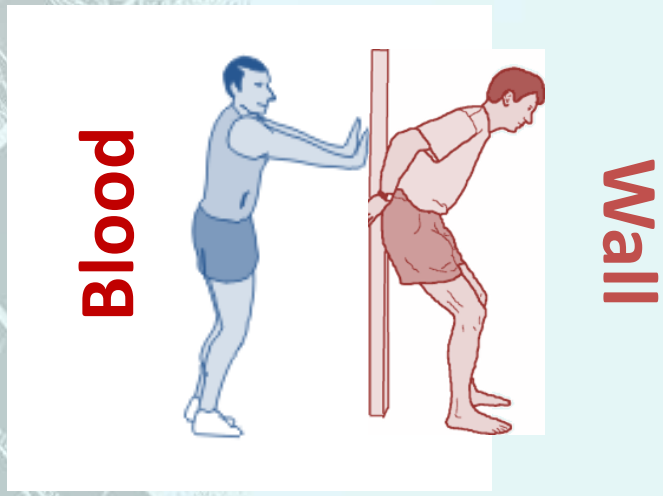
In recent years, 3-D image-based biomechanical models using finite element analysis (FEA) have been on the rise, providing additional parameters such as wall stress.

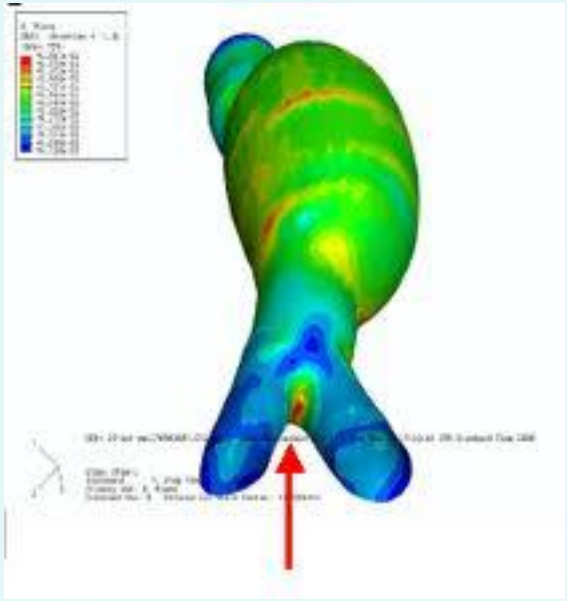
Wall stress analysis has been introduced to "predict" growth and potential rupture risk of the AAA wall, which is mostly performed using CT and sparsely with MRI.





Mechanical modeling:





However there are limitations with CTA and MRI:

Semi patient-specific mechanical AAA model

Unsuitable for longitudinal studies

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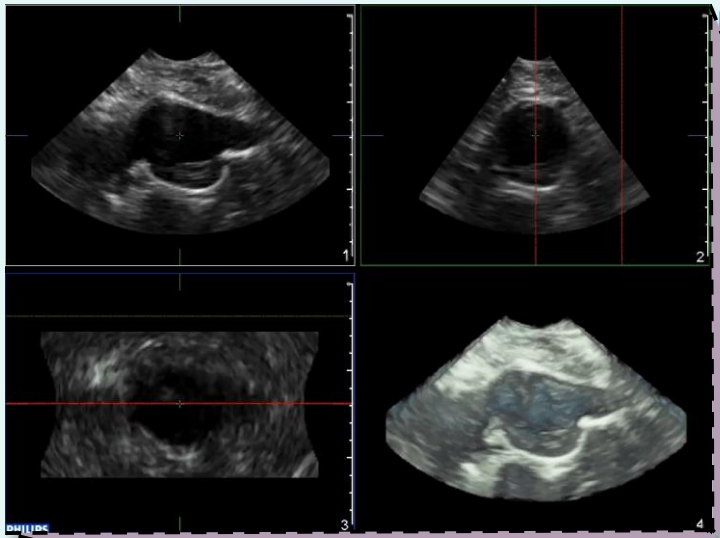
Large clinical study



Pre-operative monitoring

Acquire 3D and 4D (3D+t) US:

- 3D acquisition for geometry
- 4D acquisition for dynamic behaviour

Now:

- Following > 300 patients
- Longitudinal study
- Clinical CT data for verification

Goal:

- Develop and validate a patient-specific method using 4D ultrasound

Equipment:

Philips iU22
X6-1 matrix probe
f_c = 3.5 MHz

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CT-scan vs 4-D Ultrasound

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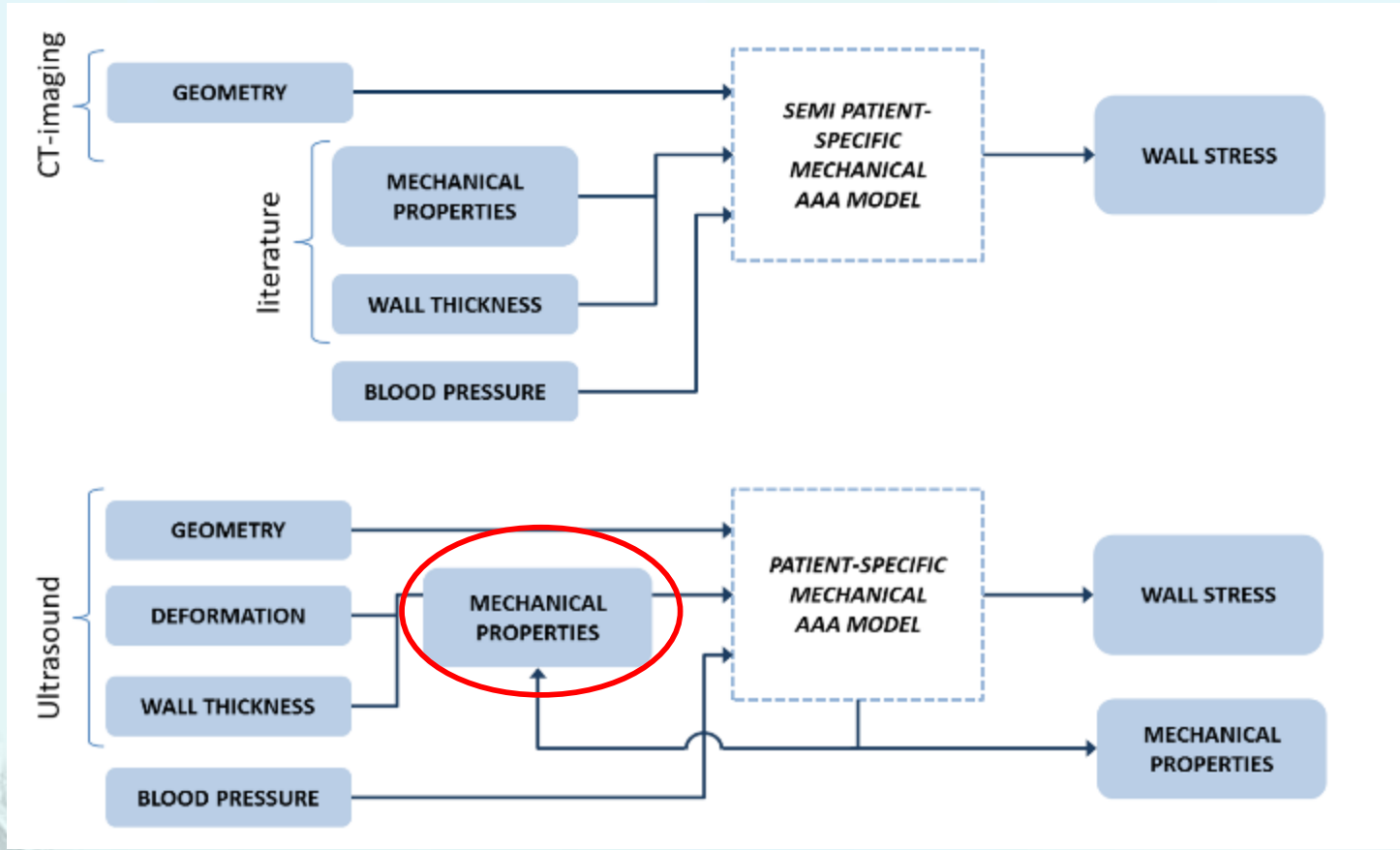

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From strain imaging & elastography to patient specific modelling

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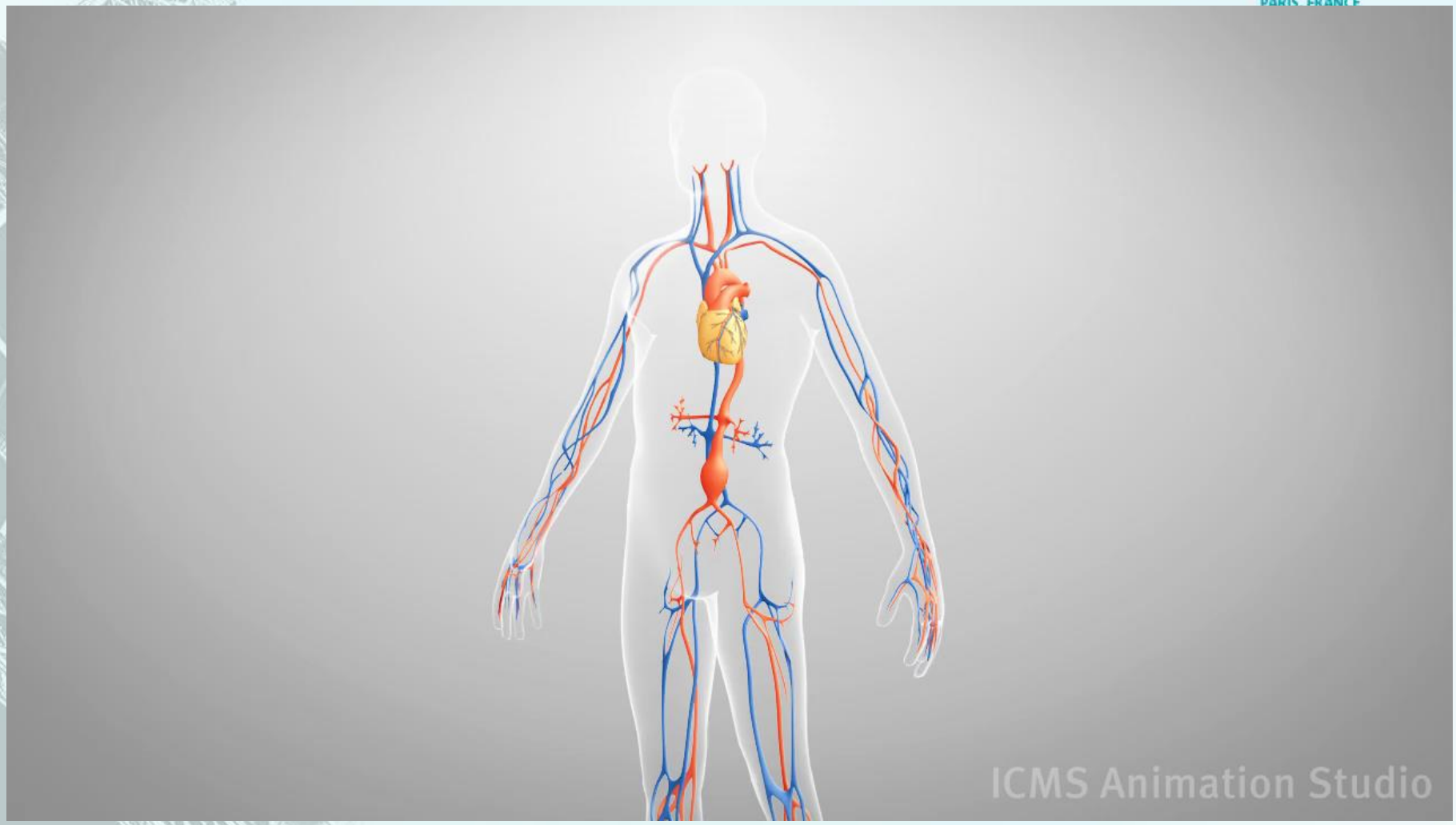

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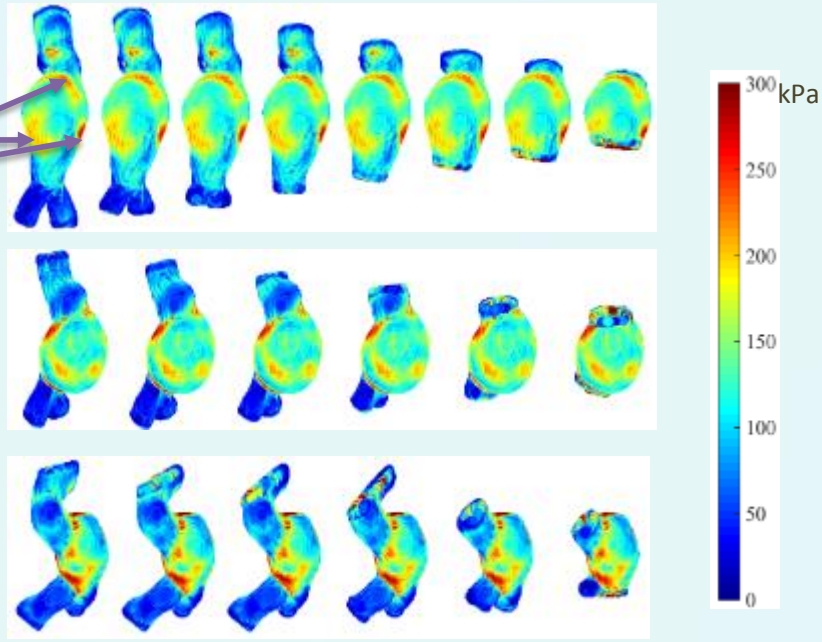
4D Ultrasound data

No ionizing radiation / contrast	4D data	Limited field of view	Low contrast
↓	↓	↓	↓
Allows follow-up over time	Mechanical characterization	Can we obtain an accurate geometry?	Can we obtain the same wall stresses as with CT?

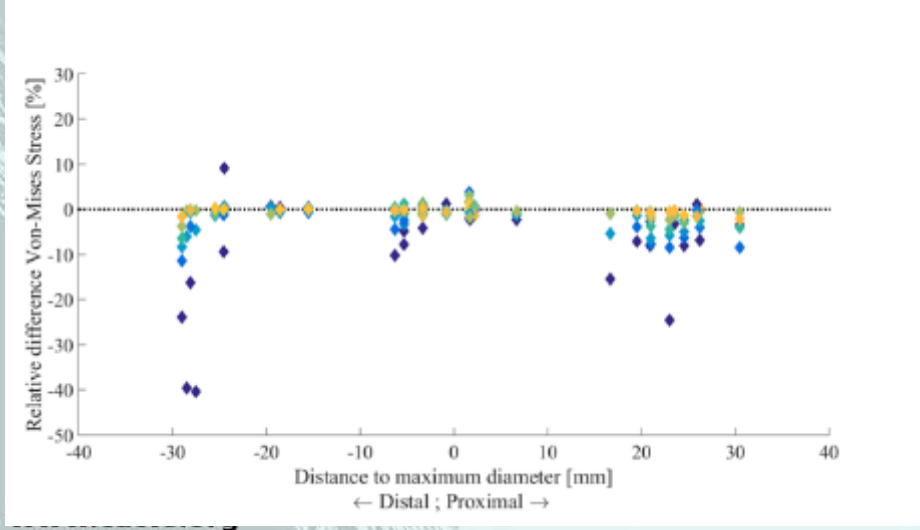
Von-Mises wall stress:

Limited field of view

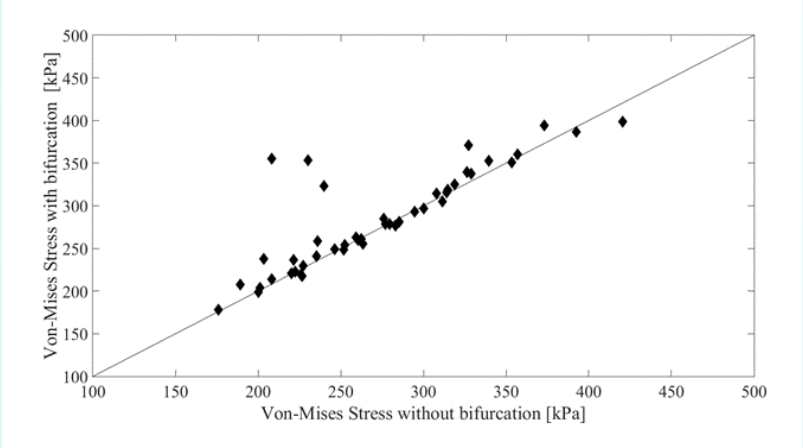
High stress regions:



You need the shoulders



You do not need the bifurcation

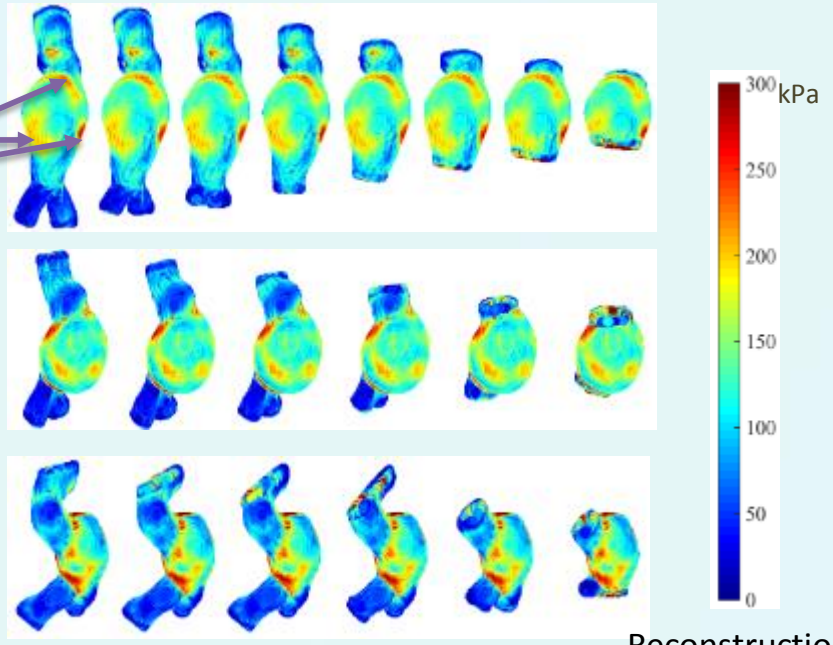


van Disseldorp et al. JBM 2016; 49:2405-12

Limited field of view

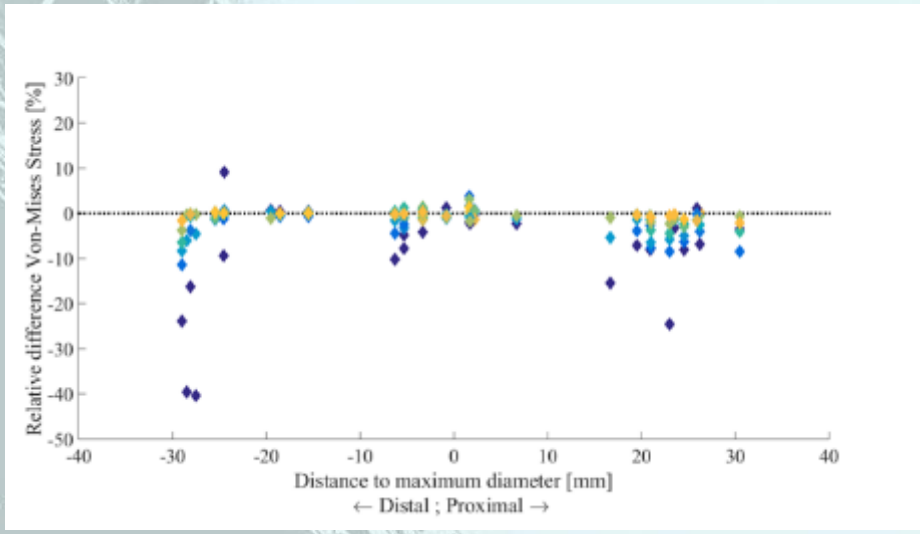
Von-Mises wall stress:

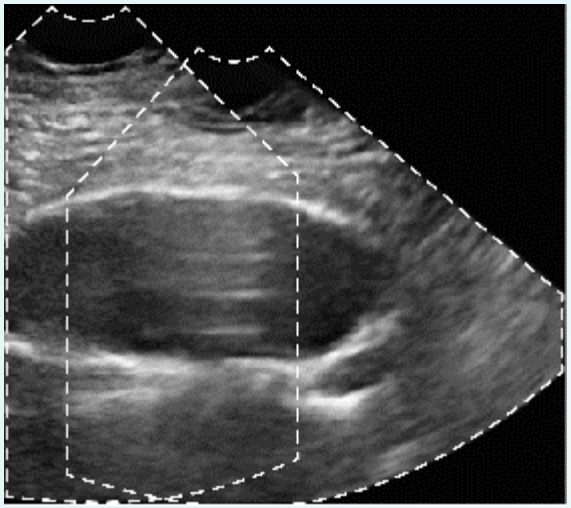
High stress regions:



Reconstruction

You need the shoulders





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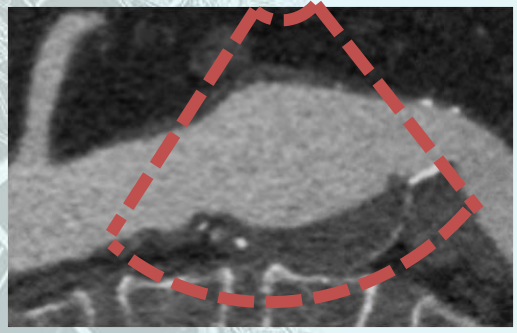
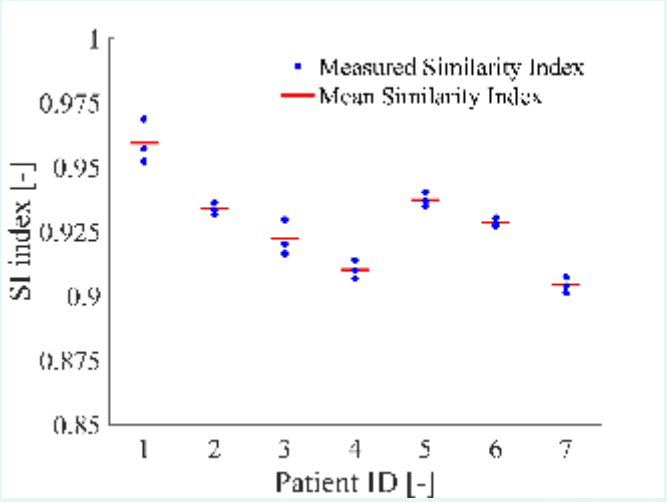
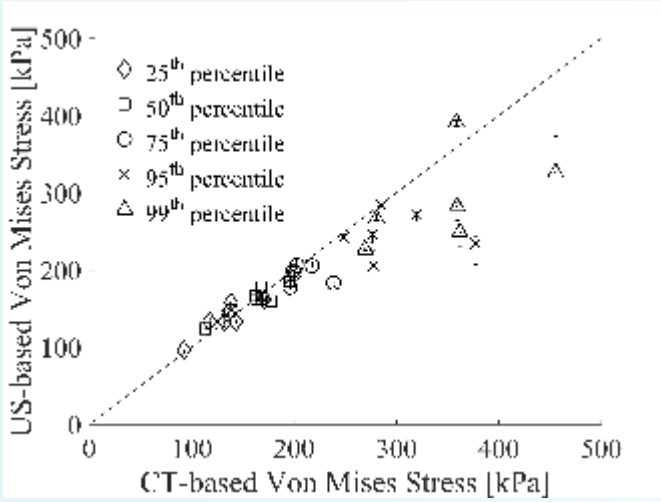
Low contrast



Similar geometry



25th to 99th percentile wall stress in agreement



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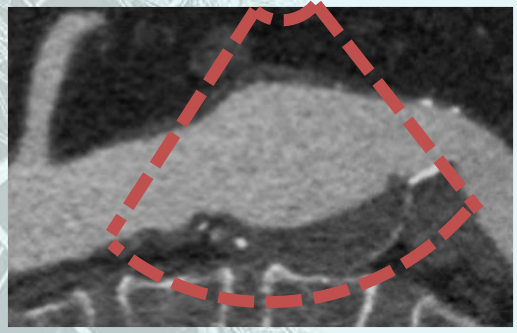
Low contrast



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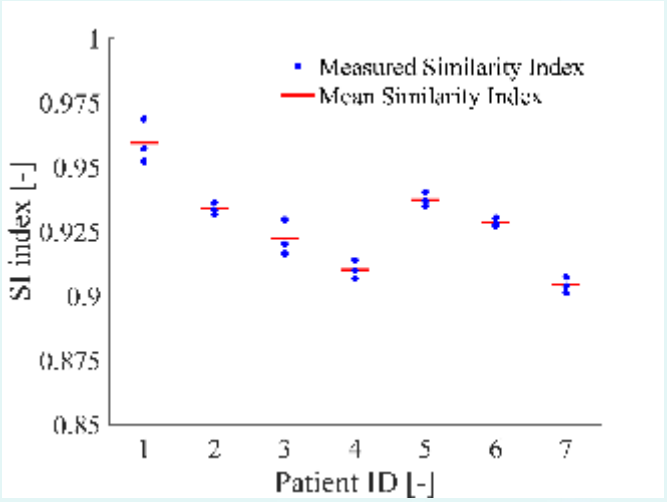

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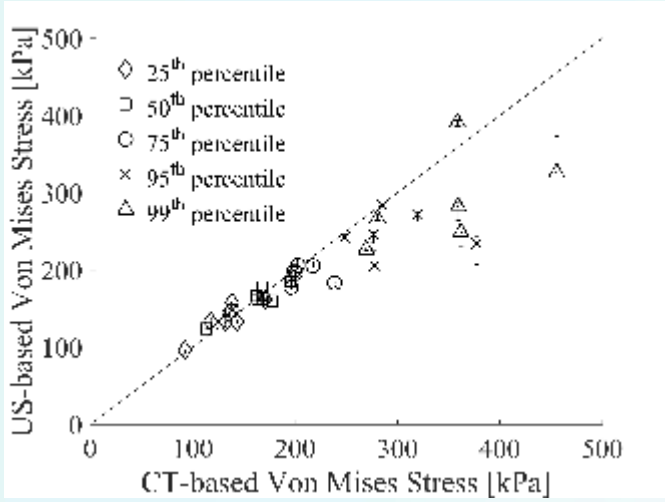

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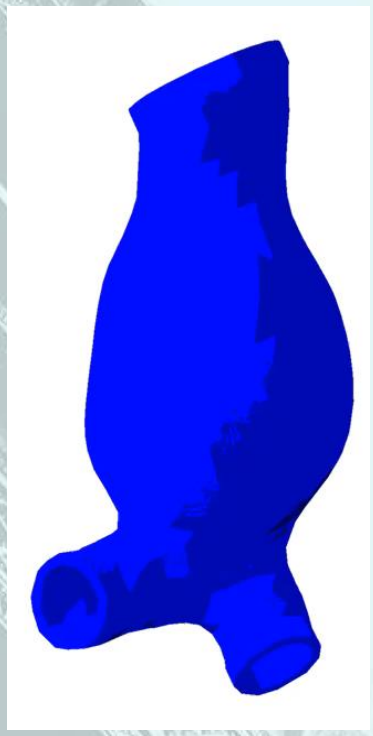
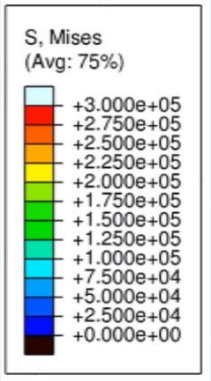
Model predictive clinical decision support

4-D ultrasound ➔Full patient specific AAA modeling





Limitations:

- Field-of-view (‘need the shoulders’)
- Manual segmentation &
- Uniform wall thickness

Current work:

- Automatic segmentation
- Multi-view 4D US
- RF capture

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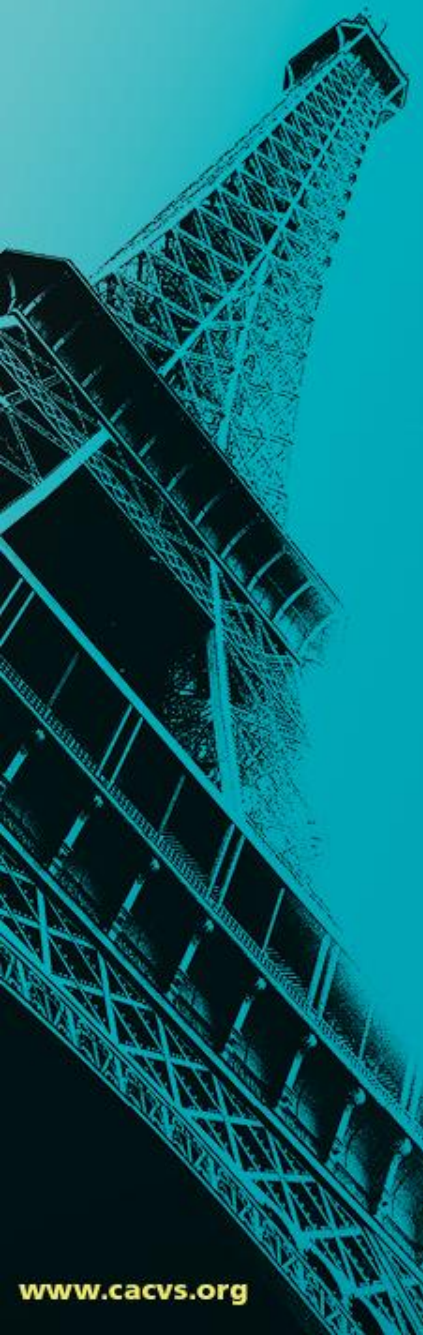

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