Abdominal Aortic Aneurysms
Wall stress analysis and mechanical characterization using 4D ultrasound

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Introduction
An abdominal aortic aneurysm (AAA) is a hazardous, asymptomatic condition that can lead to a fatal haemorrhage when ruptured (Figure 1).

The problem: Rupture risk assessment is nowadays based on the maximum diameter: an inadequate criteria. A more patient-specific approach is needed.

The aim: Perform wall stress analysis using 4D (3D+time) ultrasound (US), and characterize the mechanical behaviour of the AAA wall.

Methods
Forty patients (60-85 years) were included and gave their informed consent. 3D ultrasound imaging (Philips iU22, X6-1 matrix probe) was performed, after which the 3D displacement field was calculated using speckle tracking. For 7 out of 40 patients also CT data were available.

Finite Element Analysis
The data were manually segmented and the corresponding 3D geometry was converted into a mesh. An incompressible Neo-Hookean material model was applied to compute the wall displacements. The patient-specific shear modulus was derived by calibrating the estimated FEA wall displacements to the measured US wall motion.

Results
Patient-specific US-based wall stresses were in agreement with CT and are visualized in the US data in Figure 4.

The 99th percentile wall stress was calculated and shown as function of the AAA diameter. This revealed the presence of small AAAs with high peak wall stresses and large AAAs with relatively low stresses (Figure 5).

Discussion
This study shows that 4D US-based wall stress analysis of AAAs has the potential to aid in AAA rupture risk assessment by identifying patients at risk, and to monitor patients over time by detecting changes in wall stress and material properties.

Ongoing work includes a novel automatic segmentation and registration algorithm to include a large volume of patients (>300) and to perform and long-term follow-up.