Mechanical characterisation of AAA, using 4D ultrasound

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Disclosure

Speaker name: Marc van Sambeek

I have the following potential conflicts of interest to report:

**Consulting and speakers fee**
- WL Gore & Associates
- Medtronic

**Unrestricted research grants**
- Medtronic
- W.L Gore & Associates
- Philips Medical Systems
Evidence-based medicine is based on the outcome of populations and not on individuals.

It is quite possible that a guideline does not always indicate what is best for the individual patient.

Every patient is unique.

Towards patient-specific decision support
In 2007, Vorp concludes in his article "Biomechanics of abdominal aortic aneurysm" that about 7% of the abdominal aneurysms rupture before the 50 mm limit is reached, while on the basis of biomechanical analysis about 25% of the patients are treated unnecessarily or too early.

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
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 by CT and sparsely MR.
There are limitations with CTA and MRI:

Semi patient-specific mechanical AAA model
Unsuitable for longitudinal studies
Therefore these models are not properly validated
Pre-operative monitoring

Acquire 3D and 4D (3D+t) US:
- 3D acquisition for geometry
- 4D acquisition for dynamic behaviour

Now: Following > 400 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
Structured analysis

Structured aortic wall analysis of ultrasound data sets

- increase field of view
- automatic segmentation
- adequate geometrie
- mechanical parameters
- adequate wall stress
Increased field of view and automatic segmentation

Single 3D US

Multiple 3D US

3D US acquisition

Automatic segmentation and registration
“State-of-the-art geometrie assessment”

Quantitative results:
SI single: 0.88 – 0.95
SI multi: 0.87 – 0.94

van Disseldorp et al. JBM 2016; 49:2405-12
Elastography is a medical imaging modality that maps the elastic properties and stiffness of soft tissue.

The most prominent techniques use ultrasound or magnetic resonance imaging (MRI) to make both the stiffness map and an anatomical image for comparison.

To image the mechanical properties of tissue, we need to see how it behaves when deformed, e.g. pulse or heartbeat.
Finite element analysis based on ultrasound

Wall stress assessment using finite element analysis

Straightforward analytic techniques to assess wall stress is not possible with the complex shape of the aneurysmal wall.

Instead we can use a technique known as finite element analysis for computation of the wall stresses in each virtual AAA.

In this technique, a complex shape is divided into smaller, simpler shaped elements. The stresses over the individual elements are computed, and the solution is patched together to yield the stress distribution for the entire complex aorta.
Patient-specific decision support
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