4D ultrasound evaluation of AAAs
What is it? How can it help to predict growth and rupture rates?

Marc van Sambeek
Emiel van Disseldorp, Frans van de Vosse, Richard Lopata
Catharina Hospital Eindhoven
Eindhoven University of Technology

Disclosure
Marc RHM van Sambeek
I have the following potential conflicts of interest to report:
Consulting and speakers fee
WL Gore & Associates
Medtronic
Unrestricted research grants
Medtronic
WL Gore & Associates
Philips Medical Systems

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.

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.

CT-scan vs 4-D Ultrasound

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

Now:
Following > 320 patients
Longitudinal study
Clinical CT data for verification
Goal:
Develop and validate a patient-specific method using 4D ultrasound
Equipment:
Philips iU22 FX-1 matrix probe f0 = 3.5 MHz.
Structured analysis of all ultrasound data sets

2017

- adequate geometry
- adequate wall stress and mechanical parameters

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

2018

- increase field of view
- automatic segmentation

Multi-perspective imaging + automatic segmentation

First: 2D slice-by-slice approach
Afterwards: 3D regularization

The segmentation algorithm is based on the well-established active deformable contour models or snakes as introduced by Kass et al (1988)

These active contours are energy minimizing functions that attract towards image features (in this case the aortic wall) and on the other hand are constrained by internal forces that resist deformation of the contour.

Segmentation and registration

Important steps:
- Distal segmentation
- Combined estimate based on centerline
- Optimalisation
- Registration/merge
- Final segmentation
- Merge US data
- Combine

Validation with CT

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

Re-segmentation of merged sub-volumes
Wall stress verification

Wall stress verification with CT (N=40)

- Calculate diastolic stresses and inflate to patient-specific systolic pressure
- Percentile Von-Mises wall stress for overlapping region of AAA

Quantitative comparison

Conclusion and future perspective

- Wall stress follows the typical trend
- No difference between non- and ruptured cases
- In 3 out of 4 ruptured cases, stiffness was lower compared to the average values

Sneak preview

4D ultrasound evaluation of AAAs

- What is it? How can it help to predict growth and rupture rates?

Marc van Sambeek
Emiel van Disseldorp, Frans van de Vosse, Richard Lopata
Catharina Hospital Eindhoven
Eindhoven University of Technology