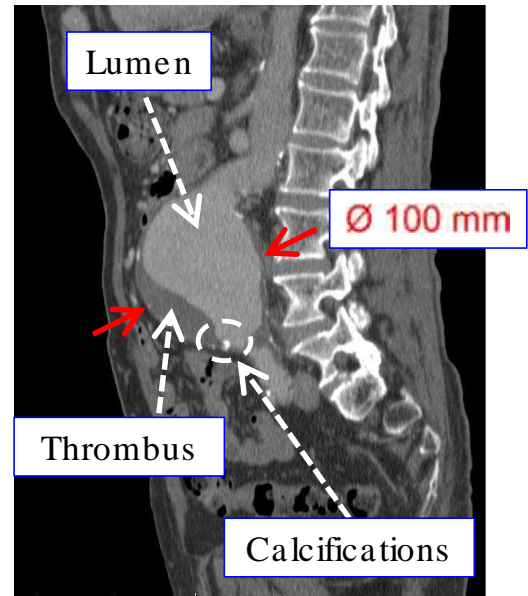
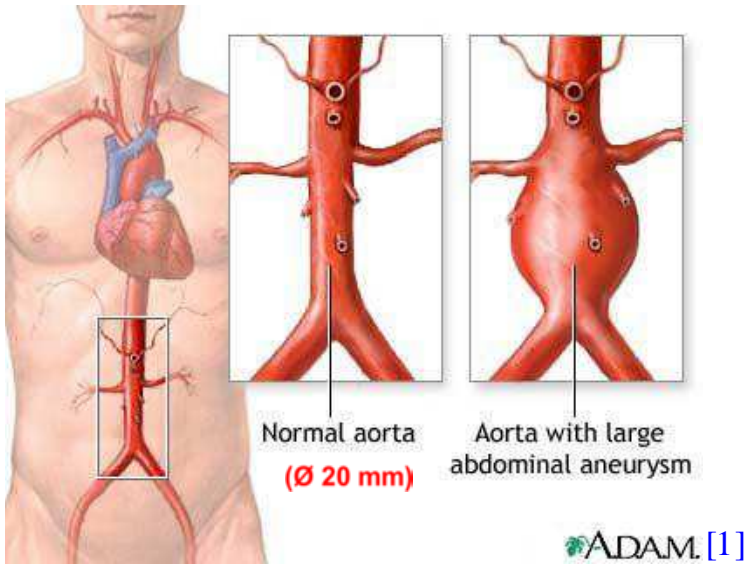


Simulation of Endovascular Repair of Abdominal Aortic Aneurysms (AAA)

By David Roy, Eng. - Ph.D.
(Clermont-Ferrand, Mars 24th 2016)



1 Clinical background



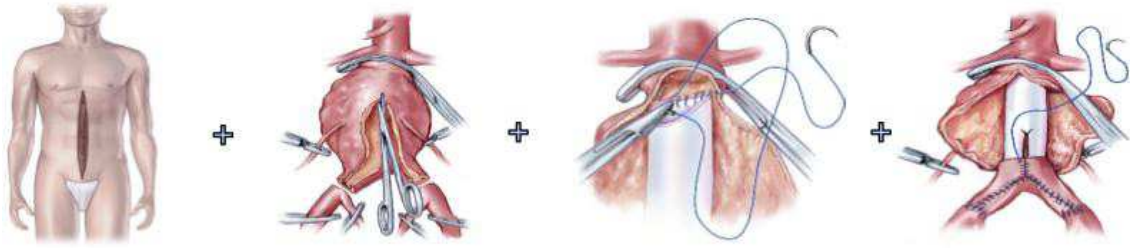
- Strong correlations with hypertension, family history, smoking habit, sedentarity.
- 13th cause of death in the USA in 2005 for Caucasians between 60 and 85 [2].

[1] <http://www.nlm.nih.gov/medlineplus>

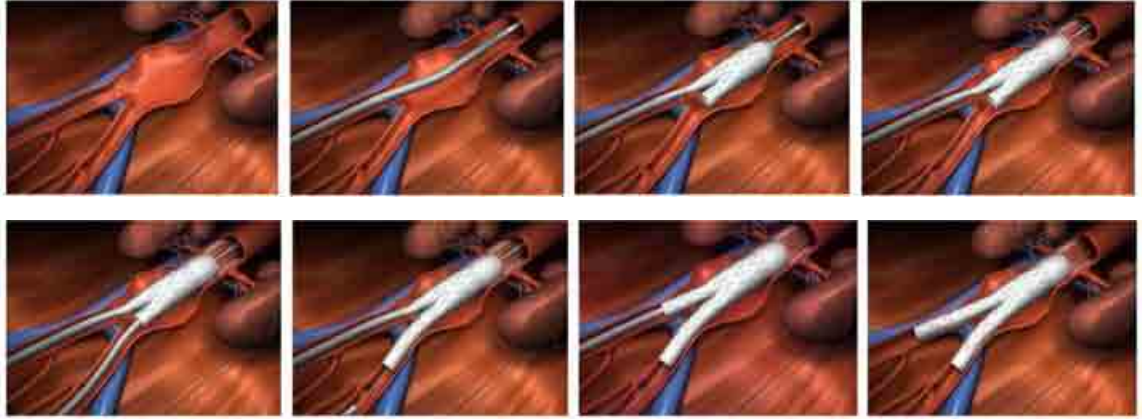
[2] Sakalihasan et al. (2005). Abdominal aortic aneurysm. *Lancet*.

2 Treatments

Open surgery [3]



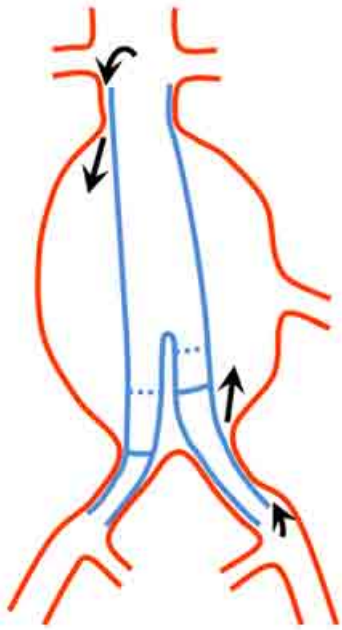
Endovascular repair (EVAR) [4]



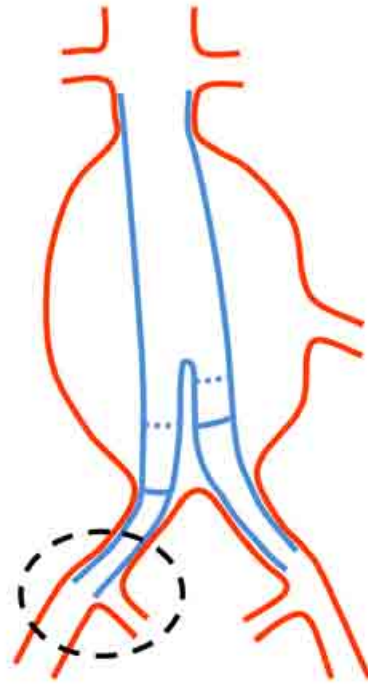
[3] Amblard, A. (2006). *Contribution à l'étude du comportement d'une endoprothèse aortique abdominale. Analyse des endofuites de type I*. PhD thesis, Institut National des Sciences Appliquées de Lyon.

[4] Cook Medical document. http://www.youtube.com/watch?v=ZC_afpYTRxw, consulted on May 05 2014.

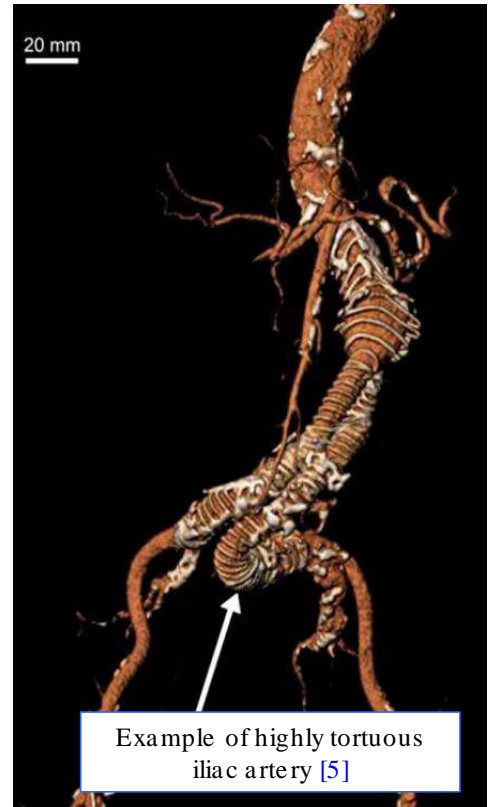
3 Main complications due to EVAR



Endoleak

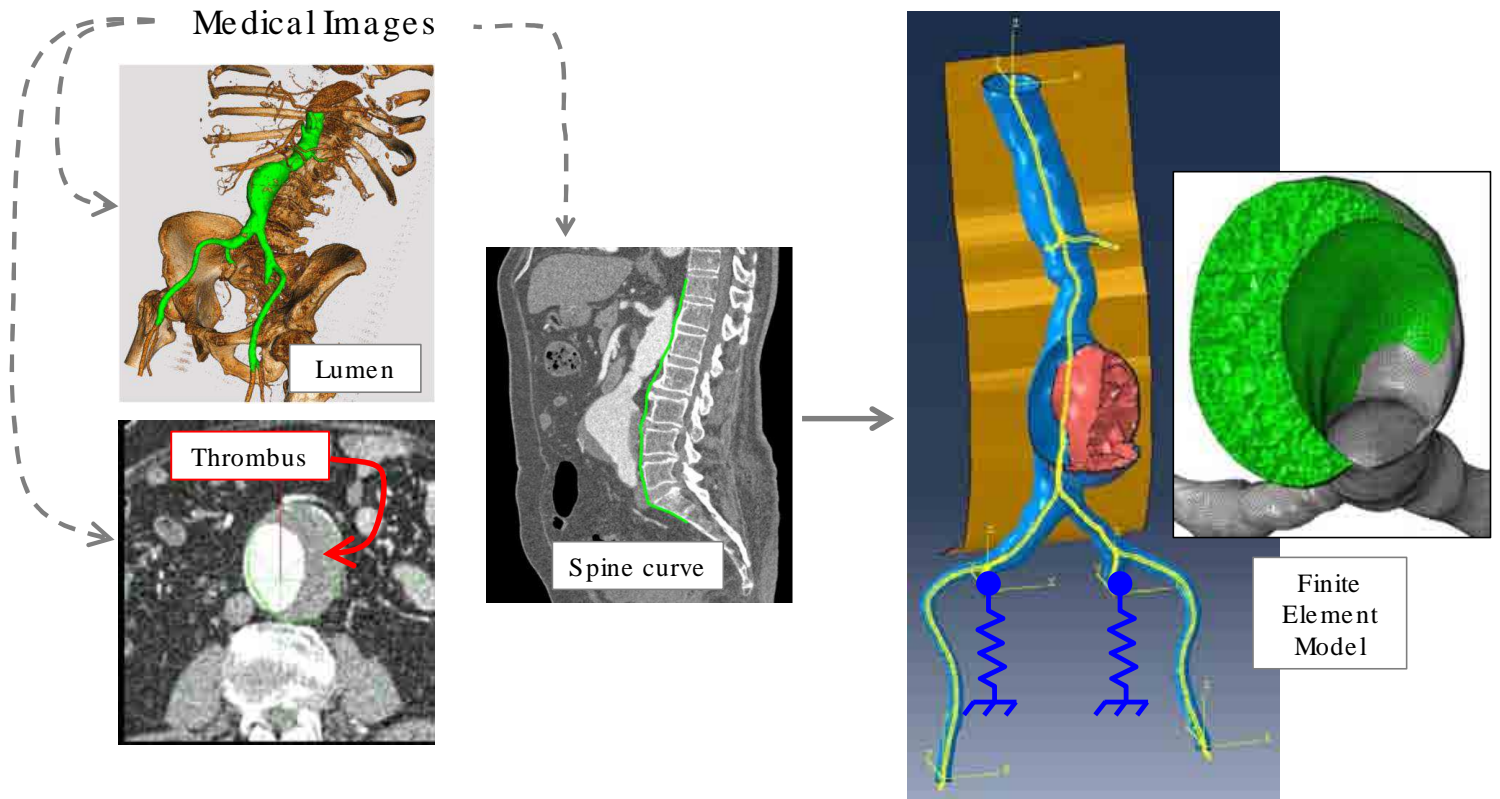


Occlusion

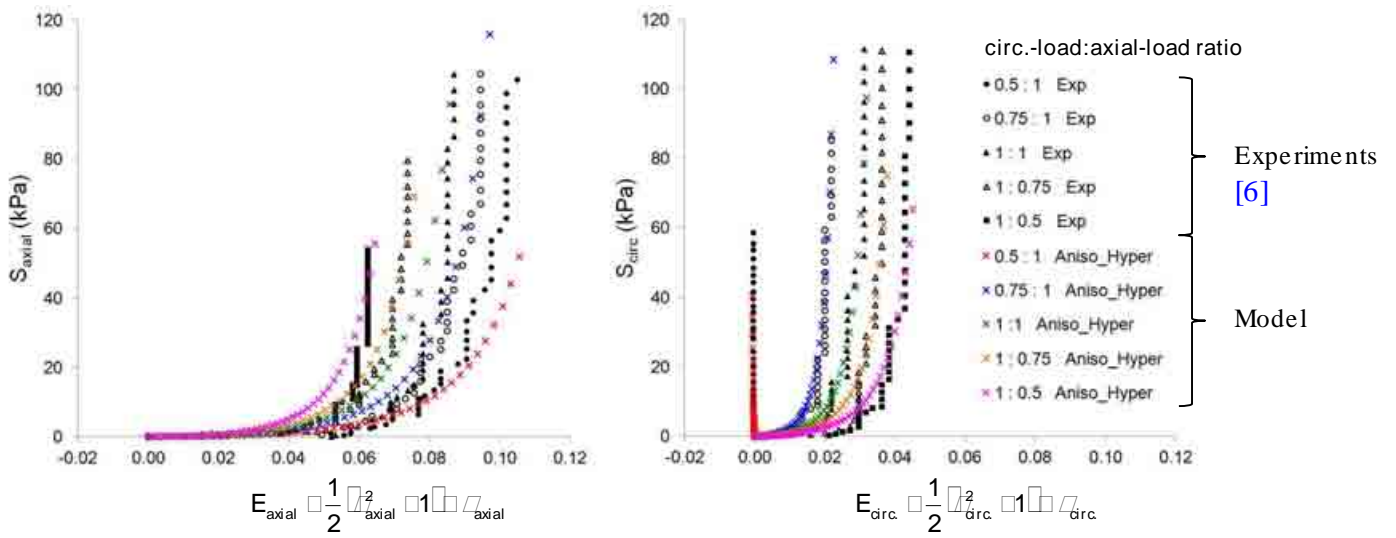
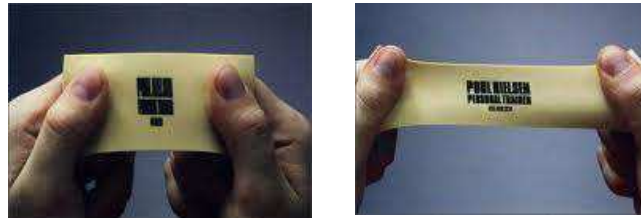


[5] Demanget et al. (2012a). Computational comparison of the bending behavior of aortic stent-grafts. *Journal of Mechanical Behavior of Biomedical Materials*.

4 AAA geometry reconstruction from CT scans

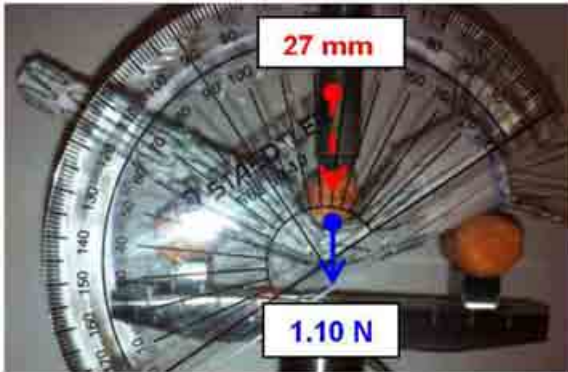


5 AAA material properties (hyperelastic model)



[6] Vande Geest et al. (2006). The effects of aneurysm on the biaxial mechanical behavior of human abdominal aorta. J Biomech.

6 Stent-graft modeling and experimental validation



Experimental study

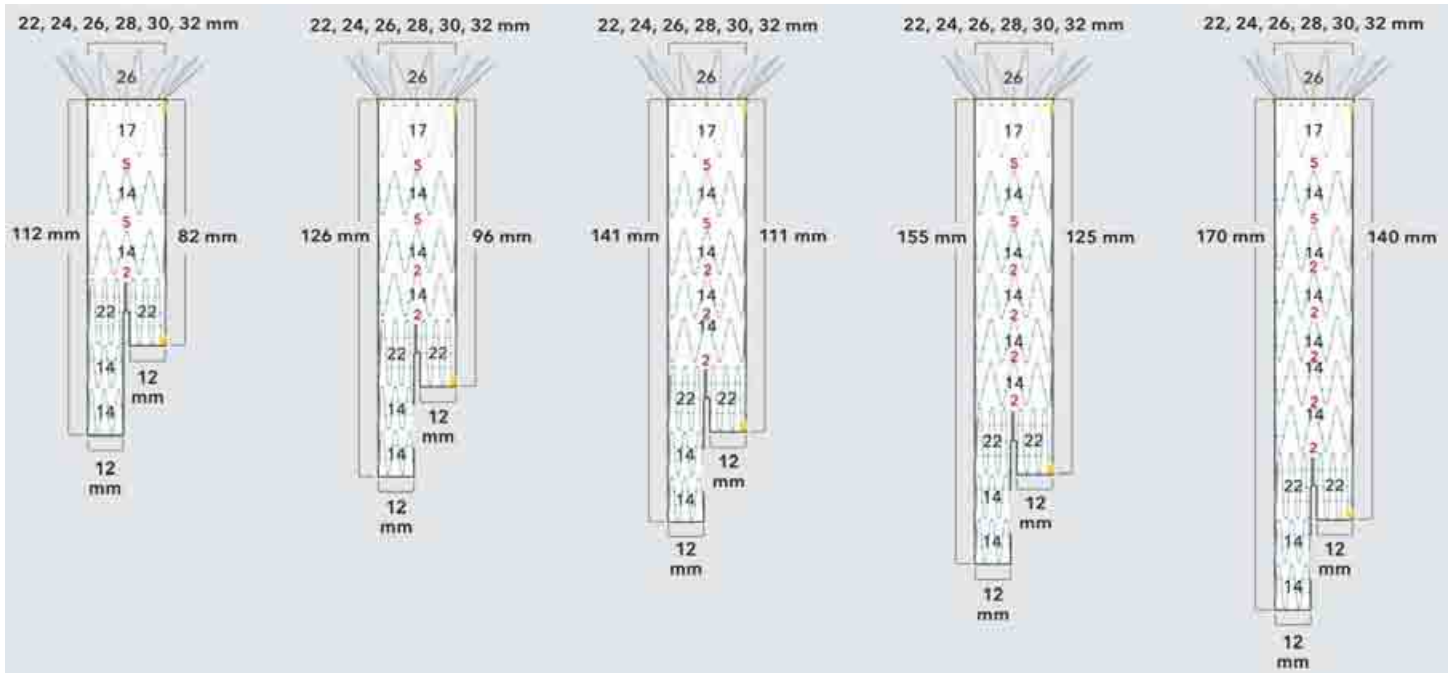


Numerical study

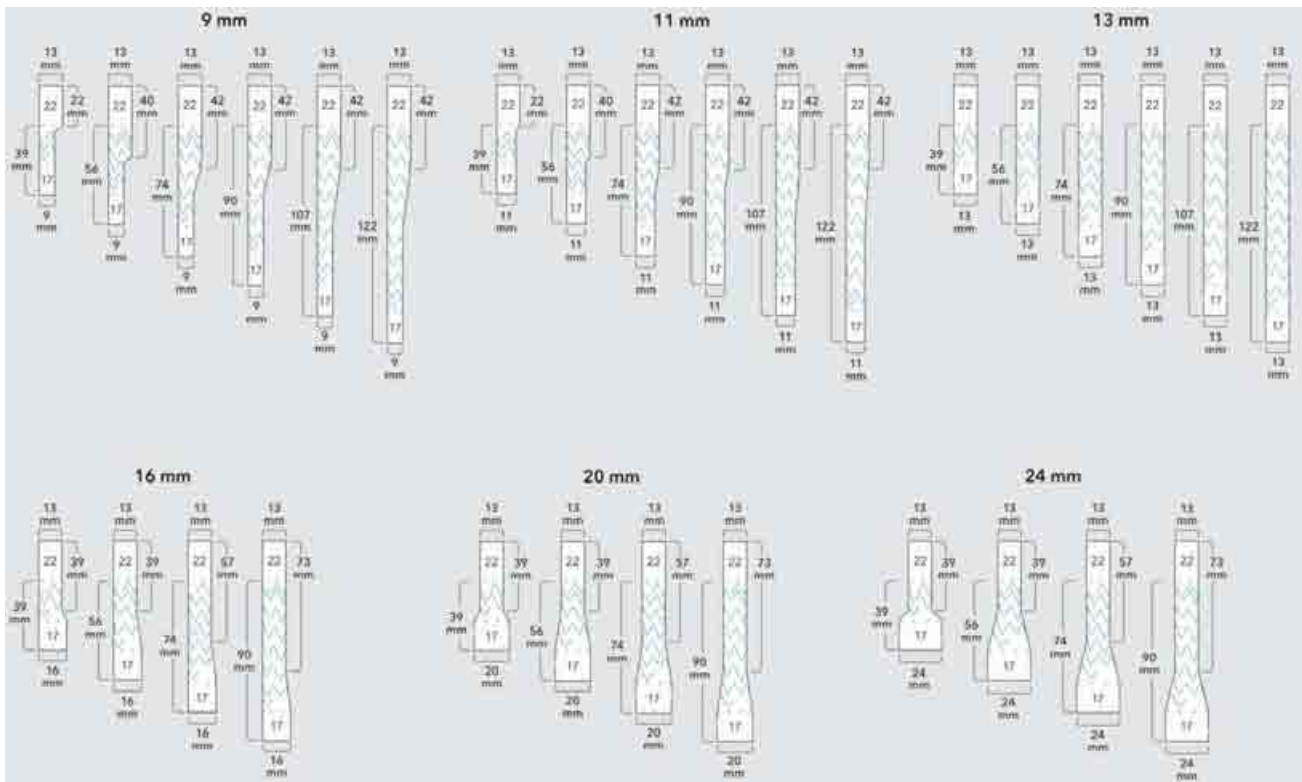
	Imposed	Measured	Simulated	Difference (%)
L-SG simple bending	F 0.30	D 79	D 78	1.27
B-SG simple bending	F 0.65	D 96	D 101.40	5.62
B-SG three-point bending	F 1.10	D 27	D 28.60	5.93
B-SG axial compression	D 12	F 0.74	F 0.75	1.35
B-SG transversal compression	D 12	F 0.62	F 0.60	3.23

Forces (N) and displacements (D) are in Newton and mm respectively.

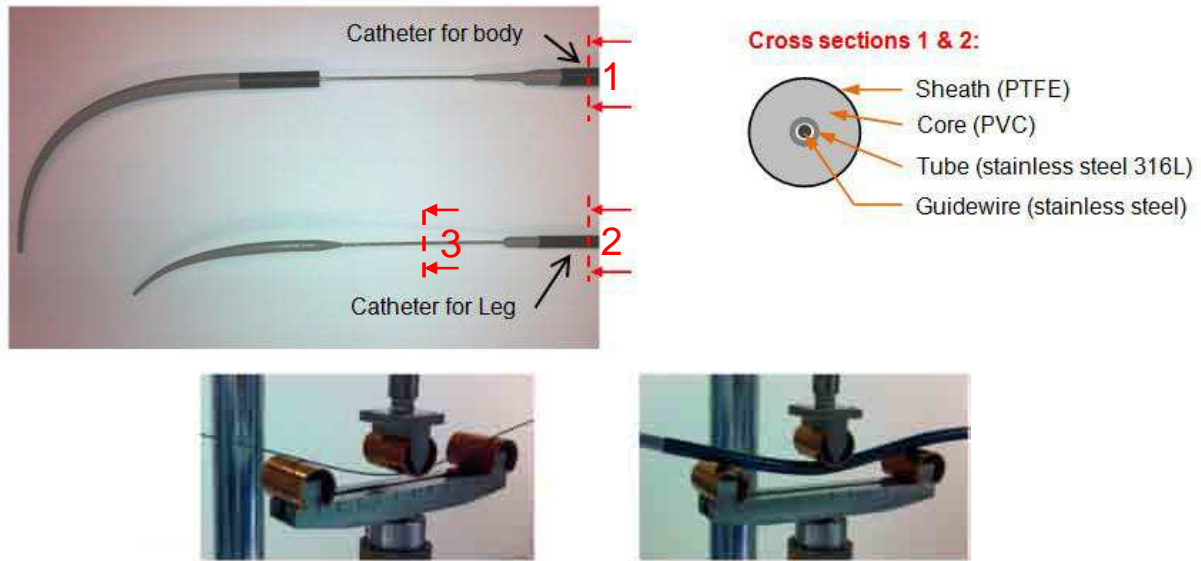
7 Body stent-grafts from Cook Medical (TFFB models) implemented in a plug-in



8 Leg stent-grafts from Cook Medical (ZSLE models) implemented in a plug-in



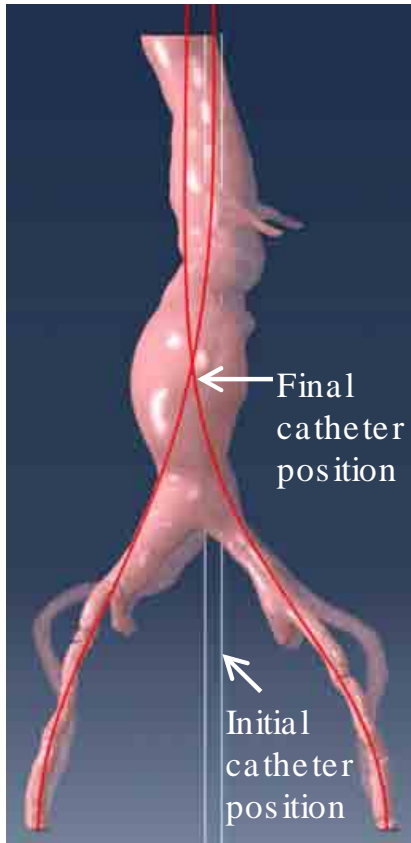
9 Guidewire & catheter mechanical characterization



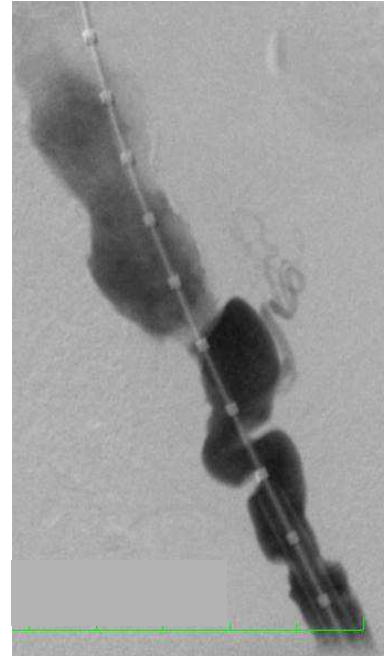
Equivalent mean properties for typical sections of body and leg catheters.

	\varnothing (mm)	E (kPa)	ν (-)	ρ (kg mm ⁻³)
1 Body outer catheter	6.85	5.740×10^5	0.3	1.673×10^{-6}
2 Leg outer catheter	5.22	1.093×10^6	0.3	1.764×10^{-6}
3 Inner catheter	1.25	1.930×10^8	0.3	8.00×10^{-6}

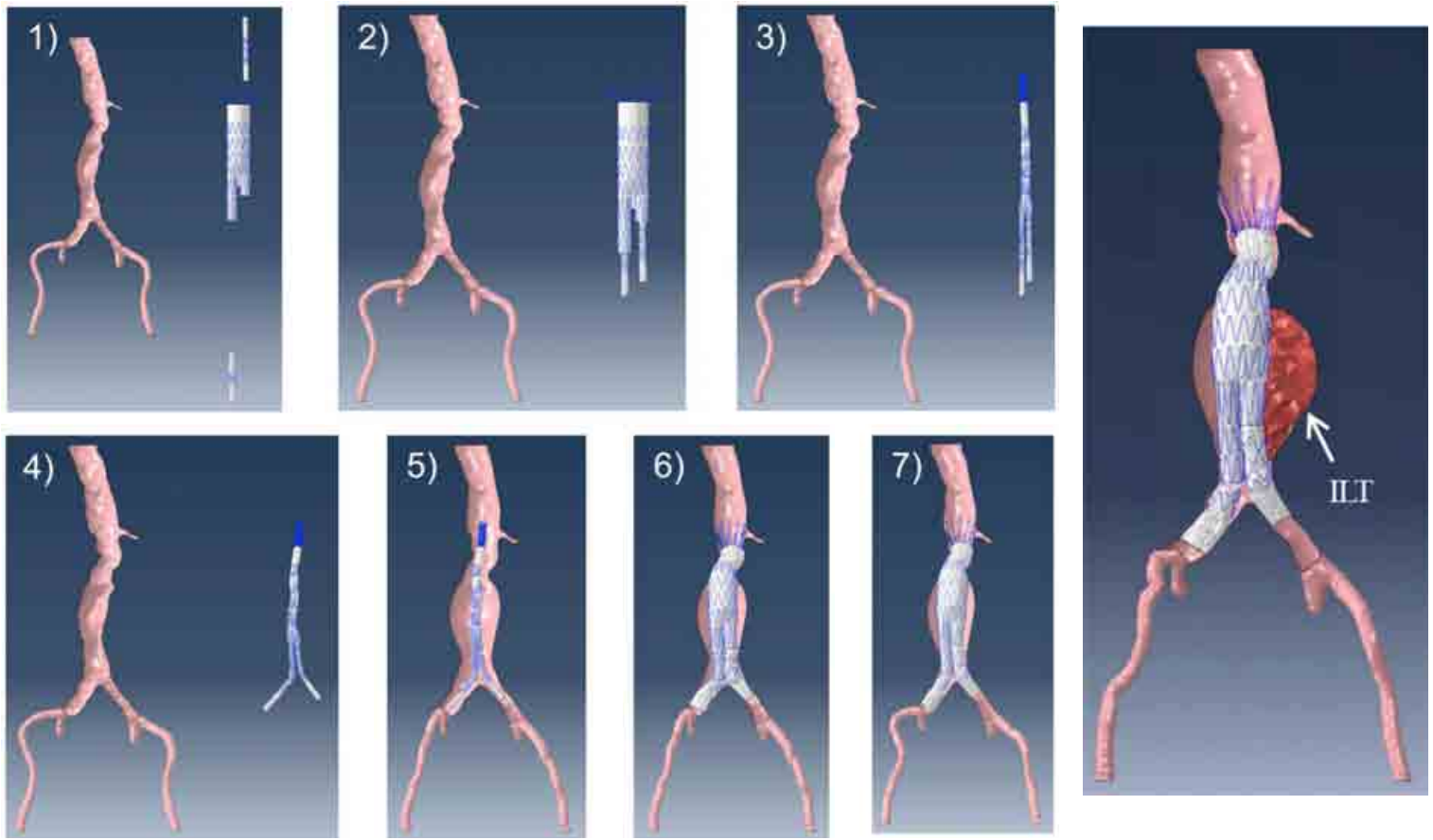
10 AAA pre-deformation due to catheter insertion



Typical real iliac deformation due to catheter insertion



11 Complete stent-graft deployment simulation (with blood pressure)



12 Prototype of graphic interface to program the simulation

EVARSim Step 1

Note: In this step the input files defining the AAA geometry are entered along with the patient's blood pressure, and consequently, the zero pressure geometry is identified as well as the centerlines corresponding to its pressurized configuration.

Patient ID:

Output Directory:

Patient Parameters: Diastolic Pressure (mmHg):
Systolic Pressure (mmHg):

AAA Input Files: Points Data File
Facets Data File

ILT Input Files: Points Data File
Facets Data File

Spine Input File: Data File

Centerlines Input File: Data File

OK Cancel

EVARSim: Step 3

Note: Both the distal diameter and length must be entered for each stent-graft (body and legs).

Warning: For legs having a distal diameter above 13 mm, only the following working lengths are available: 39, 56, 74 and 90 mm.

Body Parameter: Proximal Diameter (mm):
Body Short Length (mm):

Left Leg Parameters: Distal Diameter (mm):
Official Working Length (mm):
Angle Rotation About Z (in degrees):

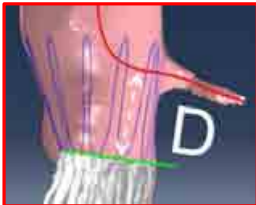
Right Leg Parameters: Distal Diameter (mm):
Official Working Length (mm):
Angle Rotation About Z (in degrees):

Warning: All overlaps must be entered as integer numbers.

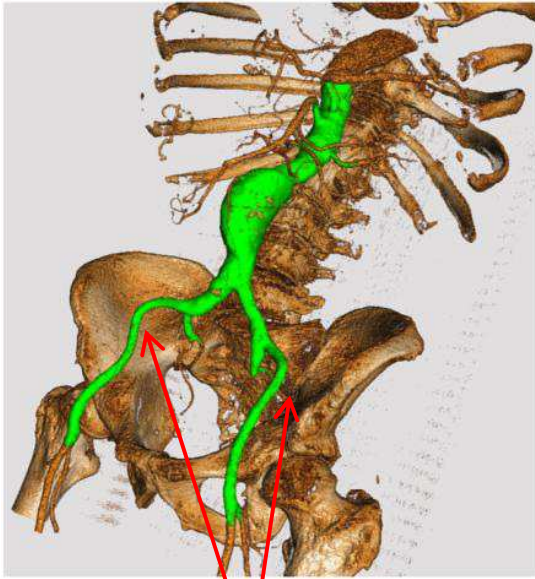
Stent-Graft Relative Positions: Distance From Left Renal Centerline To The Upper Body Graft (D) (mm): Left Leg Inside Body Overlap (mm): Right Leg Inside Body Overlap (mm):

Warning: The precedent step must be completed and the new centerlines data file must be renamed as Patient-ID_Pressurized-and-Preloaded-ZPG_Centerlines.dat (as a convention).

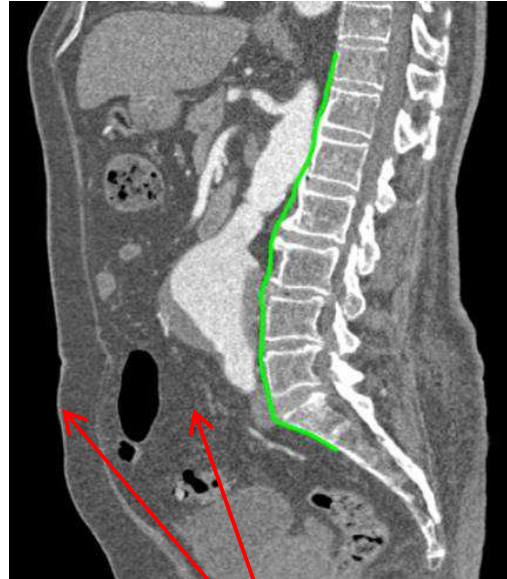
OK Cancel



13 Next steps with simulation



Modeling the pelvic bone as a rigid surface, like already done with the spine.

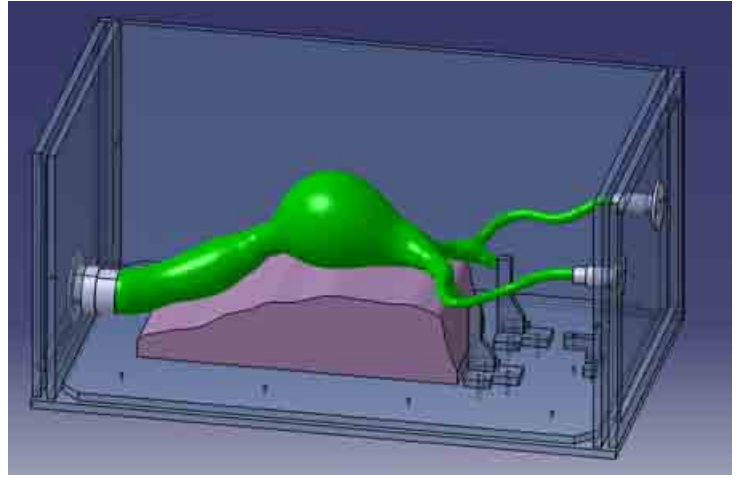


Modeling abdominal organs with a fluid material of equivalent density and stiffness, and the skin with a membrane.

14 Next steps with experimental validation (before clinical validations)



- First simple phantom made of polyurethane.
- PVA phantoms are currently tested, including a degraded PVA to simulate organs.



CAD model of a patient-specific AAA.

Thank you for your attention !

Any questions ! ?