Simulation of Endovascular Repair of Abdominal Aortic Aneurysms (AAA)

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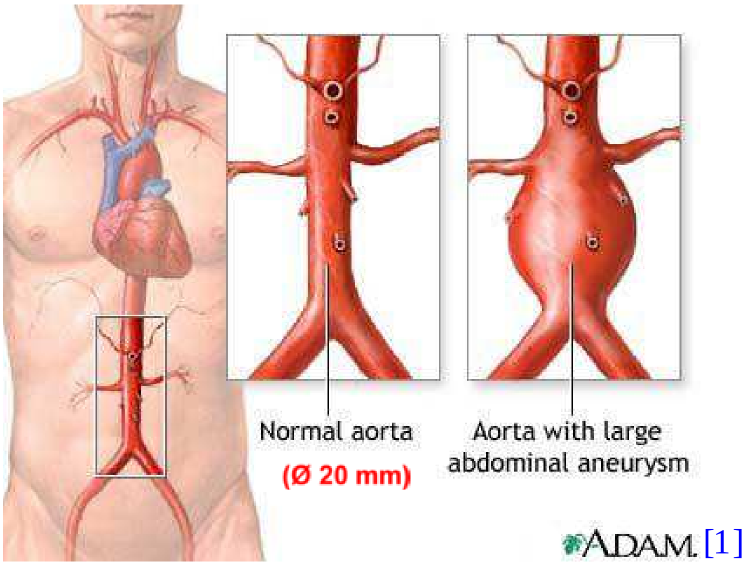
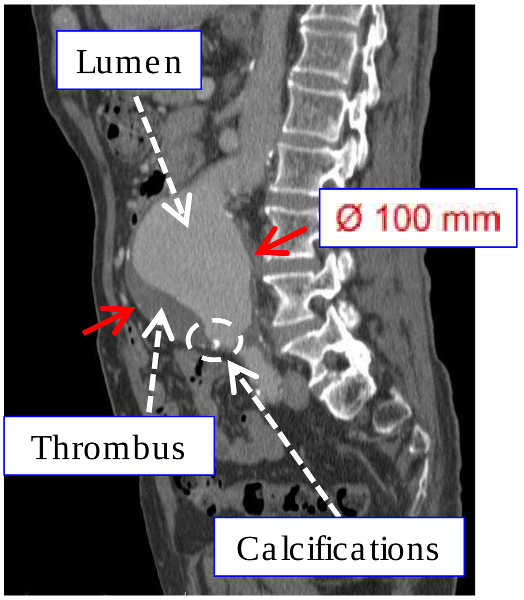
(Clermont-Ferrand, Mars 24th 2016)

1 Clinical background



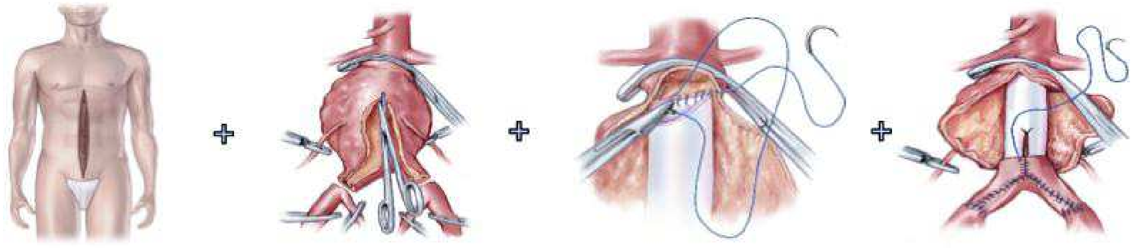


- Strong correlations with hypertension, family history, smoking habit, sedentarity.
- 13th cause of death in the USA in 2005 for Caucasians between 60 and 85 [2].

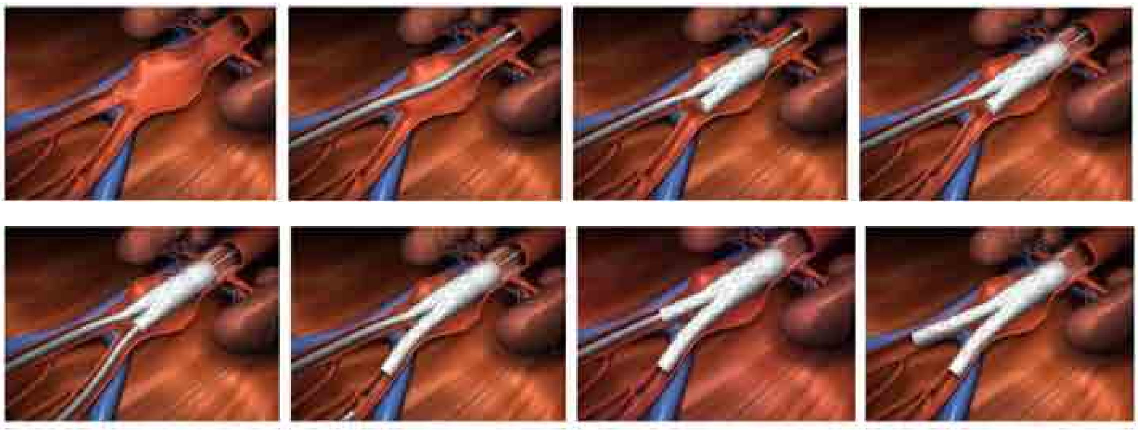
[1] http://www.nlm.nih.gov/medlineplus
[2] Sakalihasan et al. (2005). Abdominal aortic aneurysm. Lancet.

2 Treatments

Open surgery [3]

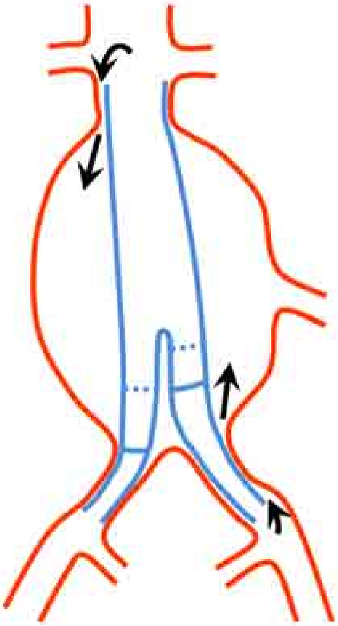


Endovascular repair (EVAR) [4]

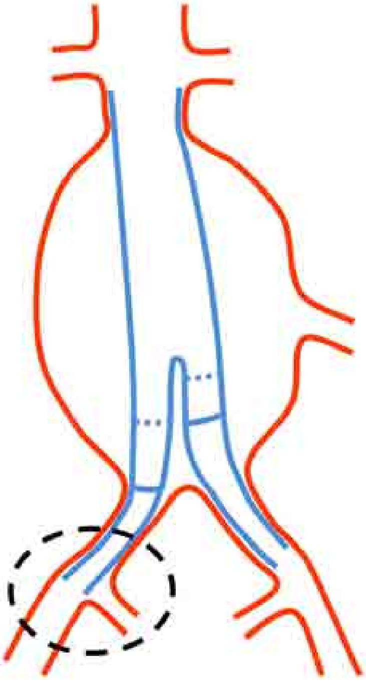


[3] Amblard, A. (2006). *Contribution à l'étude du comportement d'une endoprothèse aortique abdominale. Analyse des endofuites de type I*. PhD thesis, Institut National des Sciences Appliquées de Lyon.
[4] Cook Medical document. http://www.youtube.com/watch?v=ZC_afpYTRxw, consulted on May 05 2014.

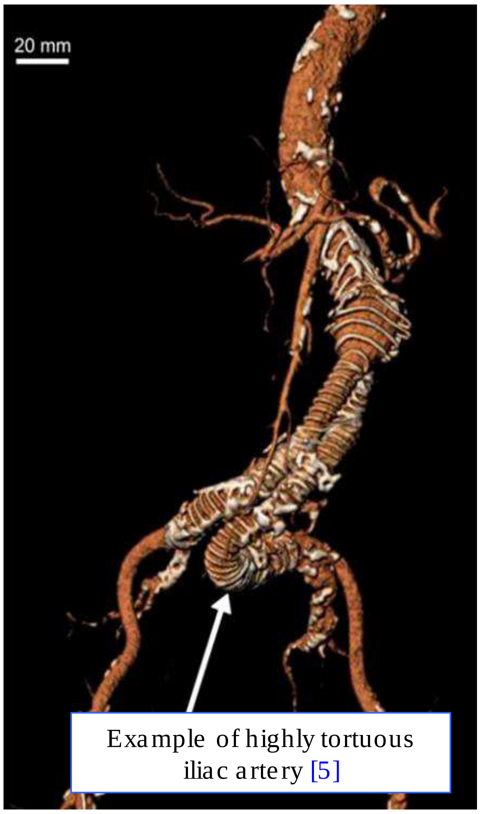
3 Main complications due to EVAR



Endoleak



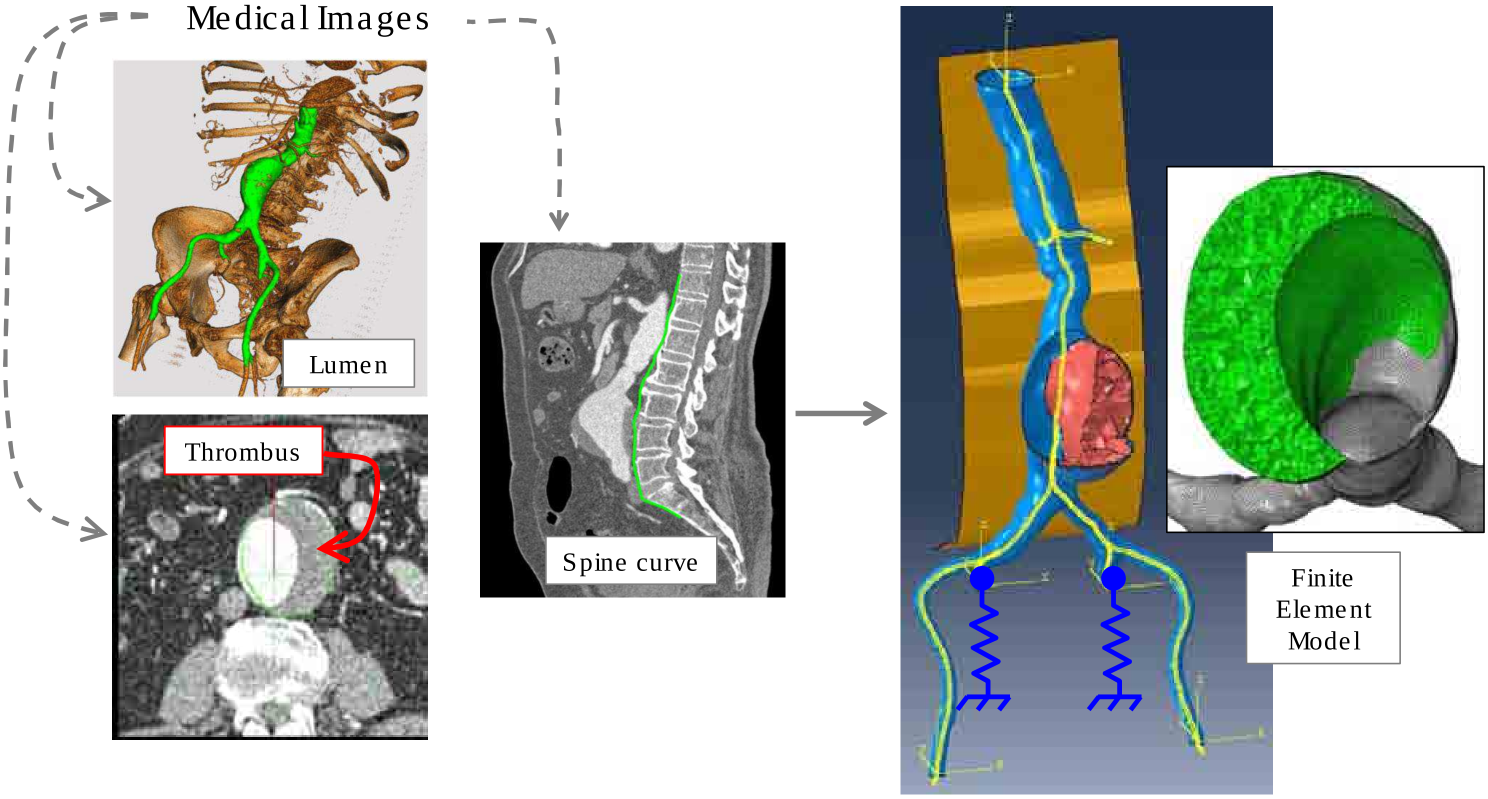
Occlusion



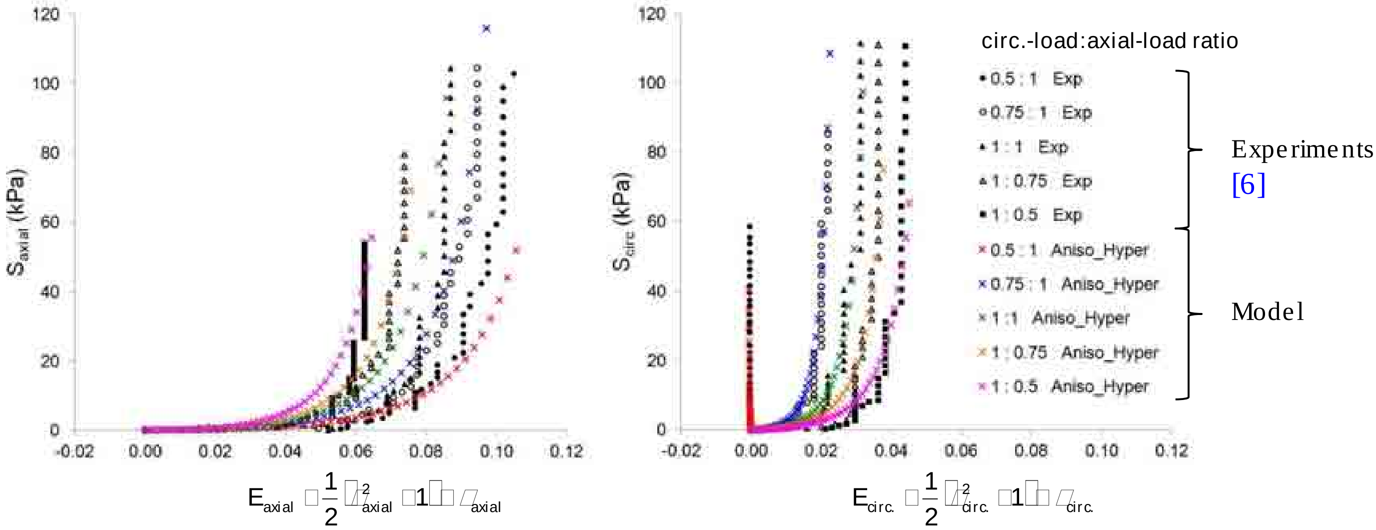
Example of highly tortuous iliac artery [5]

[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

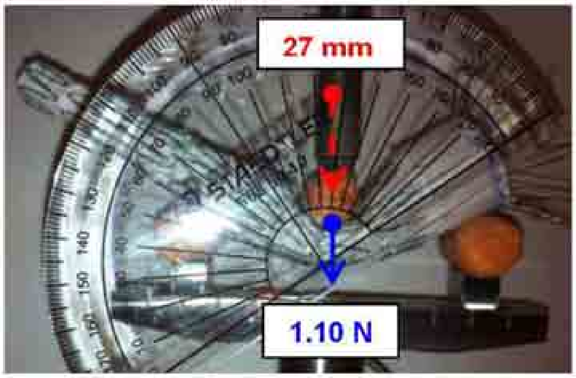


5 AAA material properties (hyperelastic model)



[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



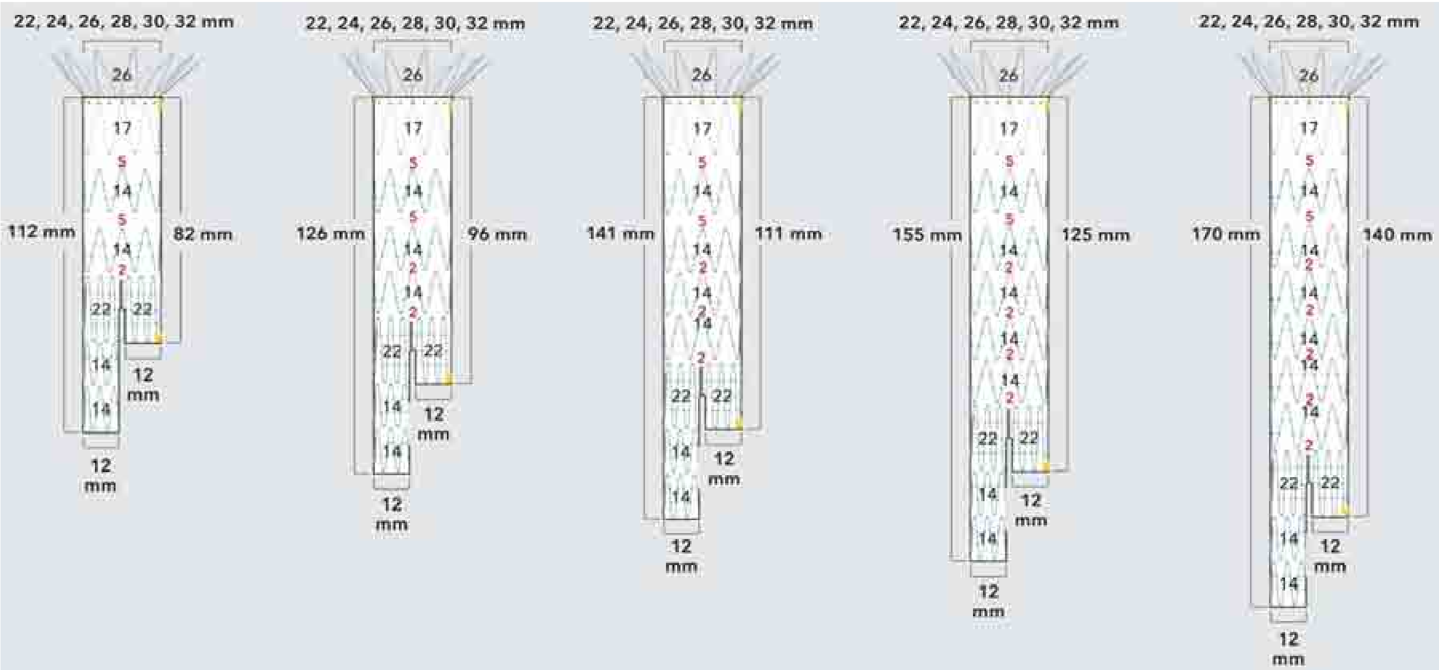
Experimental study

Numerical study

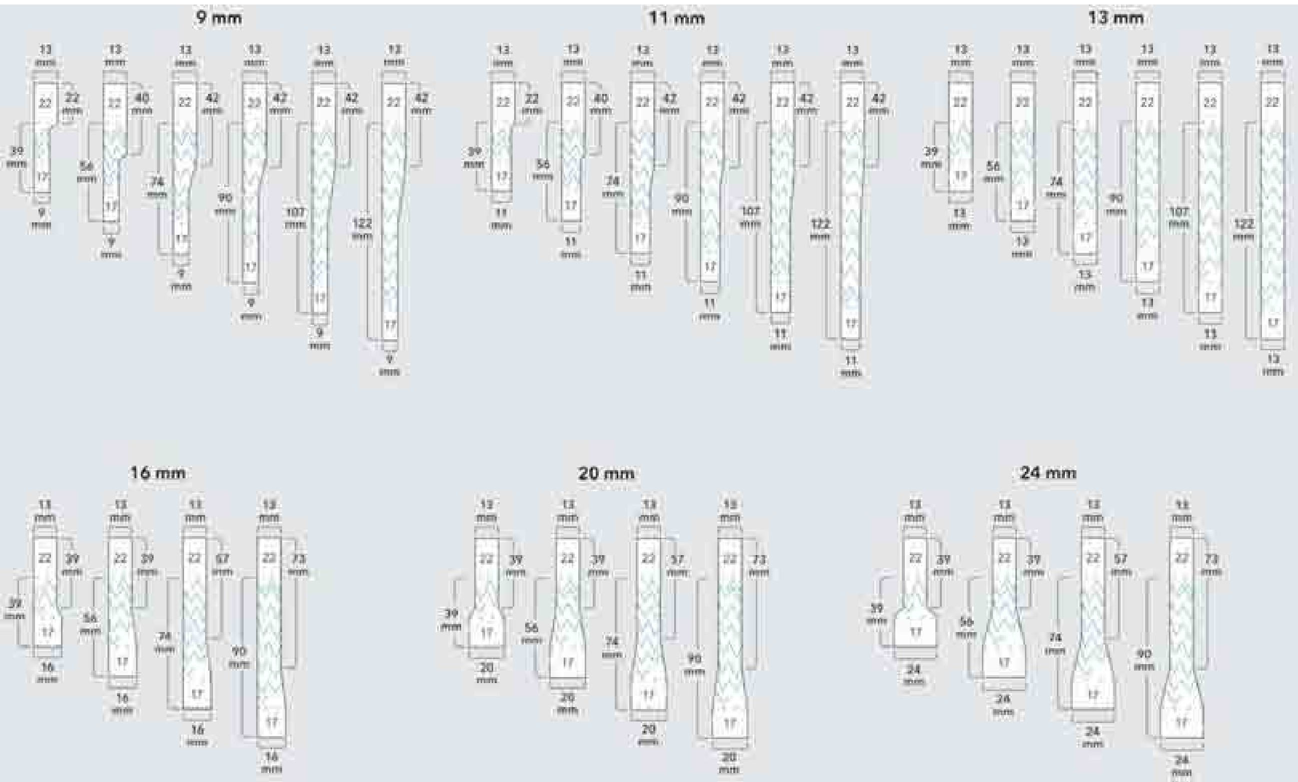
	Imposed	Measured	Simulated	Difference (%)
L-SG simple bending	F 0.30	D 79	D 78	1.27
B-SG simple bending	F 0.65	D 96	D 101.40	5.62
B-SG three-point bending	F 1.10	D 27	D 28.60	5.93
B-SG axial compression	D 12	F 0.74	F 0.75	1.35
B-SG transversal compression	D 12	F 0.62	F 0.60	3.23

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

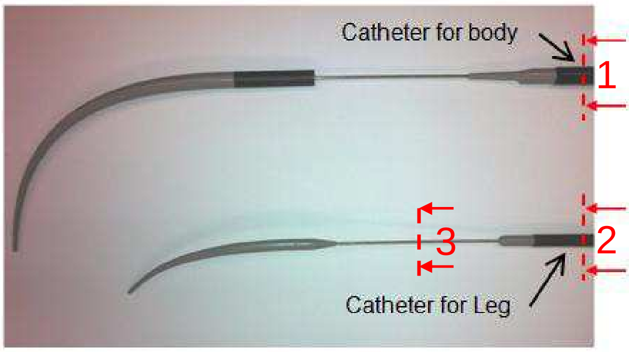
7 Body stent-grafts from Cook Medical (TFFB models) implemented in a plug-in

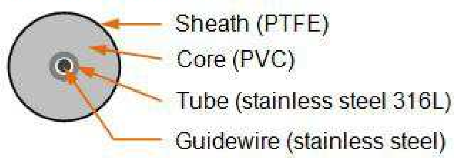


8 Leg stent-grafts from Cook Medical (ZSLE models) implemented in a plug-in



9 Guidewire & catheter mechanical characterization

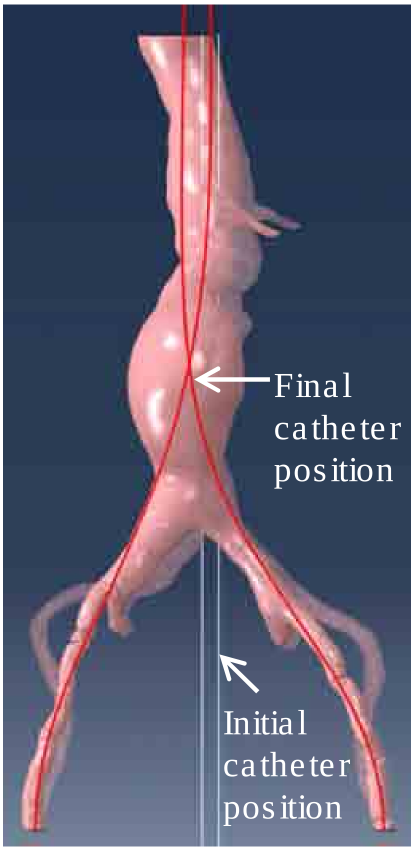




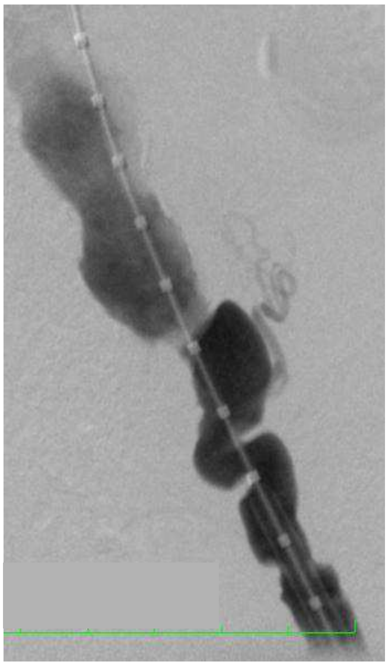
Equivalent mean properties for typical sections of body and leg catheters.

		Ø(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}

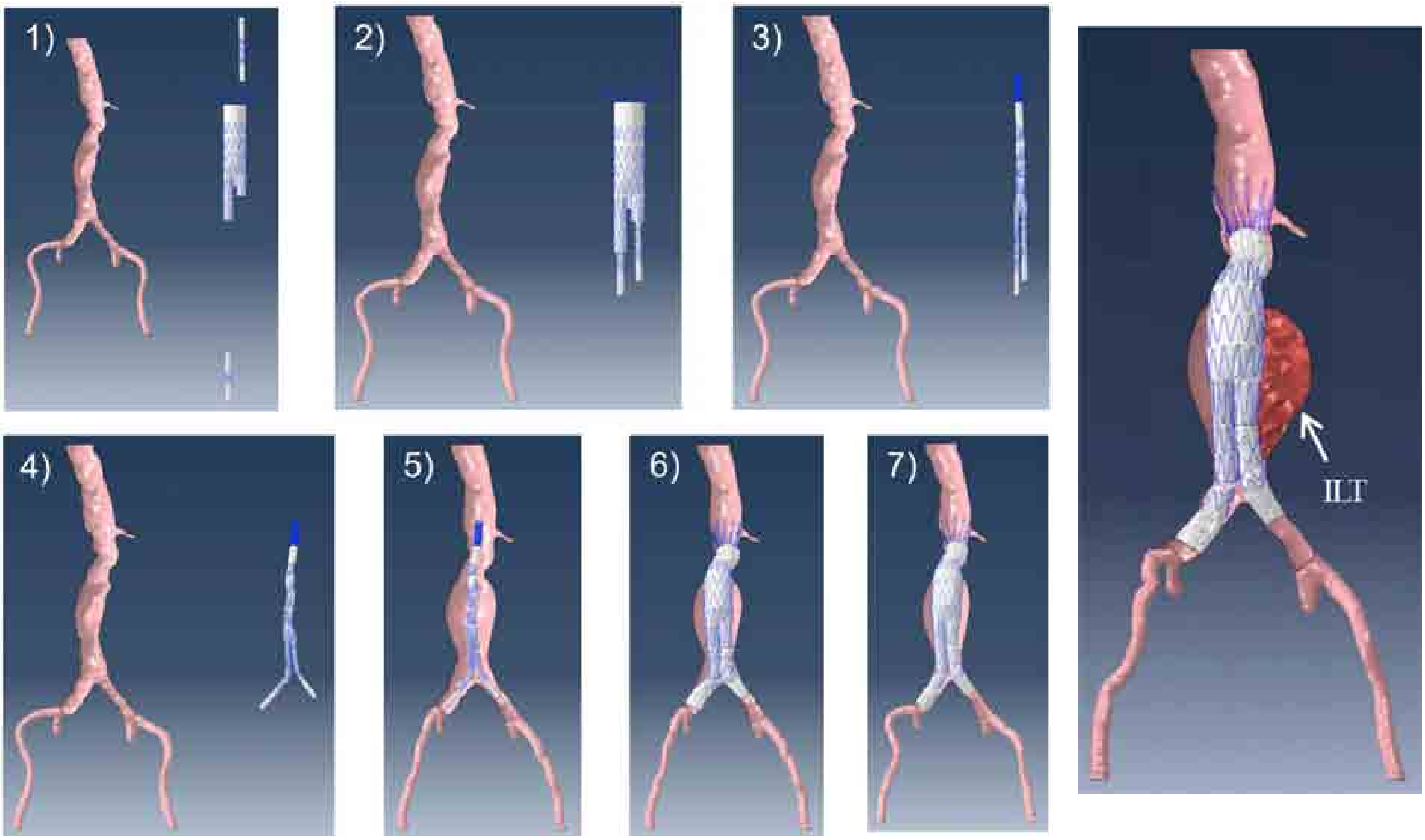
10 AAA pre-deformation due to catheter insertion



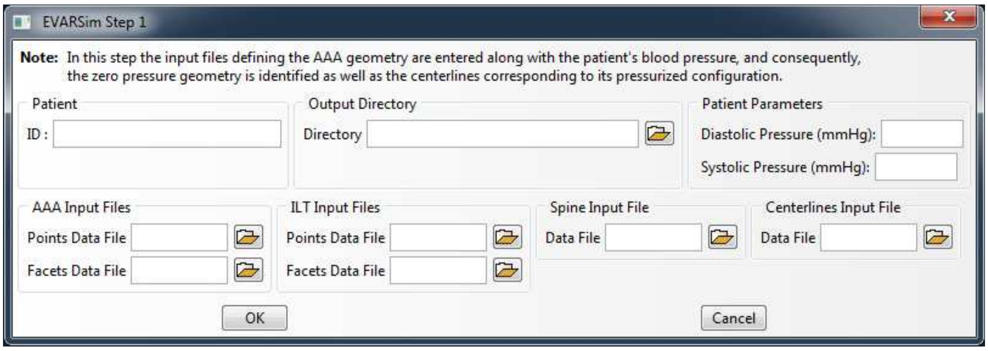
Typical real iliac deformation due to catheter insertion

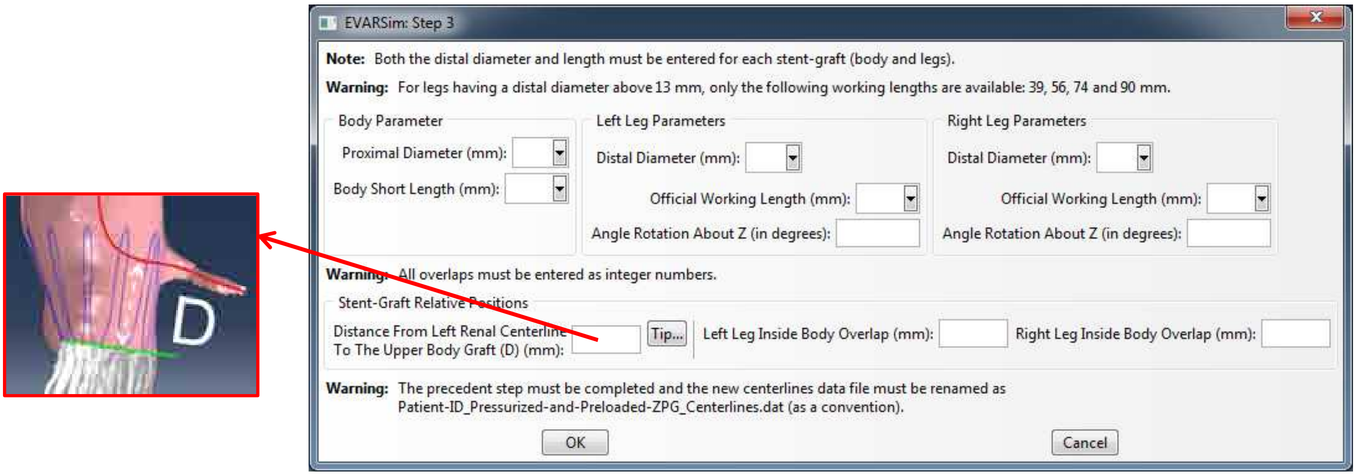


11 Complete stent-graft deployment simulation (with blood pressure)

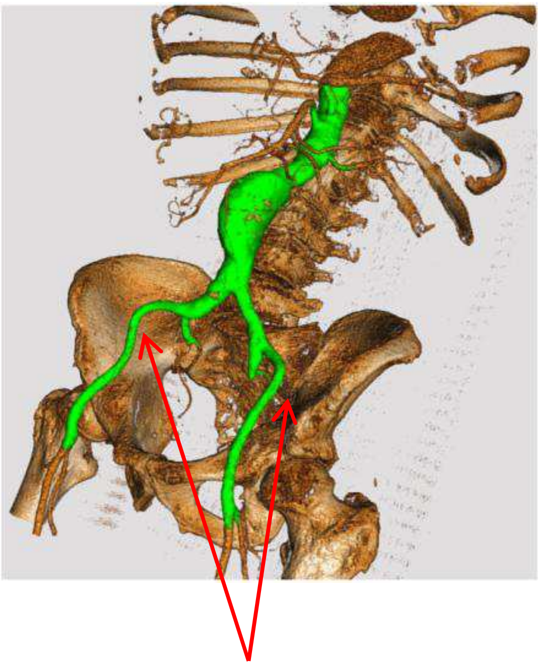


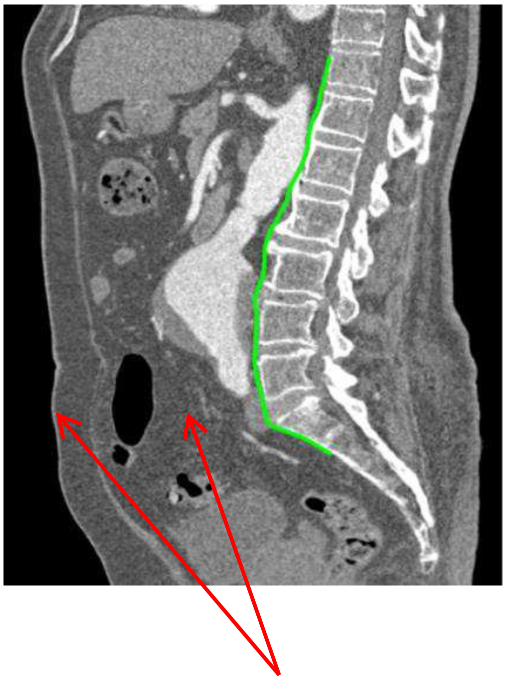
12 Prototype of graphic interface to program the simulation





13 Next steps with simulation



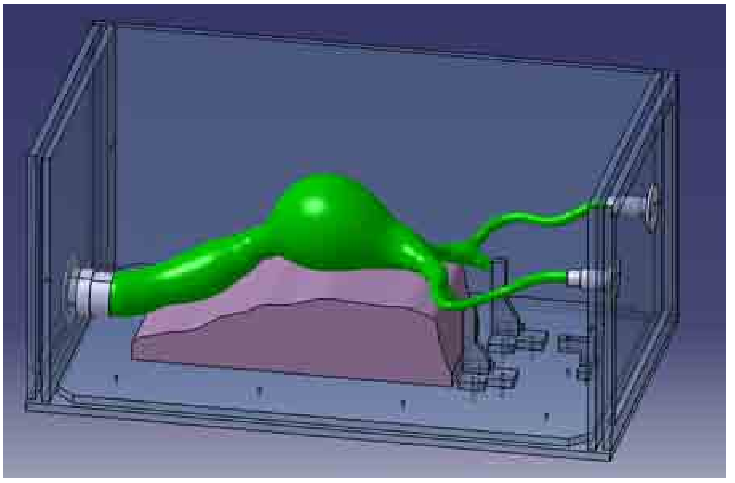


Modeling the pelvic bone as a rigid surface, like already done with the spine.

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 !?