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Une école de l'IMT

Towards real-time simulation of clinical thinking in surgery

Stéphane Avril

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SINCE 1816

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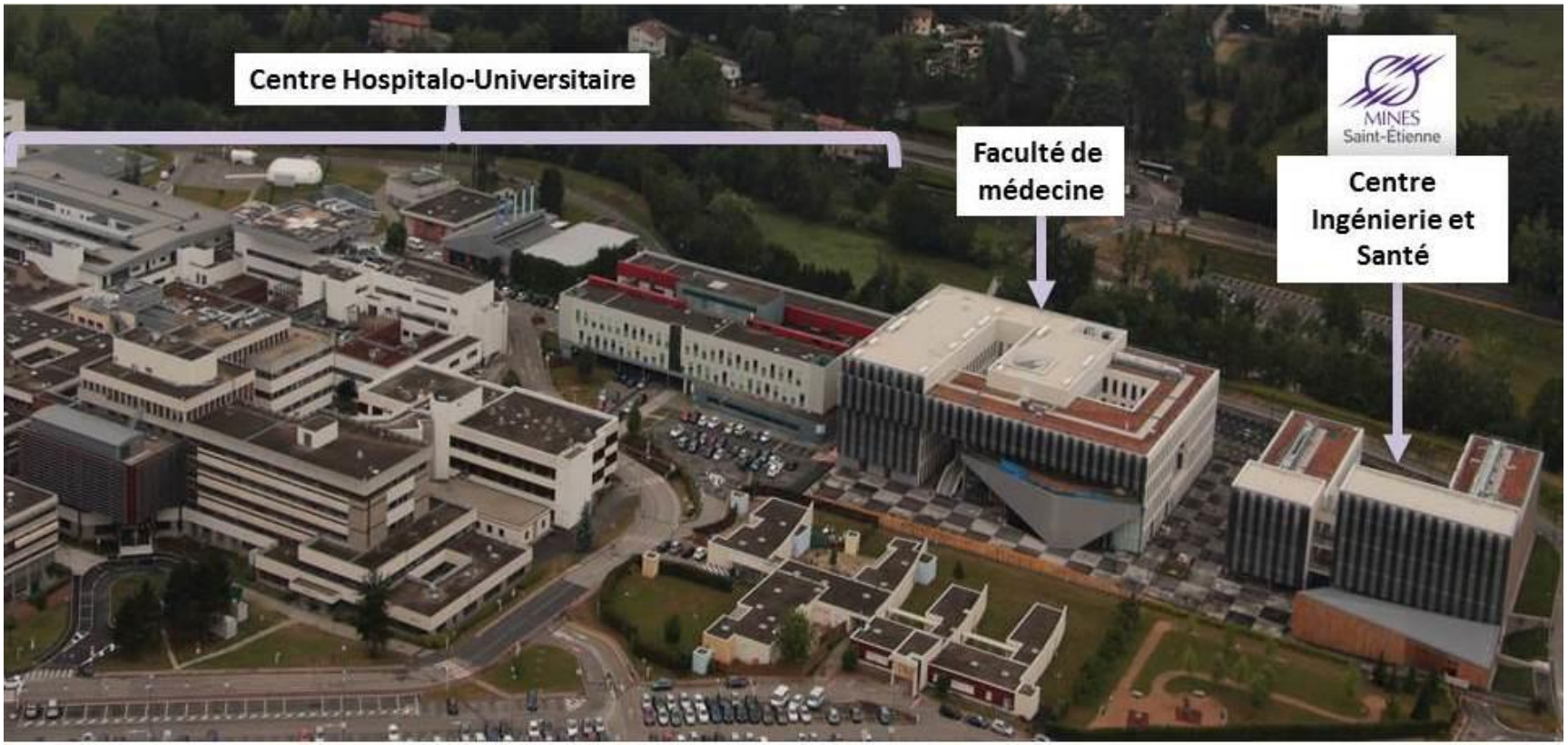
Centre Ingénierie et Santé

"Improving health through science and engineering"



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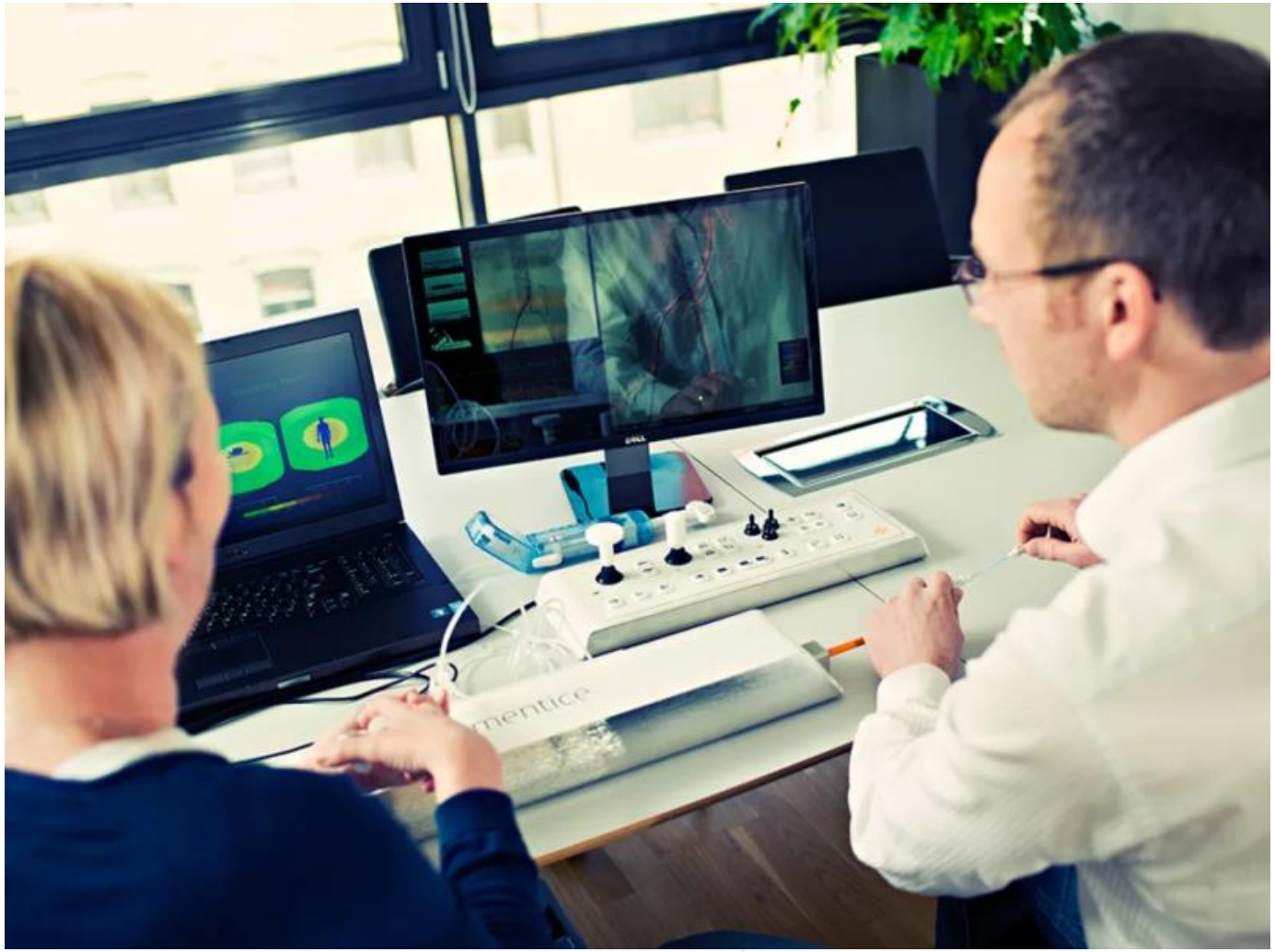


Vascular surgery - AAA

AAA occur in ***5%*** of male people aged 65 years or older

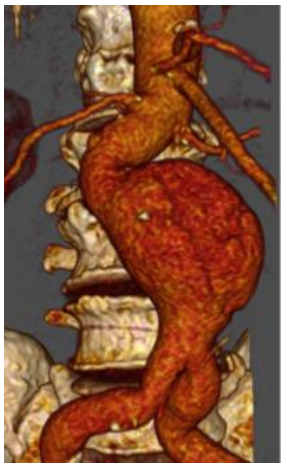
Mostly asymptomatic

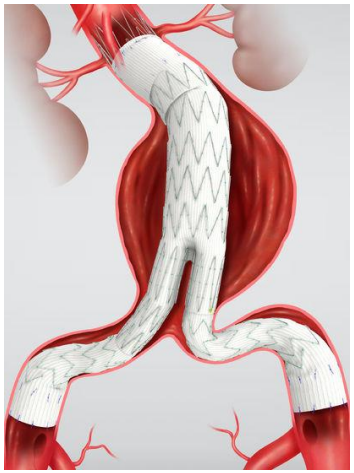
Rupture of aneurysms : ***15 000 deaths / year*** in the USA

Has to be treated before rupture

Open aortic surgery

Endovascular repair (100 000 / year)

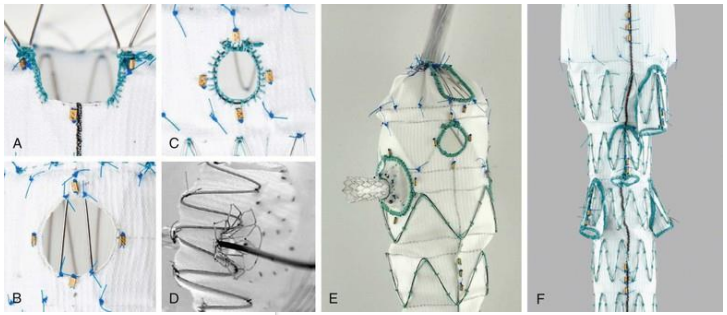




Clinical outcomes of EVAR

Strong influence of stent-graft design

Better outcomes with 3rd generation stent-grafts

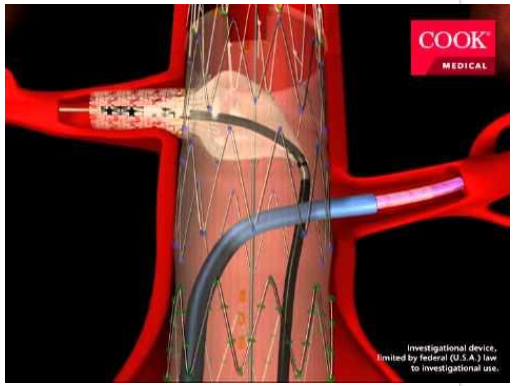


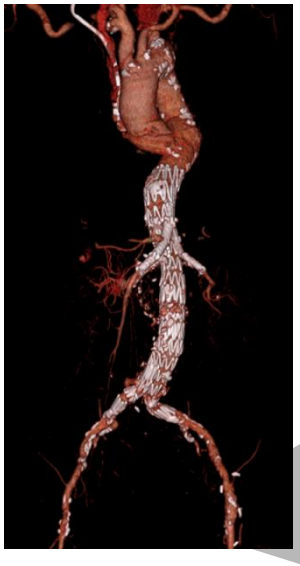
Strong influence of surgeon experience

Patient selection

Stent-graft positioning

Catheterization





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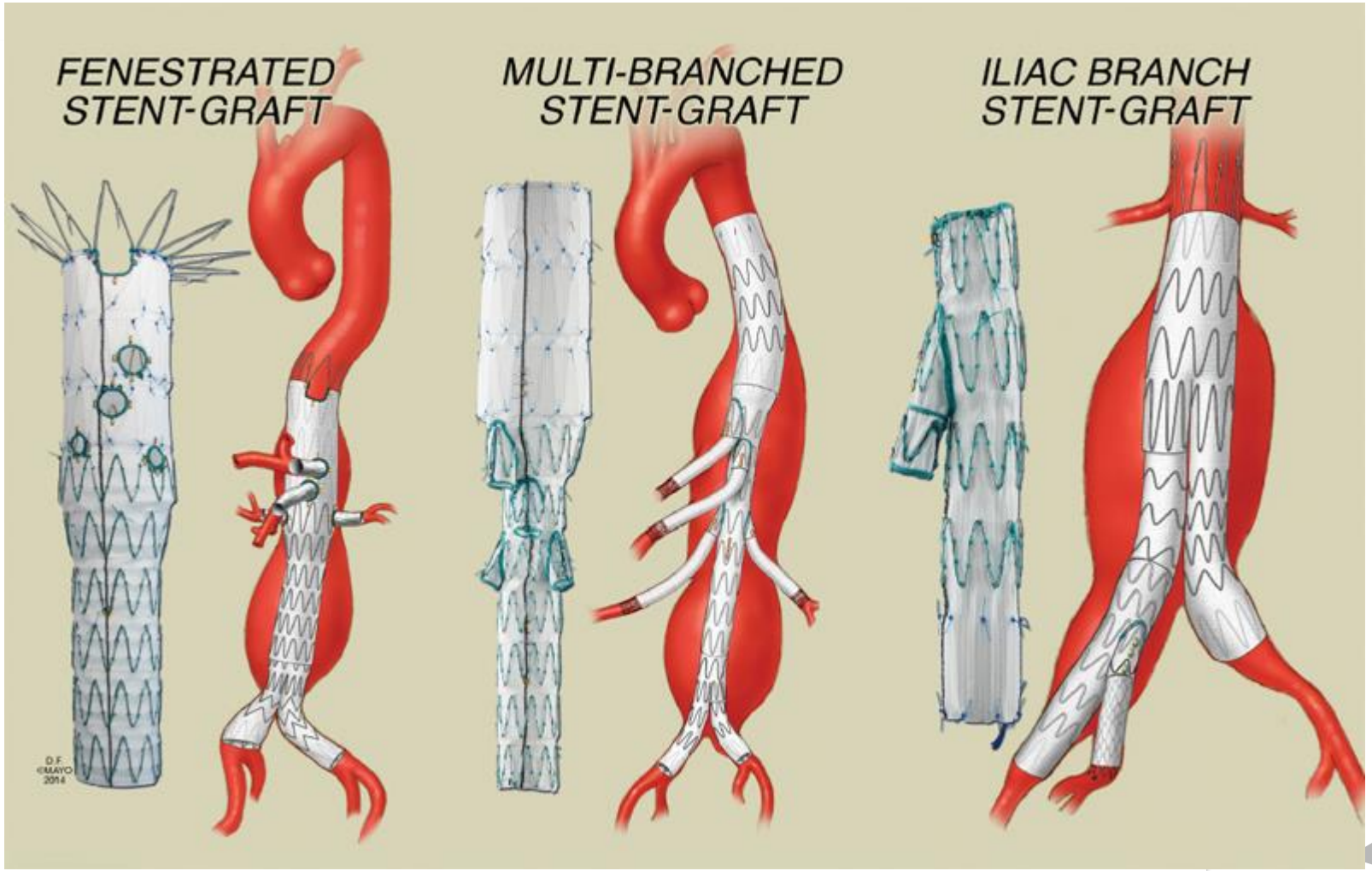
More and more complex procedures



EVAR workflow

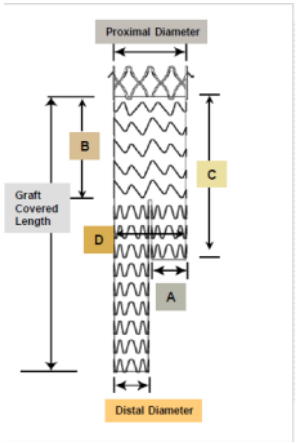
Choice of the type of repair (Open surgery vs Endo)

Patient age, comorbidities and preferences, Aorto-iliac morphology

Anticipation of intra and post-operative complications

Choice and sizing of the stent-graft to be implanted

Planning software



Proximal Diameter	Distal Diameter	Graft Covered Length	A	B
23	13	120	12	40
23	13	145	12	50
23	13	170	12	50
25	13	120	14	40
25	13	145	14	50
25	13	170	14	50
25	16	120	14	40
25	16	145	14	50
25	16	170	14	50
28	13	120	14	40
28	13	145	14	50
28	13	170	14	50
28	16	120	14	40
28	16	145	14	50
28	16	170	14	50
32	16	120	14	40
32	16	145	14	50
32	16	170	14	50
36	16	145	14	50
36	16	170	14	50

Stent-graft sizing chart

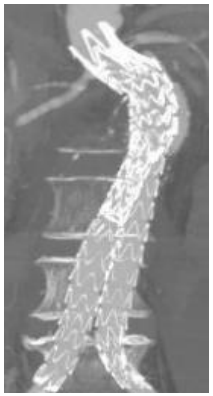
Clinical objectives

Secure EVAR interventions using numerical finite-element simulations

Easier /faster preoperative planning

Predict EVAR outcome

Avoid complications



COMPLEX CASES

Aorto-iliac tortuosities

Supra-renal and thoracoabdominal aneurysms (fenestrated and branched stent-grafts)

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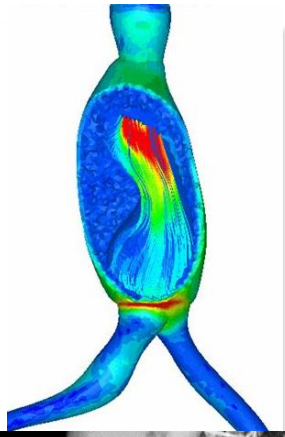
Simulation in vascular applications

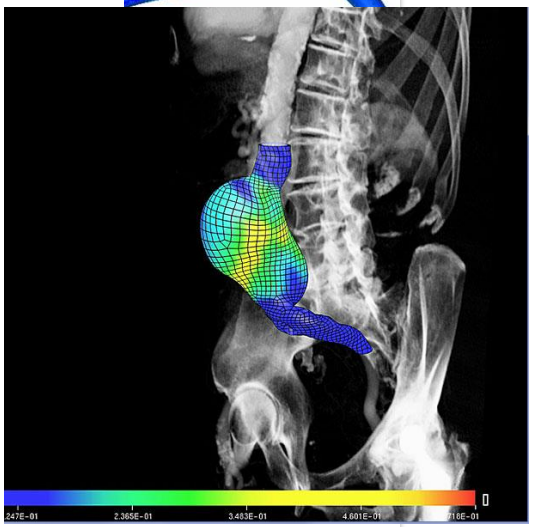
New insights on aneurysm rupture mechanisms

- **Arterial wall mechanics**
- **How does it rupture ?**
- **When ?**

New patient-specific decision making tool

- **Patient-specific**
- **From medical images**

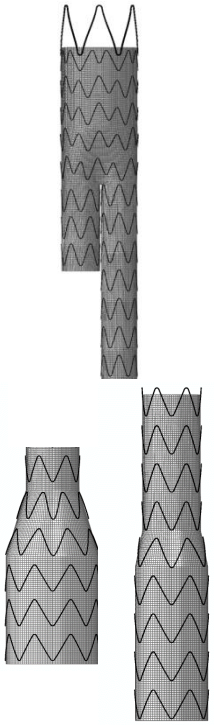




Validated model of stent-grafts

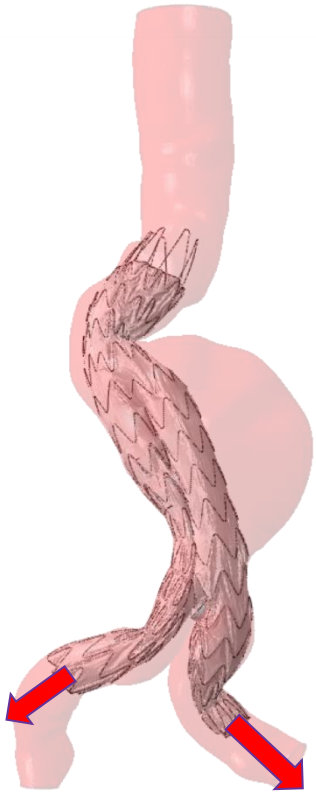
Approach of stent-graft deployment

[Demanget et al., 2012, *Ann Biomed Eng*]



FE models

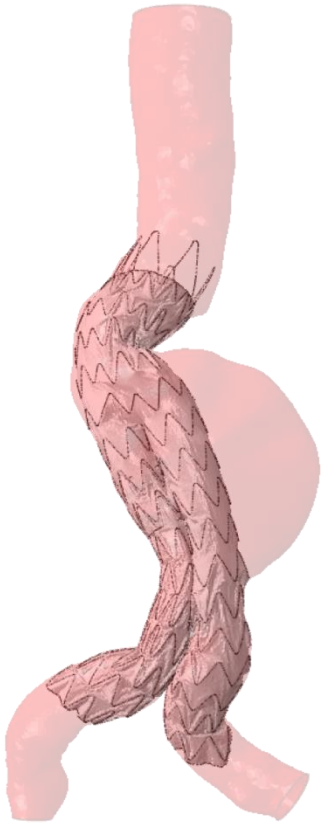
Stent-graft mechanics



Stent-graft in **preoperative geometry**

Mechanical equilibrium

Stent-graft and aorta mechanics



Equilibrium **post-deployment**

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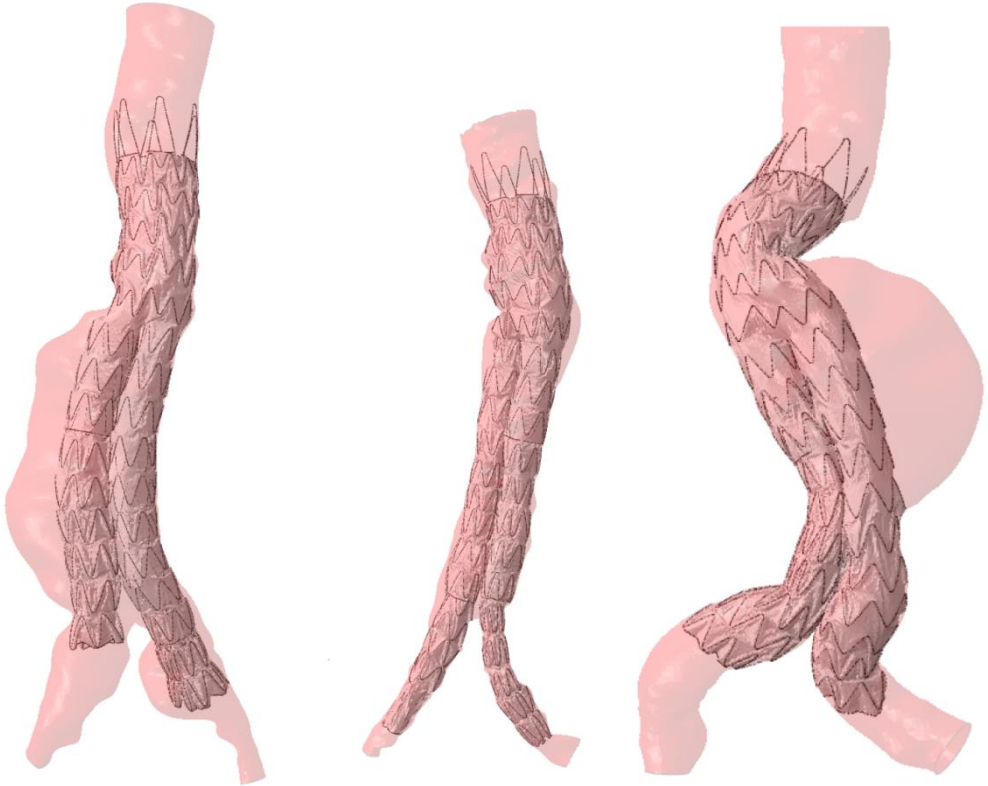
First clinical validations in 2014



Comparison

Red: simulation

Grey: CT-scan

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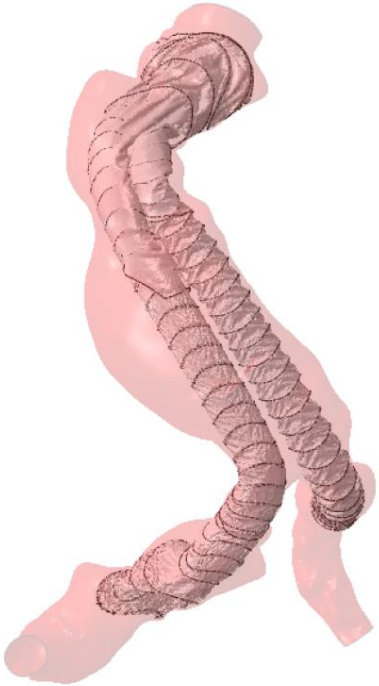
Extensions to all types of EVAR devices in 2015



Simulation **Comparison** **Red: simulation** **Grey: CT scan**

[Perrin et al., 2016, JMBBM]

Cohort of highly complex cases in collaboration with stent-graft companies… on going

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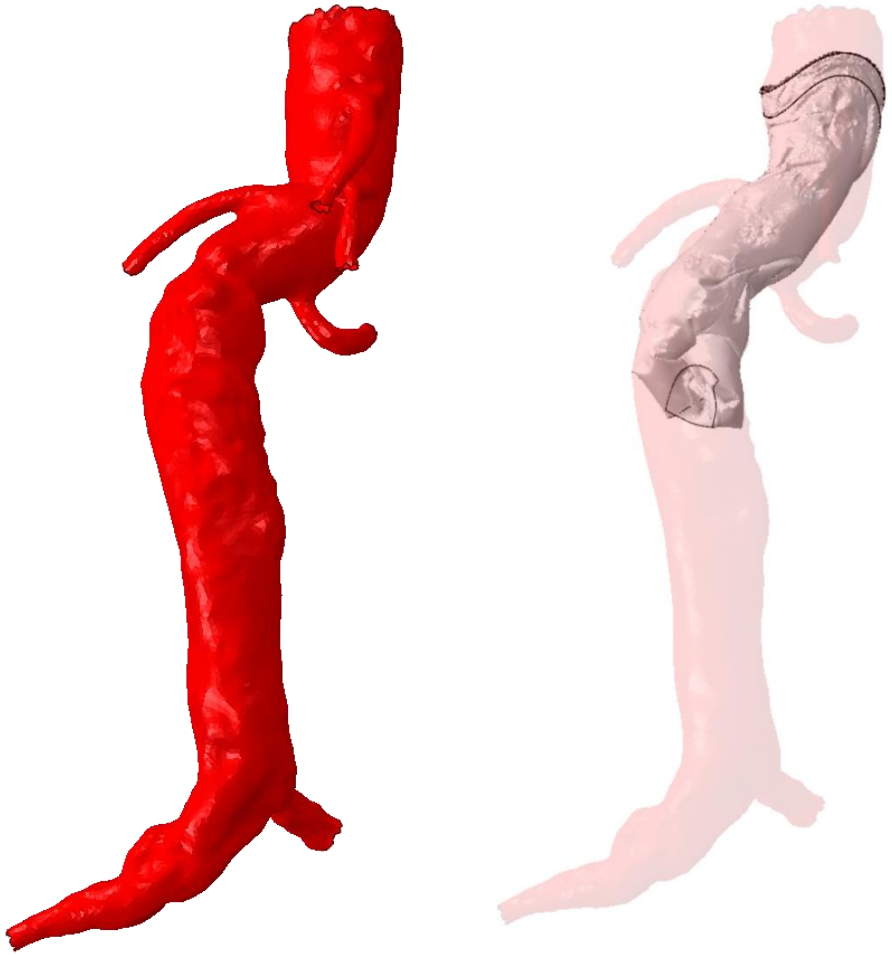
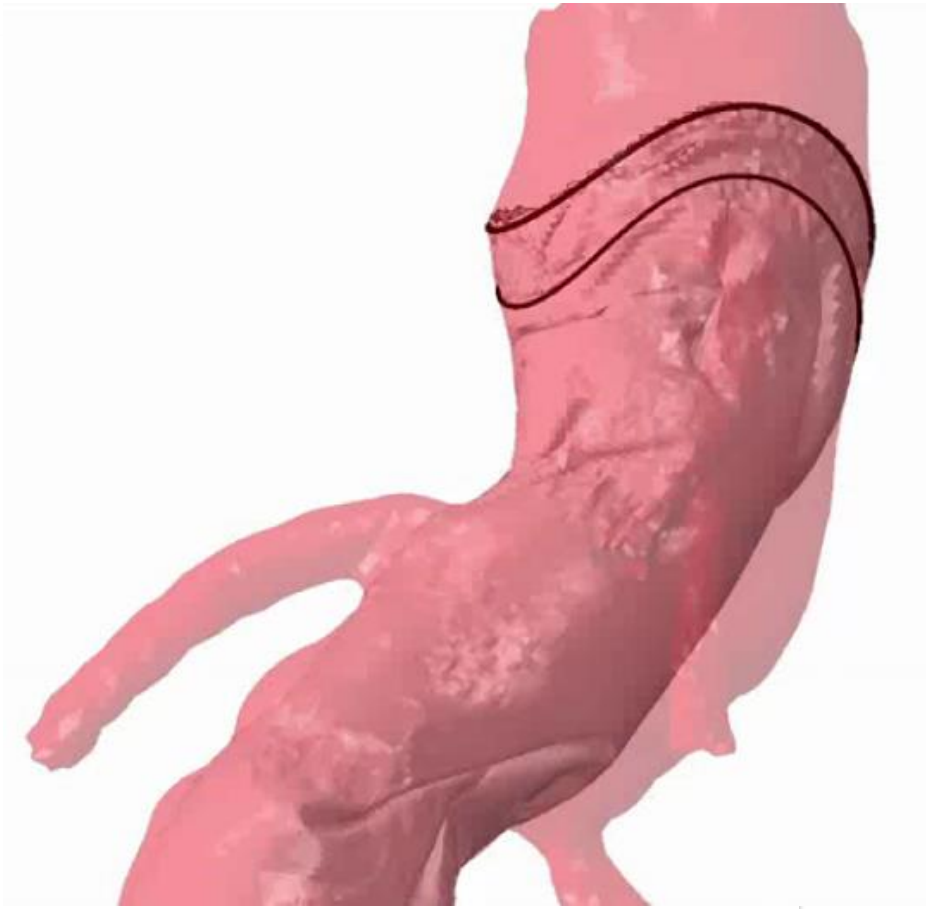
Fenestrated stent grafts in 2016





European patent

Creation of the start-up Predisurge in 2017

- Preuve de concept

  >50 cas simulés avec succès
  Études cliniques en cours

Validation des simulations (rouge) par comparaison aux scanners postopératoires (gris)

Simulation d'endoprothèse fenêtrée

Intégration dans les SI des établissements (salles hybrides)

Ou

Plateforme de simulation en ligne (interface + serveurs de calcul)

Prototype d'interface

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Soon in the operating theater?

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HPC challenges

Complex physics with soft solids, fluid structure interactions, contact nonlinearities and biology

Precision requires enough resolution in time and space

Clinicians wants real time simulations

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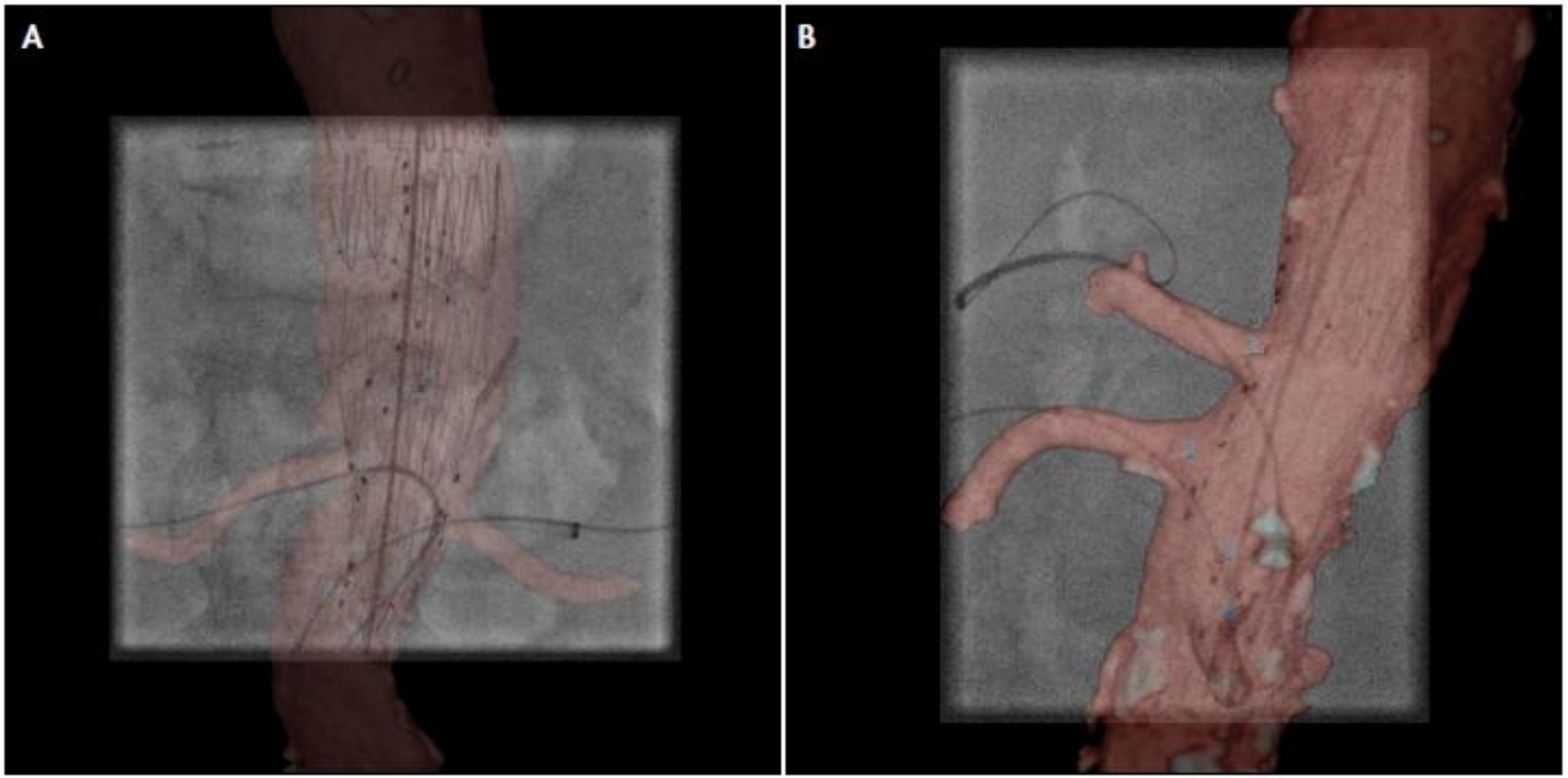
Towards numerical assistance during surgery



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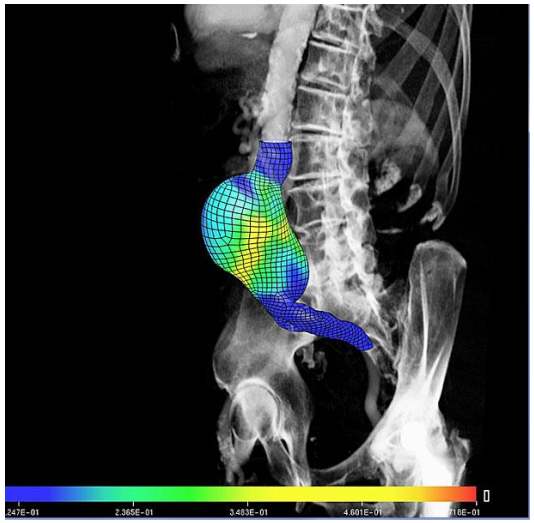
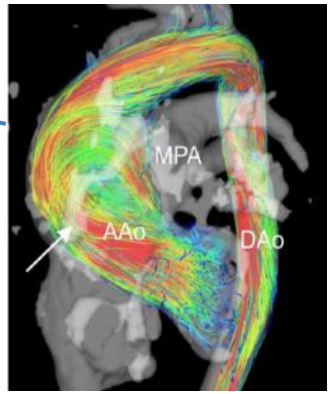
Models including biology



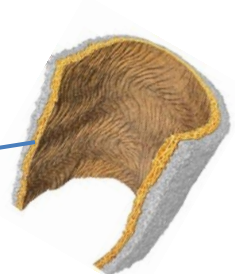
Clinical application

Application to mice models of aortic aneurysms

Identification of regional variations of material properties in aortas



Development of mechanobiological models



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Hospital demonstrator

Combinatorial optimisation

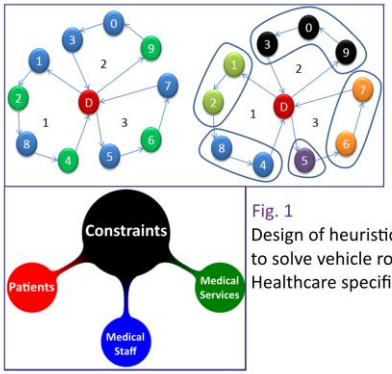


Fig. 1
Design of heuristics and metaheuristics to solve vehicle routing problems with Healthcare specific constraints.

Data analysis

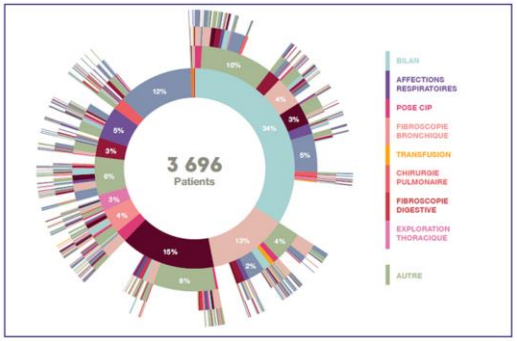


Fig. 2 A thorough analysis of large data mass from 3696 patients.

Discrete event simulation

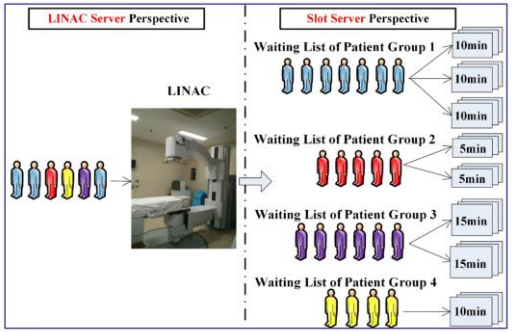


Fig. 3 Modeling, simulation and optimisation of the use of medical equipment.

Process modeling

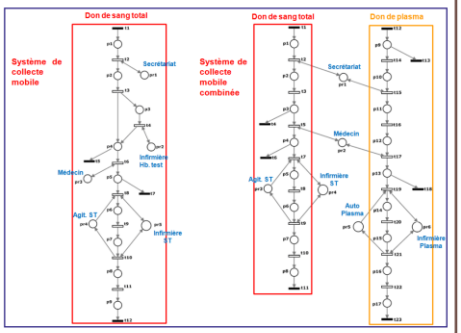


Fig. 4
Petri modeling of a mobile blood collection system.

Hospital demonstrator

La salle de contrôle de l'hôpital du futur

Cluster de calcul haute performance	Casques de réalité virtuelle	Tablettes, équipements de visualisation	Licences de logiciels de simulation/ optimisation

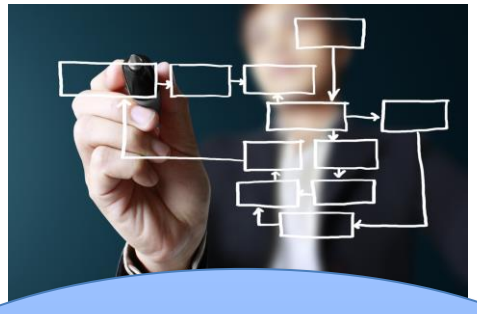
- **Visualisation en temps réel des activités de l'hôpital**
  - Occupation des lits
  - Demande en soins
  - Evaluation de performances
- **Virtualisation de scenarios de simulation**
  - Immerger les praticiens dans une nouvelle organisation
  - Faire tester de nouvelles technologies
- **Apprentissage personnalisé**
  - Mise à disposition des applications à distance
  - Lien avec l'open lab pour la continuité

Hospital demonstrator

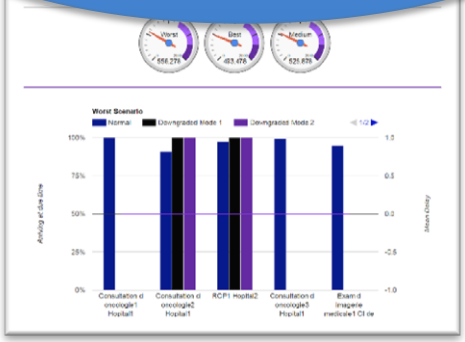
Cycle de co création avec le support du démonstrateur

Problème
+
Données

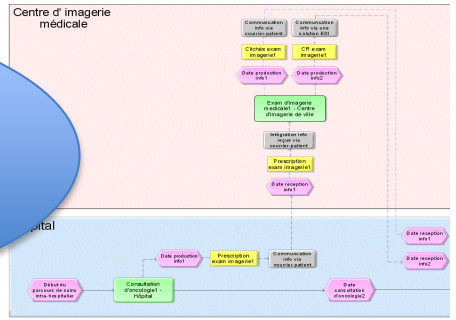
Co création



Prototypage rapide



Indicateurs de performance



Plateforme de modélisation générique

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Merci
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