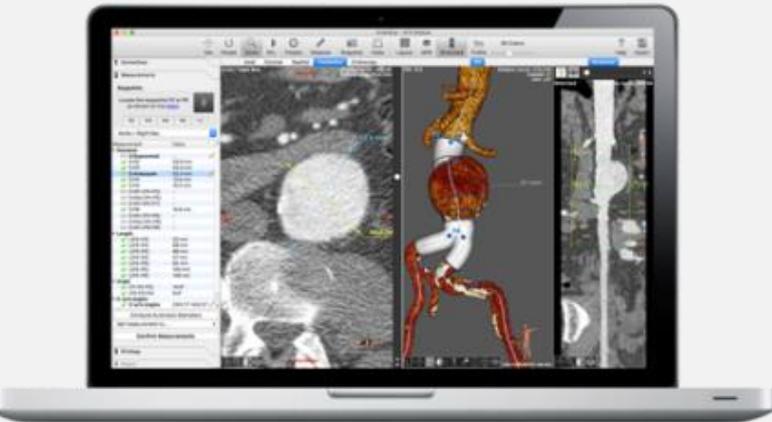




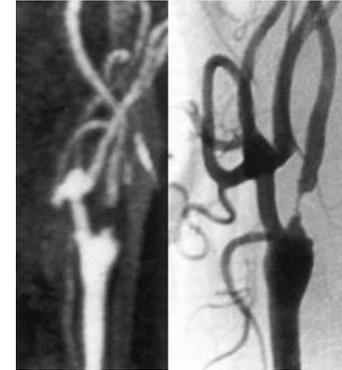
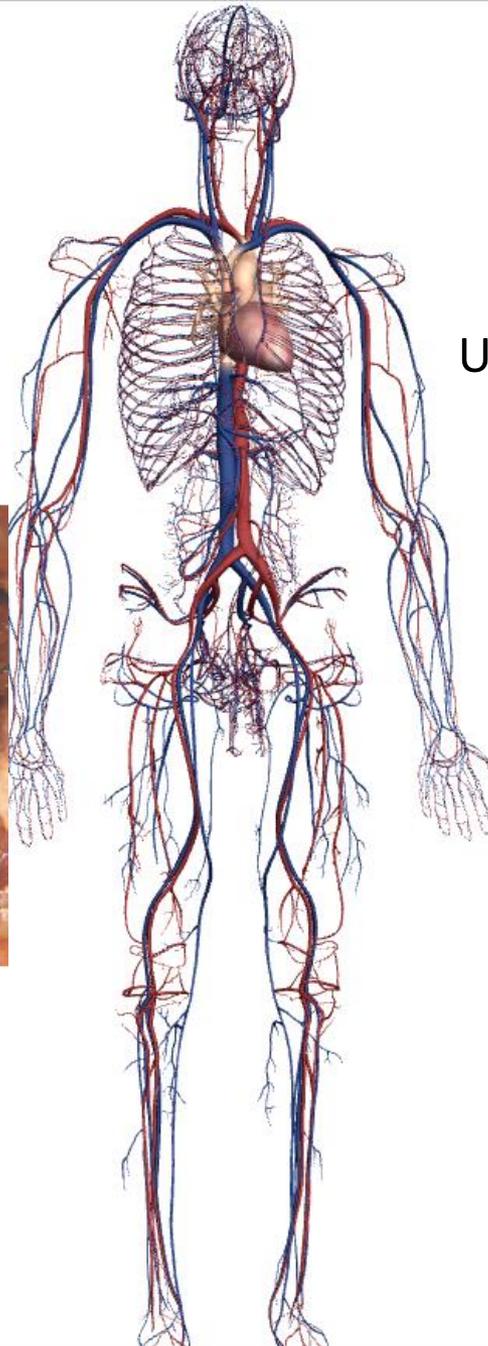
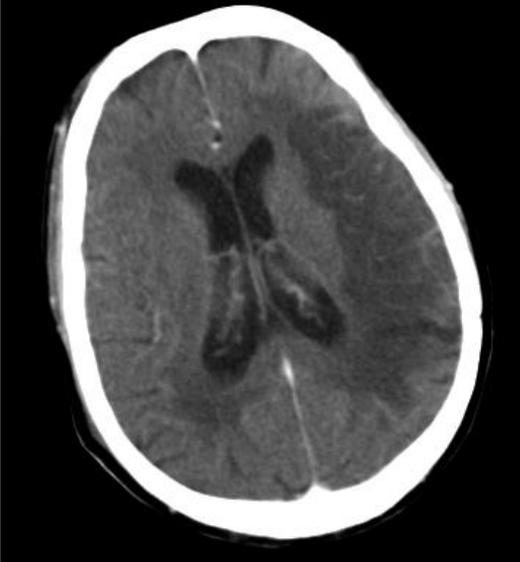
Chirurgie vasculaire assistée par ordinateur

Apport des technologies dans la pratique des interventions
cardiovasculaires



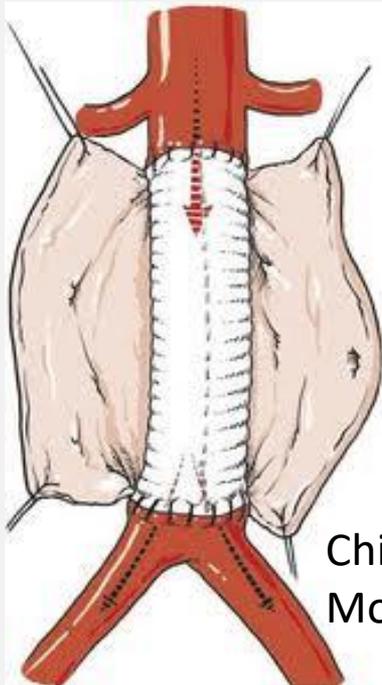
Antoine Lucas, Chirurgien des Hôpitaux, LTSI, CHU Rennes

Artériopathie oblitérante Une maladie de toutes les artères

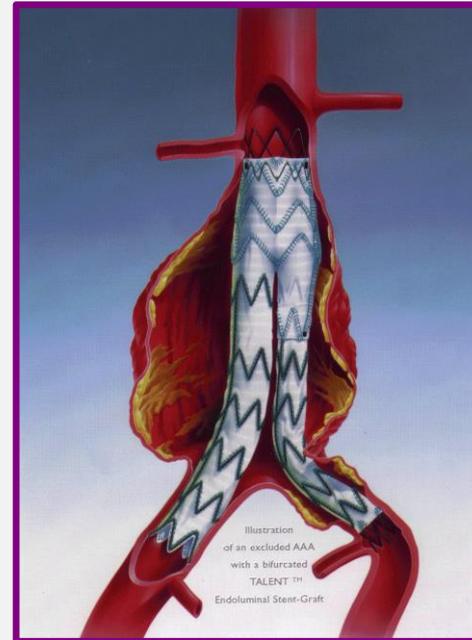




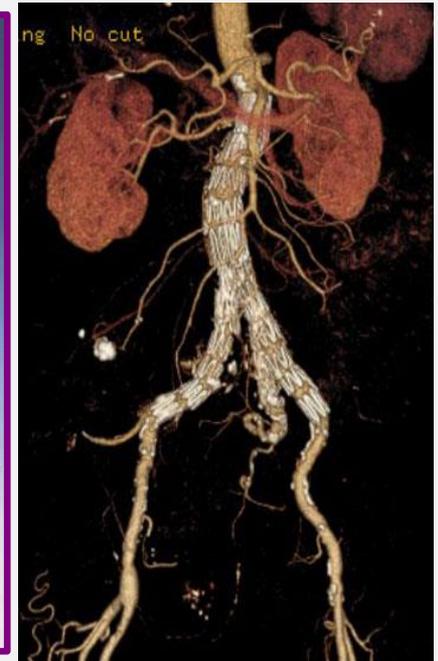
Chirurgie des anévrysmes de l'aorte



Chirurgie ouverte
Mortalité de 4 à 12%



Chirurgie endovasculaire
Mortalité < 1%



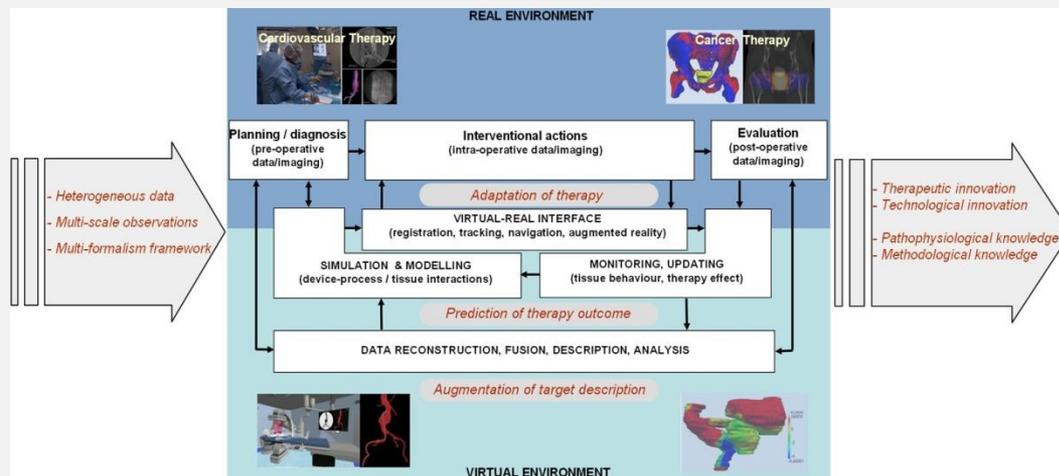
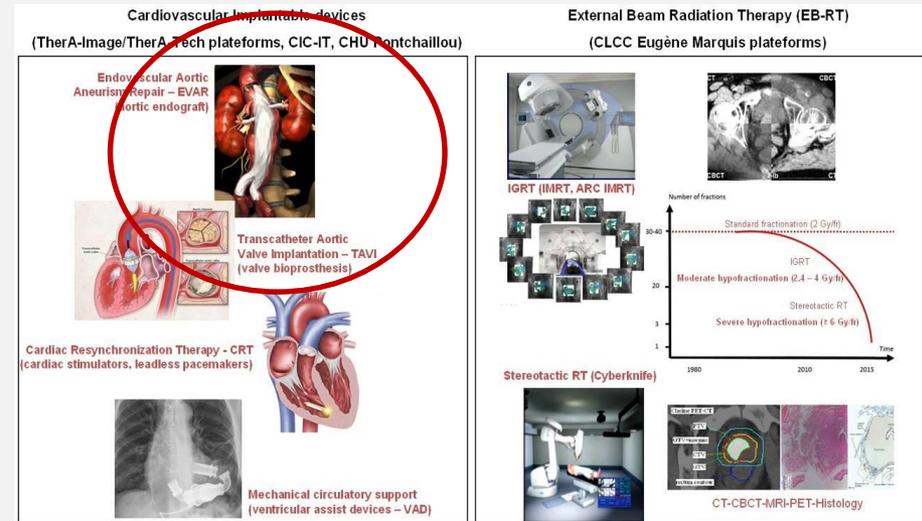
IMPACT (LTSI) : contexte, thématique et approche

Domaines : thérapies mini-invasives guidées par l'image
thérapie cardiovasculaire, radiothérapie externe

Objectif : optimisation et personnalisation de la stratégie interventionnelle

Défis :

- structures anatomopathologiques déformables et/ou en mouvement
- observations physio-pathologiques pré-/per-/post-traitement, multi-modales, multi-échelles



Coopération entre réel/virtuel spécifique patient

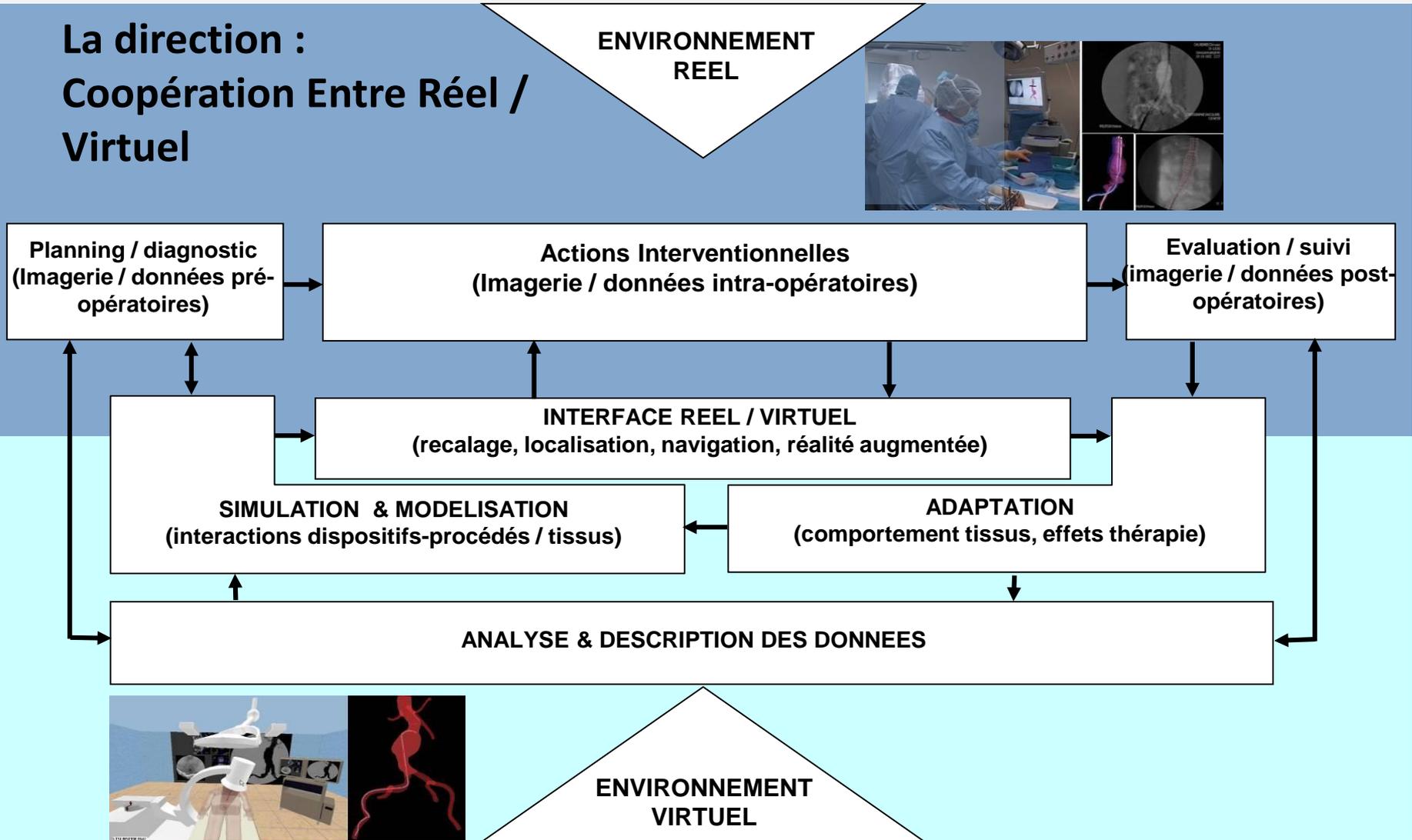
une approche intégrative pour la personnalisation du traitement

Axes de recherche :

- Description augmentée de la cible
- Prédiction des effets du traitement
- Adaptation de la thérapie

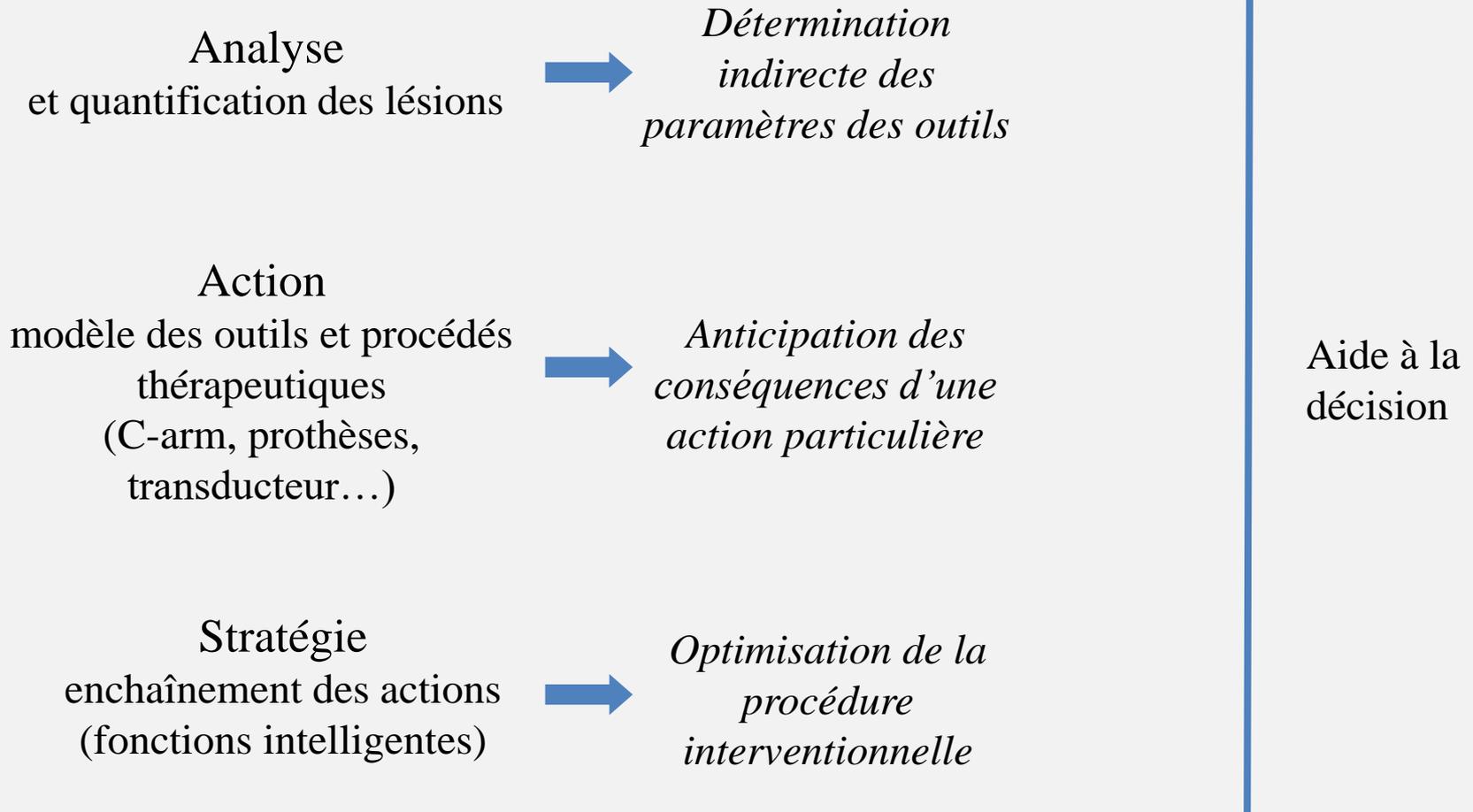


La direction : Coopération Entre Réel / Virtuel





Planning interventionnel





Imagerie de reconstruction et d'analyse au bloc opératoire :

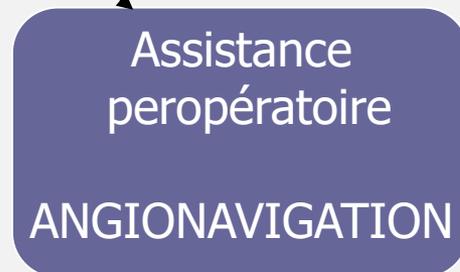
- 3 étapes -



Choix du dispositif le plus adapté à l'anatomie du patient



Simulation de cathétérisme,
positionnement du C-arm,



Travailler en 3D, information
pariétale, Déformation des tissus...



Endosize. (Therenva)





EndoSize - Patient Database

File Help

Import CD Folder Archive Action Open Slices selection Reset Export Delete

Smart Folders Show all Last day Last week Last month

Filter by type

- EVAR
- TEVAR
- Fenestrated EVAR
- Peripheral

Search

Patient Name	Exam Date	Importation	Images	Inter-slice	Physician	Description	Birthdate	Institution
▶ BLOLU - 81 y/o - ♂								
▶ BOI - ♂								
▶ BONSI - 86 y/o - ♀								
▶ BOT - ♂								
▶ CFD - 64 y/o								
▶ CFD - 73 y/o								
▶ CFD - 83 y/o								
▶ COE - ♂								
▶ DEPDI - ♂								
▶ DEoja - ♂								

Bookmark

INTELIX™

EVAR
 TEVAR
 Fenestrated EVAR
 Peripheral
 TAVI
 Cardiatis
 AFX
 Nelix

Follow-up exam (n months) Post-op

Last opened date

Age at exam date

Physician

Institution

List of Reports ▼

Local Database

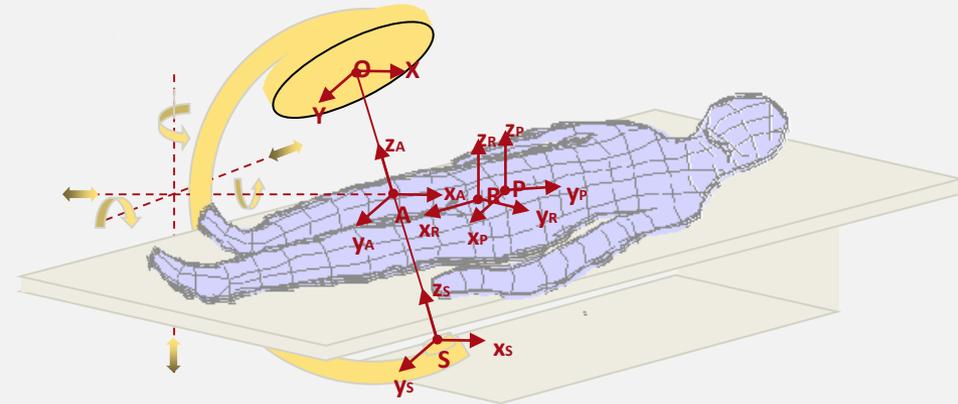
- CAC-DB1-MILGE
- CAC-DB1-SIMPI
- CAC-DB2-DAH
- CAC-DB2-TRI
- DB
- GrosseDB
- External Database (USB)



Définition d'un référentiel commun*

Mise en correspondance préop. / perop.

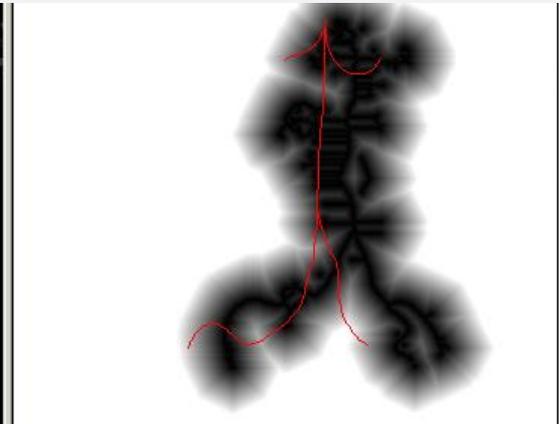
Calibrage, Recalage 3D/2D :
transformations géométriques



- Informations apportées par l'EV :
- Choix des paramètres, primitives
 - Répétition préopératoire



Image peropératoire

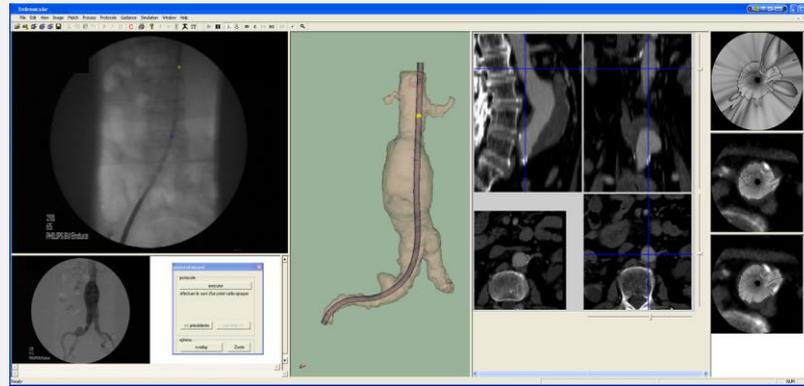


Carte de distance

* Gestes médico-chirurgicaux assistés par ordinateur : [Cinquin et al, IEEE EMB 1995], [Taylor et al, MIT press 1996]

3 - Angio-Navigation, Assistance peropératoire – Pratique idéale : ENDONAUTE (Thérenva)

- Positionnement 3D précis et sécurisé
- Visualisation 3D : vaisseaux, paroi, calcifications, thrombus et stent
- Temps Réel
- Intégration dans une salle d'opération standard
- Conservation des protocoles cliniques



* EndoNaut : premier prix 2008 de l'AGBM pour les technologies médicales innovantes

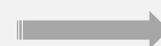
* Brevet : Haigron P., Lucas A. FR 02/04898 (PCT WO 03/088143 A2). Université de Rennes 1

Les expérimentations :

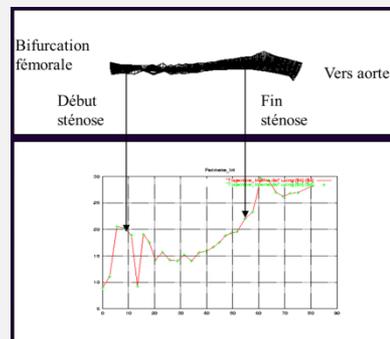
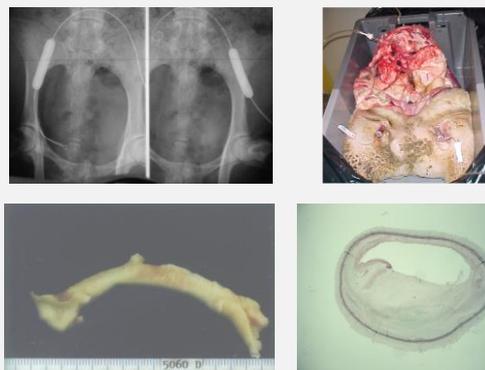
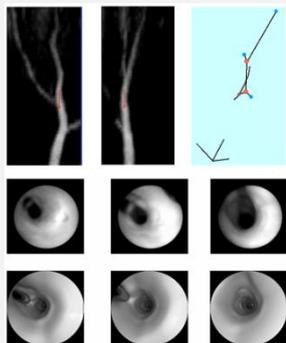
1999



2002



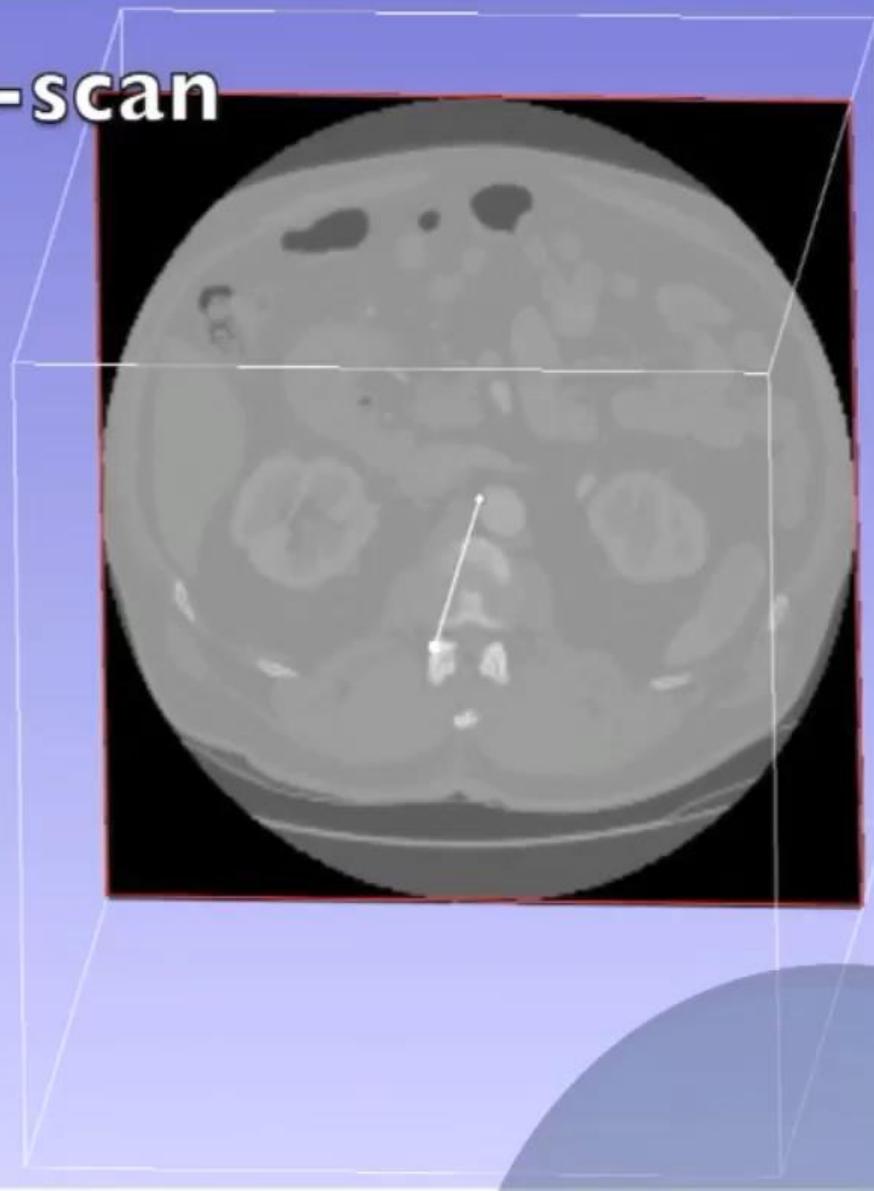
2014

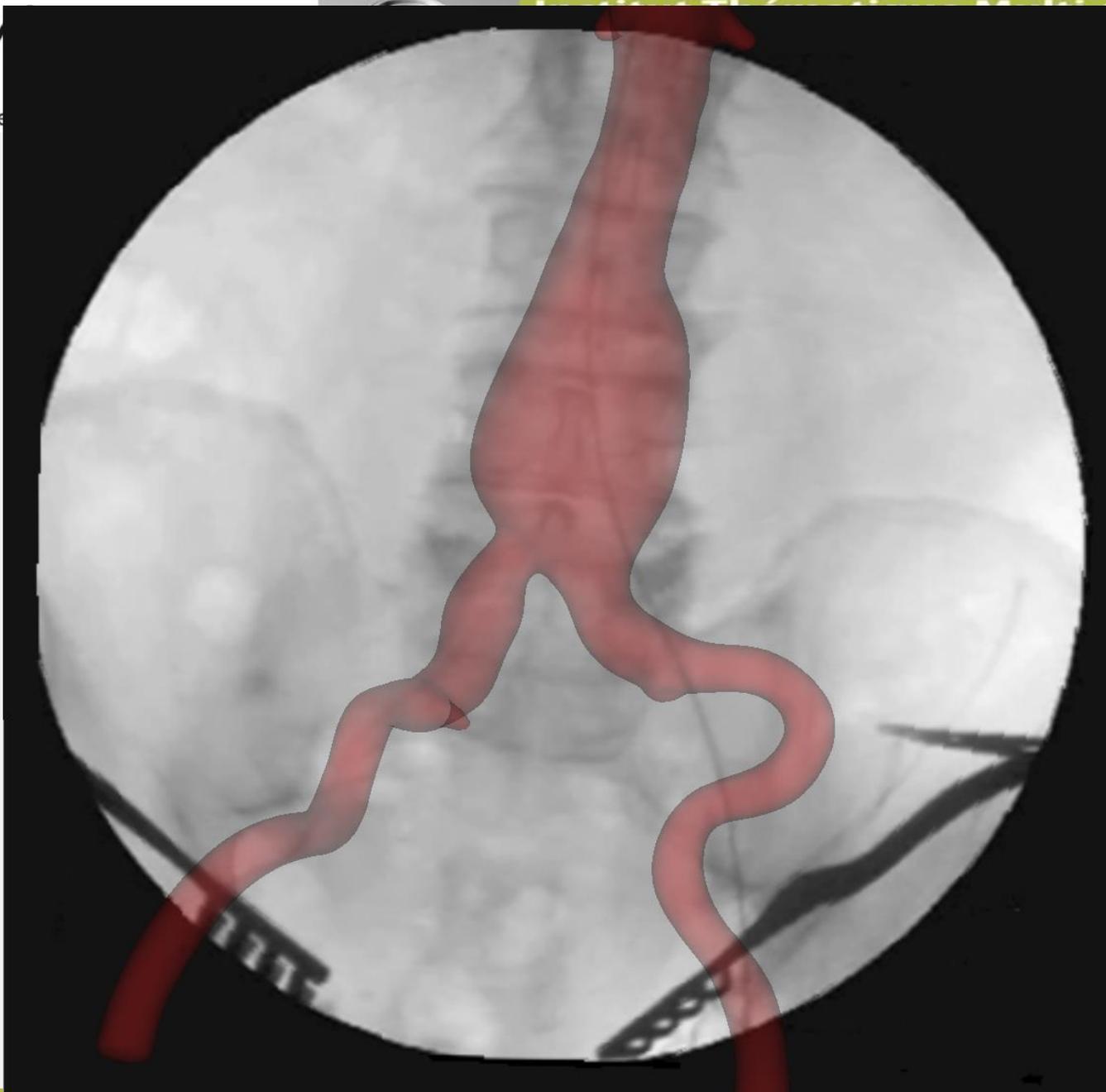


TherA-Image



Preop CT-scan







Dimensionnement
Analyse et description
des données patient

Déformations
Modélisation
interactions
outils/tissus

Planning
Simulation des outils (c-
arm, Cathéter, endoprothèse)

EndoNaut (Therenva)

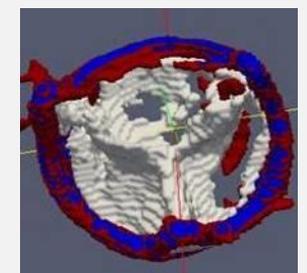


Localisation
magnétique 3D*

Réduction de la fluoroscopie

Navigation per-op.
Interface de réalité
augmentée

TAVI***



* Localisation magnétique: LTSI, TIMC & CHU Grenoble, Therenva

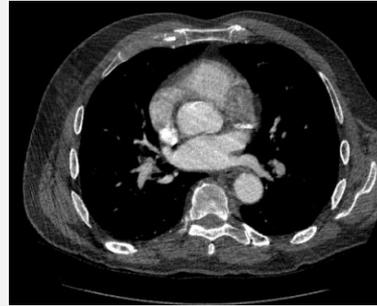
** TecSan ANGIOVISION : LTSI, ANSYS, LaMCoS, Therenva, CIC-IT Rennes, CHU Henri Mondor

*** ITEA2 MEDIATE (Philips, Institut Telecom) : LTSI, Therenva, Philips Medisys, iXR, SQI



Simulation of vasculature deformation

Collab. LTSI,
LaMCos,
ANSYS, Therenva



Preoperative CT Scan



EndoSize®

Nodes position and
table of connectivity



Aorta thickness



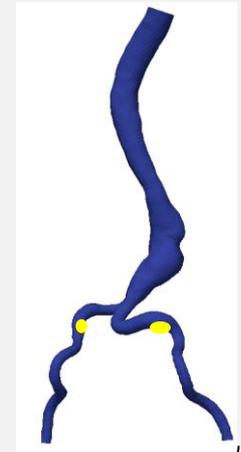
Calcification map



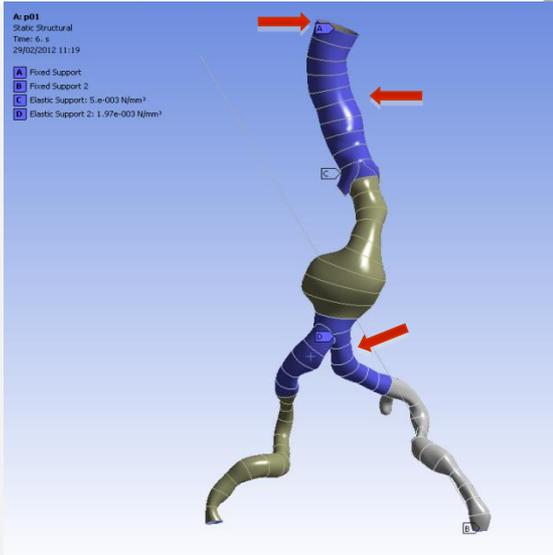
Distance between
aorta and bones



Fixation points



Simulation of vasculature deformation



Fixed supports:

- Superior extremity
- Introduction point

Elastic supports:

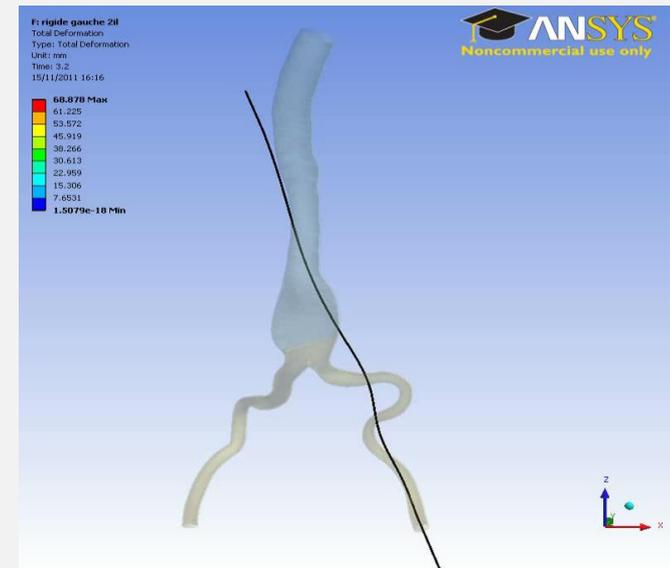
- Link to spine
- Common iliac arteries, which are less deformable than external iliac arteries
(stiffness value to be tuned)

1-Initialisation of the guidewire:

The guidewire is placed on a precomputed path which constrains it into the vessel and minimizes its bending energy

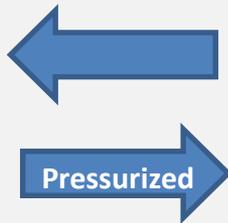
2-Relaxation:

Contact activation and progressive relaxation of the guidewire until equilibrium state

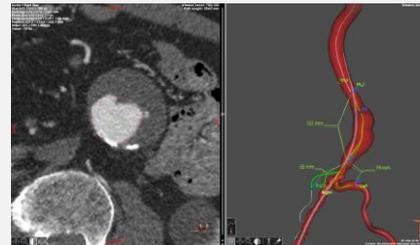


Simulation of vasculature deformation

Aorta geometry without blood pressure



Aorta reference geometry
Unknown constraint strain
Aorta reference geometry
known constraint strain



Device insertion

Flexible catheters, Stiff guidewires
Delivery system



*Collab. LTSI,
LaMCos,
ANSYS, Therenva*



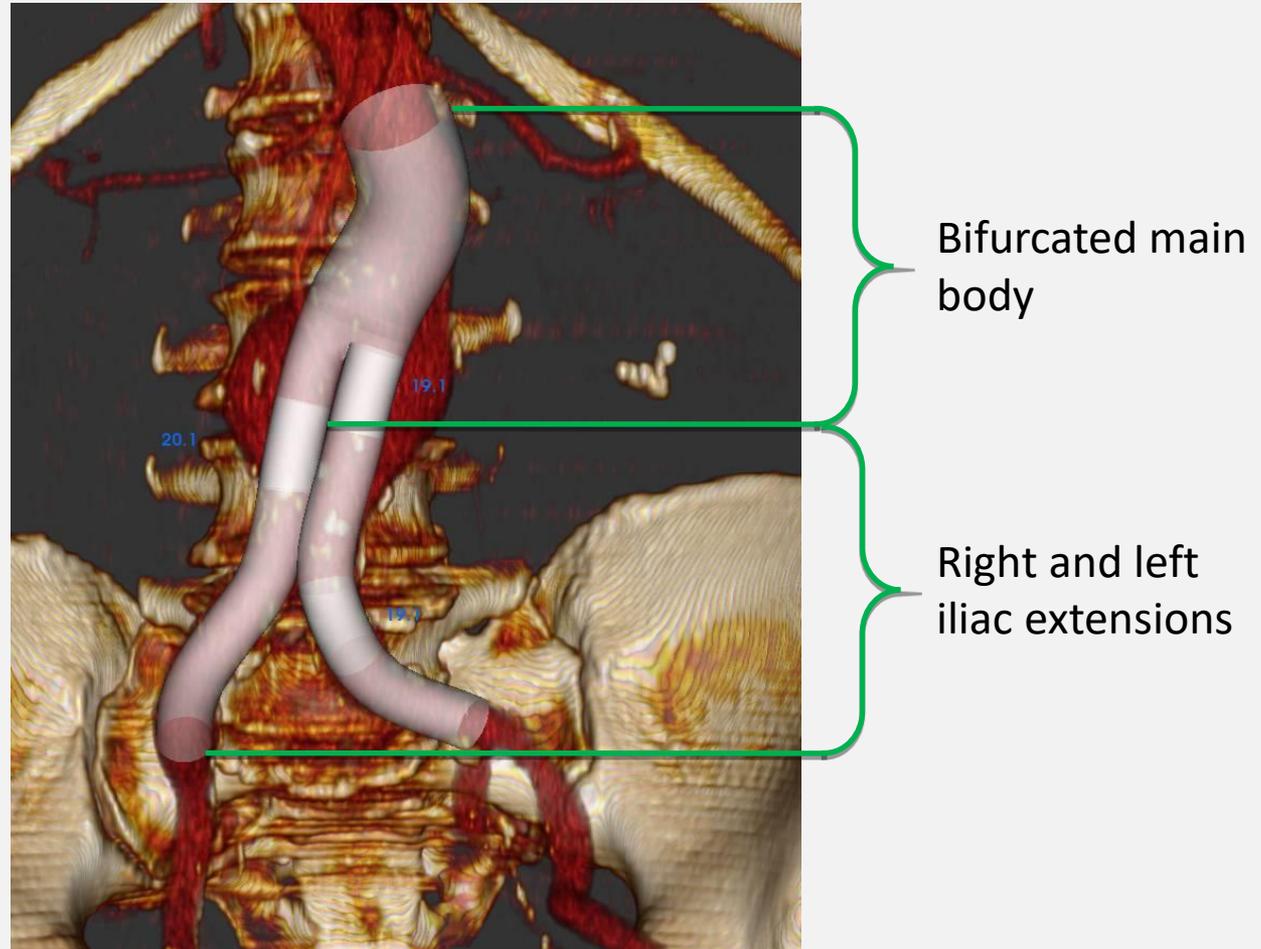
Imposed velocity
to lower extremity



Gindre J, Bel-Brunon A, Kaladji A, Dumenil A, Rochette M, Eniche A, Haigron P, Combescure A. **Finite Element Simulation of the Insertion of Guidewires During an Evar Procedure: Example of a Complex Patient Case, a First Step toward Patient-Specific Parameterized Models.** International Journal for Numerical Methods in Biomedical Engineering. 2015; 31:e02716.



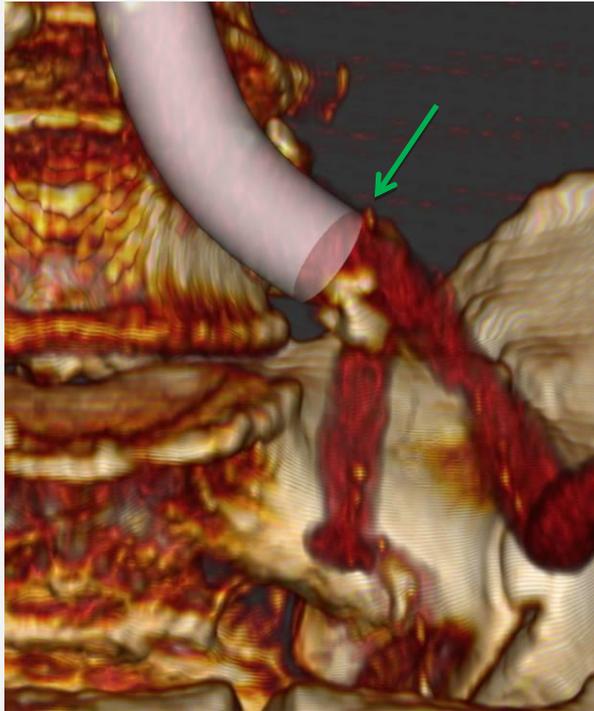
Real / Virtual Cooperation



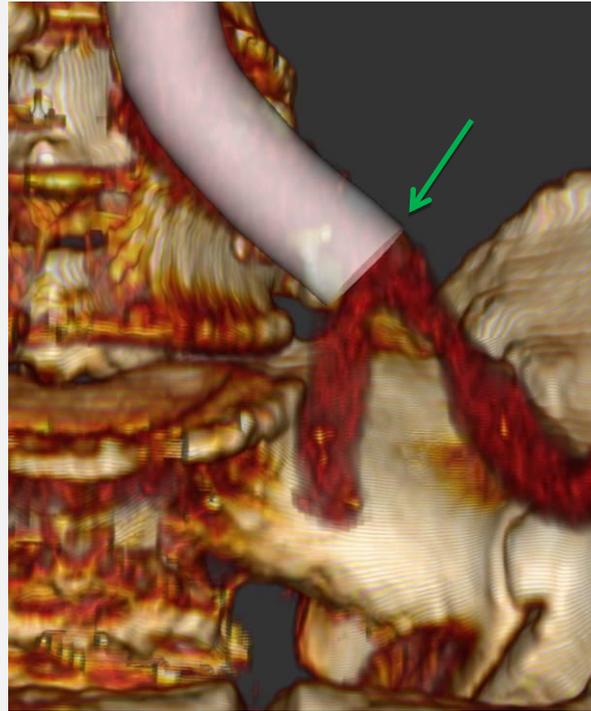
Duménil A, Kaladji A, Gindre J, Castro M, Rochette M, Göksu C, Lucas A, Haigron P. **Visualization of stent-graft placement in deformed vascular structure in EVAR procedure.** Proceedings of MICCAI - Stent'13, 2nd MICCAI Workshop on Computer Assisted Stenting. Nagoya, Japan, sep. 22-26, 2013.

Real / Virtual Cooperation

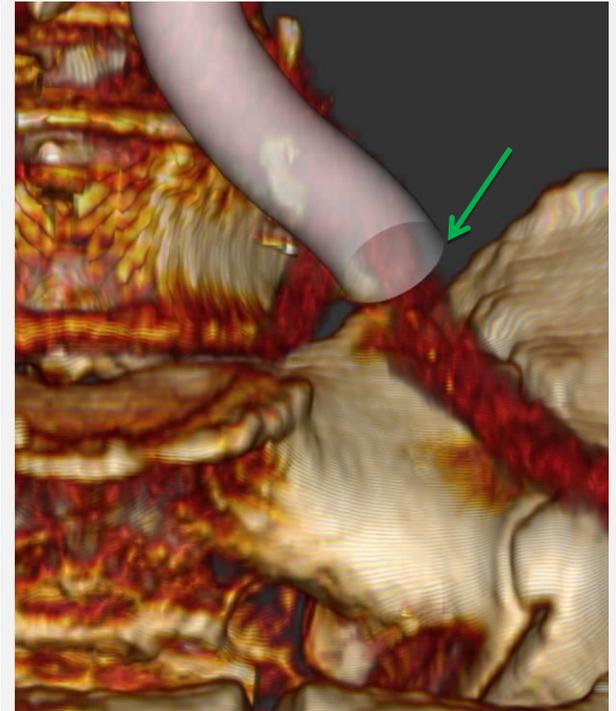
Stent-graft placement in undeformed and deformed CT-scan



Undeformed CT-scan



CT-scan deformed by
guidewire



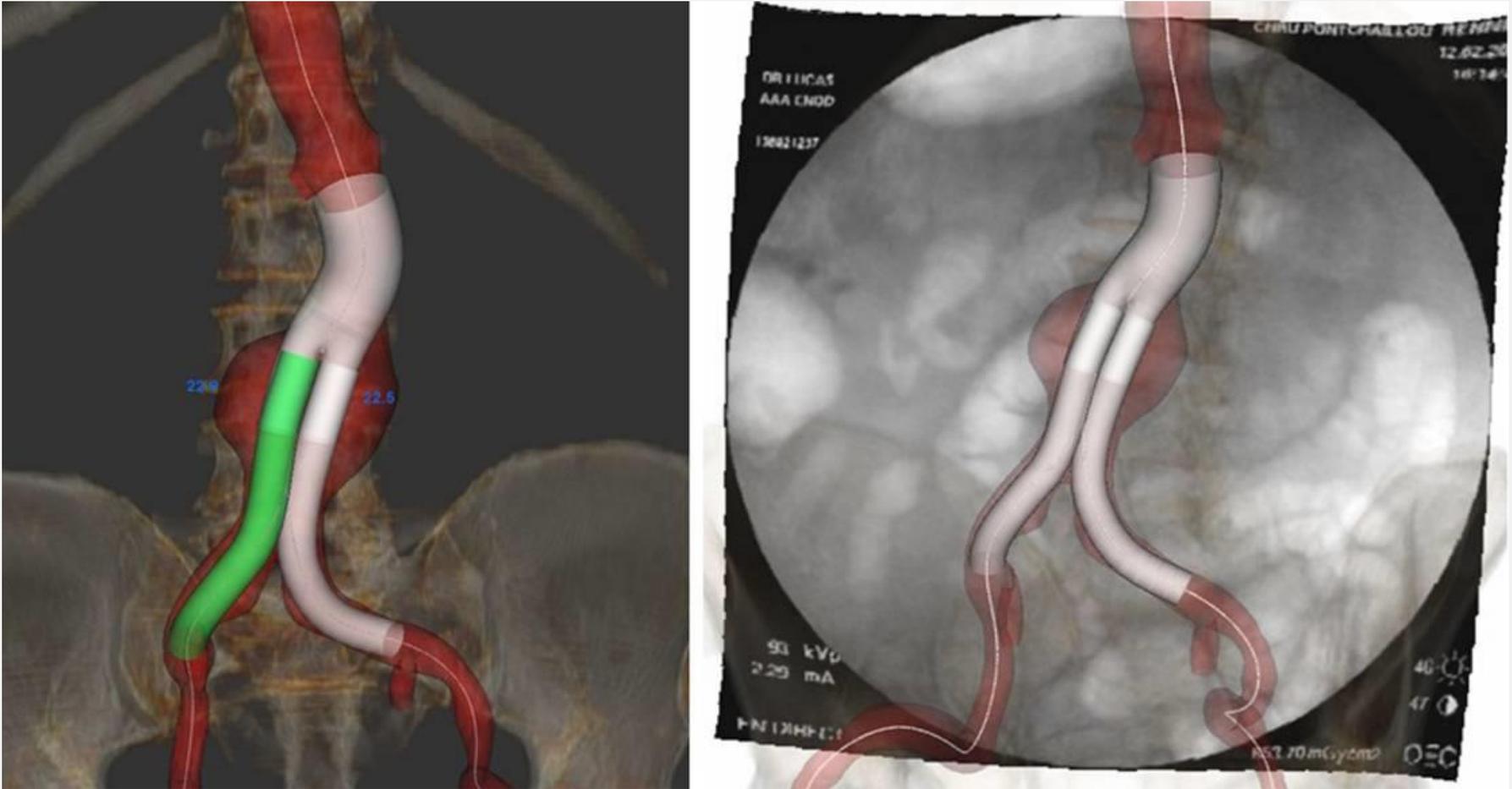
CT-scan deformed by
delivery system

Duménil A, Kaladji A, Gindre J, Castro M, Rochette M, Göksu C, Lucas A, Haigrón P. **Visualization of stent-graft placement in deformed vascular structure in EVAR procedure.** Proceedings of MICCAI - Stent'13, 2nd MICCAI Workshop on Computer Assisted Stenting. Nagoya, Japan, sep. 22-26, 2013.



3D-2D fusion for computer assisted Endovascular Aortic Aneurysm Repair Real / Virtual Cooperation

Virtual pre-deployment → augmented perception (/decision)

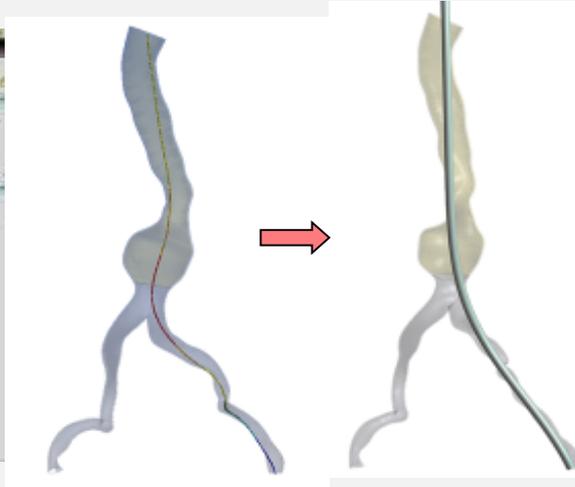
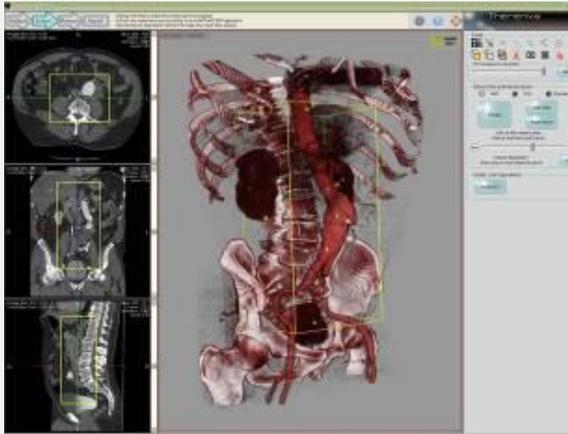


Duménil A, Kaladji A, Gindre J, Castro M, Rochette M, Göksu C, Lucas A, Haigron P. **Visualization of stent-graft placement in deformed vascular structure in EVAR procedure.** Proceedings of MICCAI - Stent'13, 2nd MICCAI Workshop on Computer Assisted Stenting. Nagoya, Japan, sep. 22-26, 2013.

3D-2D fusion for computer assisted Endovascular Aortic Aneurysm Repair

Pre-op / Intra-op Matching

ANR Project ANGIOVISION



Patient specific FEM simulation of device / tissue interactions:

Definition of an anatomico-mechanical model, pre- / intra-operative registration and matching, parametrization

Collab. LTSI, ANSYS, Therenva



Finite-Element-Based Matching of Pre- and Intraoperative Data for Image-Guided Endovascular Aneurysm Repair

Aurélien Duménil*, Adrien Kaladji, Miguel Castro, Simon Esneault, Antoine Lucas, Michel Rochette, Cemil Göksu, and Pascal Haigrón

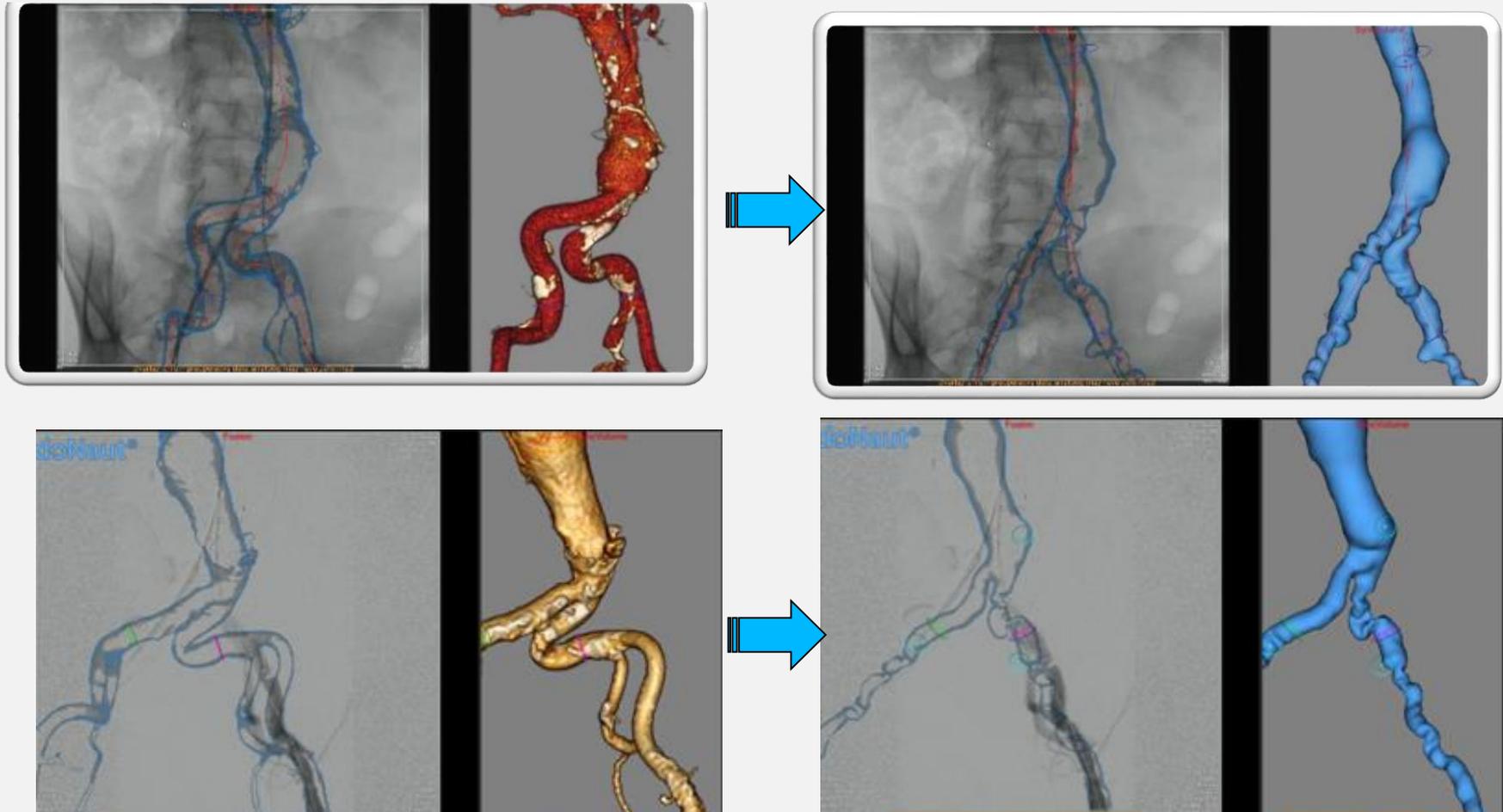


Augmented Angio-Navigation:

Intra-operative localization, 2D X-ray Imaging (reduction of X-rays and contrast)

Assistance per-opératoire

Simulation biomécanique



Gindre J, Bel-Brunon A, Kaladji A, Dumenil A, Rochette M, Lucas A, Haigron P, Combescure A. **Finite Element Simulation of the Insertion of Guidewires During an Evar Procedure: Example of a Complex Patient Case, a First Step toward Patient-Specific Parameterized Models.** International Journal for Numerical Methods in Biomedical Engineering. 2015; 31:e02716.



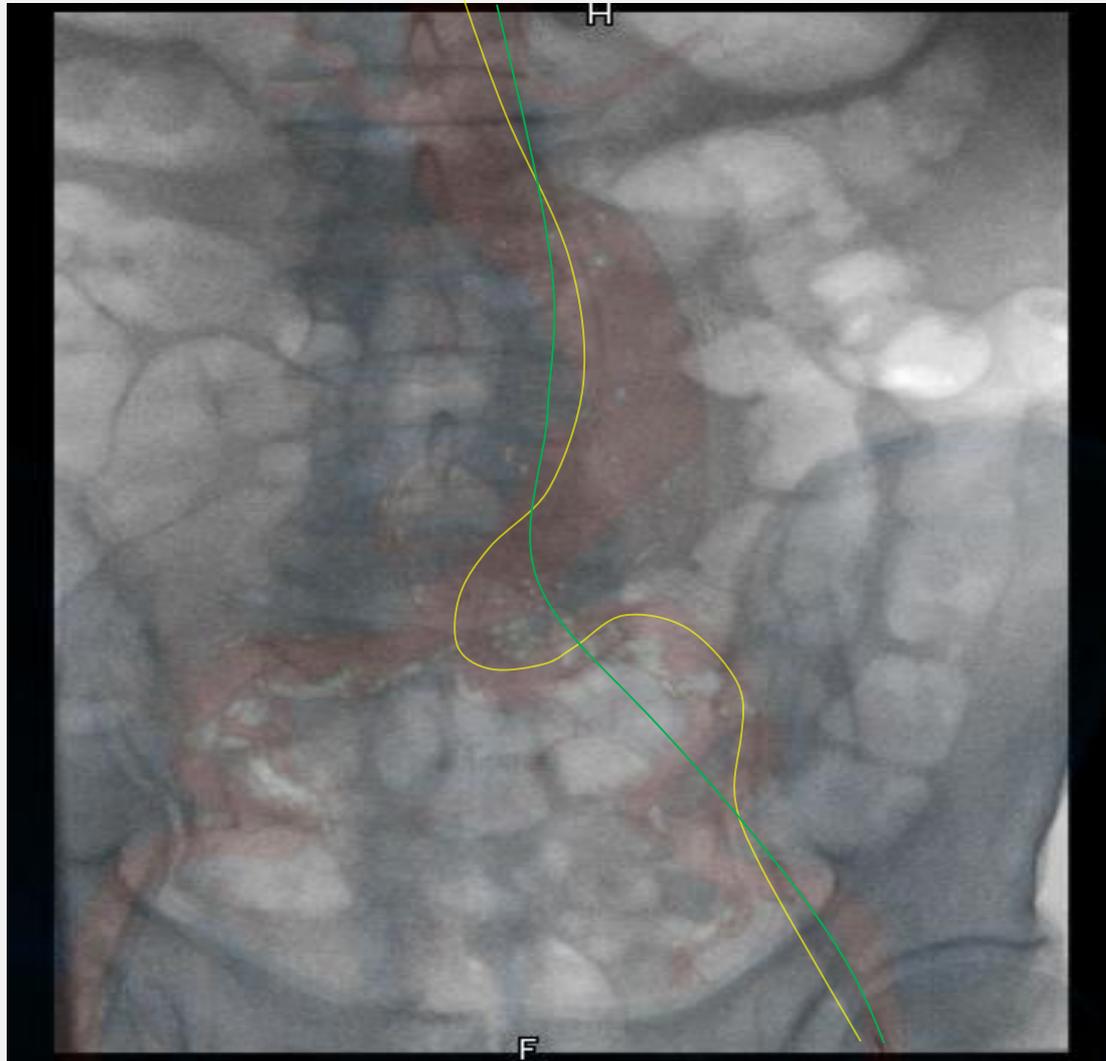
Assistance per-opératoire

Procédures membres inférieurs

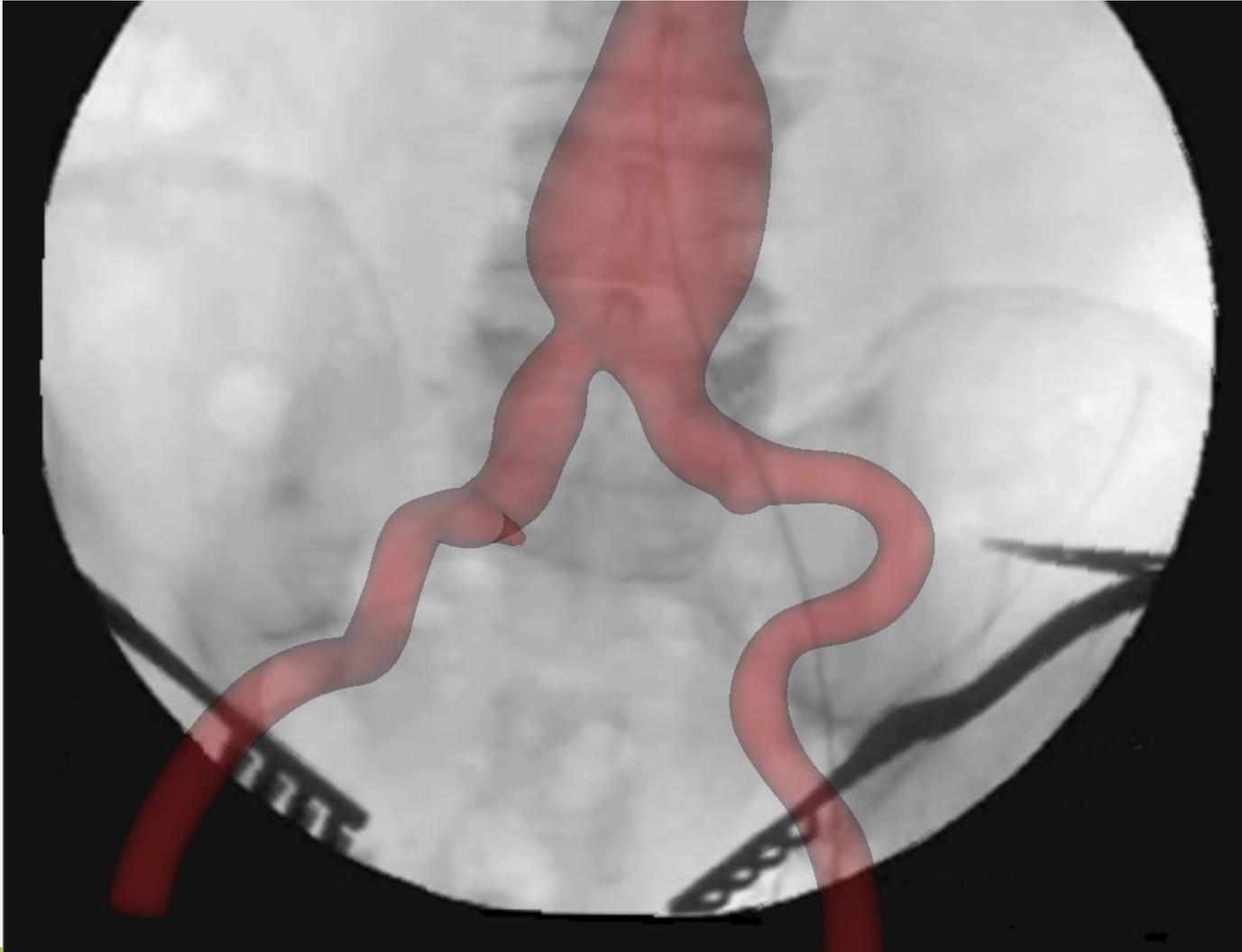


Pre-op / Intra-op Matching

3D-2D fusion for computer assisted Endovascular Aortic Aneurism Repair



Roadmap sans correction des déformations



Roadmap avec correction des déformations



Assistance per-opérateur

EndoNaut – Procédures aorto-iliaques



san
nce nationale
et de la santé



RENNES
Institut Thématique Multi-Organismes
Technologies pour la



Implantabilité d'une endoprothèse abdominale sur une cohorte de 624 patients consécutifs

Jacques Tomasi, Claire Dupont, Reda Belhaj Soulami,
Antoine Lucas, Pascal Haigron, Jean-Philippe Verhoye

CHU de Rennes



CHIRURGIE
THORACIQUE CARDIAQUE ET VASCULAIRE

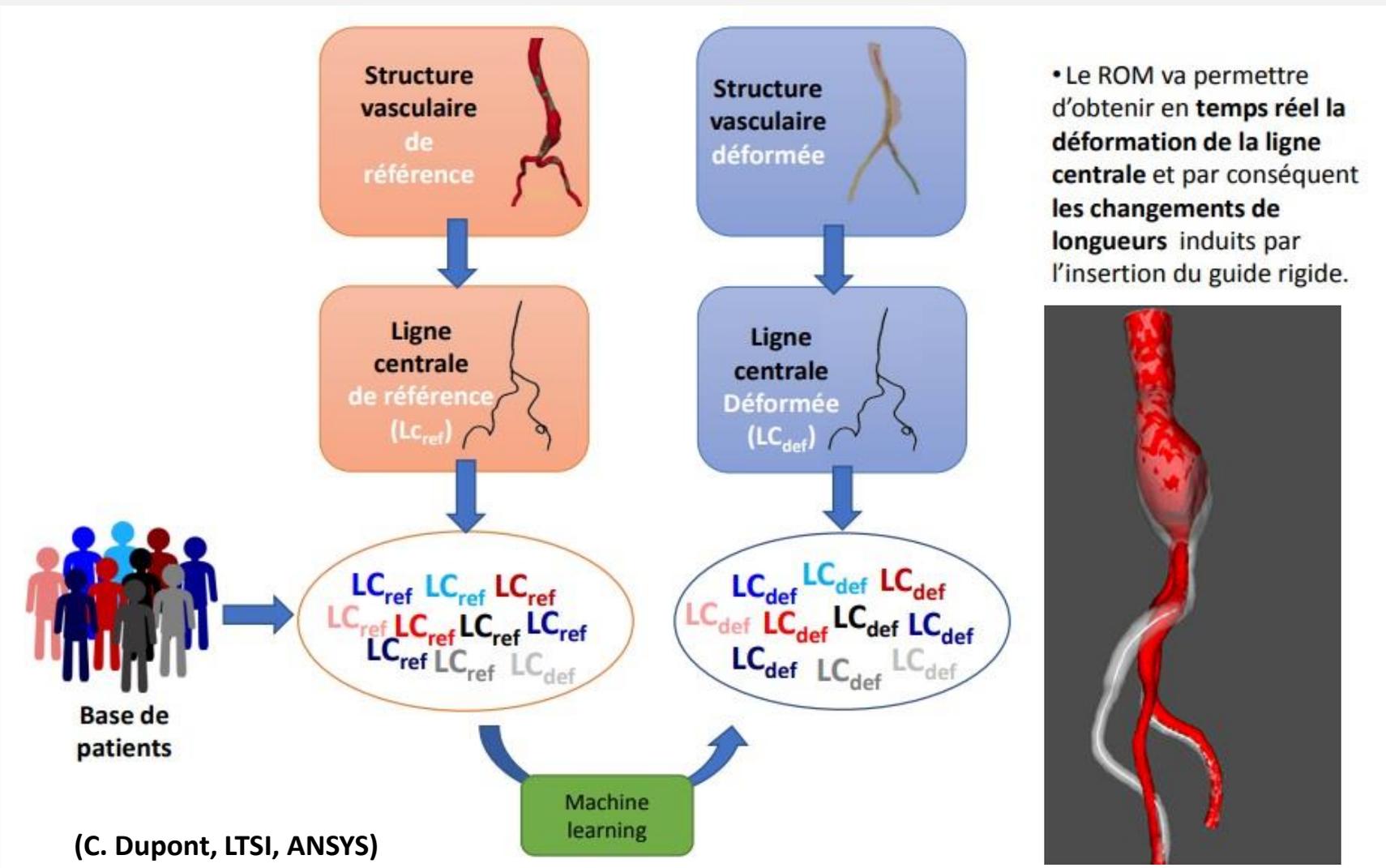


Conclusion

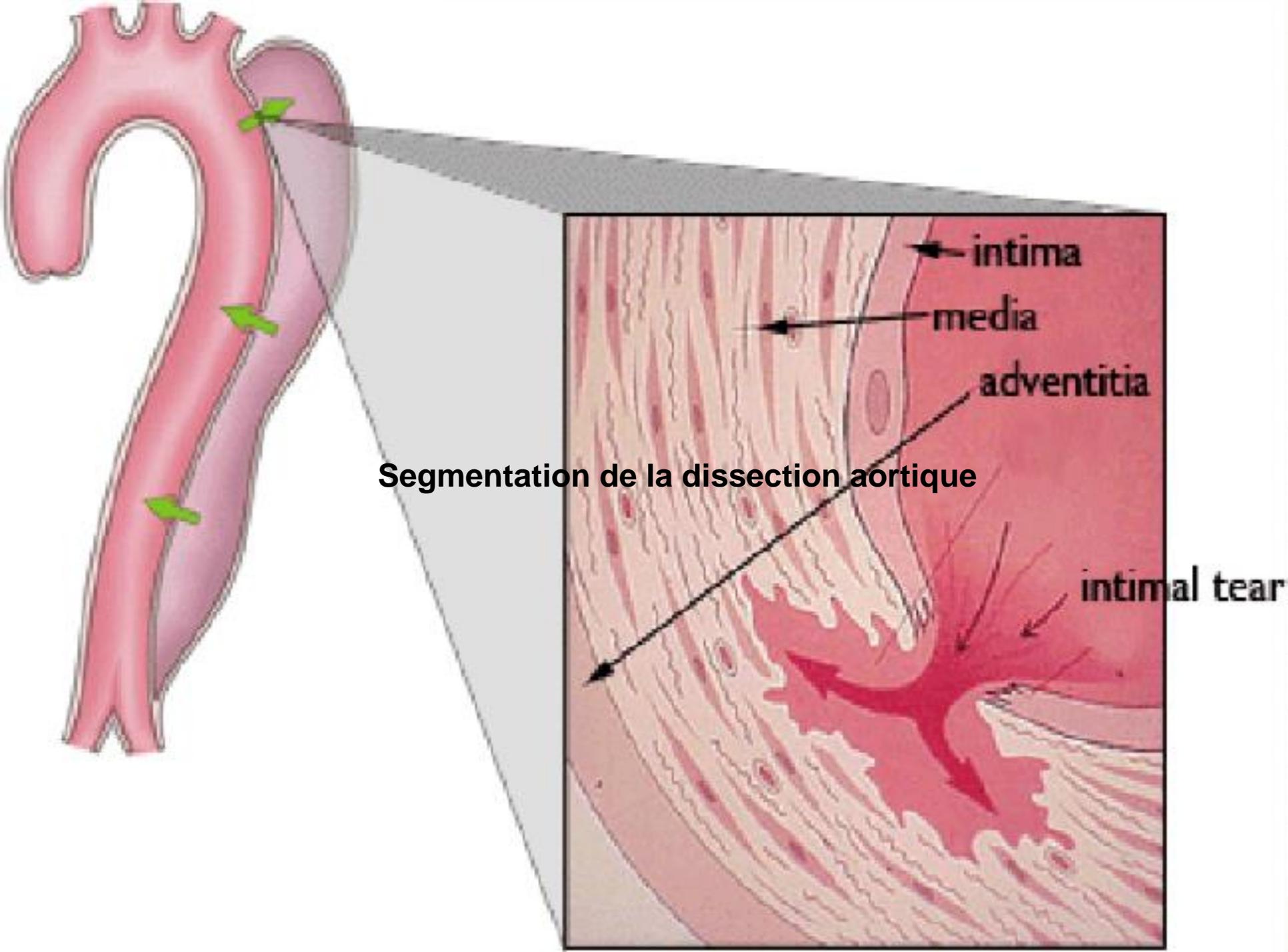
- Eligibilité standard de 70,6 % sur cette cohorte
 - 76,28 % avec une Endurant
- De nombreuses techniques permettent de dépasser les limites
 - Collet
 - Accès
- Etude Rétrospective uniquement anatomique sur TDM

Réduction de Modèles (ROM) : Détermination de la géométrie artérielle déformée par le guide rigide par apprentissage.

(Validation en cours)



(C. Dupont, LTSI, ANSYS)

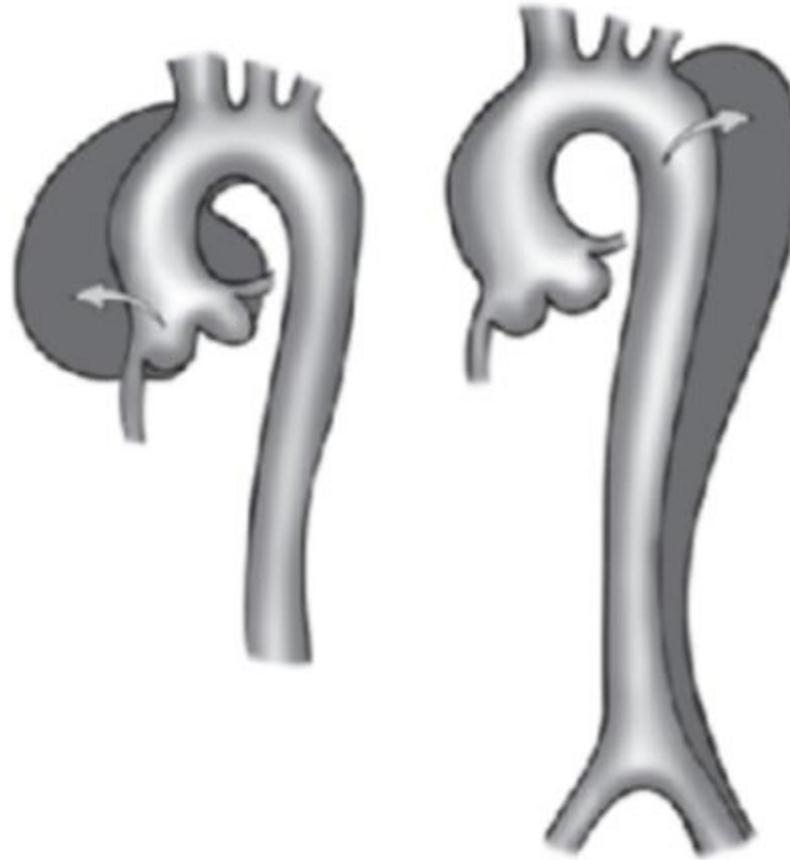




Stanford Type A



Stanford Type B



Si complication, décision facile intervention à risque !

- Operative risk in open surgery

- Mortality 25-50 %
- Paraplegia 7 %
- Stroke 9 %
- Akute kidney insufficiency 19 %

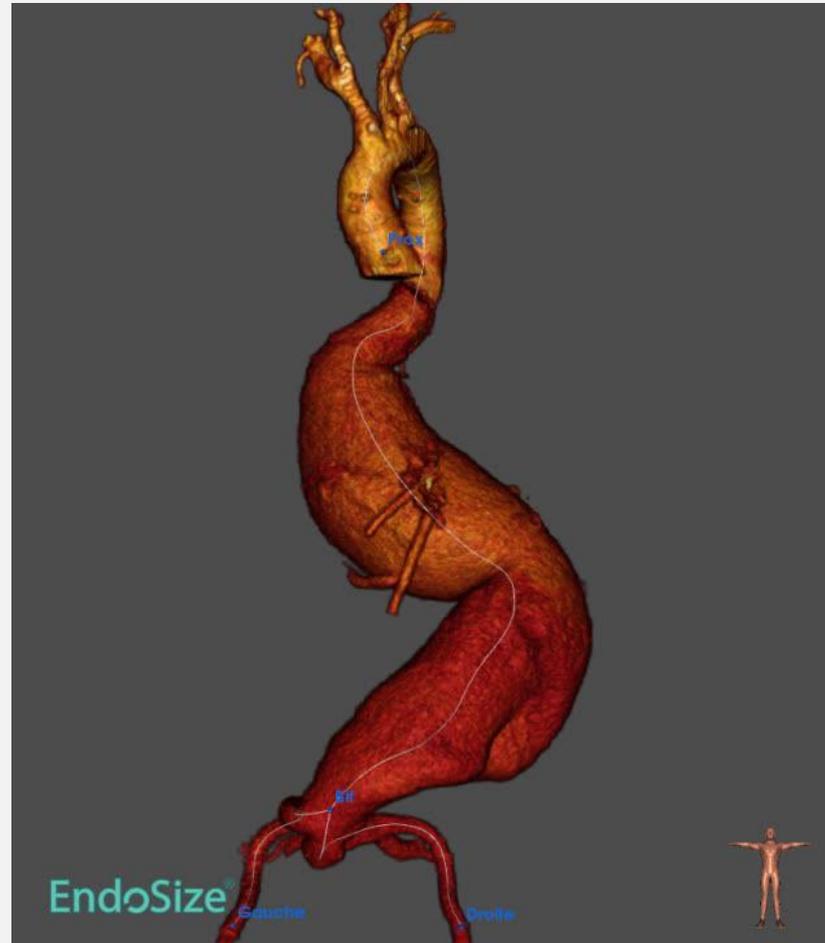
Fattori R, Tsai TT, Myrmet T, Evangelista A, Cooper JV, Trimarchi S, Li J, Lovato L, Kische S, Eagle KA, Isselbacher EM, Nienaber CA. Complicated acute type B dissection: is surgery still the best option?: a report from the International Registry of Acute Aortic Dissection. *JACC Cardiovasc Interv* 2008;**1**:395–402.

- TEVAR

- 50 patients
- 30 days
- Paraplegia 8 %

Heijmen RH, Thompson MM, Fattori R, Goktay Y, Teebken OE, Orend KH. Valiant thoracic stent-graft deployed with the new captivia delivery system: procedural and 30-day results of the Valiant Captivia registry. *J Endovasc Ther* 2012;**19**:213–225.

Evolution Anévrismale





Simulation numérique de la dissection aortique Segmentation automatique des chenaux circulants

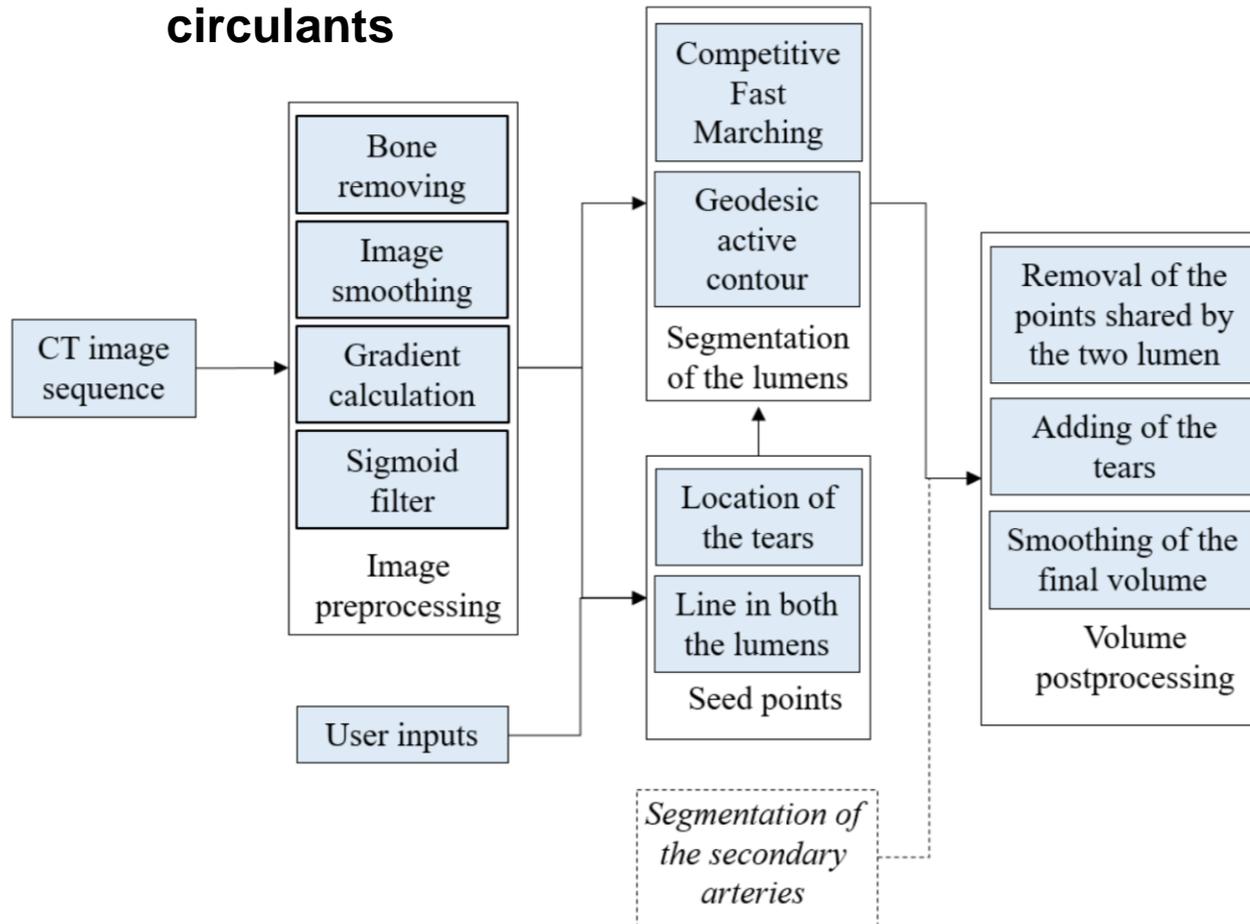
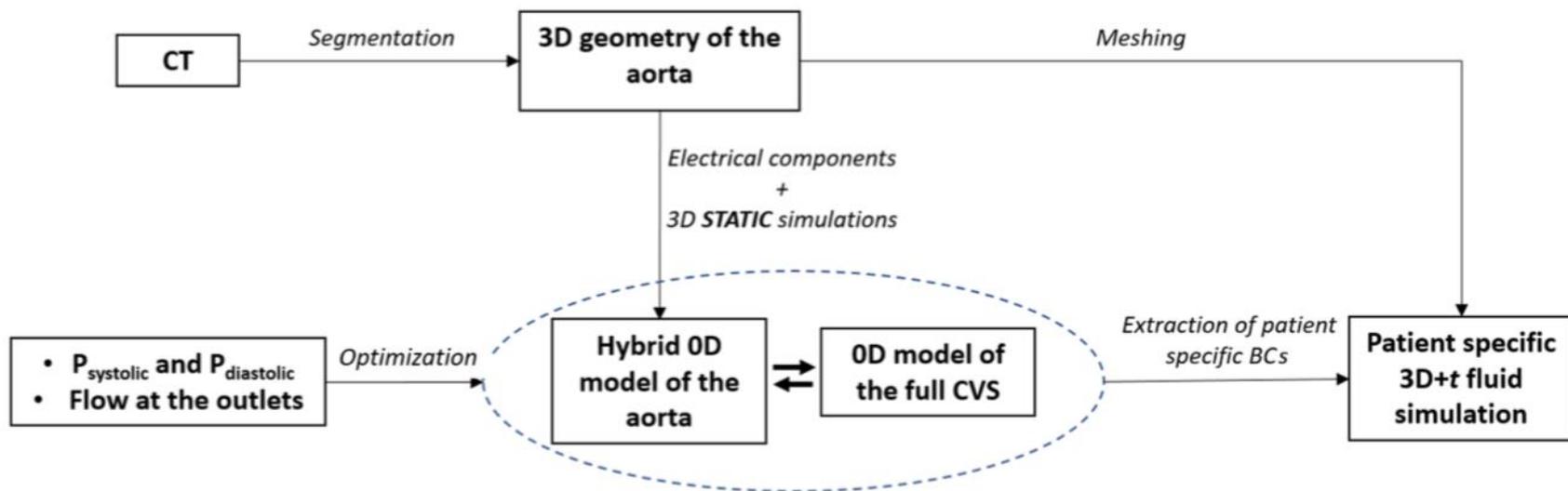


FIGURE 3 – Schéma des différentes étapes de la méthodes de segmentation.



Simulation numérique de la dissection aortique

- Schéma des différentes étapes de la méthode de simulation dynamique spécifique patient.



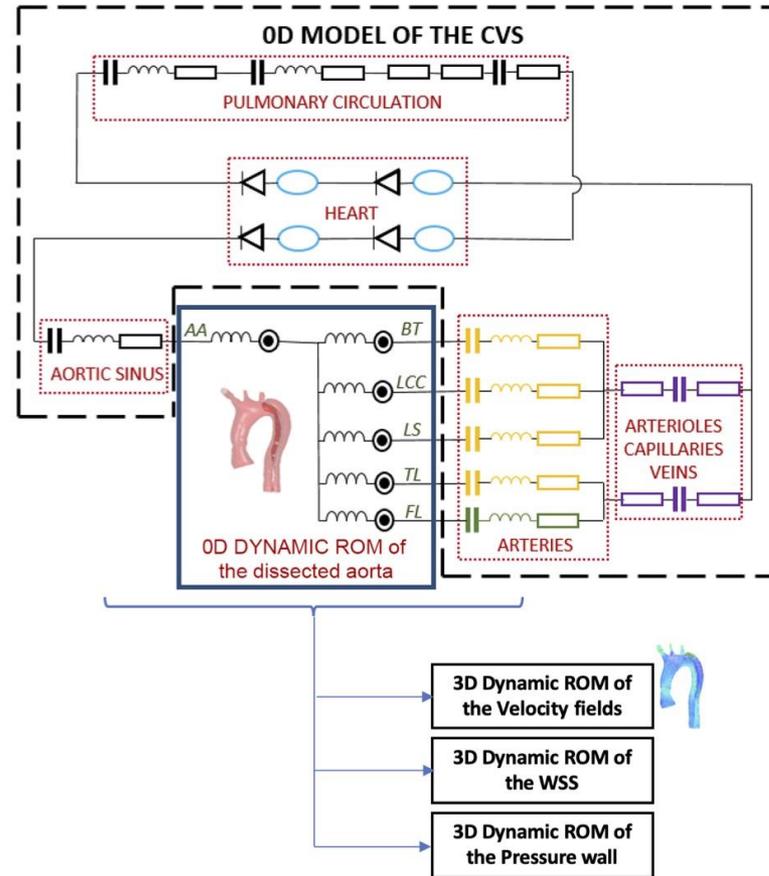
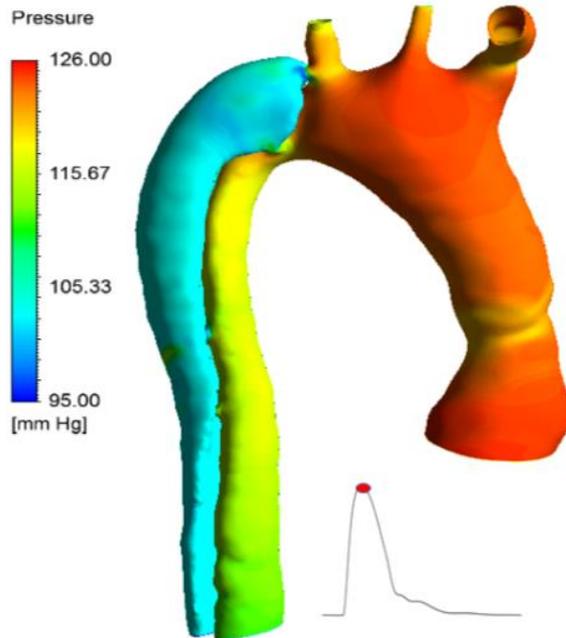


Figure 9 : Modèle OD final

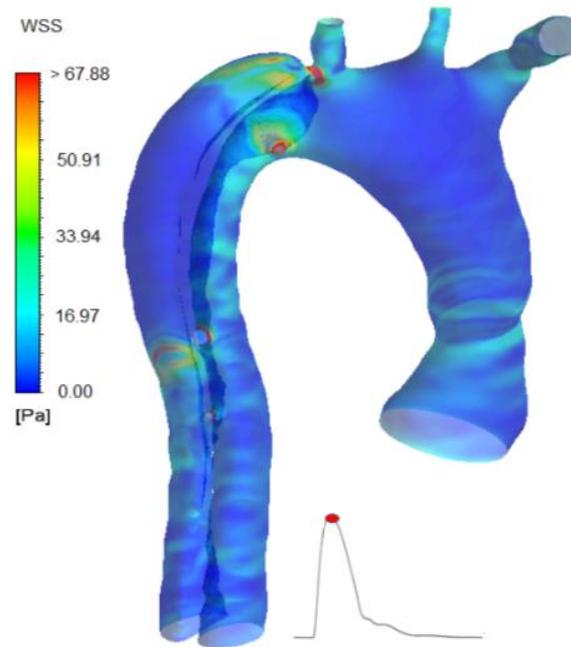
AA : Ascending Aorta ; BT : Brachiocephalic Trunk ; LCC : Left Common Carotid ; LS : Left Subclavian ; TL : True Lumen ; FL : False Lumen



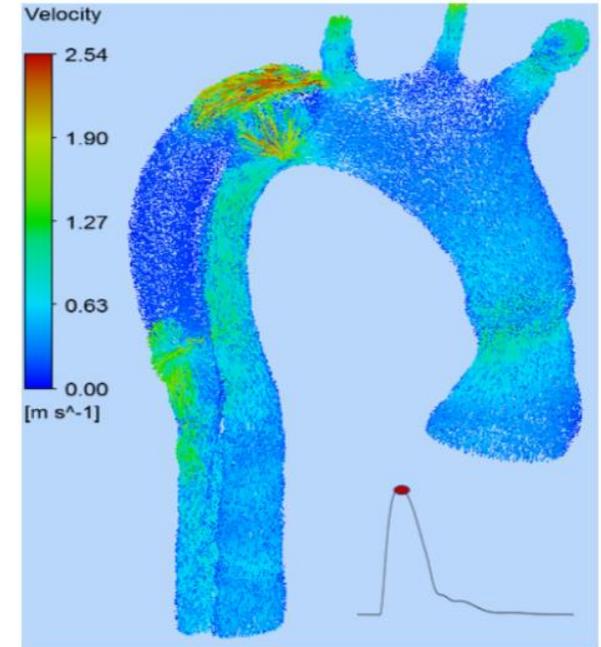
Résultat de la simulation dynamique de l'aorte au pic de la systole. a) Pression à la paroi. b) Contraintes de cisaillement. c) Champs de vitesse.



(a)



(b)



(c)



Imagerie augmentée par la simulation pour l'aide à la décision en chirurgie de la dissection aortique

- Simulation « élément fini » = 17 à 24 heures de calcul pour 3 cycles cardiaques
- Réduction de modèle = 2 minutes de calcul pour une heure de cycle cardiaque.
- Un modèle de fatigue à la paroi de l'aorte devra être ajouté pour souligner les zones présentant un risque de rupture !

Conclusion :

