UN JUMEAU NUMÉRIQUE DE L’AORTE CONTRE LA RUPTURE D’ANÉVRISME

STÉPHANE AVRIL
CENTRE INGÉNIERIE ET SANTÉ

Centre Hospitalo-Universitaire

Faculté de médecine

Centre Ingénierie et Santé
STRONG AND HISTORICAL COLLABORATIONS WITH CLINICIANS
PrediSurge

The aortic lab

TAA

AAA

IA

Peak Stress

TAA Stent-Graft

High

Low
Team of +20 researchers involving permanent faculty (biomechanics, vascular surgery), postdocs and PhD students.

Financial support of the European Research Council (ERC) with grants of 3.5 million euros (ERC-2014-CoG BIOLOCHANICS and ERC-2014-StG AArteMIS).

5 years project (2015-2020) which has the ambitious objective of predicting computationally the risk of rupture of aortic aneurysms for every patient.
Our vision is that the mechanical properties, the strength, the wall stress of the aorta, and their evolutions during the growth of an aneurysm or after endovascular repair, can be predicted on a patient-specific basis by computational models.

We have been developing these computational models for 8 years and validating them on different cohorts.
EXPERIMENTAL CHARACTERIZATION CAMPAIGN

In situ mechanical testing

Multi-photon confocal microscopy

X-ray micro-tomography

Fiber-scale analysis
NUMERICAL MODELING ACROSS SCALES

Local mechanical modeling and analysis

Fiber level analysis (ex: stress distribution)

Image from [Stevens et. al. 2017, PLOS One]
Preoperative dynamic imaging
4D MRI → CAD → Mesh

Validation 1

Boundary Conditions

Numerical Solution → Streamlines, velocity

Bulge inflation test → Postoperative sample

Validation 2

TAWSS
WORKFLOW

Clinical problem → Computer model → Model prediction → Clinical intervention

Branched stent (left), fenestrated stent (centre) and ChEVAR technique (right)

Planning
- Faster
- More reliable
- More precise

Procedure
- Less invasive
- Less traumatic
- Shorter
- Less risky
- Cheaper

Increase of endovascular surgery indications

Follow up
Start-up

Towards numerical assistance during vascular surgery
MECHANOBIOLOGY…

Figure G&R1

DEVELOPMENT

MATURITY

Adventitia
Media
Intima
Smooth Muscle Cells
Fibroblasts
Collagen
Endothelial Cells
Elastic Lamina
Elastic
BL
Recruited SMC

Layering SMC
Collagen
Elastin

Intima
Media
Adventitia
Smooth Muscle Cells
Fibroblasts

Recruited SMC EC BL

EC
BL
ECM regulation

ECM proteolysis

G&R
ROLE OF SMOOTH MUSCLE CELLS

Humphrey et al, Science 2014
Monitoring mechanical regulation and epigenetics

Predicting patient-specific pathophysiology and drug effects
ACKNOWLEDGEMENTS

Funding:
ERC-2014-CoG BIOLOCHANICS

Joan Laubrie
Jamal Mousavi
Di Zuò
Yiqian He
Olfa Trabelsi
Aaron Romo
Jin Kim
Pierre Badel

Frances Davis
Victor Acosta
Solmaz Farzeneh
Francesca Condemi
Cristina Cavinato
Jérôme Molimard
Baptiste Pierrat
Claudie Petit

Ambroise Duprey
Jean-Pierre Favre
Jean-Noël Albertini
Salvatore Campisi
Magalie Viallon
Pierre Croisille

Chiara Bellini
Matthew Bersi
Jay Humphrey
Christian Cyron
Fabian Braeu
Nele Famaey