Prévention des plaies de pression : comment la biomécanique des tissus mous peut-elle assister les dispositifs médicaux?

Yohan Payan

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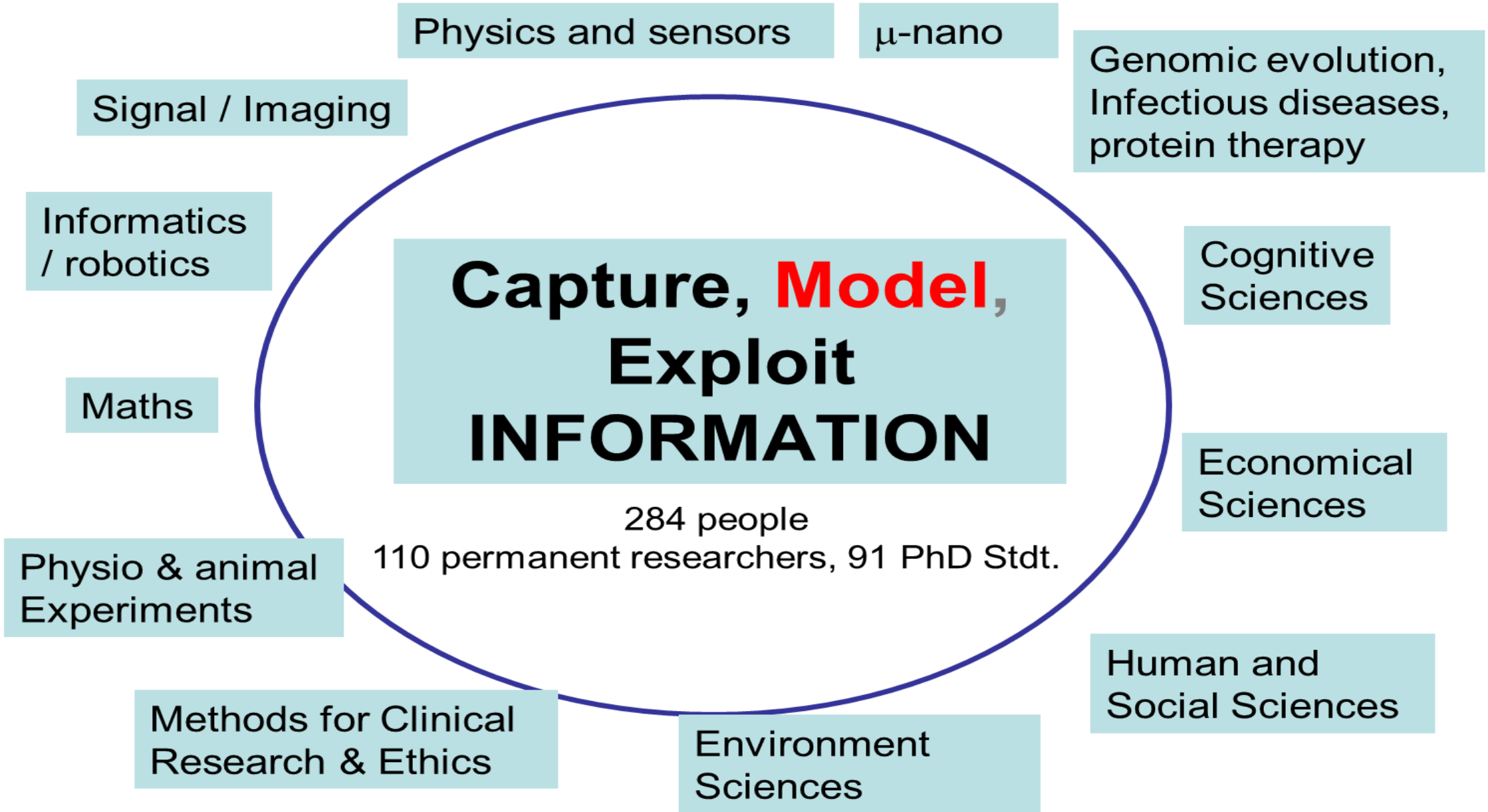
www.timc.fr/BIOMECA

TIMC Lab


Physics and sensors
μ-nano
Genomic evolution, Infectious diseases, protein therapy
Signal / Imaging
Informatics / robotics
Cognitive Sciences
Capture, Model, Exploit INFORMATION
Maths
Economical Sciences
284 people
110 permanent researchers, 91 PhD Stdt.
Physio & animal Experiments
Human and Social Sciences
Methods for Clinical Research & Ethics
Environment Sciences

BIOMÉCA Team

TIMC Lab

Biomechanics of human soft tissue and materials

TRANSLATIONAL RESEARCH

Basic research

Experimental research

Applied research

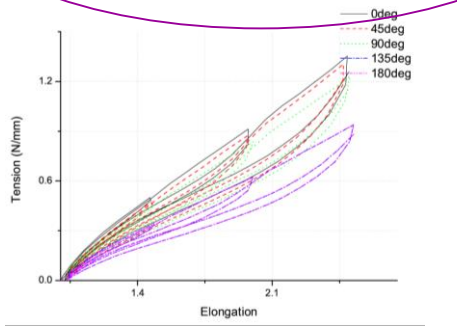
Clinical research

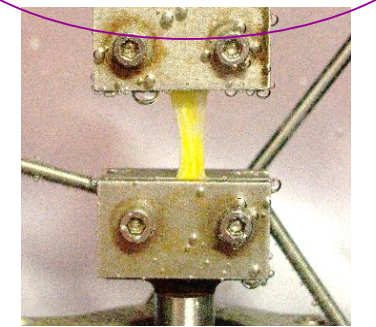
Original constitutive laws

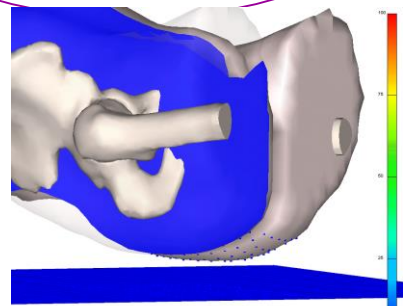
Experimental Mechanics

Numerical simulations

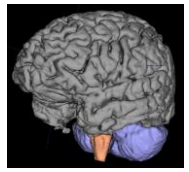
Transfer towards medical application





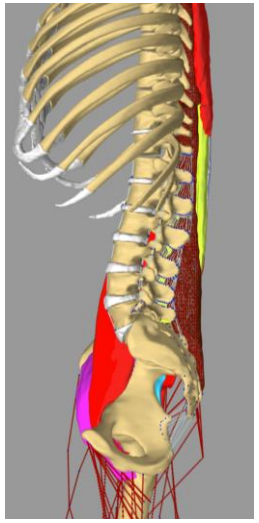


Current modeling works



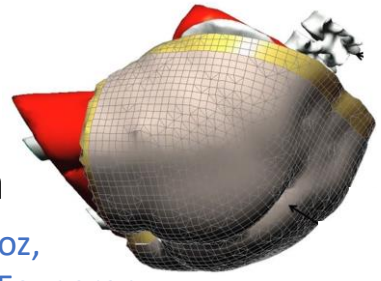
brain

Bucki, Lobos, Morin



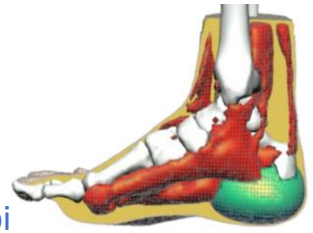
spine

Pissonnier



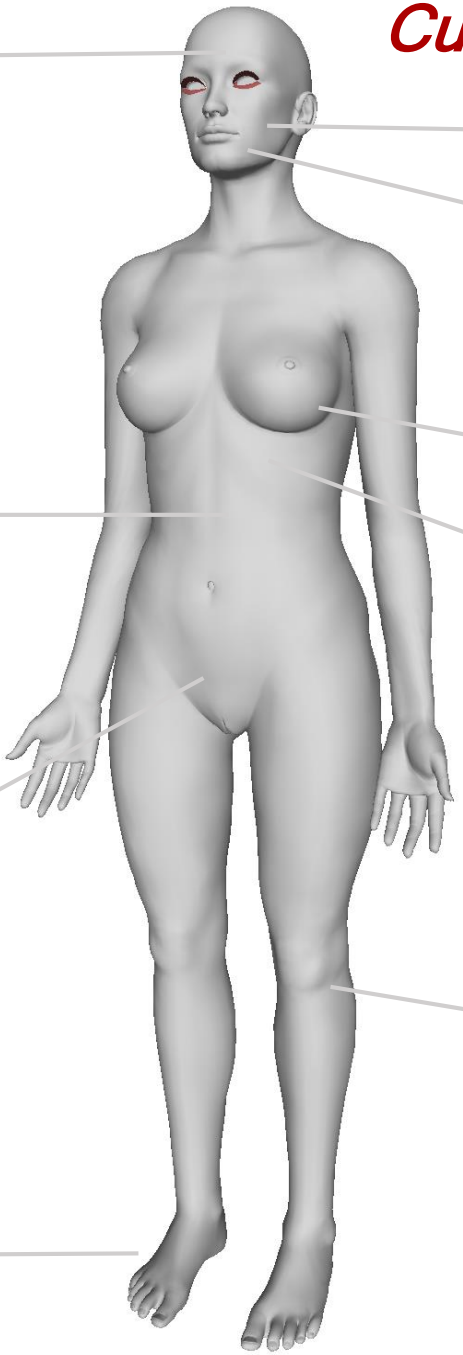
sacrum

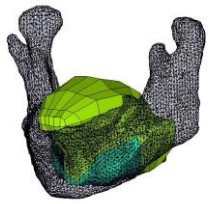
Bucki, Luboz, Mukhina, Fougeron



foot

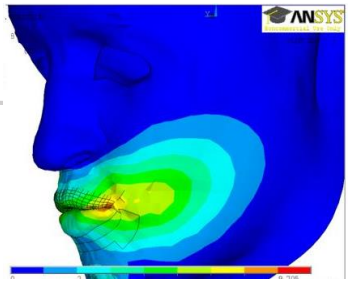
Perrier, Trebbi





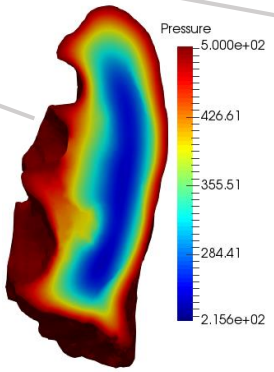
tongue

Gerard, Buchaillard, Hermant, El Mouss, Calka



face

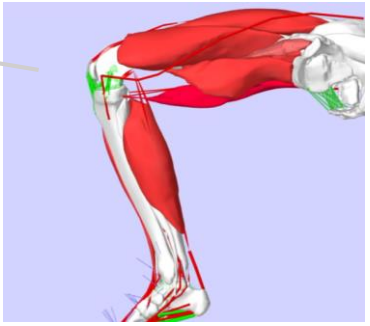
Chabanas, Nazari



lung Alvarez

breast

Mira, Masri, Briot

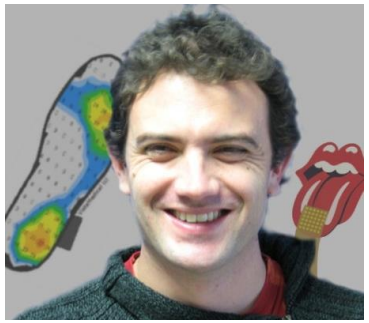


knee

Elyasi

Soft tissue modeling in the context of pressure ulcer prevention

Antoine Perrier



Olivier Chenu

Vincent Luboz

Marek Bucki

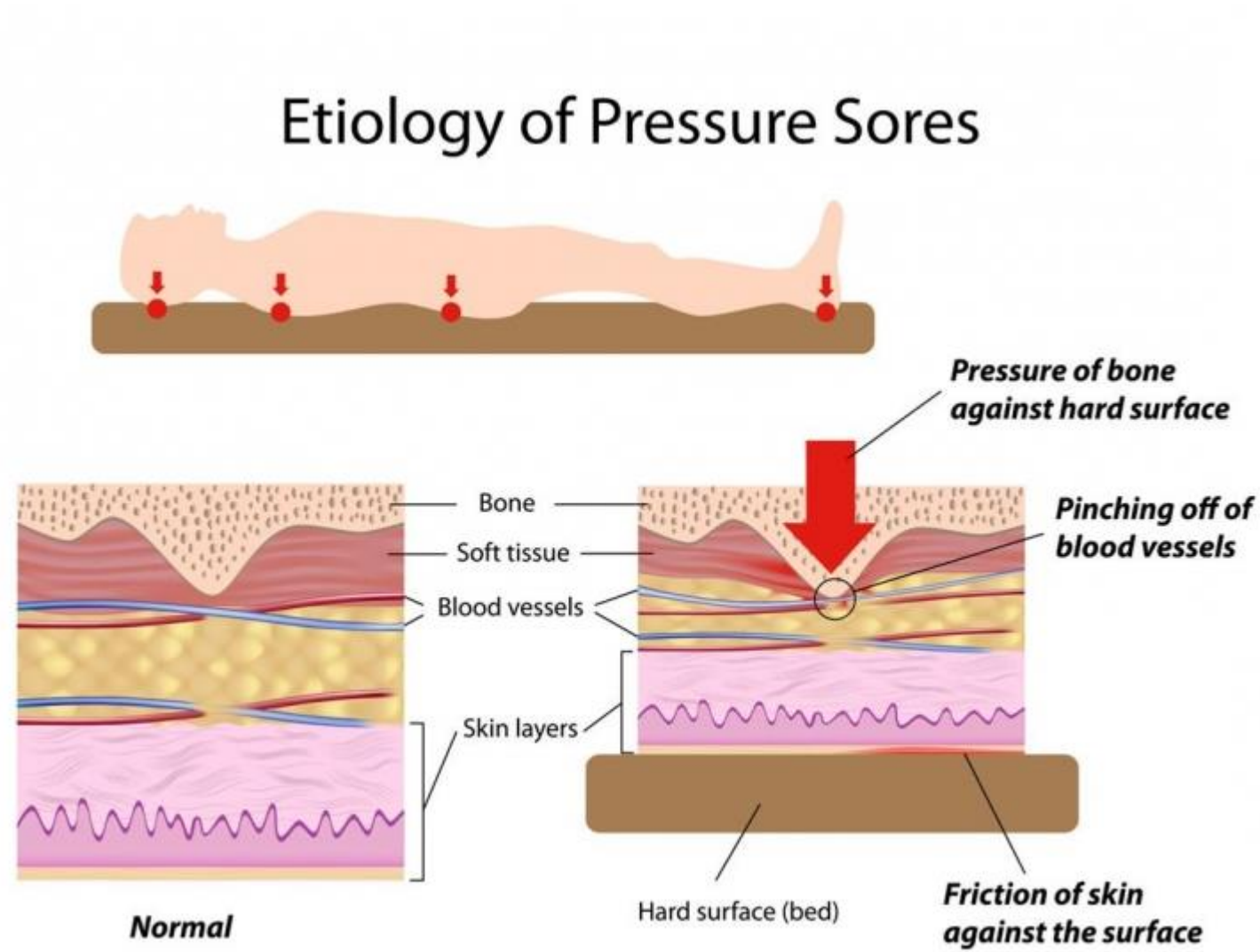
Elaheh Elyasi

Ekaterina Mukhina

Nolwenn Fougeron

Alessio Trebbi

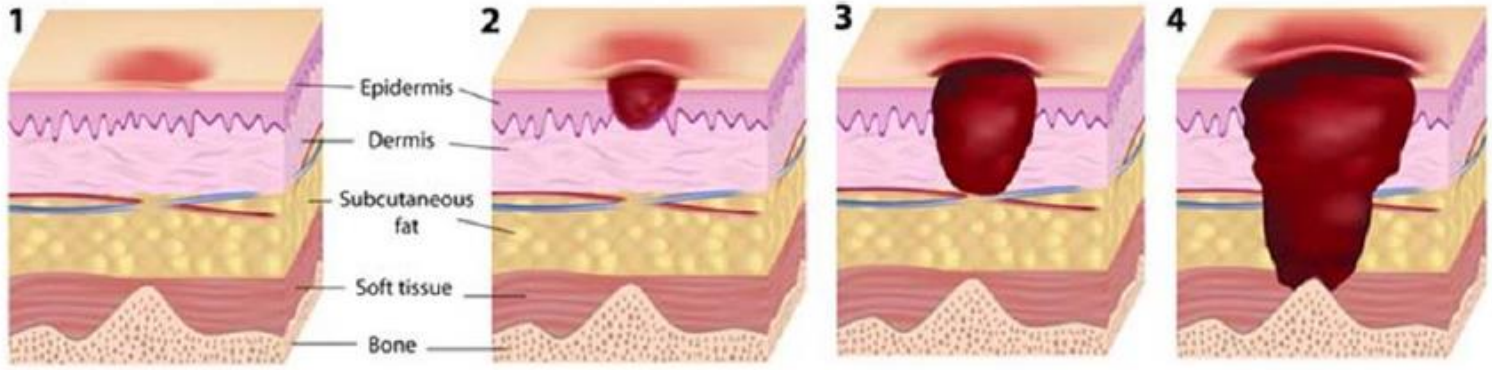
Pressure ulcers (PU)



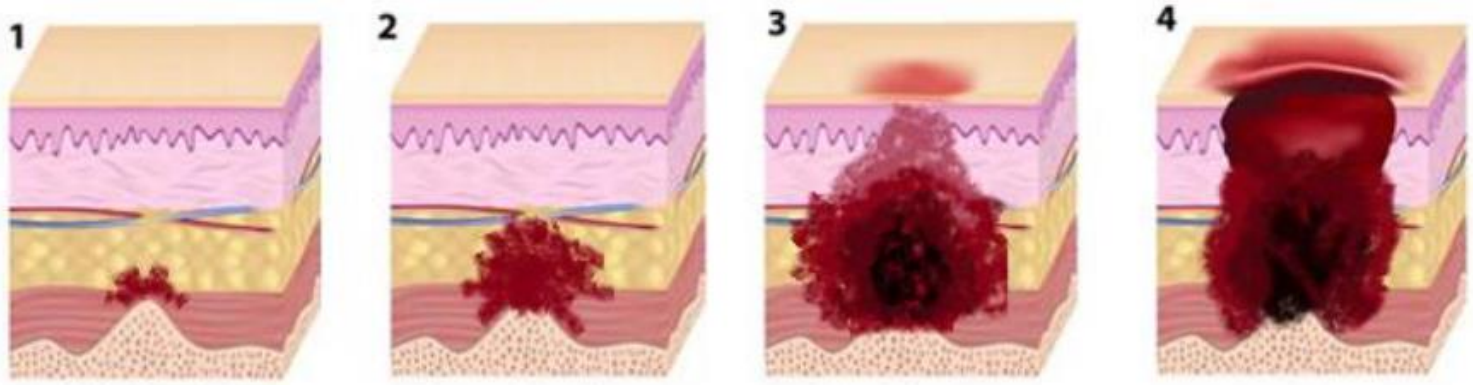
Pressure ulcers

Two processes

Superficial: possible to detect visually



Deep tissue: not possible to detect visually



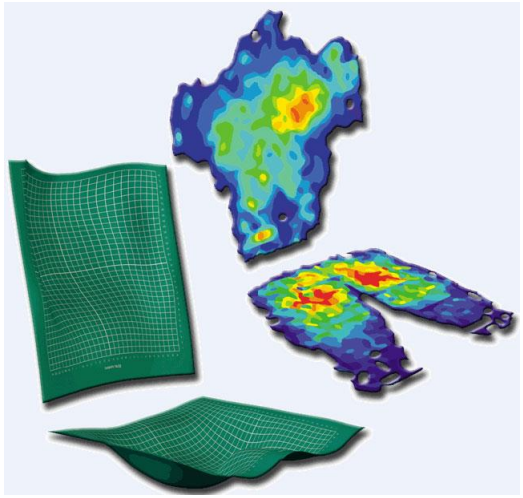
Pressure ulcer prevention

A prevalence of 10% at hospital

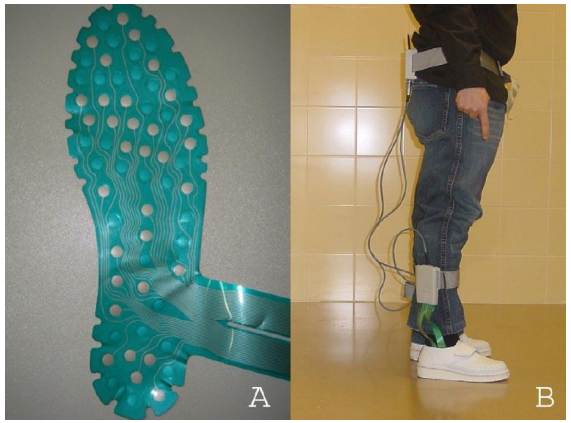
A prevalence of 20% among SCI persons

A foot cut every 30s because of diabetes

Pressure measurements at skin surface



Tekscan Inc.

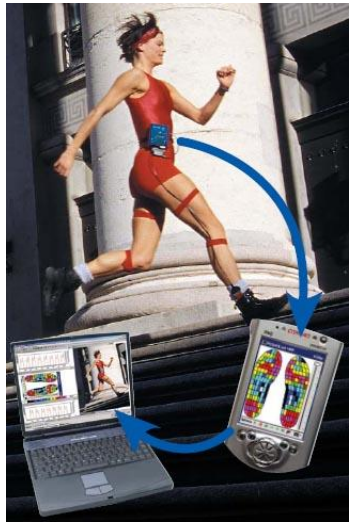


BioFoot® insoles

F-Scan®, Tekscan

Xsensor Inc.

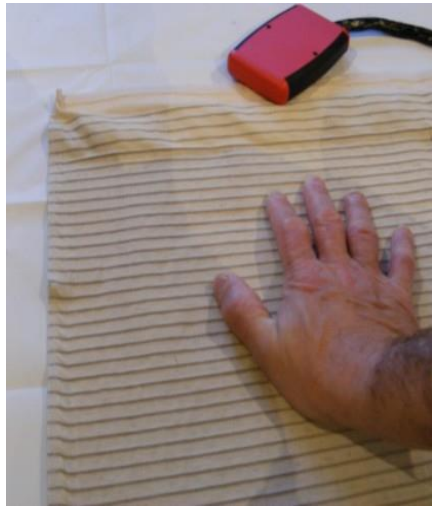
Vista Medical

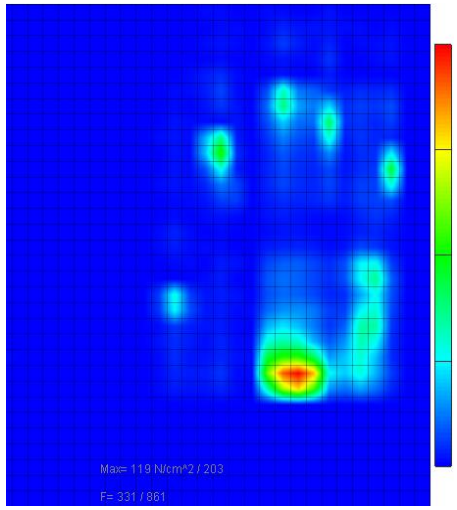


Pedar shoes LilaBox

Pressure measurements at skin surface

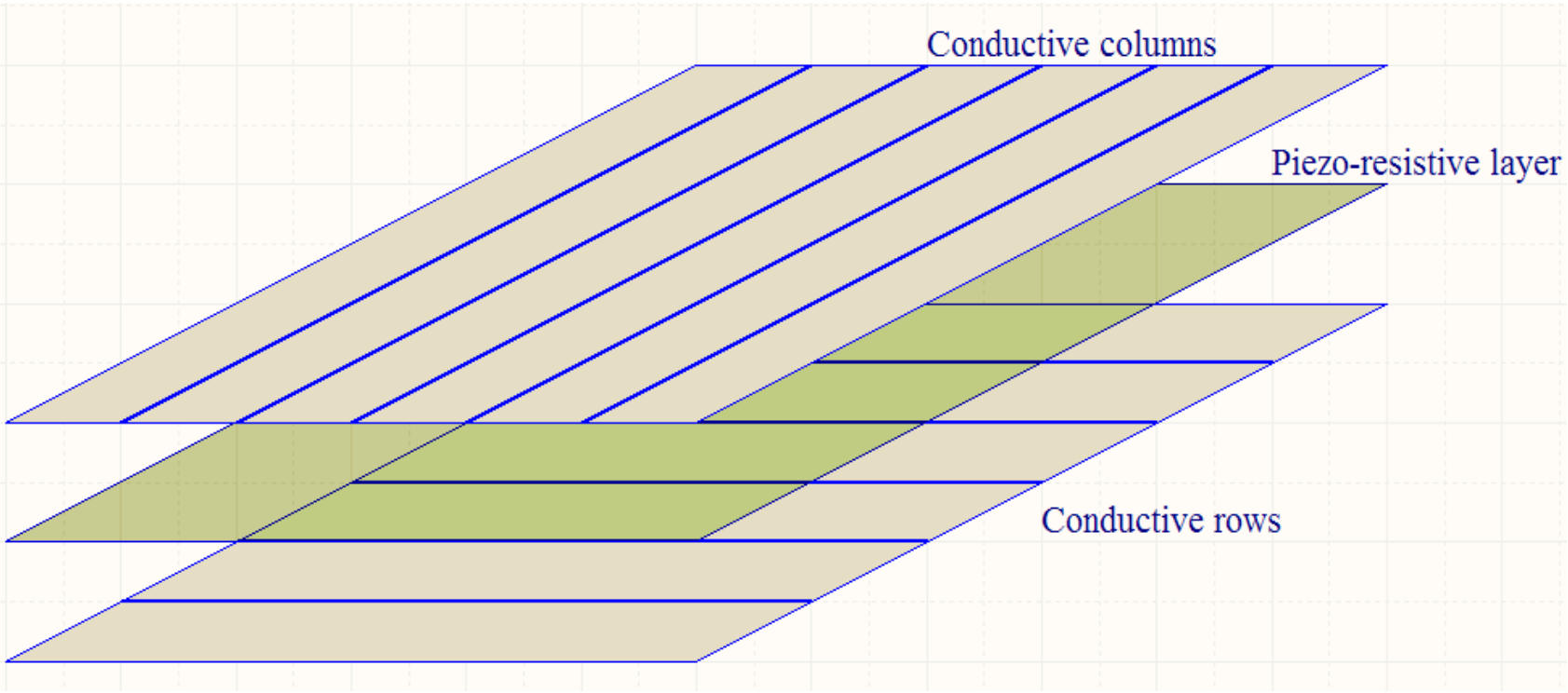
An embedded pressure mat 100% textile





Pressure measurements at skin surface

An embedded pressure mat 100% textile



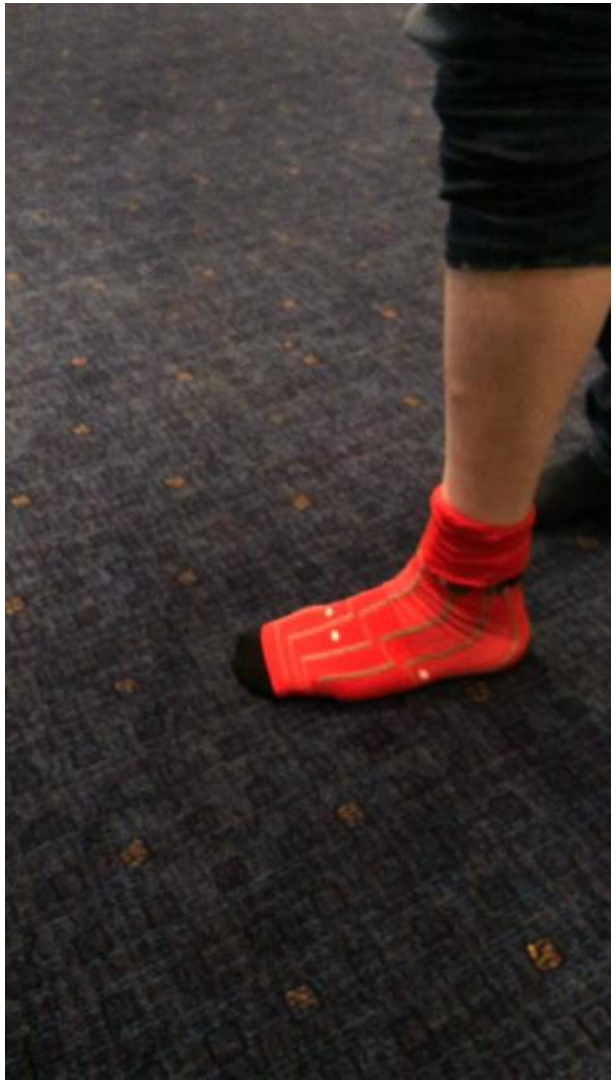
- Two outer layers form a matrix that defines the spatial resolution of the sensor: the nylon fibers coated with silver conduct current

- Any normal forces exerted onto the middle layer change the electrical resistance of the material : fibers are coated with polymers

Cannard F., Diot B., Lavarenne A, Lavarenne E., Vuillerme N. & Payan Y. (2016). *Device intended for measuring pressure from a flexible, foldable, and/or extendable object made of a textile material and comprising a measurement device* - Num: US 9,448,127 B2.

Pressure measurements at skin surface

An embedded pressure mat 100% textile

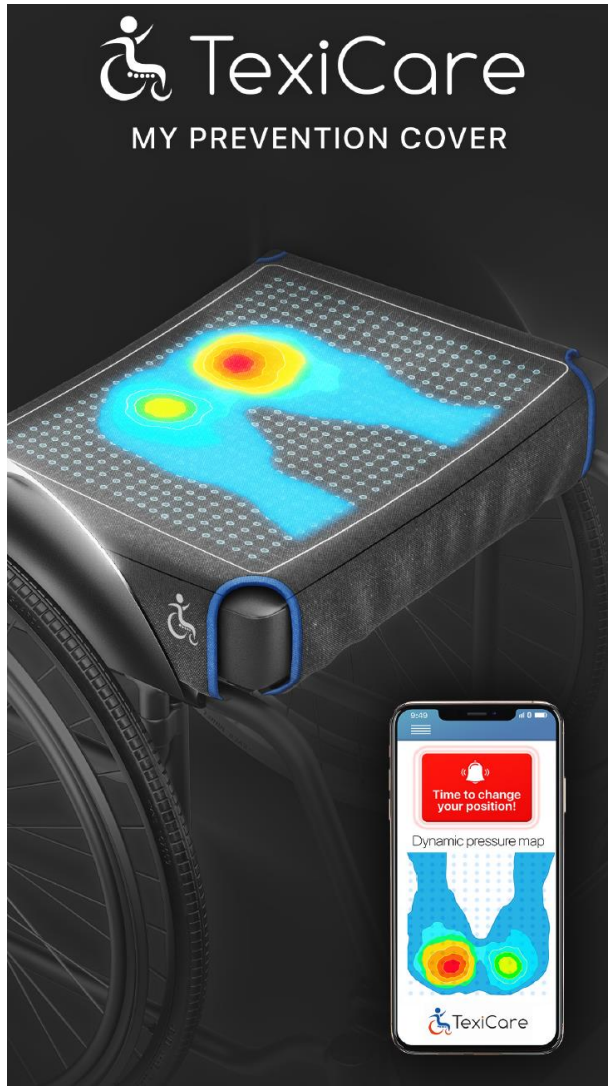


- Central unit + bluetooth

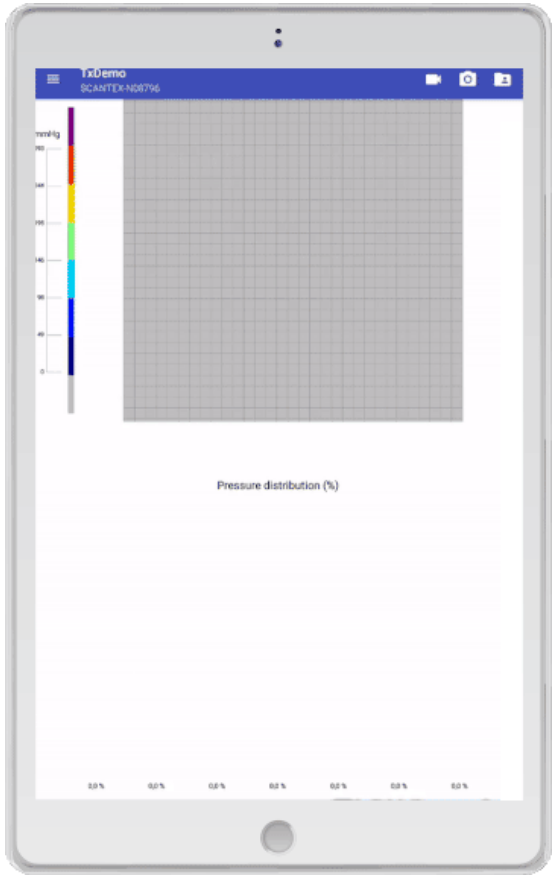
Perrier A., Vuillerme N., Luboz V., Bucki M., Cannard F., Diot B., Colin D., Rin D., Bourg J.P. & Payan Y. (2014). Smart Diabetic Socks: Embedded device for diabetic foot prevention. *Innovation and Research in BioMedical engineering*, Vol 32 n°2, pp. 72-76.

Pressure measurements at skin surface

An embedded pressure mat 100% textile



TEXIS
Sense for Life



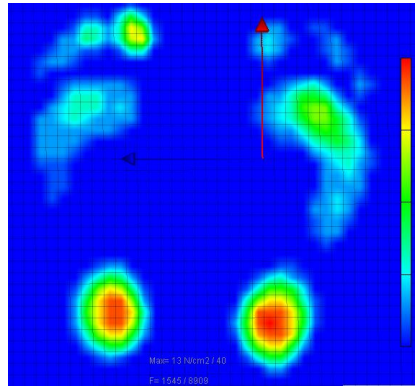
Pressure measurements at skin surface

An embedded pressure mat 100% textile

Technological transfer of the textile sock (some tens thousands of socks sold in the US by Palarum Company)

Pressure measurements at skin surface

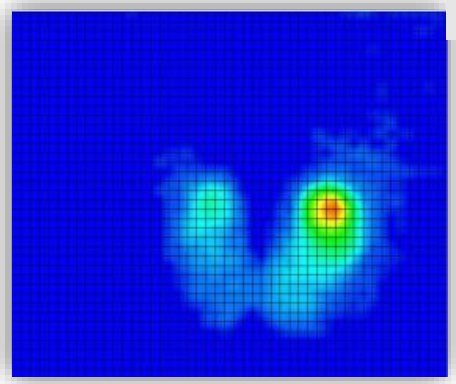
An embedded pressure mat 100% textile



Pressure measurements at skin surface

An embedded pressure mat 100% textile

Patient #1



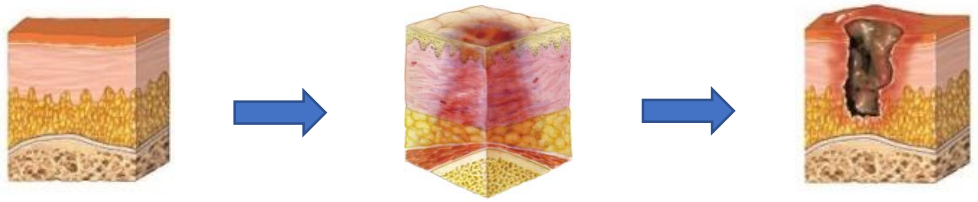
Measuring the pressure at skin surface is not sufficient to estimate pressure ulcer risks

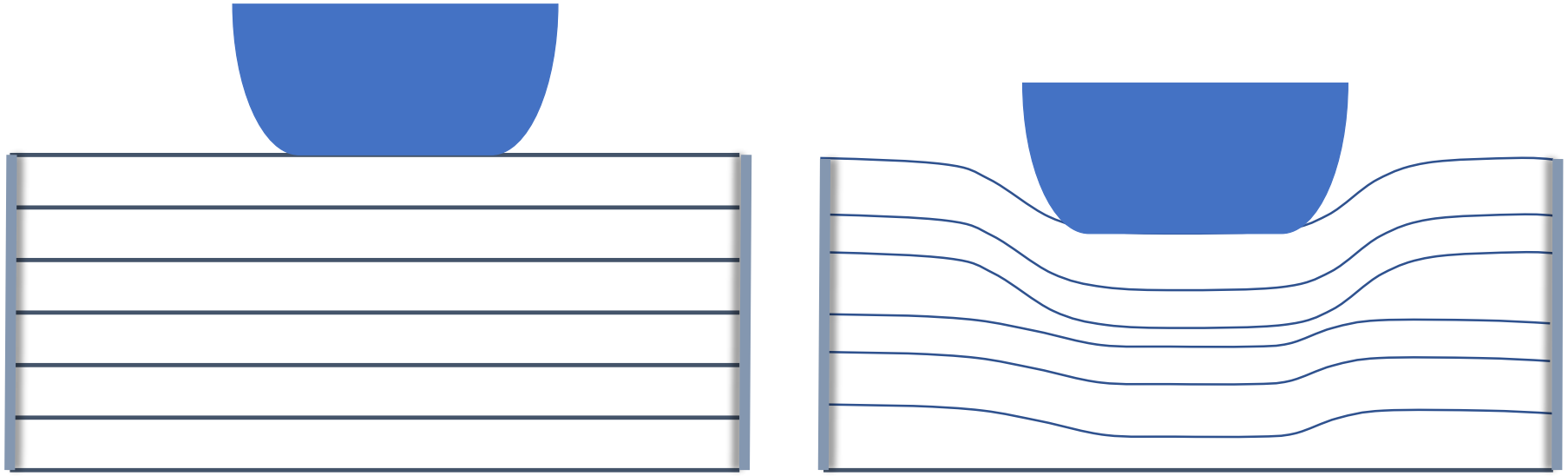
Subject-specific internal tissue strains should be monitored to avoid PU

No biomarker to measure internal strains in a relevant way

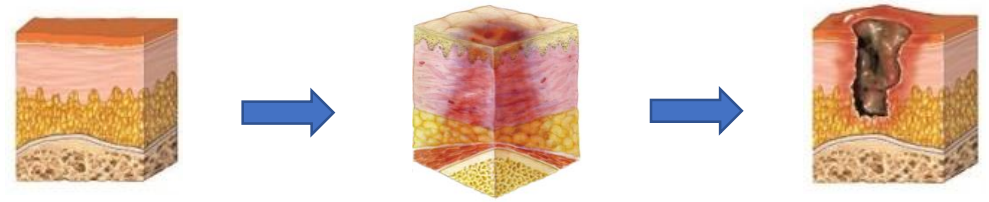
tient #4

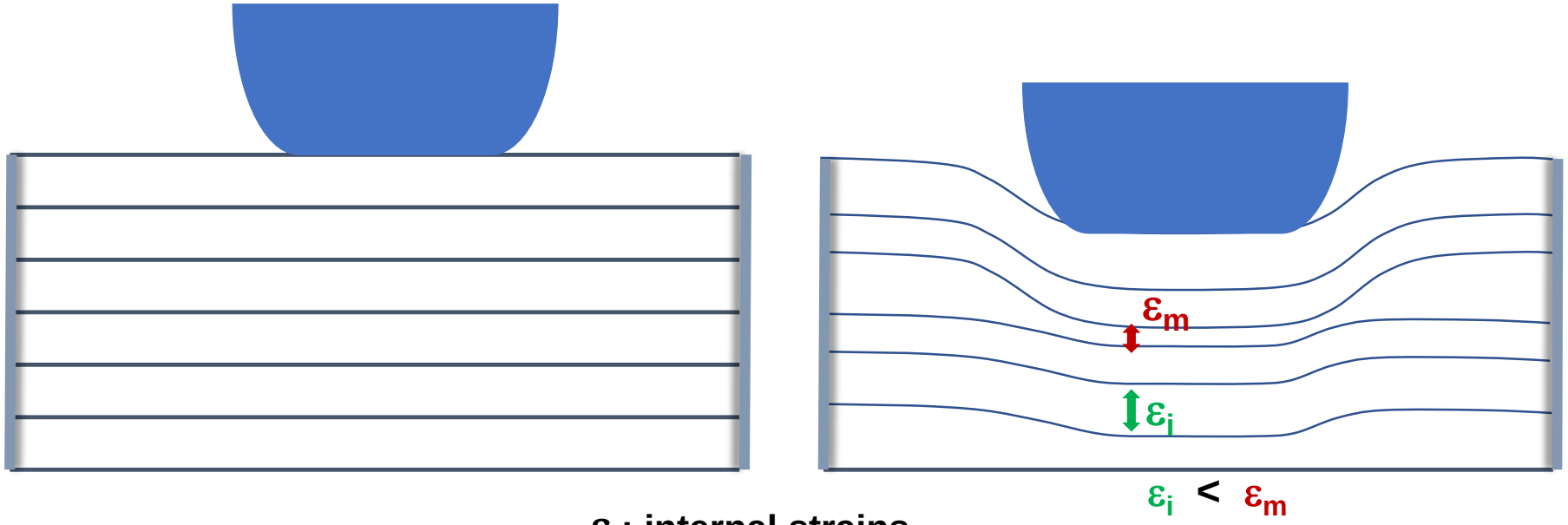
Etiology of Deep Tissue Injuries





Etiology of Deep Tissue Injuries





ε : internal strains

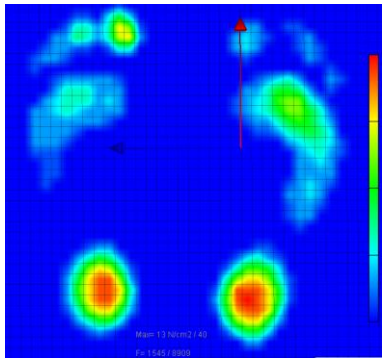
ε_i : « ischemia » deformations threshold (around 20%)

ε_m : « mechanical » deformations threshold (around 50%)

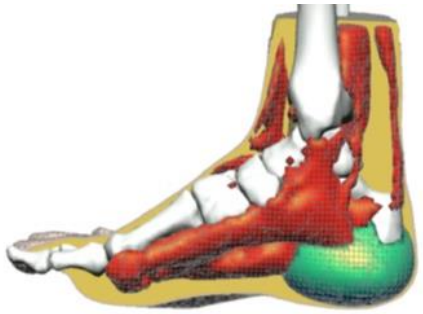
A “numerical” biomarker to compute the internal strains

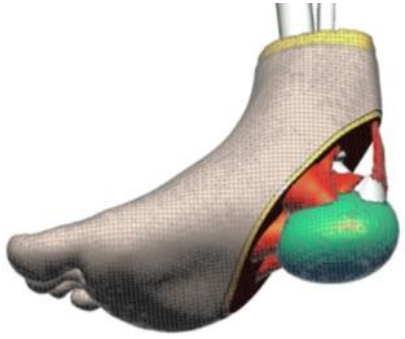
A biomechanical Finite Element model

1. An embedded measurements of the pressure at skin surface



2. An on-line estimation of the internal strains with a patient-specific biomechanical model of the soft tissues

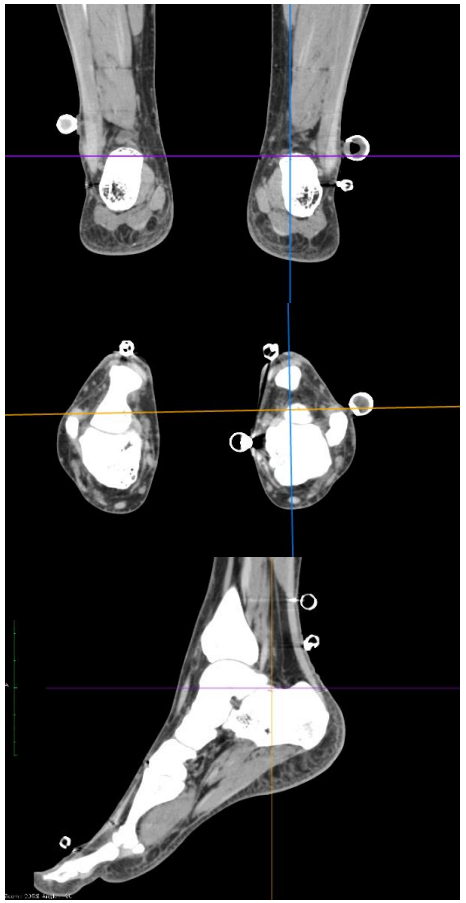




How to build a patient-specific model in a clinical routine?

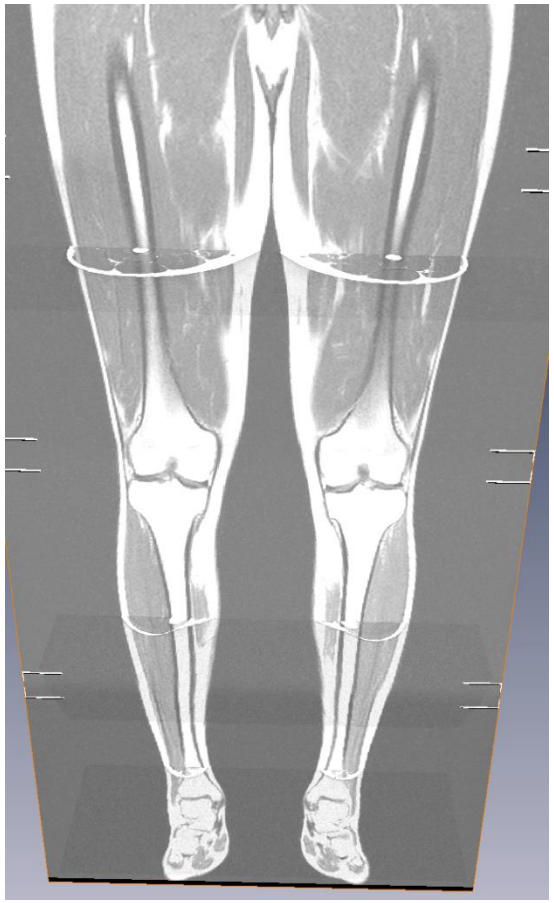
Patient-specific foot geometry

CT Scan



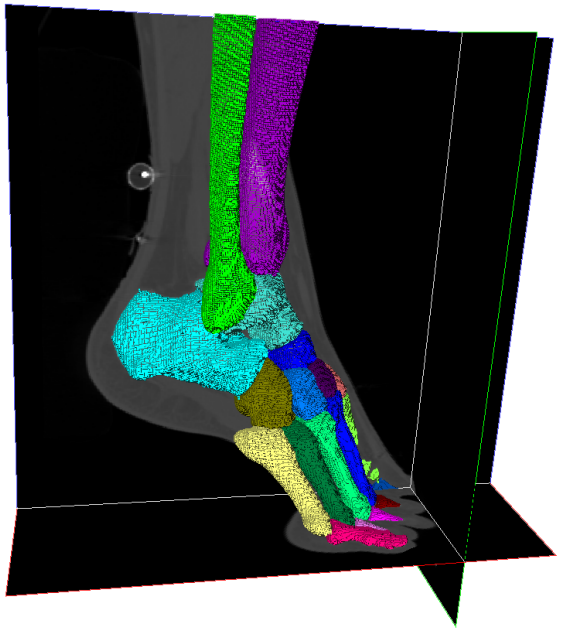
EOS

MRI



How to build a patient-specific model in a clinical routine?

Patient-specific foot geometry



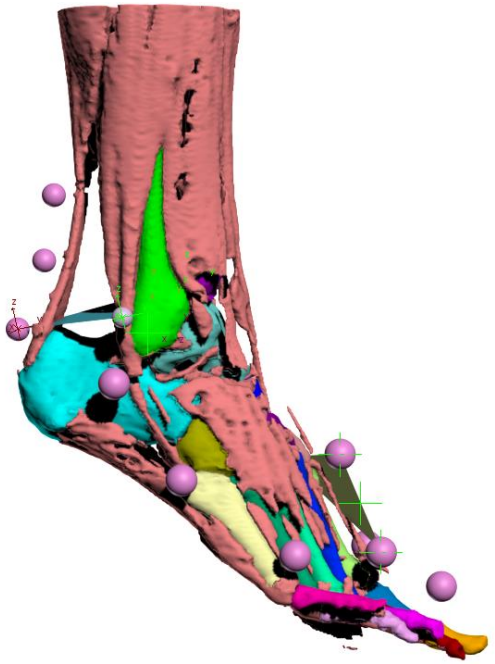
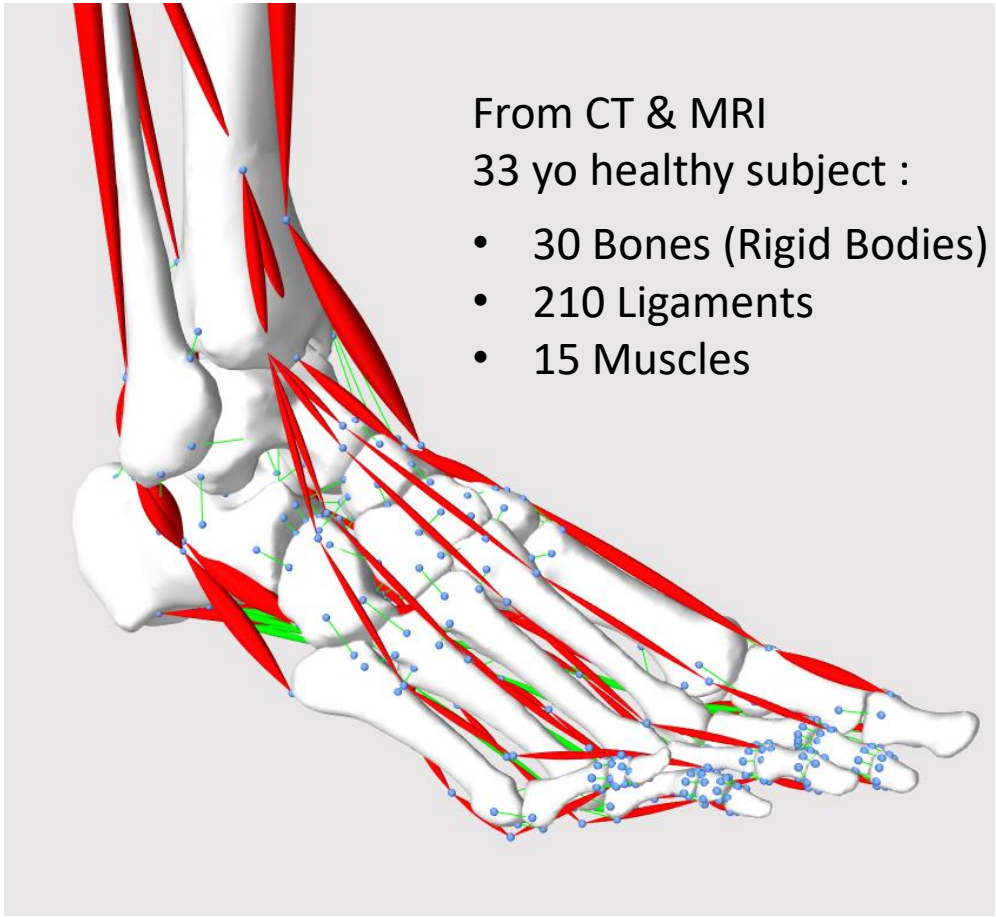


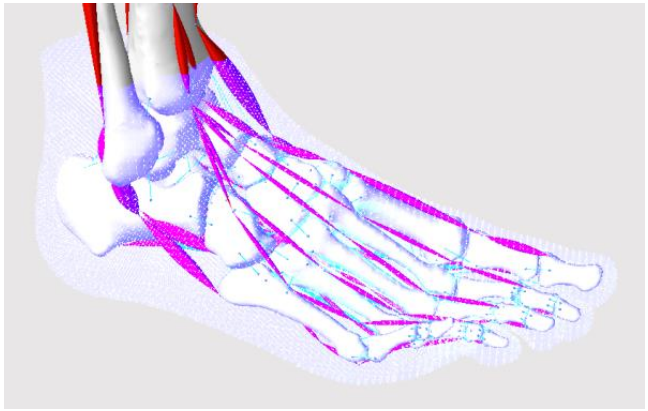
Image segmentation
(machine learning techniques based on CNN)

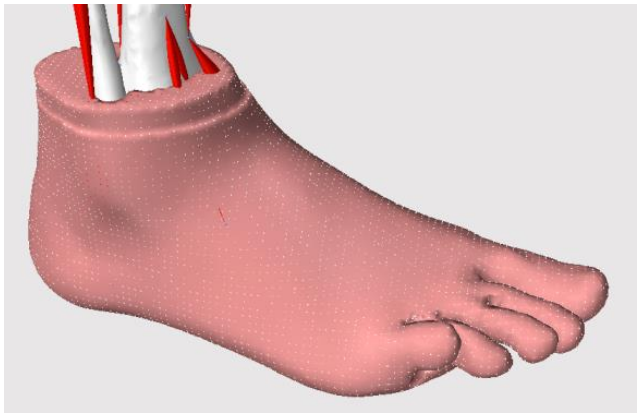


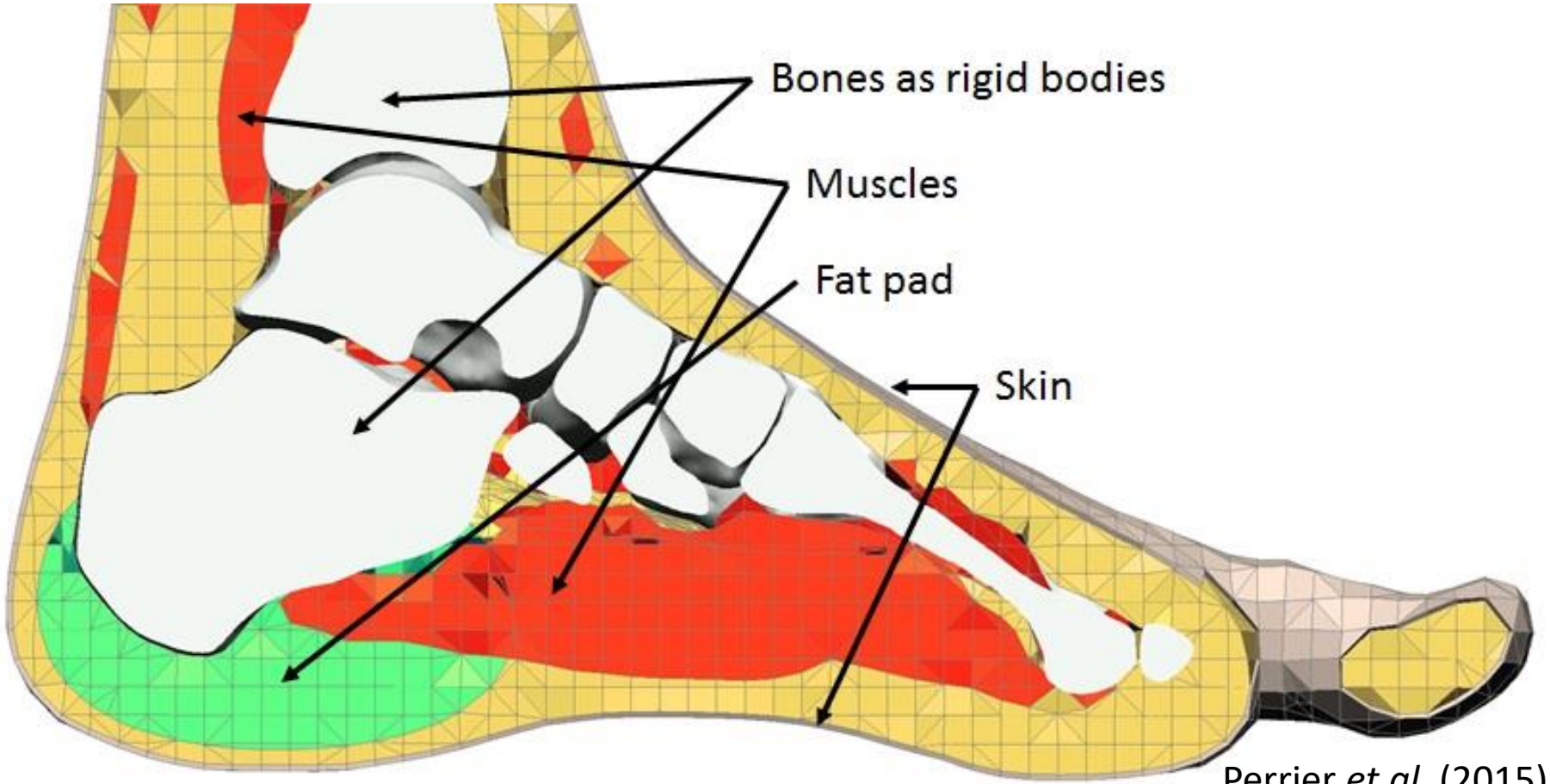
Perrier *et al.*, 2015

How to build a patient-specific model in a clinical routine?

Patient-specific foot geometry



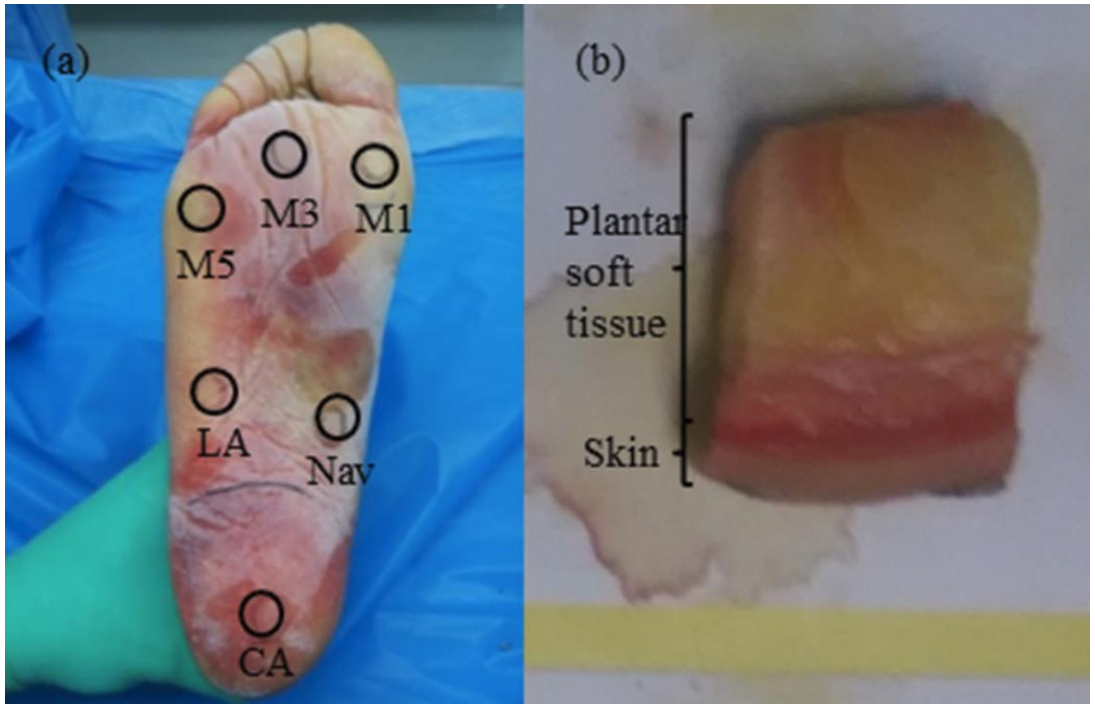


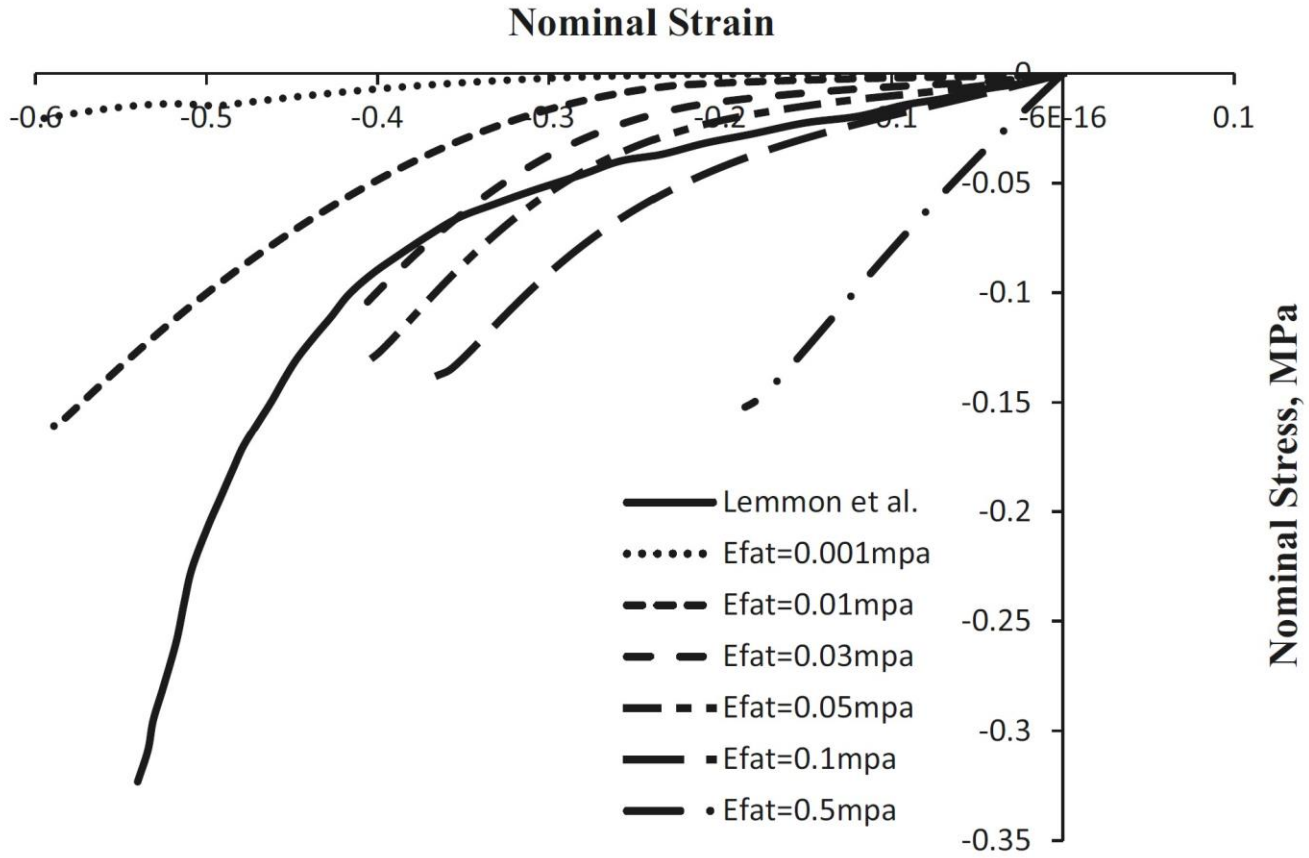


Perrier *et al.* (2015)

How to build a patient-specific model in a clinical routine?

Generic constitutive parameters

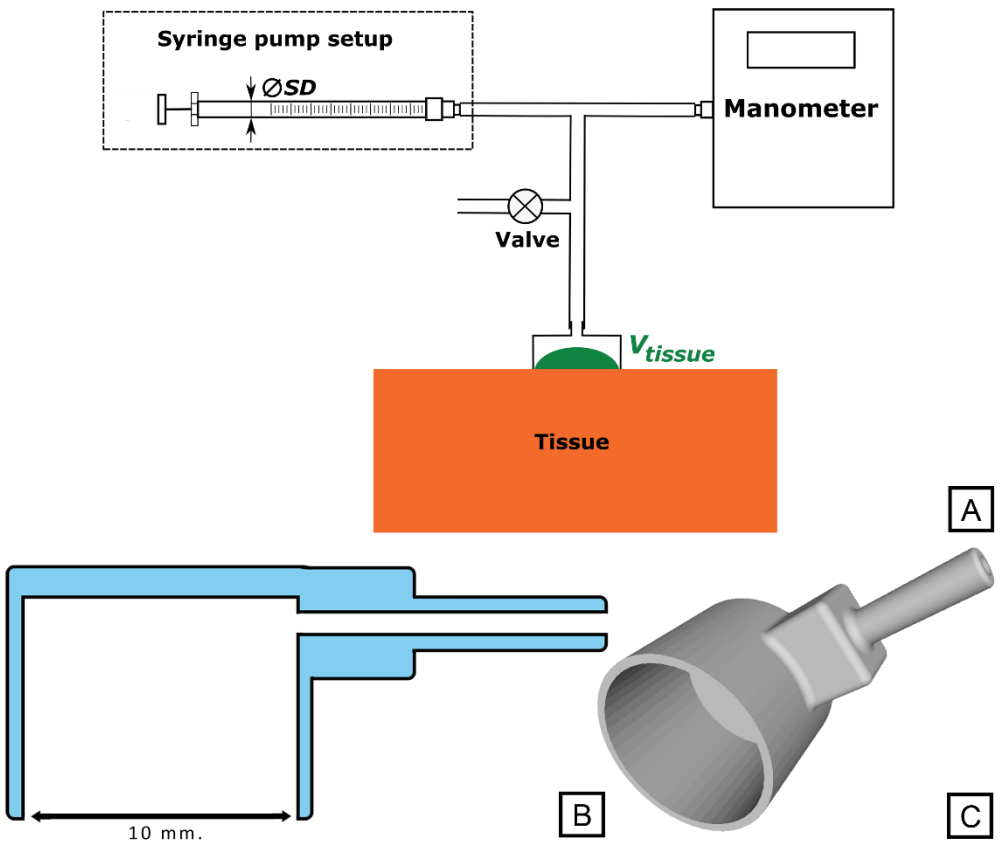


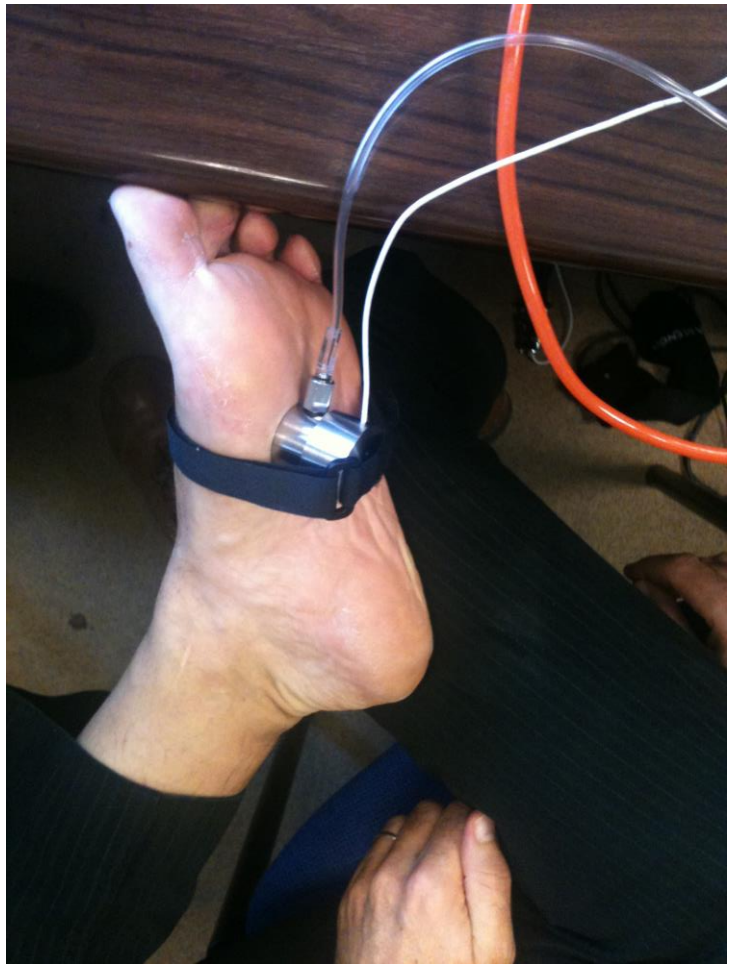


Ou *et al.*, 2018

How to build a patient-specific model in a clinical routine?

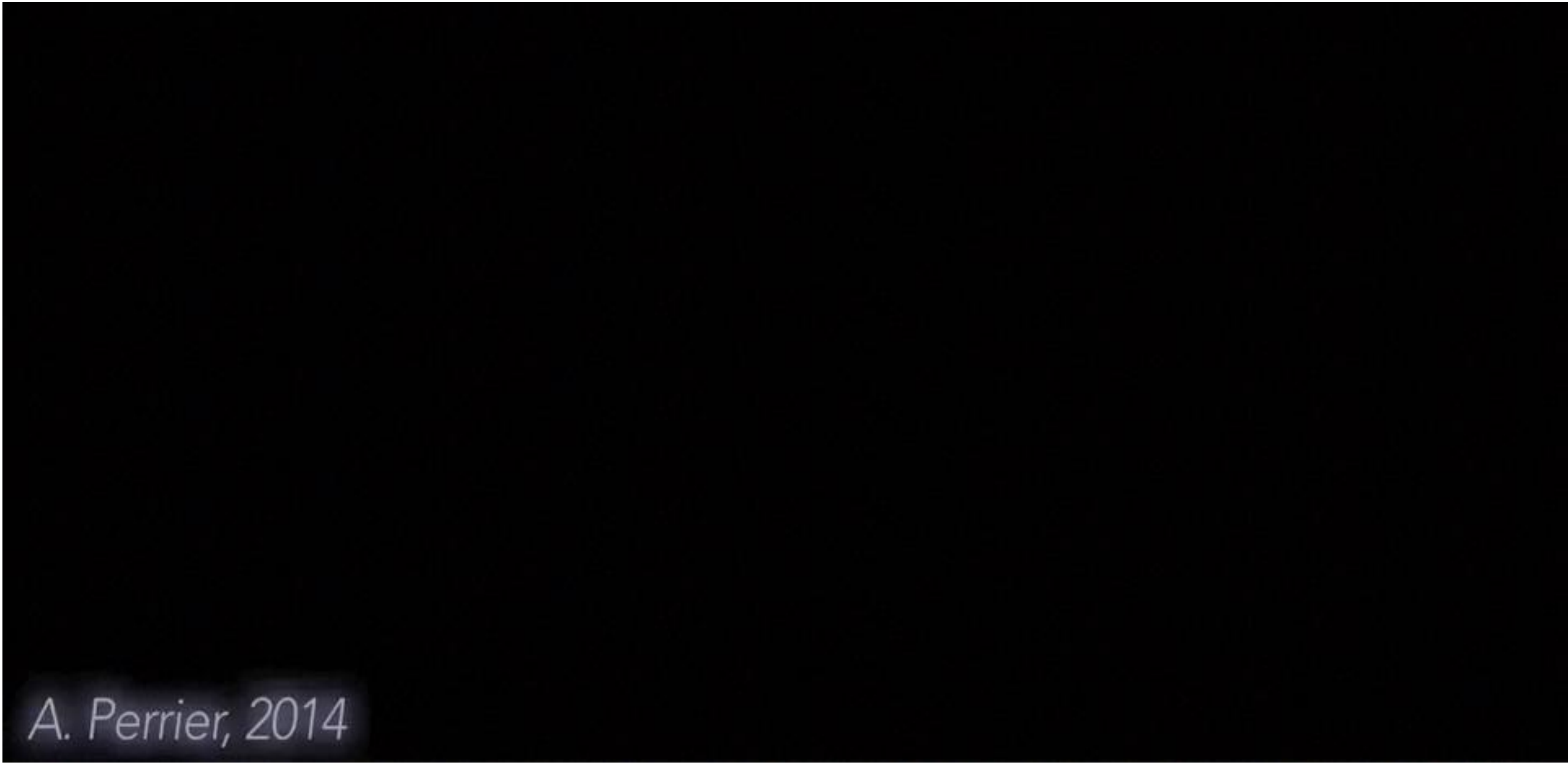
Patient-specific constitutive parameters



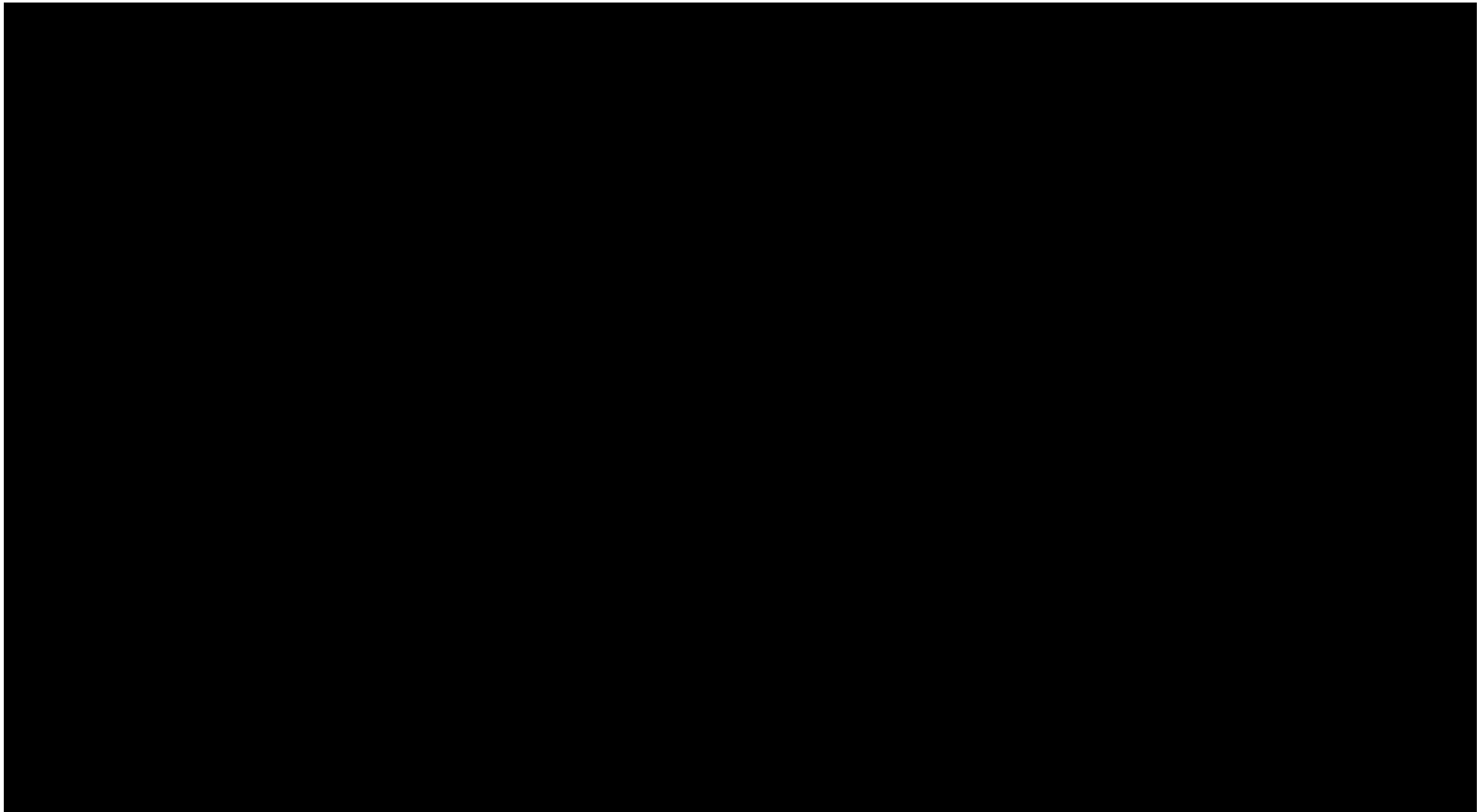


***In vivo* tissue aspiration - VLASTIC**, Elahi *et al.*, 2019

Finite Element foot model



Finite Element foot model



Finite Element models to estimate pressure ulcers risks

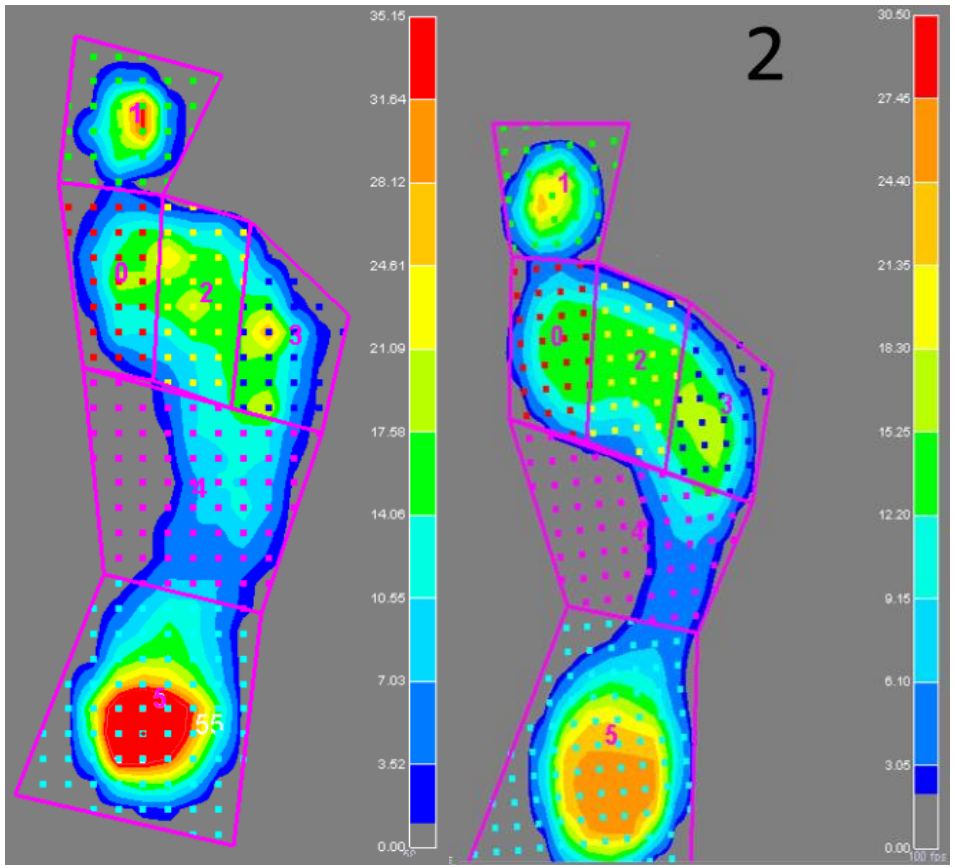
« Models have to be validated »

Finite Element models to estimate pressure ulcers risks

« Models have to be validated »

Plantar pressures

Simulated Real



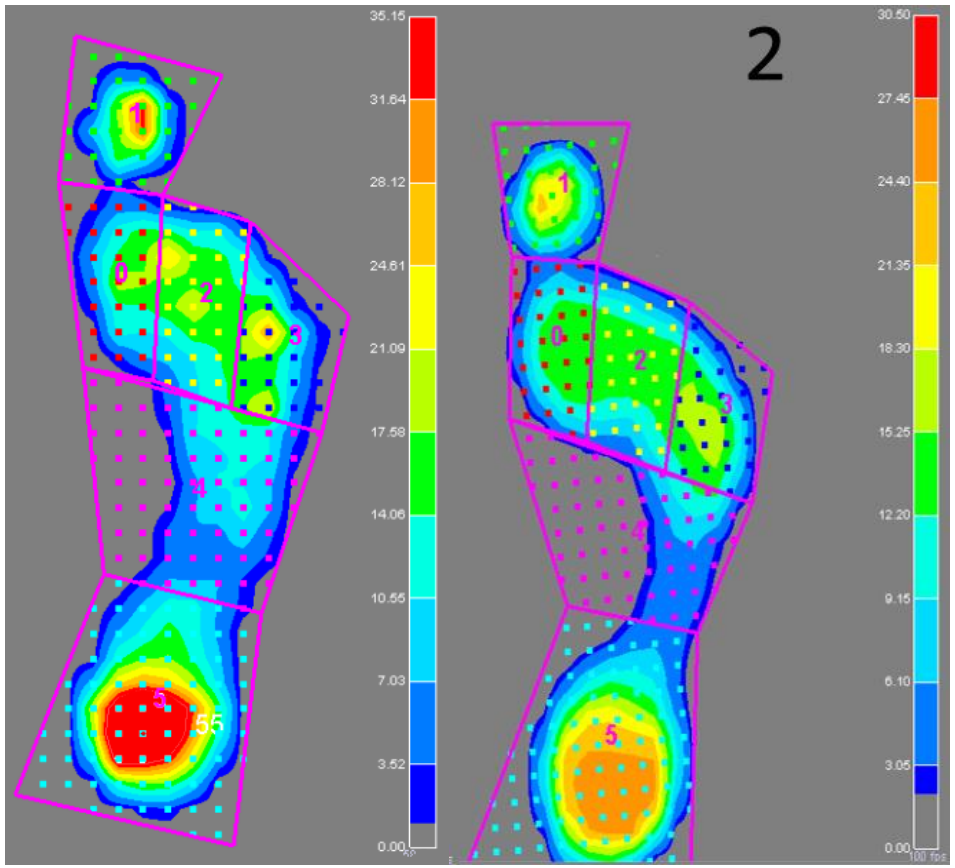
Perrier *et al.*, 2015

Finite Element models to estimate pressure ulcers risks

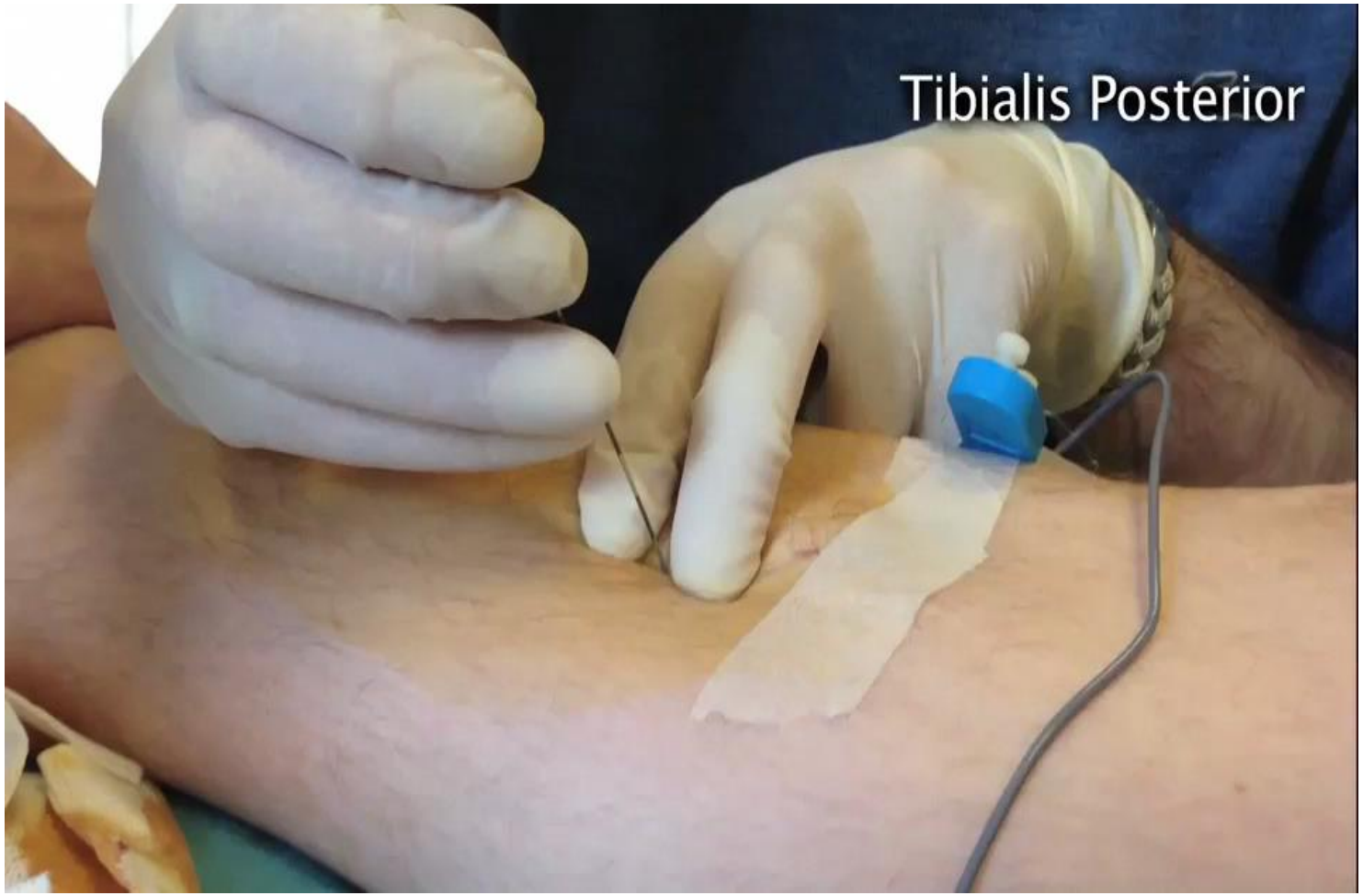
« Models have to be validated »

Plantar pressures

Simulated Real

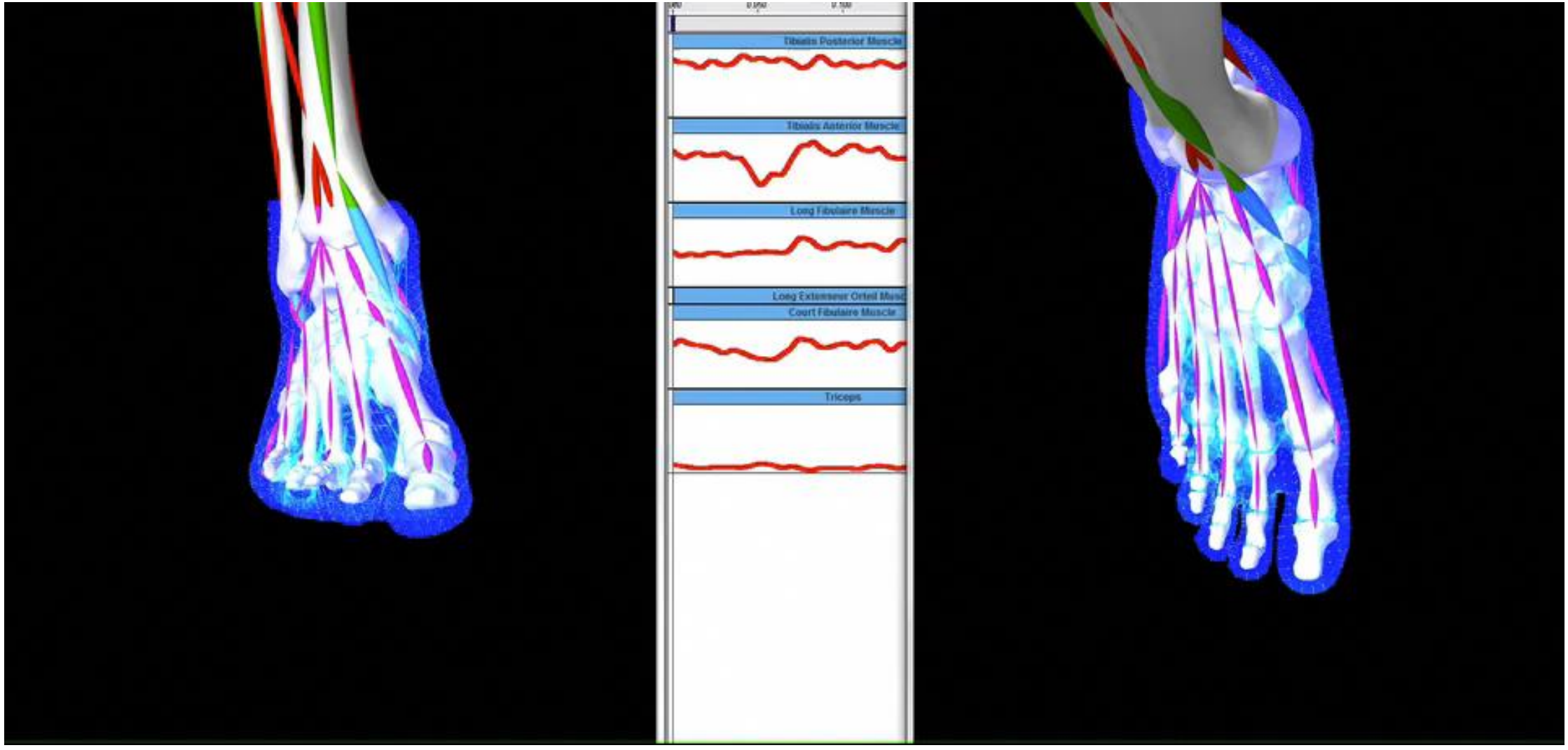


Perrier *et al.*, 2015



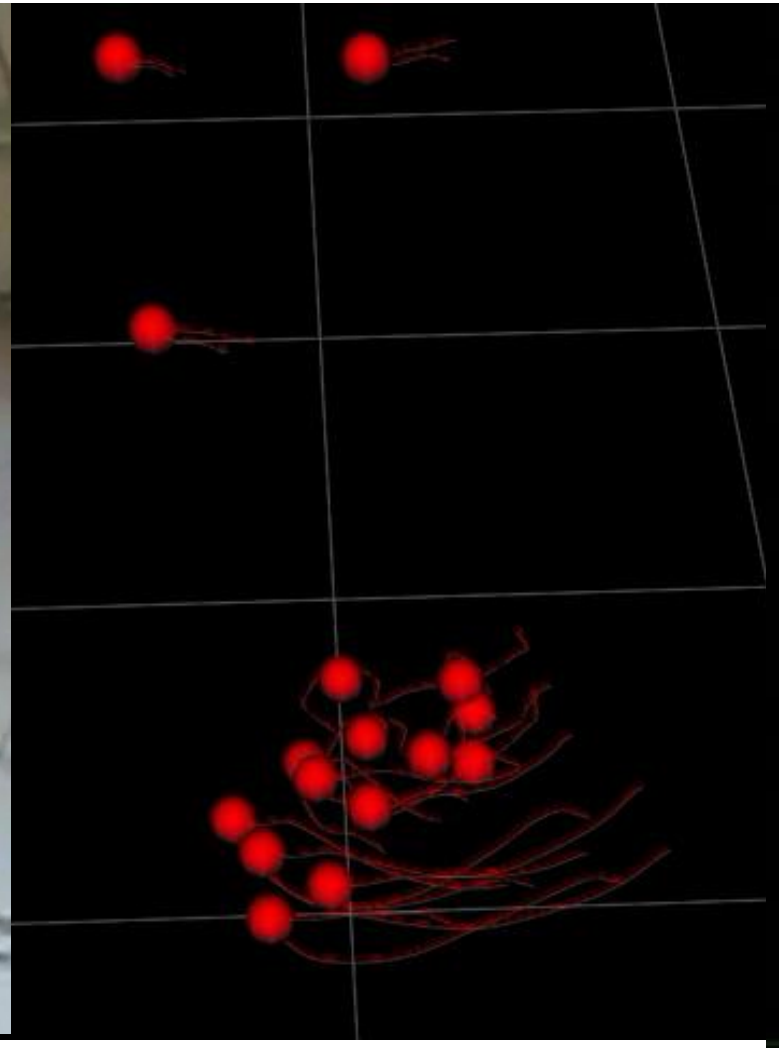
Finite Element models to estimate pressure ulcers risks

« Models have to be validated »



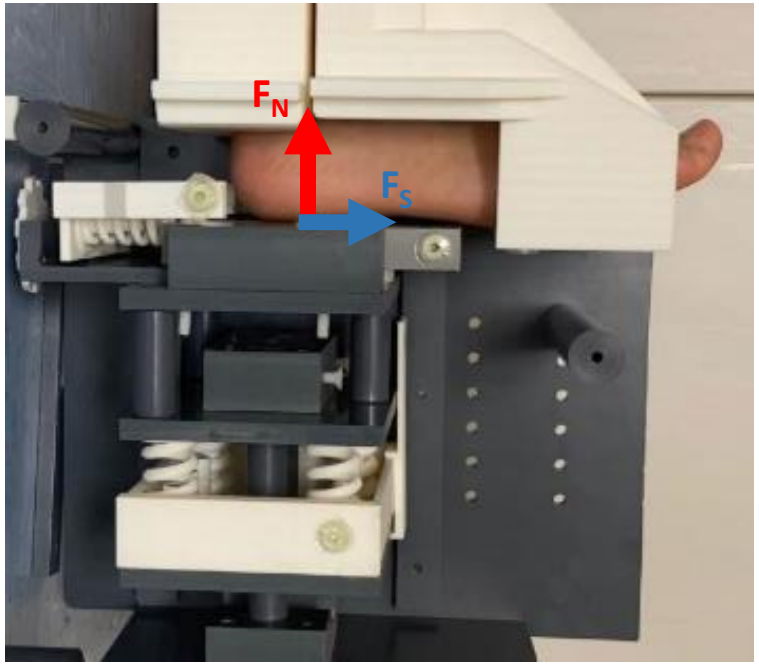
Finite Element models to estimate pressure ulcers risks

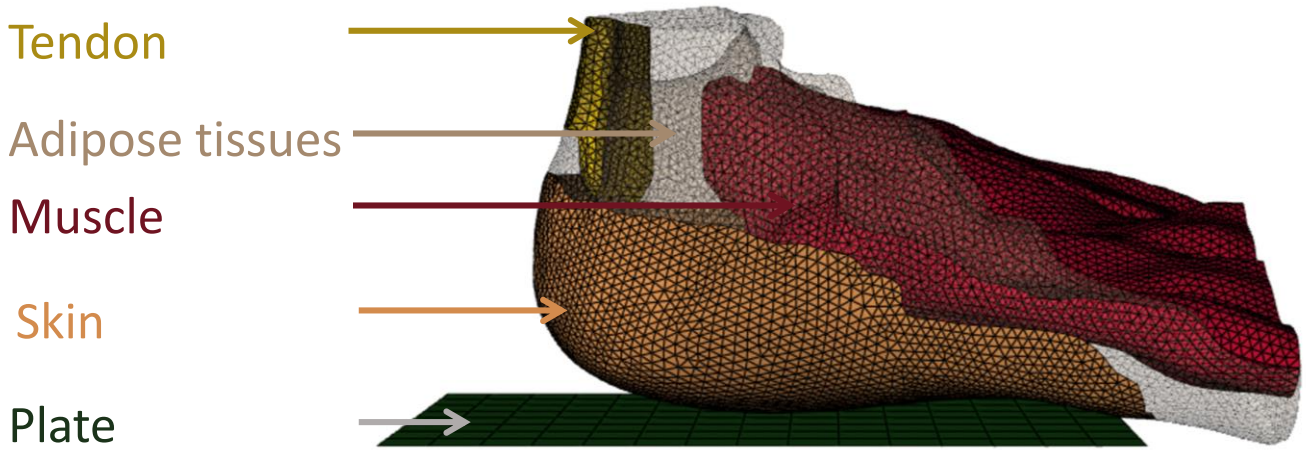
« Models have to be validated »

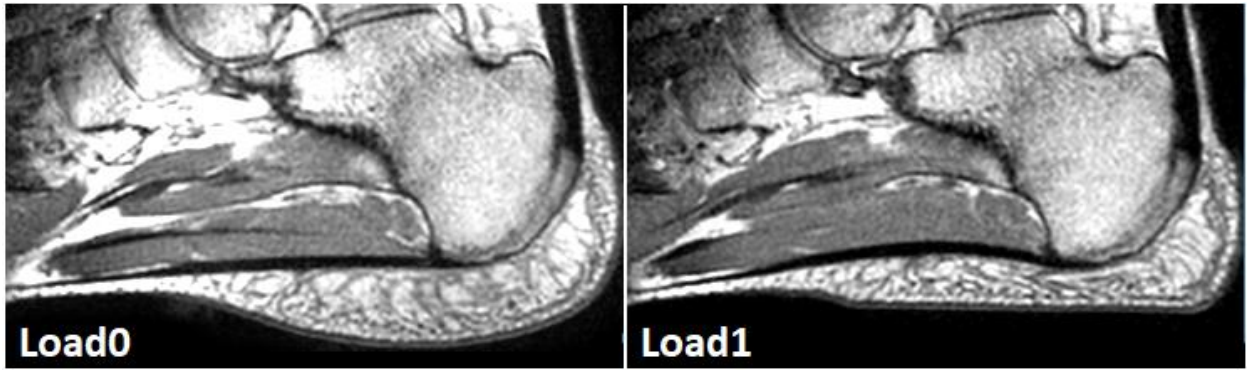


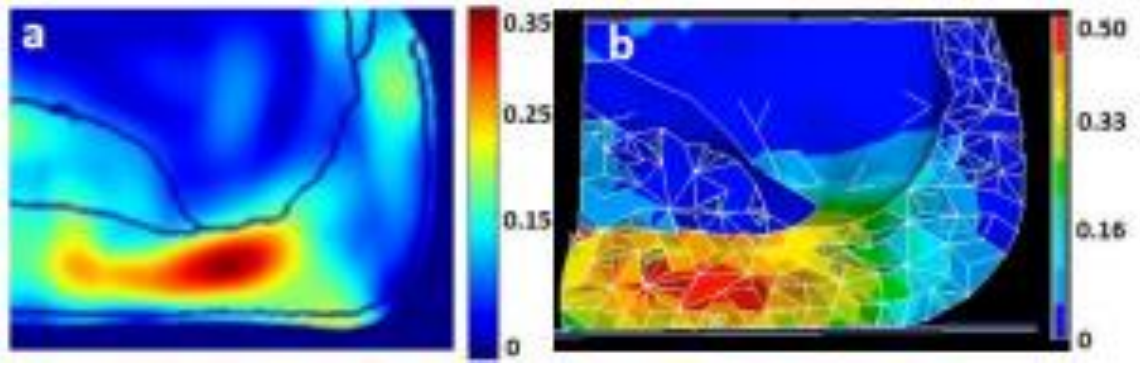
Finite Element models to estimate pressure ulcers risks

« *Models have to be validated* »





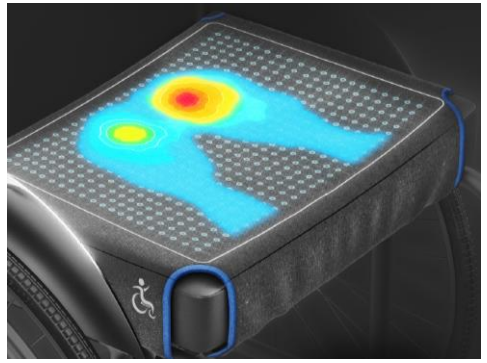




Strains measured through MRI

Strains simulated by the model

Trebbi *et al.*, 2022



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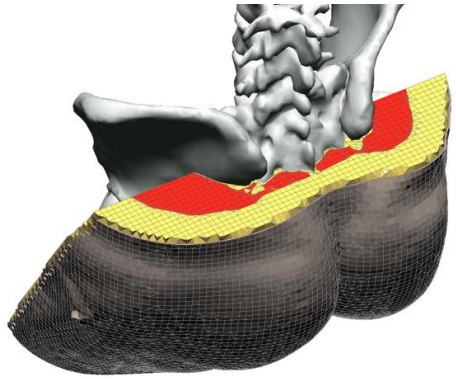
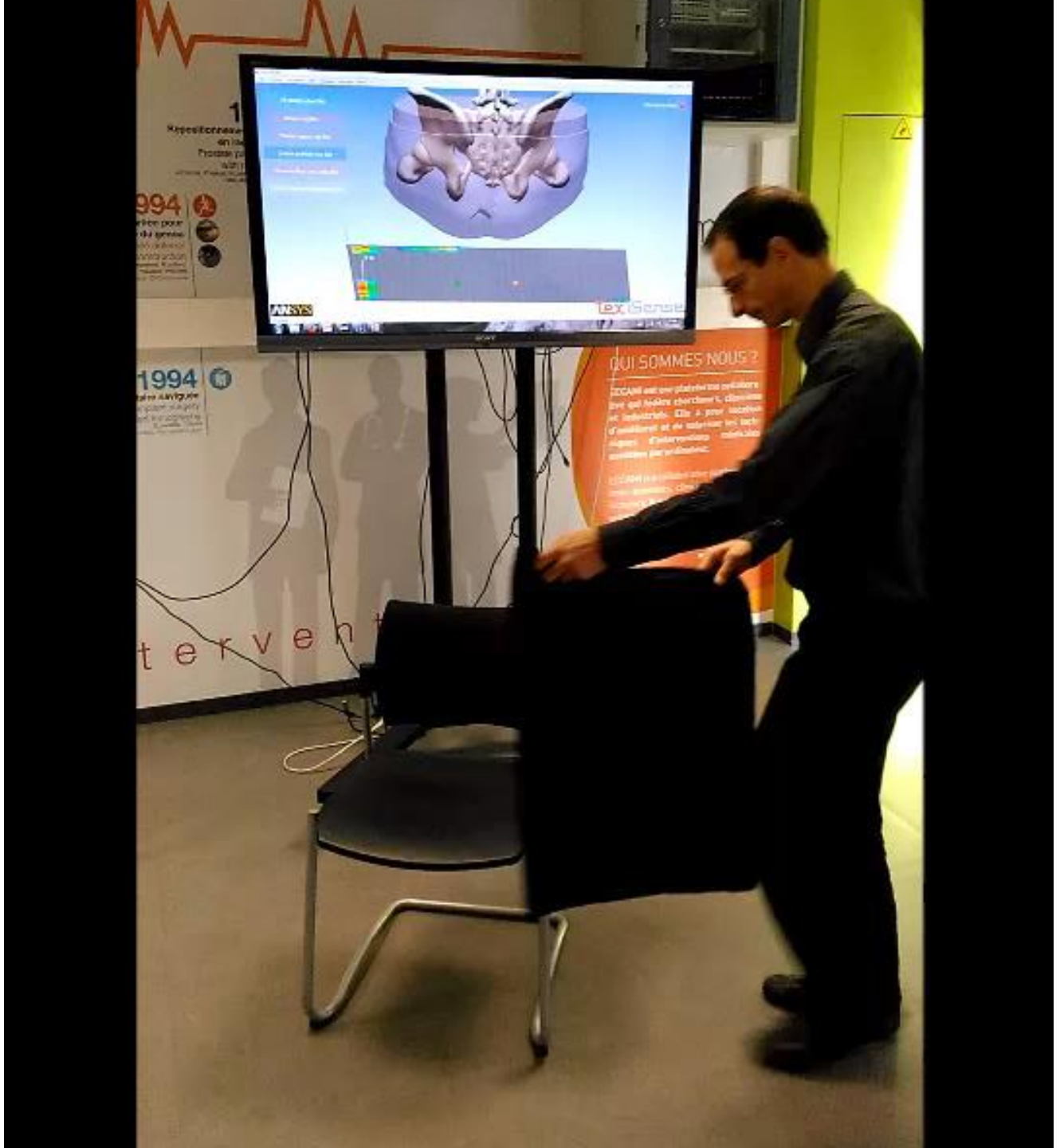


Reduced Order Modeling



Société de Biomécanique
Grenoble 2023

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