

What can be said, using mathematical modeling, about the internal pressure distribution in a leg given a surface pressure?

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Conflict of interest: co-inventor¹ and CEO² of PressCise AB



CHALMERS

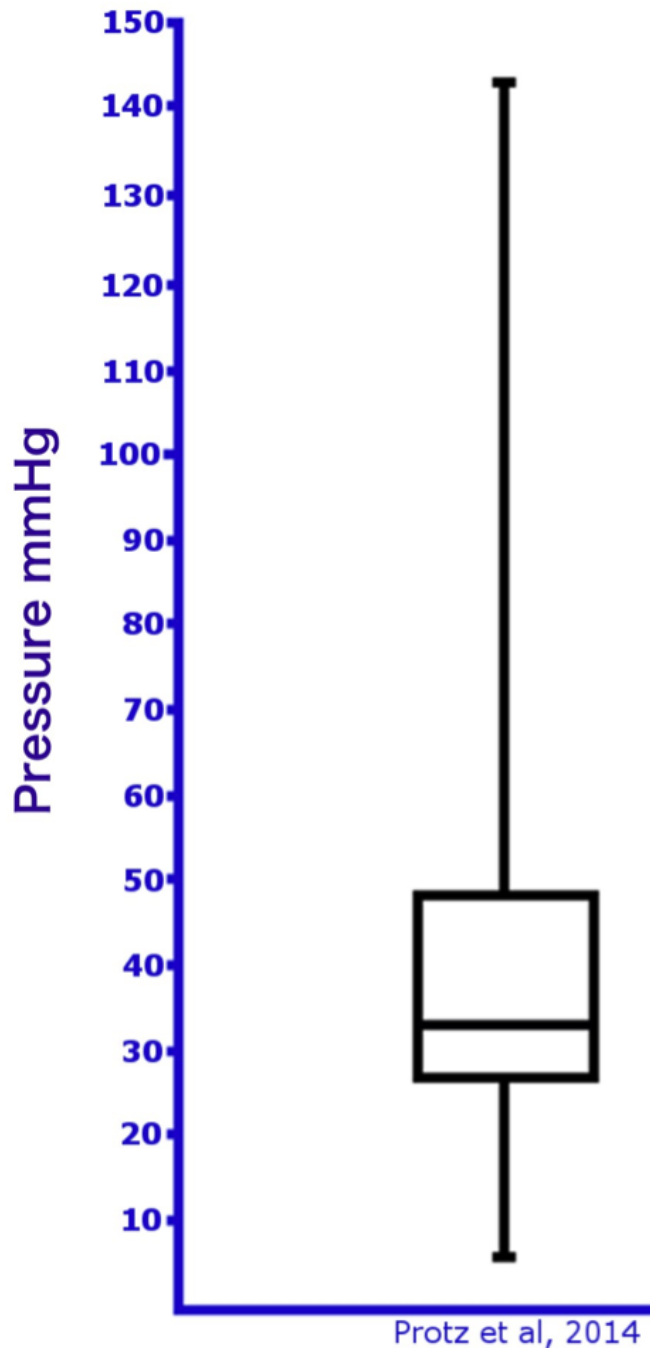


GÖTEBORGS UNIVERSITET

State of the art

Yeah, but does it matter?

- What happens under the skin?
- Isn't Pascal law going to level out everything anyway?
- We need class 2!
- What is the right pressure anyway?
- Doesn't that vary between individuals?



Yes, it does matter

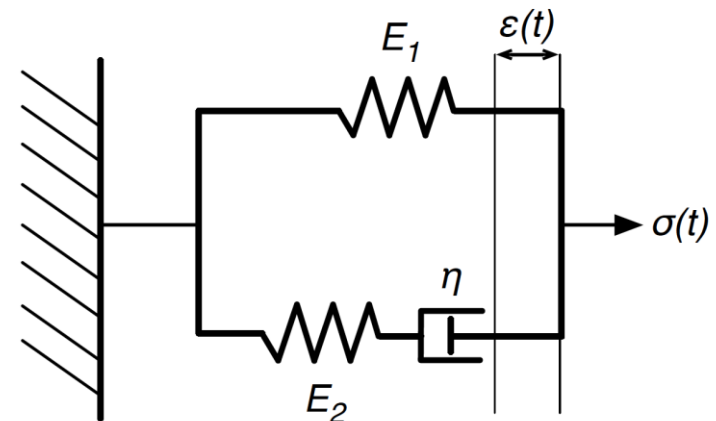
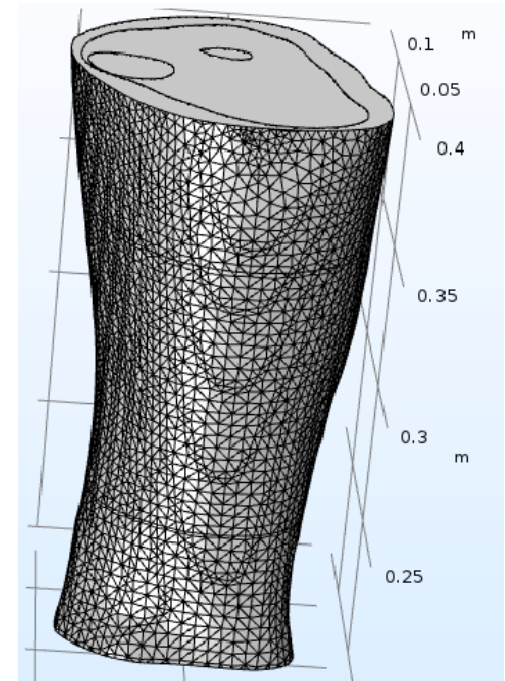
- 10:15 – 11:30 WHAT HAPPENS ON THE VEINS UNDER COMPRESSION?
- Let's say we get a goal pressure at a given vein. How on earth do we obtain that given the almost chaotic situation displayed in the Protz studies to evidence based personalized precision treatment?

What happens in the leg when a compression is applied?

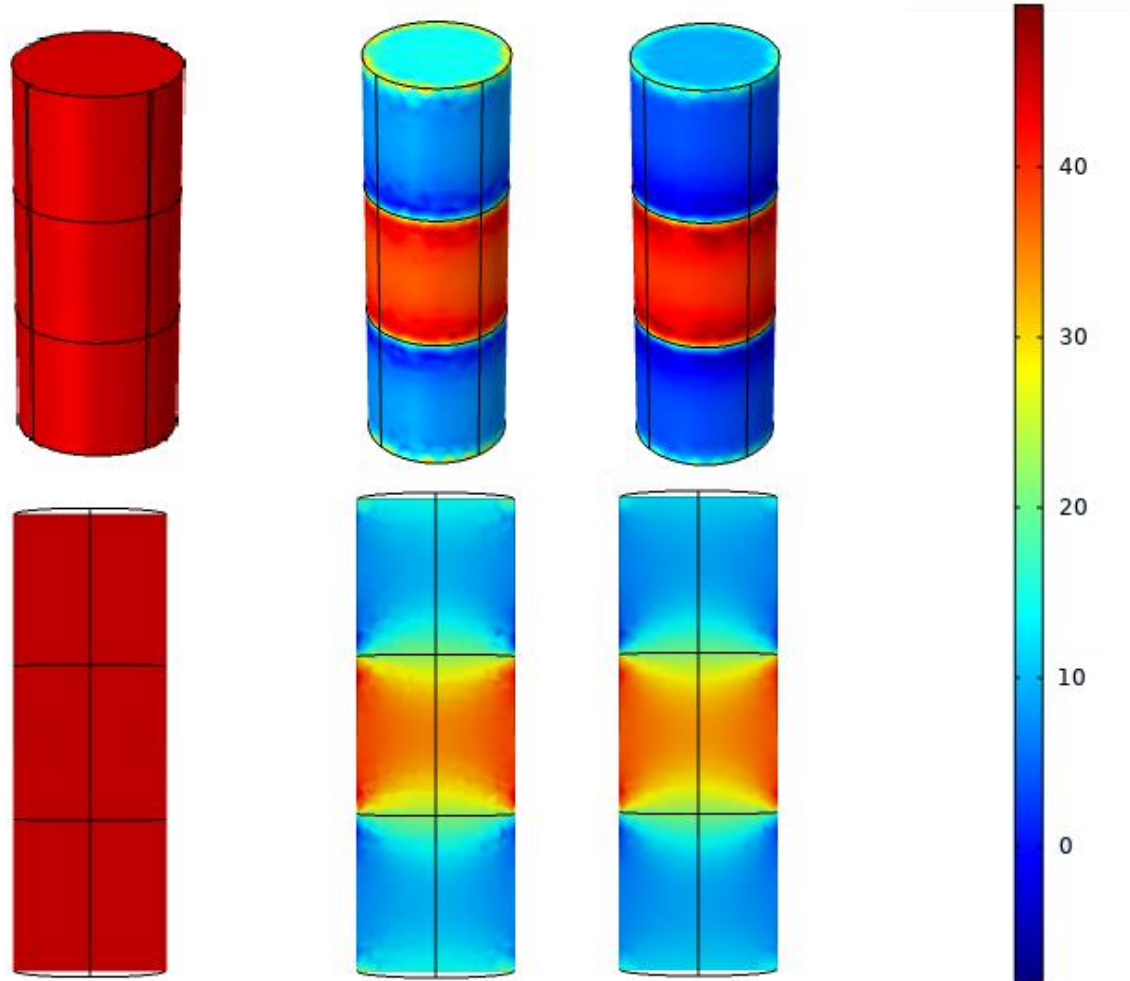
- Does Pascal Law suffices to describe the situation?
- No, and that can be shown “in silico” by using numerical analysis of a mathematical model
- What is a model?
- and how does it work?
- Given the model, how does that help us obtain the target pressure?

The work flow

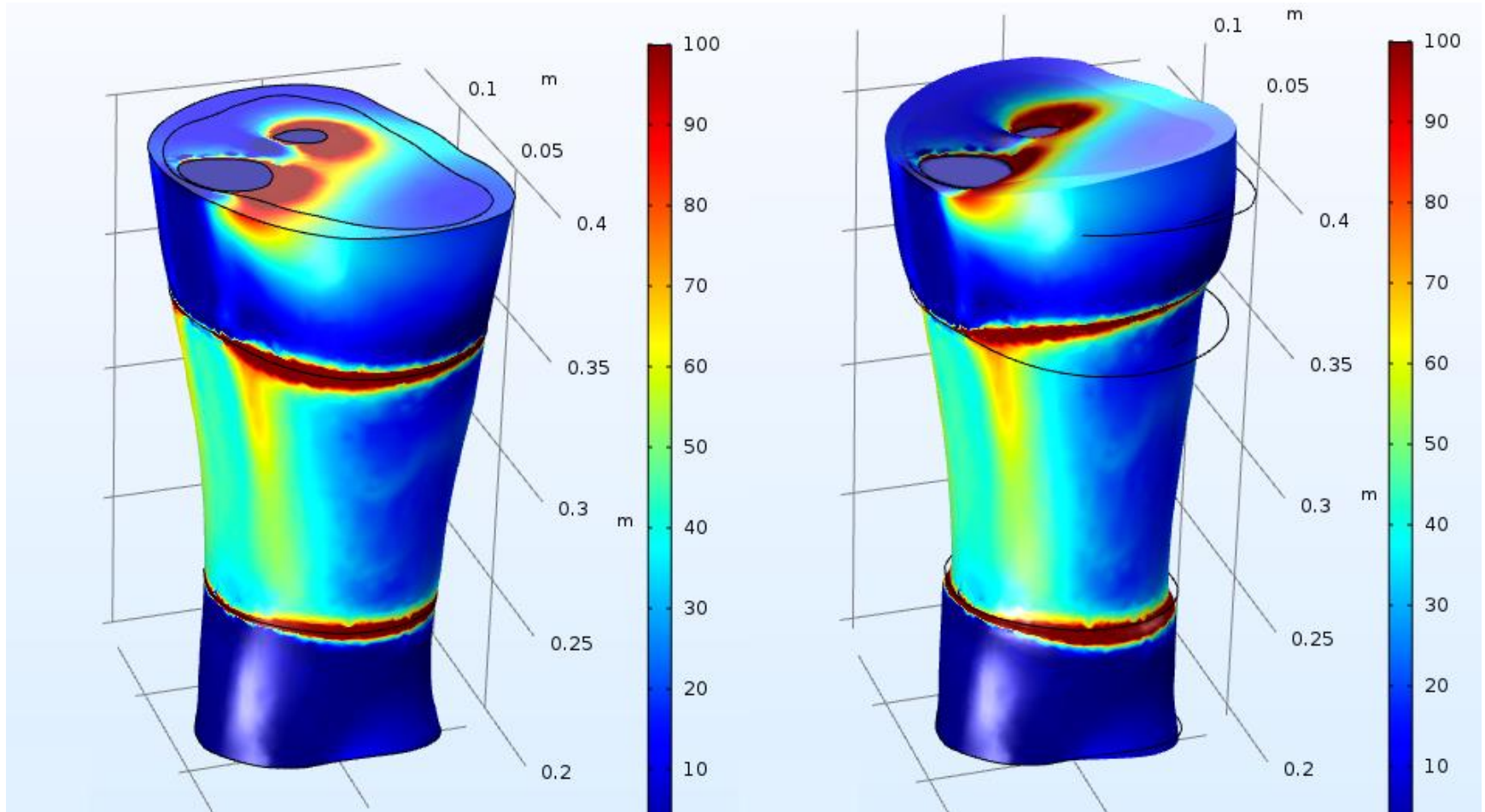
- A mathematical model as a simplified description of the underlying physics.
- Simplification: view the leg as a composition of viscoelastic units.
- i.e. neither a fluid, nor a solid



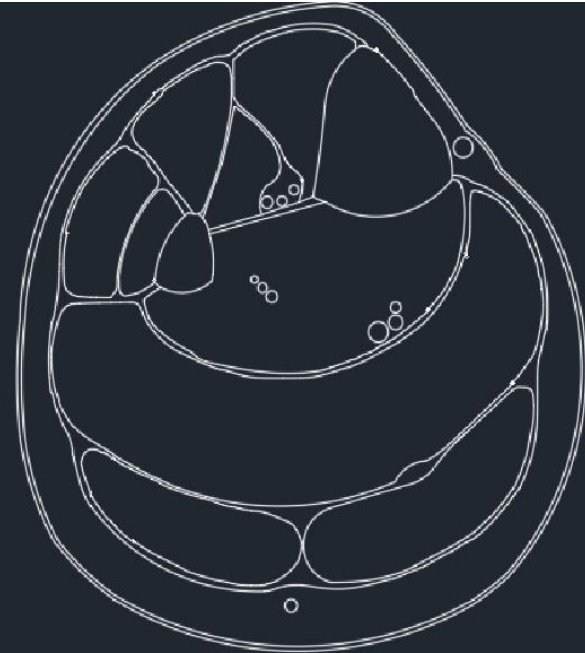
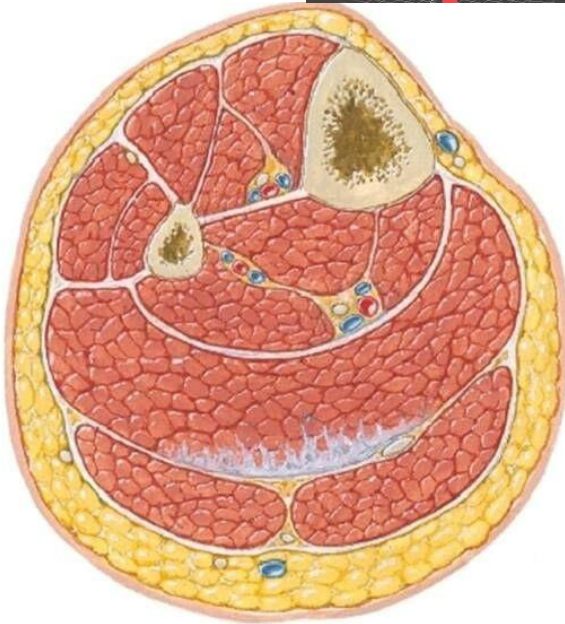
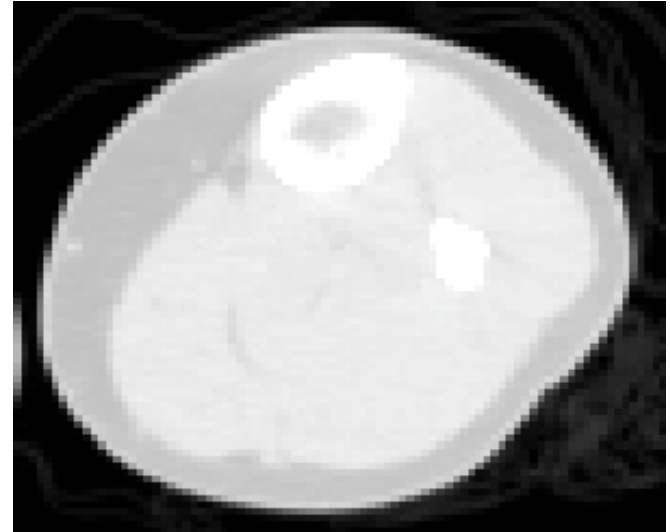
No, the leg is not a fluid



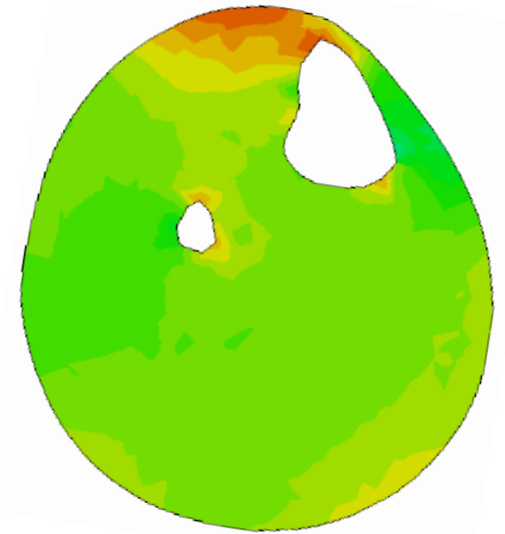
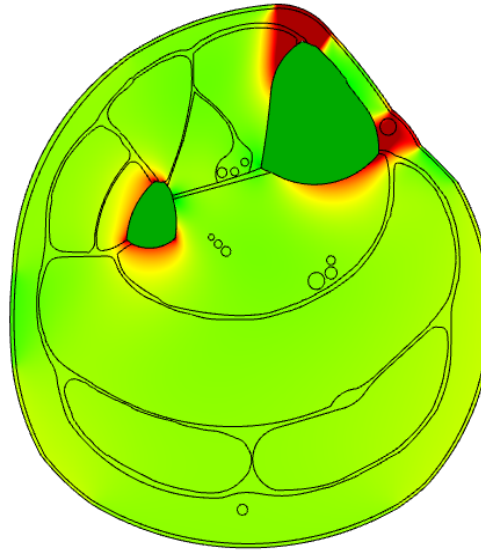
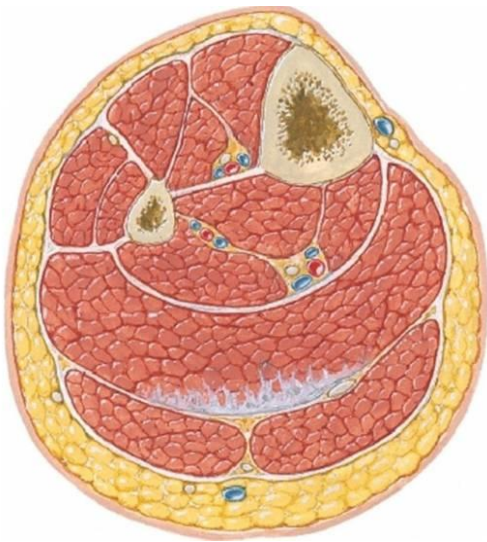
Adding deformation



Back to the work flow

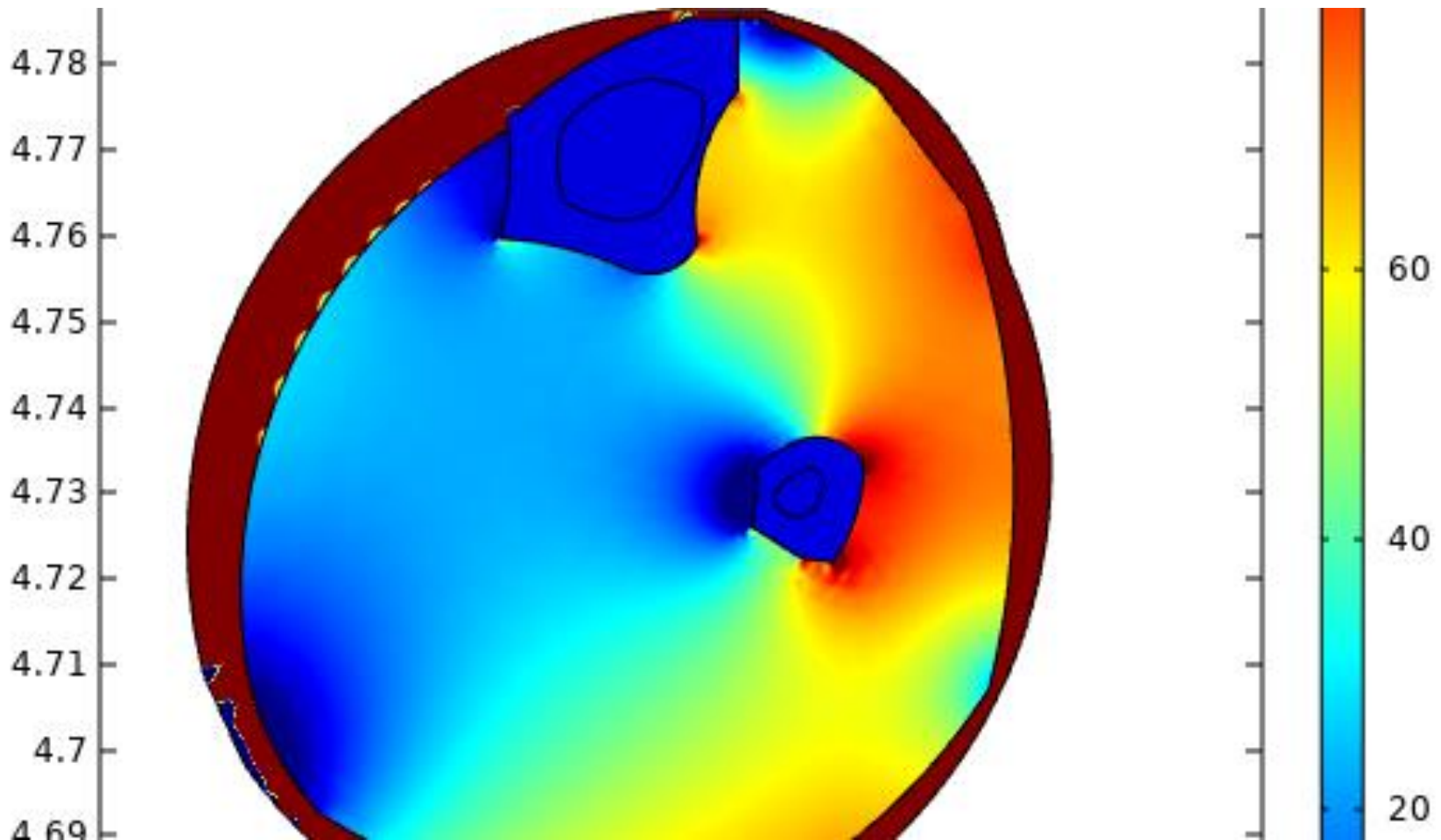


Add an interface 25 mmHg pressure:



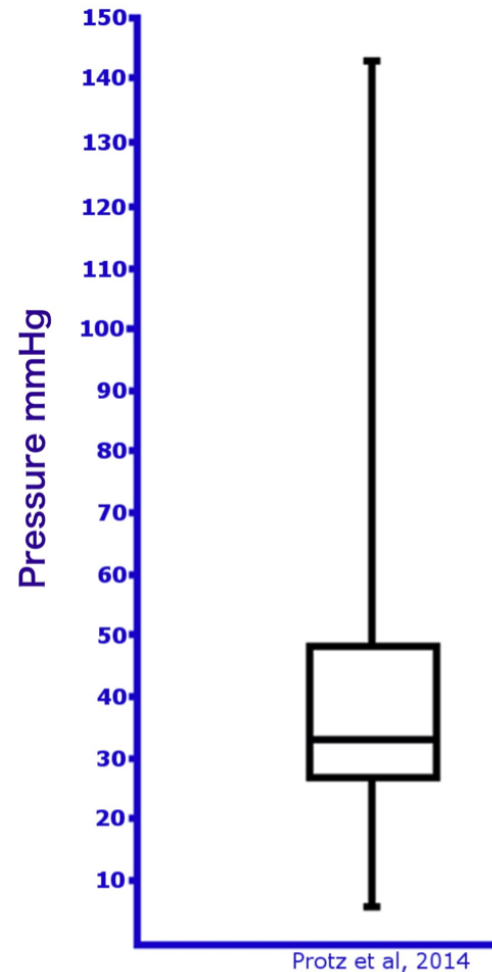
Stéphane Avril, et al,
SAINT-ETIENNE

Higher pressure, shape change as well



Ok, but how do we obtain that boundary pressure?

- Either use conventional bandage systems, measure, adjust, and repeat
- Or, the Lundatex system from PressCise:
- And then pick the right bandage until you reach your target



But what if we want different internal pressures at different target veins?

- Now it's getting really hard! Impossible even?
- We can tackle that as well (world premiere) at least for two veins (so far).

Settings

Parameters

Label: Parameters 1

Parameters

Name	Expression	Value	Description
a	$-\pi/2$	-1.5708	Plats för pad
Ae	$2 \cdot R \cdot A$	0.044 m	Bredd av pad
A	0.4[rad]	0.4 rad	Vinkel av pad
R	55[mm]	0.055 m	Genomsnittlig radie
H	10[mm]	0.01 m	Höjd av pad
sigma	200[N/m]	200 N/m	
B	$\arccos(R/(R+H))/4$	0.14052 rad	Vinkel av Skugga
Pi	σ/R	3636.4 N/m ²	Tryck utan pad
Pe	$P_i \cdot (2 \cdot R \cdot B + A_e) / A_e$	4913.8 N/m ²	Tryck med pad
Pv1	2600 [N/m ²]	2600 N/m ²	Sökttryck Small Saph vein
Pv2	1800[N/m ²]	1800 N/m ²	Sökttryck Post Tibial vein

Graph



110

100

90

80

70

60

50

40

30

20

10

0

Mess



Draw

Primitives

Operations

Other

Settings

Mesh

Build All

Label: Mesh 1

Mesh Settings

Sequence type:

Physics-controlled mesh

Physics-Controlled Mesh

Element size:

Normal

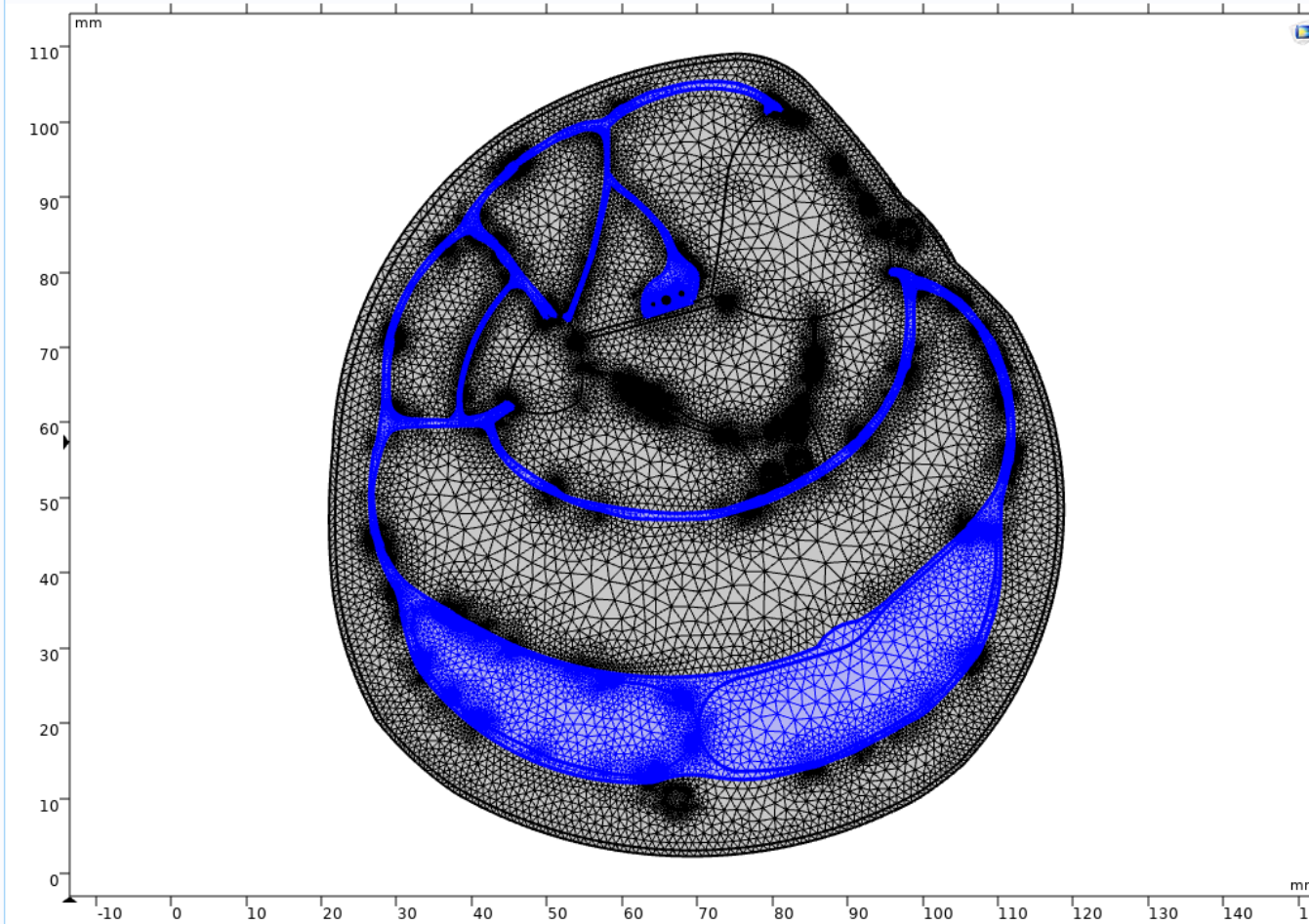
Contributor

Use

Solid Mechanics (solid)



Graphics



Messages × Progress Log Probe Table 1 ×



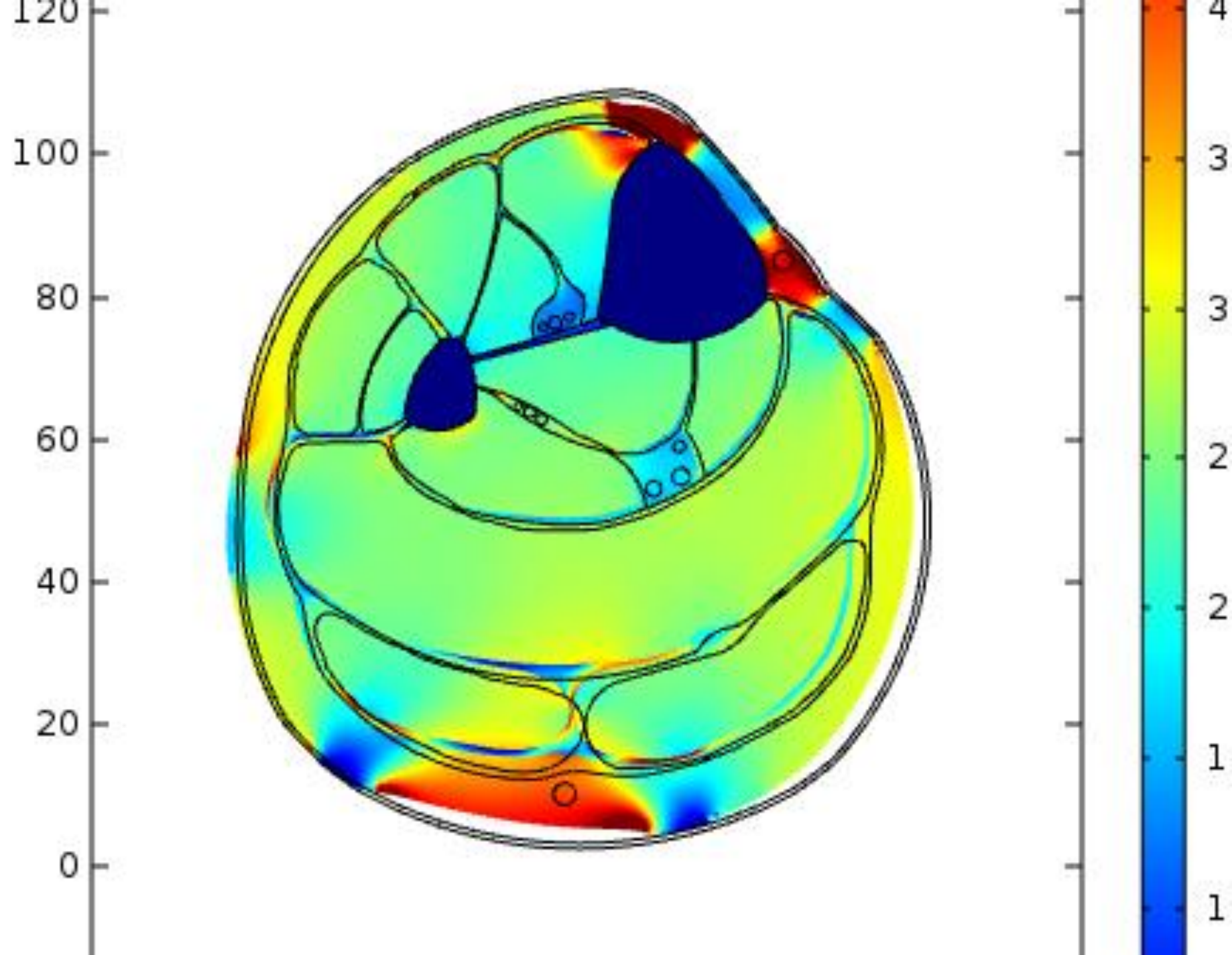
COMSOL Multiphysics 5.4.0.346

Warning: The preference setting Number of cores is ignored because the environment variable 'OMP_NUM_THREADS' is set to '4'.

Warning: The number of allocated threads 4 exceeds the number of available physical cores (2).

[May 22, 2019 12:48 PM] Your COMSOL 5.4 installation is up to date.

[May 22, 2019 12:50 PM] Opened file: C:\Users\torbjrn\Dropbox\MT_Marcus\Optimization\Point_opt_aHA.mph



Settings

Analytic

Plot Create Plot

Label: Analytic 3

Function name: an3

Definition

Expression: $\text{if}(\text{abs}(\text{sys2.phi}-a+A+B)<B,0,\text{an1}(\text{curv}))$

Arguments: sys2.phi, curv

Derivatives: Automatic

Periodic Extension

Units

Arguments: rad, 1/m

Function: N/m^2

Advanced

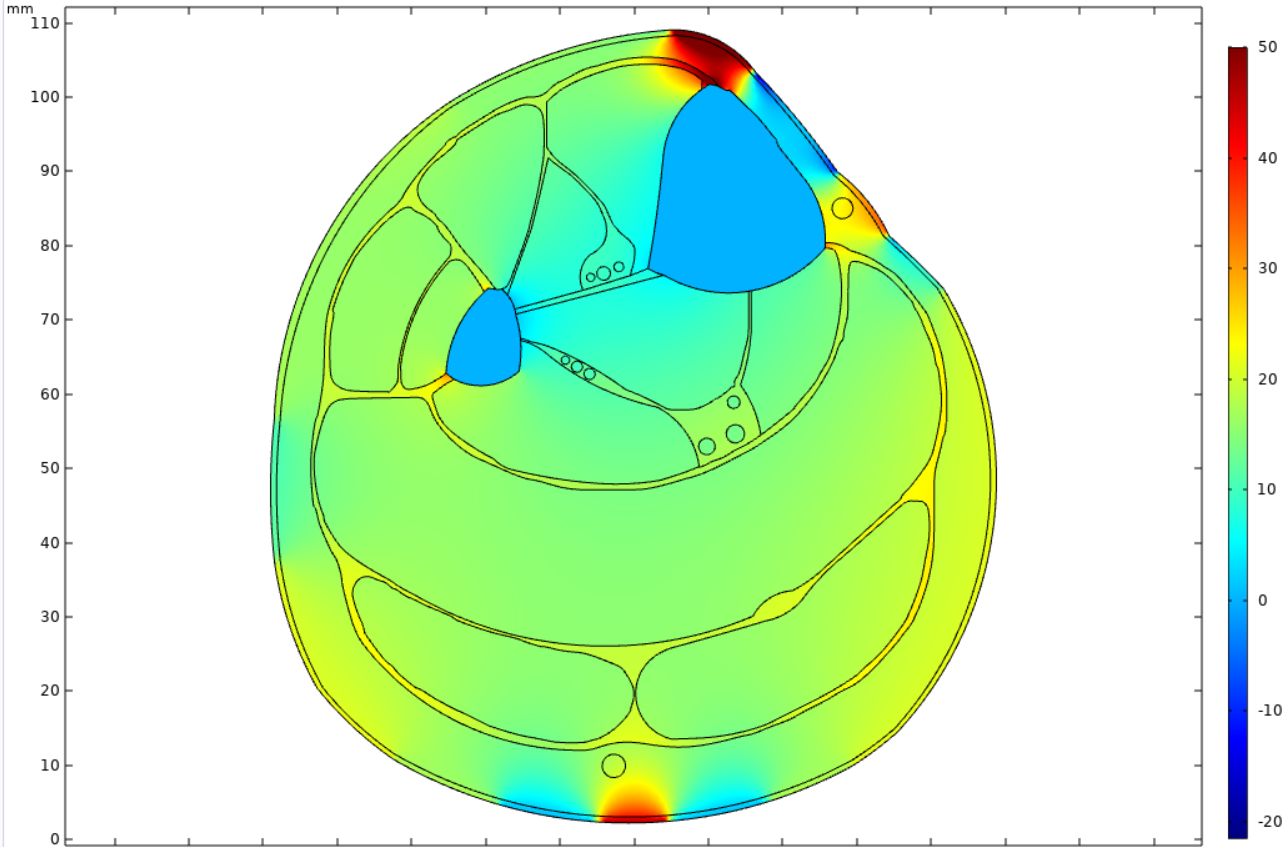
Plot Parameters

Argument	Lower limit	Upper limit
sys2.phi	0	1
curv	0	1

Graphics Convergence Plot 1 Probe Plot 1

mm

a=-1.5708 H=0.01 m A=0.1 rad



Messages

Progress

Log

Accumulated Probe Table 6

0.85 e-12 AUTO 0.5 e-1 0.50 e-3 0.85

a	H (m)	A (rad)	Pressure (N/m^2), Point: (67.581, 9.4996)	Pressure (N/m^2), Point: (80.338, 52.941)	Objective ($\text{kg}^2/(\text{m}^2\text{s}^4)$), Global Variable Probe 1
-1.5708	0.010000	0.10000	2603.9	1816.3	282.11
-1.2708	0.010000	0.10000	1624.0	1794.5	9.5258E5

Conclusion

- It is already today possible to give a precise, well defined internal compression treatment that is patient specific. At least in principle.

Thank you – tack så mycket!