Macro/microscopic imaging for biomechanical investigations

example: image-based reactive deformable bioconduits

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Input: medical image (acquisition)

X-ray computed tomography (**MSHCT**, **EBCT**)	X-rays absorption
Nuclear magnetic resonance imaging	Proton environment
NMRV	local flow field
DTMRI	fiber orientation
MR tagging	organ displacement
3D US echography	Tissue physical (mechanical) prop
low cost, lighter equipment	but less advanced technology
image-guided therapy	
IVUS	vessel wall imaging
Tissue-Doppler US	tissue motion
Elastography	strain data
USD	local flow field (superficial vessels)
Nuclear imaging (**SPECT**, **PET**)	Radioactive isotope concentration physiologic function

→ Data fusion for structure–function relationships

CT - spatial resolution

to couple physiologic activity to the underlying anatomy
$\longrightarrow$ needs in suitable time and space resolution

CT	Δx, Δy (mm)	Δz (mm)	Matrix	Slice number
MSSCT function mode	0.5	0.6	512×512	4
MSSCT volume mode	0.5	0.6	512×512	$\mathcal{O}(100)$
SS-EBCT	0.7	1.5–3	512×512	~ 100
MS-EBCT	1	8	360×360	2–8

CT - temporal resolution

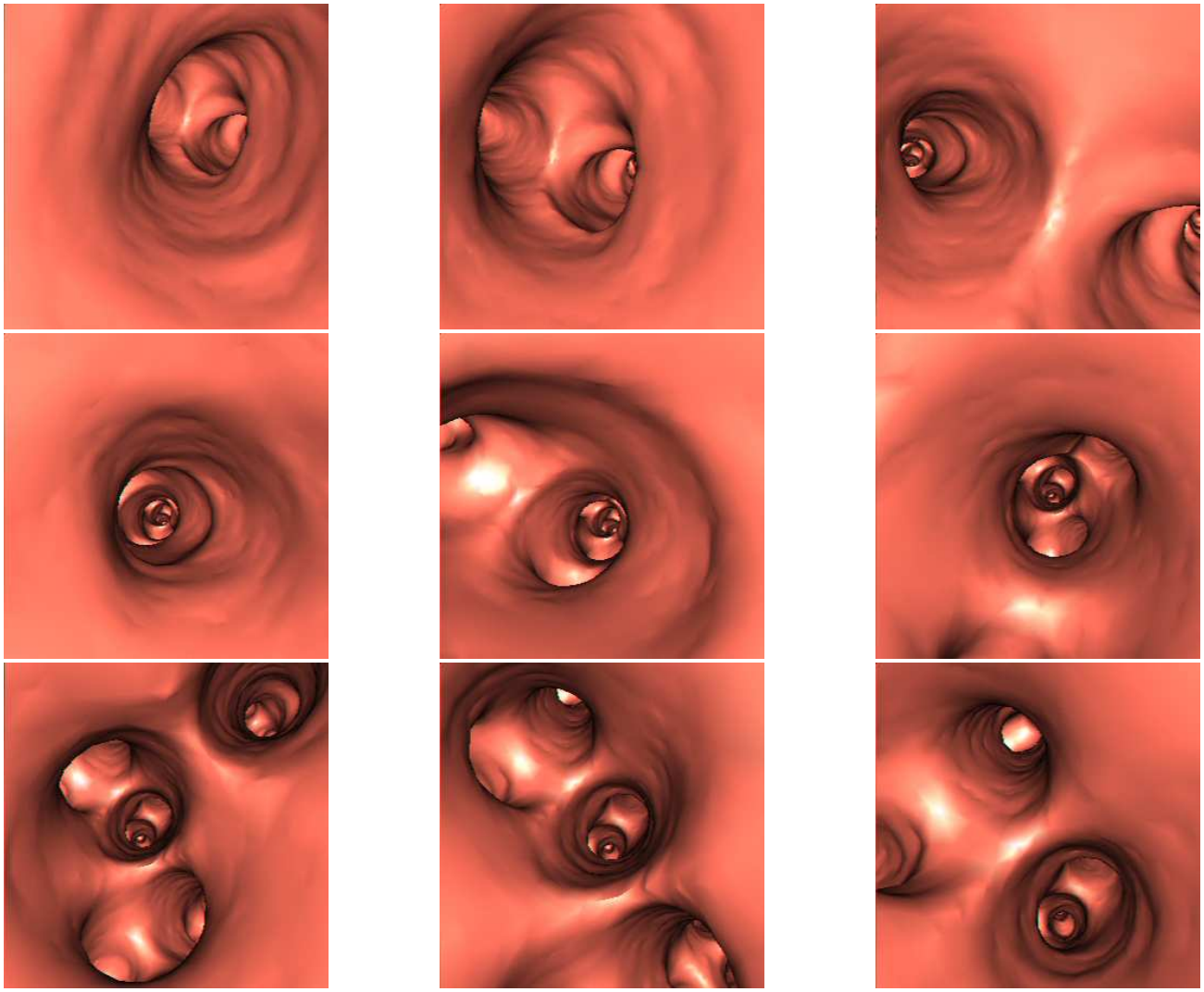
CT	Slice scan time (ms)	Temporal image number
MSSCT function mode	300	60
MSSCT volume mode	300	4
SS-EBCT	50	1
MS-EBCT	30	6–40

Three-dimensional reconstruction

- *Markov random field models*
- *Deformable models*
- *Level set*
- *Finite octree*
- *Implicit surfaces*
- *Snakes*
- *Slice connection algorithms*
- *Marching-cube approaches*
- *Delaunay tetrahedralization algorithms*

$\rightarrow$ polygonal model + surface simplification algorithms

Computer-aided diagnosis - virtual endoscopy

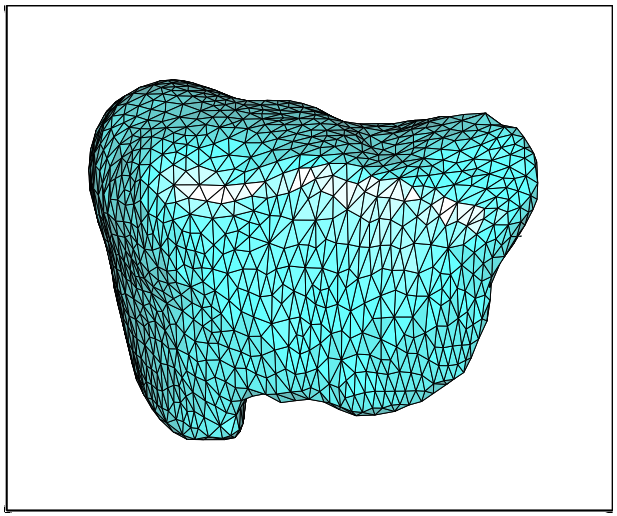


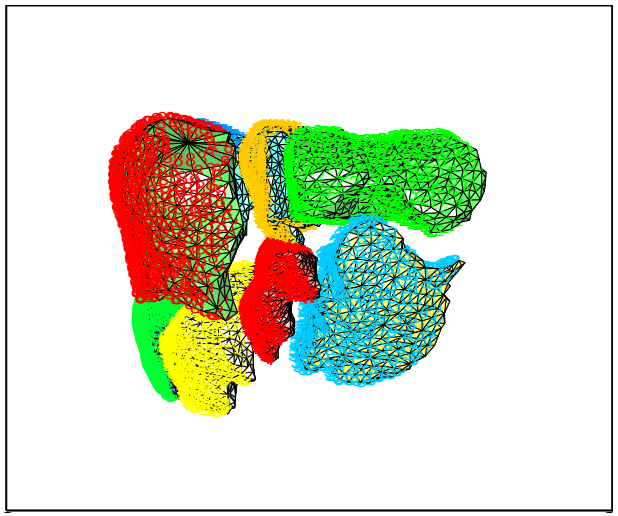
Virtual bronchoscopy views along a selected airway path, from the trachea to the left upper lobe apical bronchus, based on the axis data set of the model

Lobar decomposition from perfusion

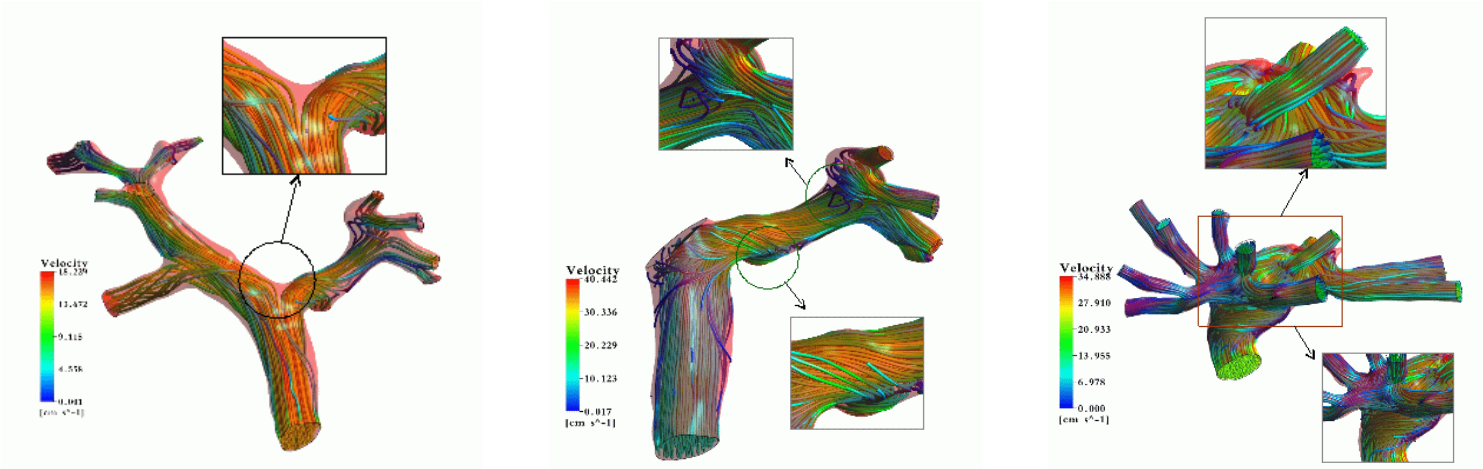
Virtual decomposition based on vasculature distribution leading to 8 functional (not anatomical) liver lobes

Goal to provide dissection surfaces to the surgeon





Liver transplantation: angiogenesis

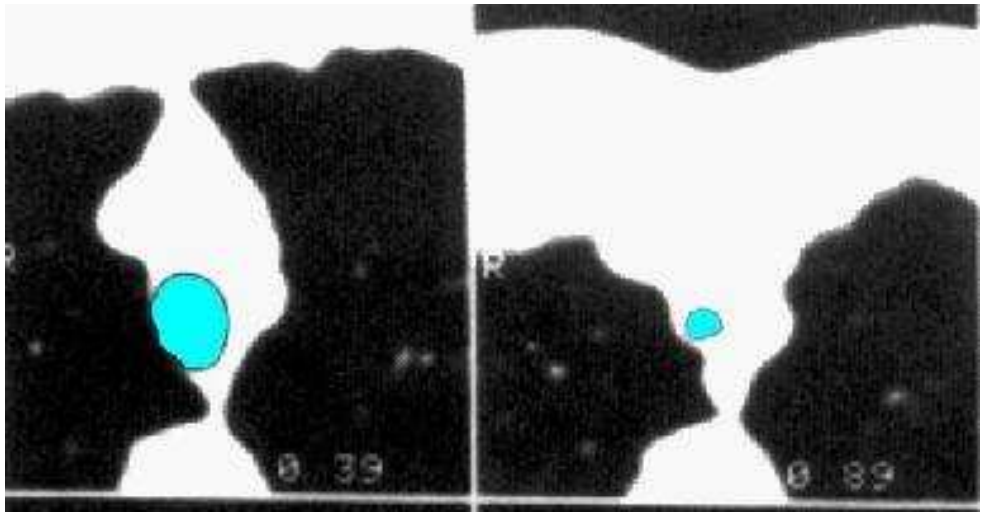


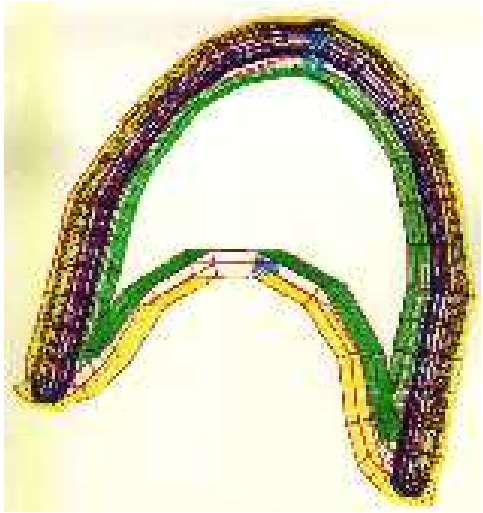
Cooperation between signaling pathways primed by mechanical stresses and chemical species (need in functional imaging)

stimulator activity depends on the simultaneously activated signaling pathways

VEGF without TGFβ1	endothelial cell survival
VEGF + TGFβ1	transient cell apoptosis (necessary for pruning)

Airway deformability: forced expiration





Rem 1 : 80% reduction in cross-section area

Rem 2 : chocking ($Ma = 1$)
(wall distensibility, not air compressibility) c: O[10 m/s], c: O[100 m/s]

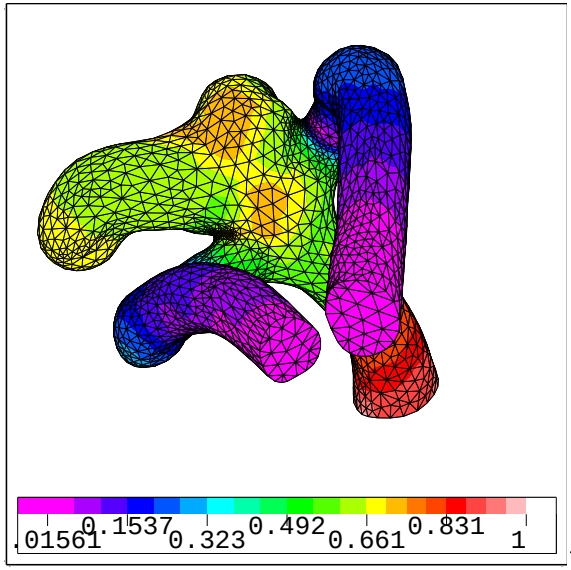
Rem 3 : collapse + torsion $\longrightarrow$ asymmetric defo

Rem 4 : values of material constants $\longrightarrow$ *in vivo* elastography

Rem 5 : contact of solid boundaries
neither ALE, nor fictituous domain, $\longrightarrow$ another numerical technique

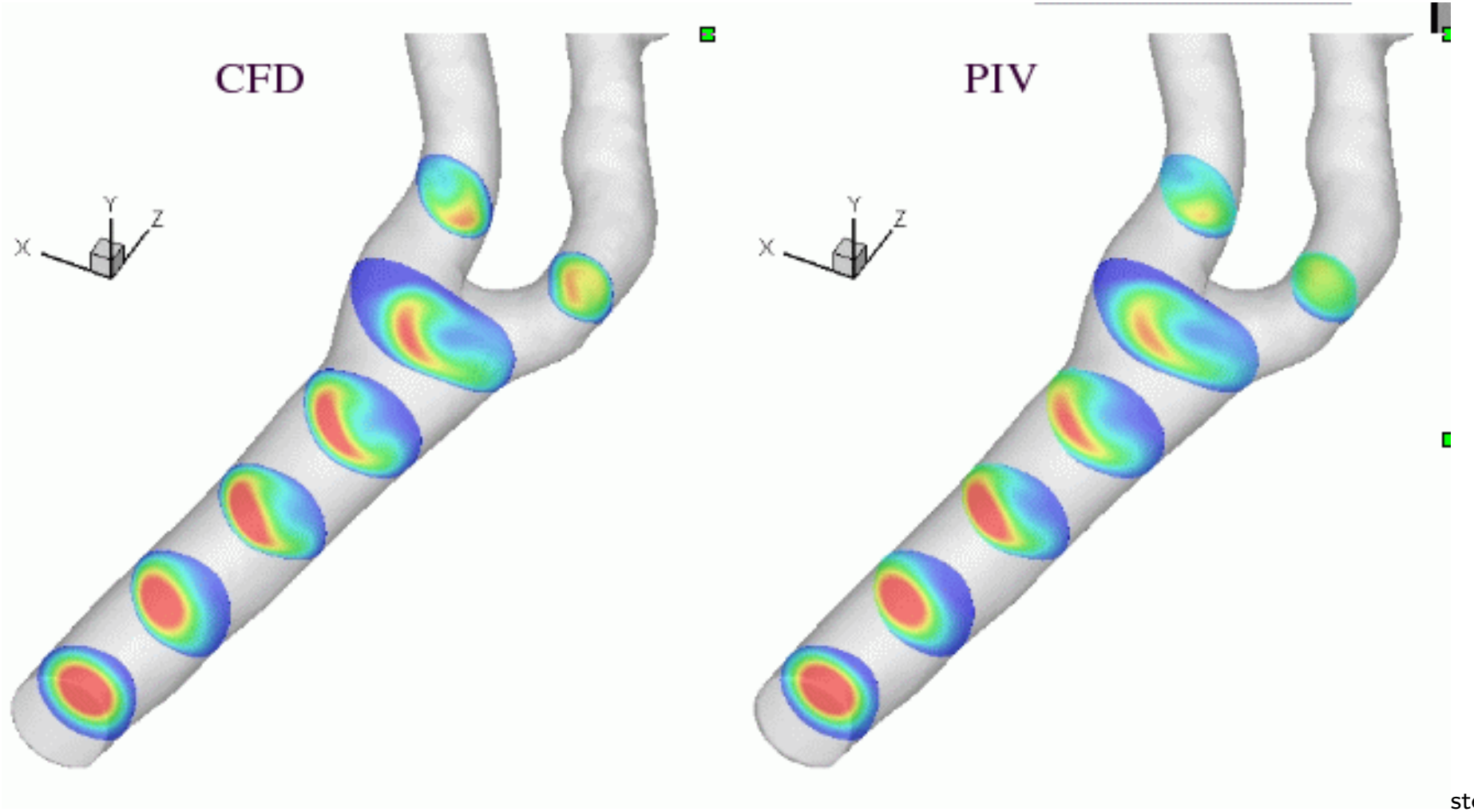
Image-based computational models of blood flows

Cerebral saccular aneurism, bifurcation type



$\longrightarrow$ therapy strategy recommendation

Num./Exp. comparison



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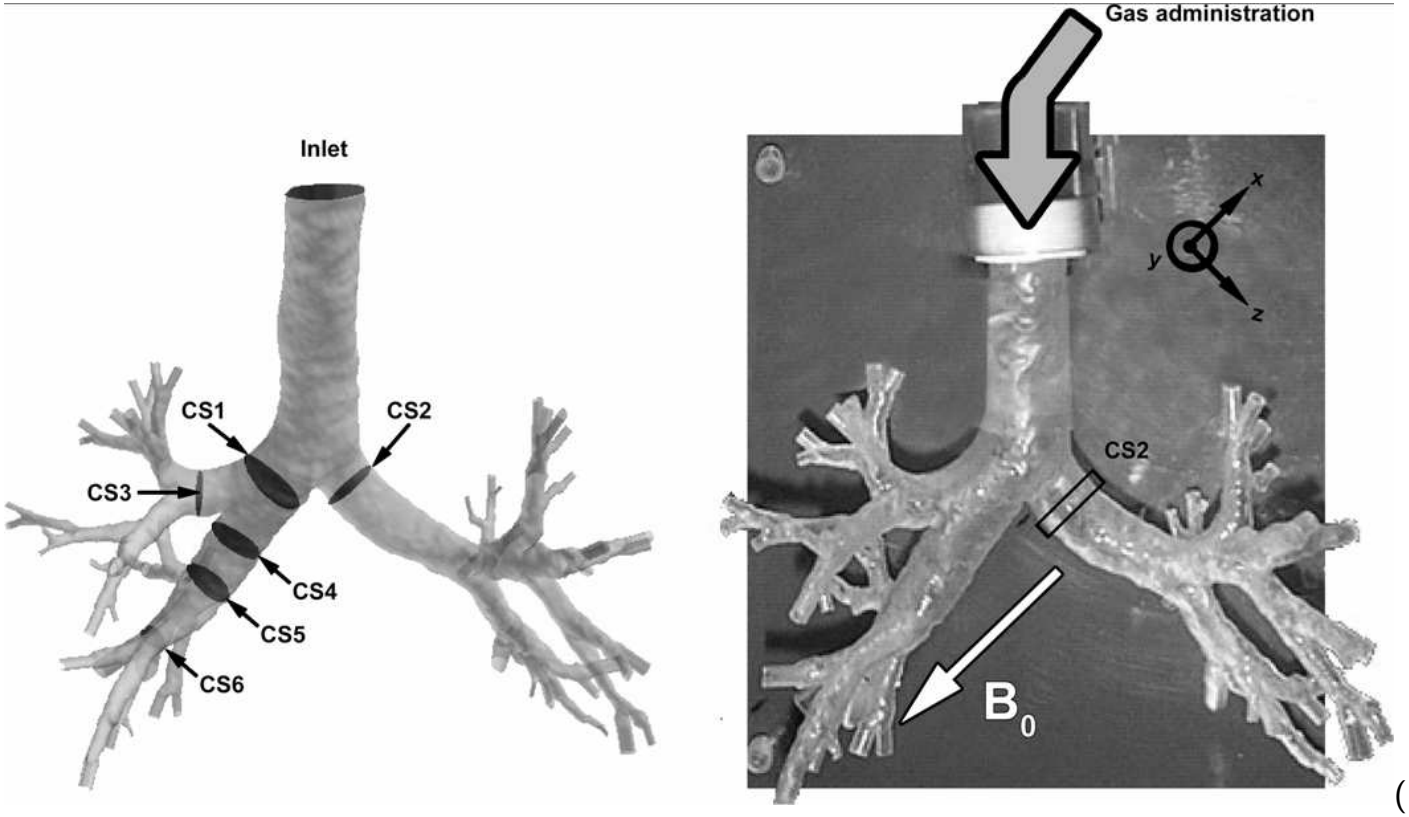
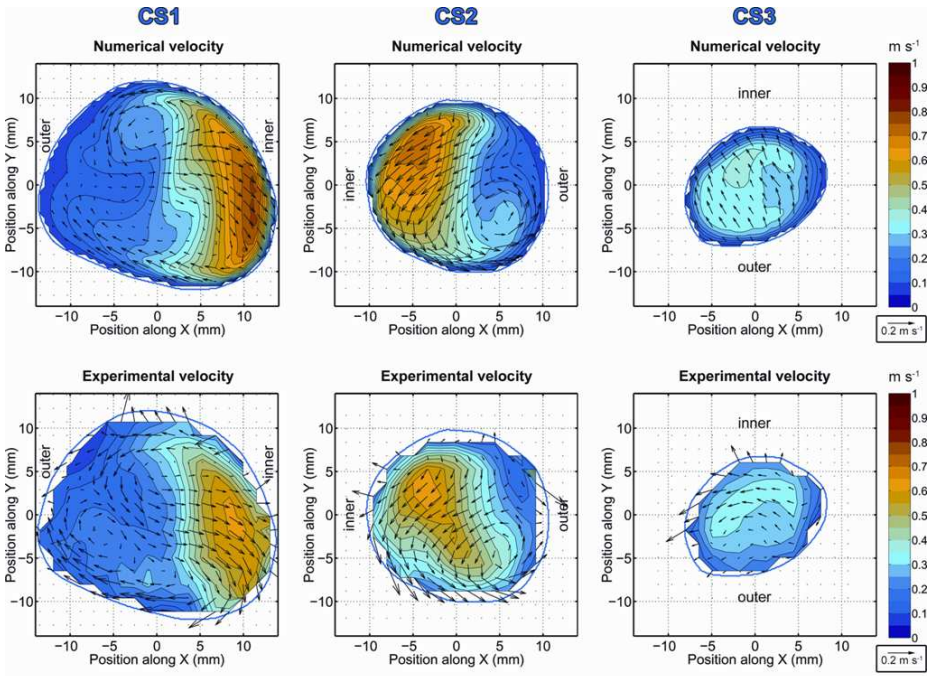
flow – context VAD (MAF, AG, MT, JV)

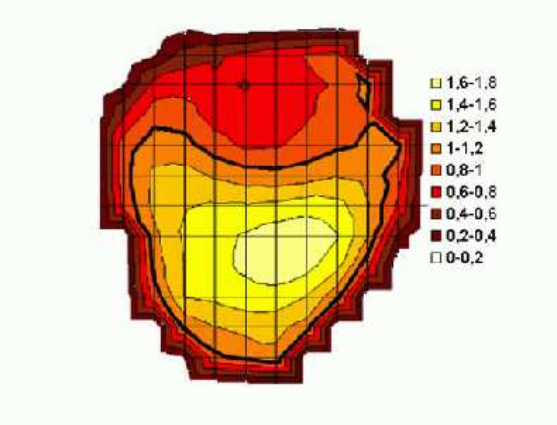
Num./Exp. comparison



(RMOD)

Num./Exp. comparison & *in vivo* NMRV



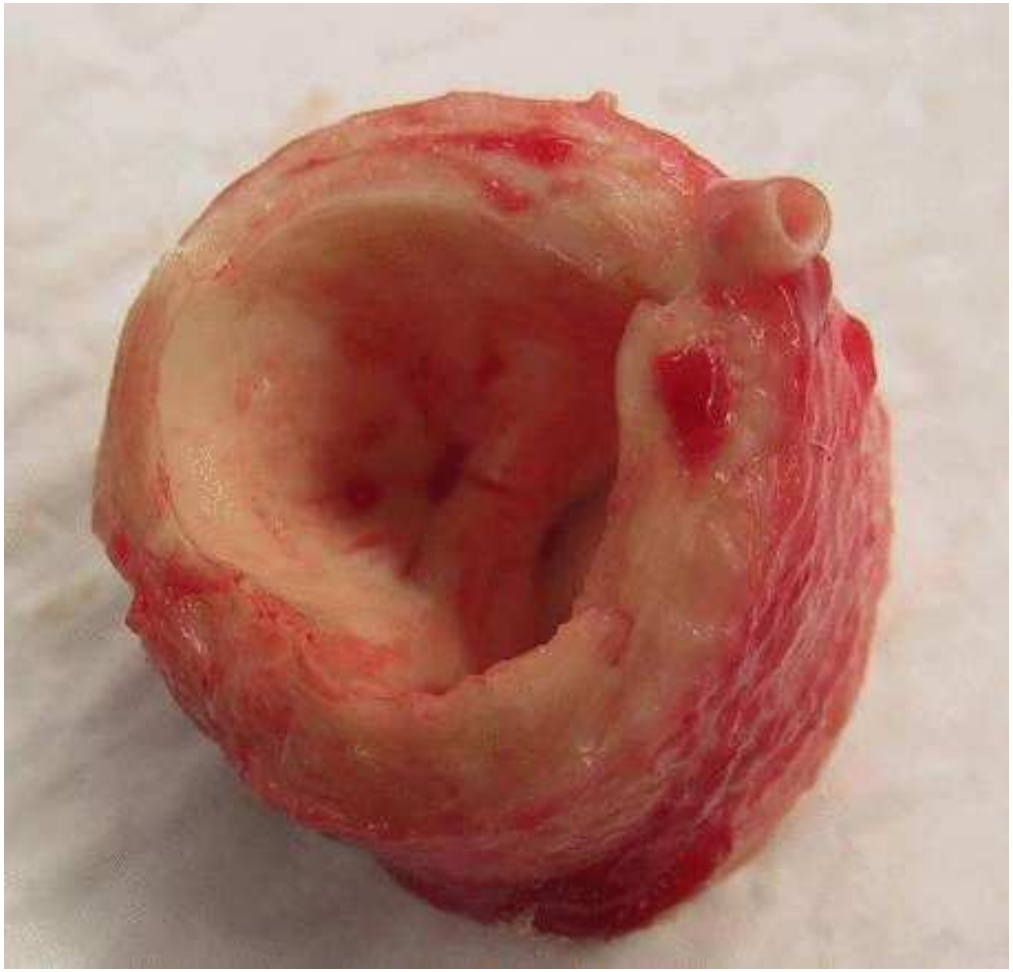


Trachea: 4 *cm* downstream from the larynx, inspiration flow of 140 ml/s

RMOD; L Vial PhD thesis, L de Rochefort - CIERM)

Wall adaptation

Biological materials: reactive (to environmental stimuli - chemical, physical, mechanical)

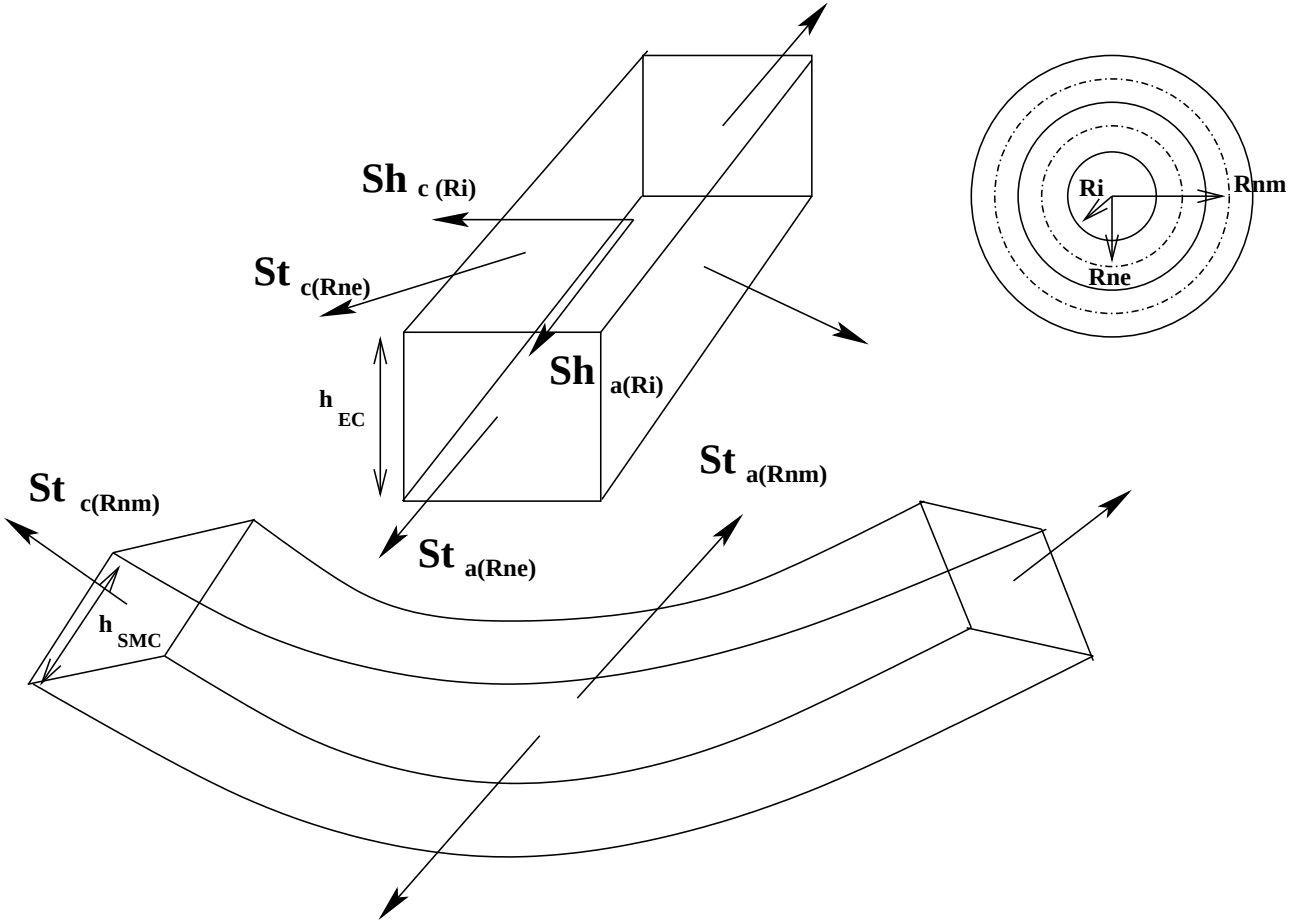


Mechanotransduction components

Goal: to mimick behavior of living tissues

Stimuli	mechanical, physical, chemical
Receptors	GPCRs, RTKs
Ion channels	Ca^{++}, K^{+}, Na^{+}, Cl^{-} channels
Adhesion molecules	integrins, cadherins, IgCAMs
Transport	caveolin
Second messengers	IP3, cGMP
Vasoactive compounds	PGI2, NO, ET1
MAPK production	ERK1/2
Gene expression	cFos, cJun

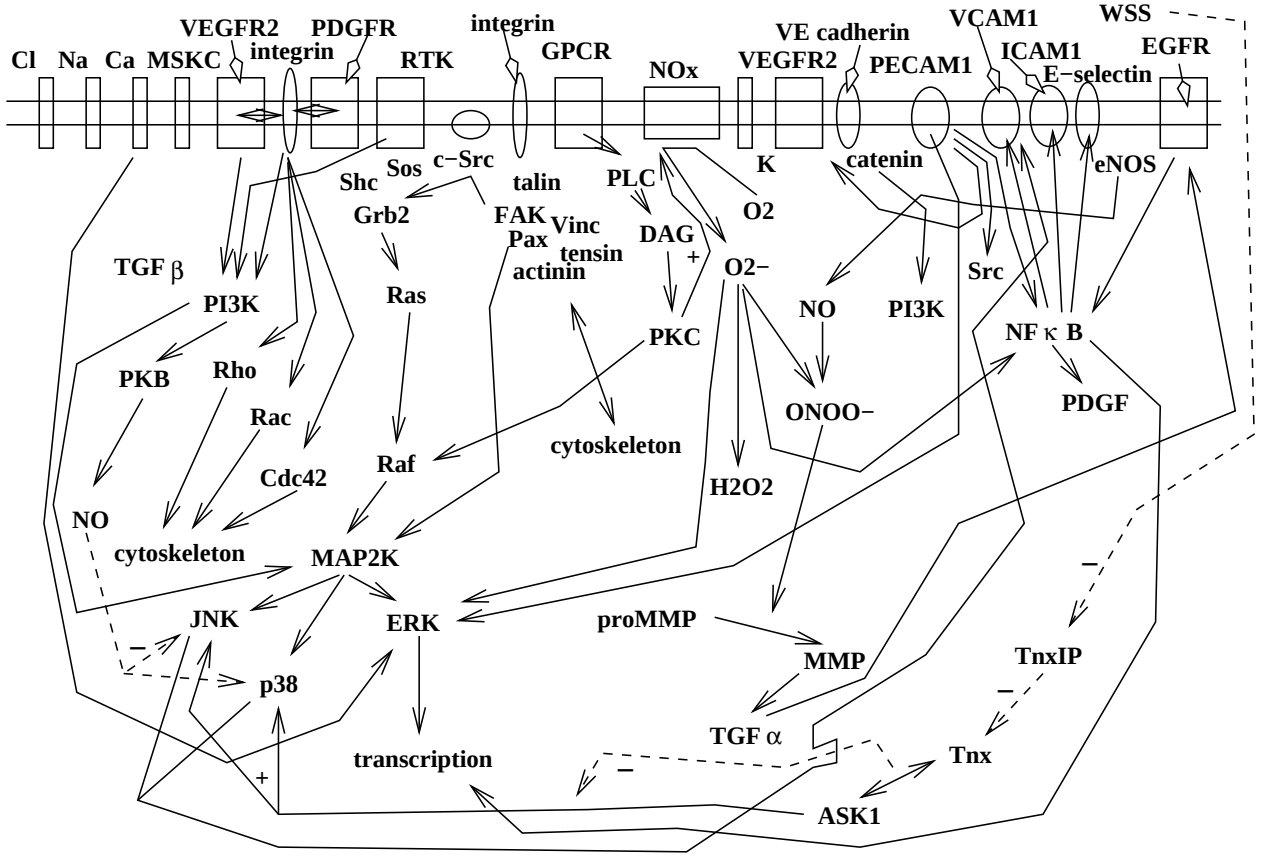
A fundamental couple: vascular EC and SMC



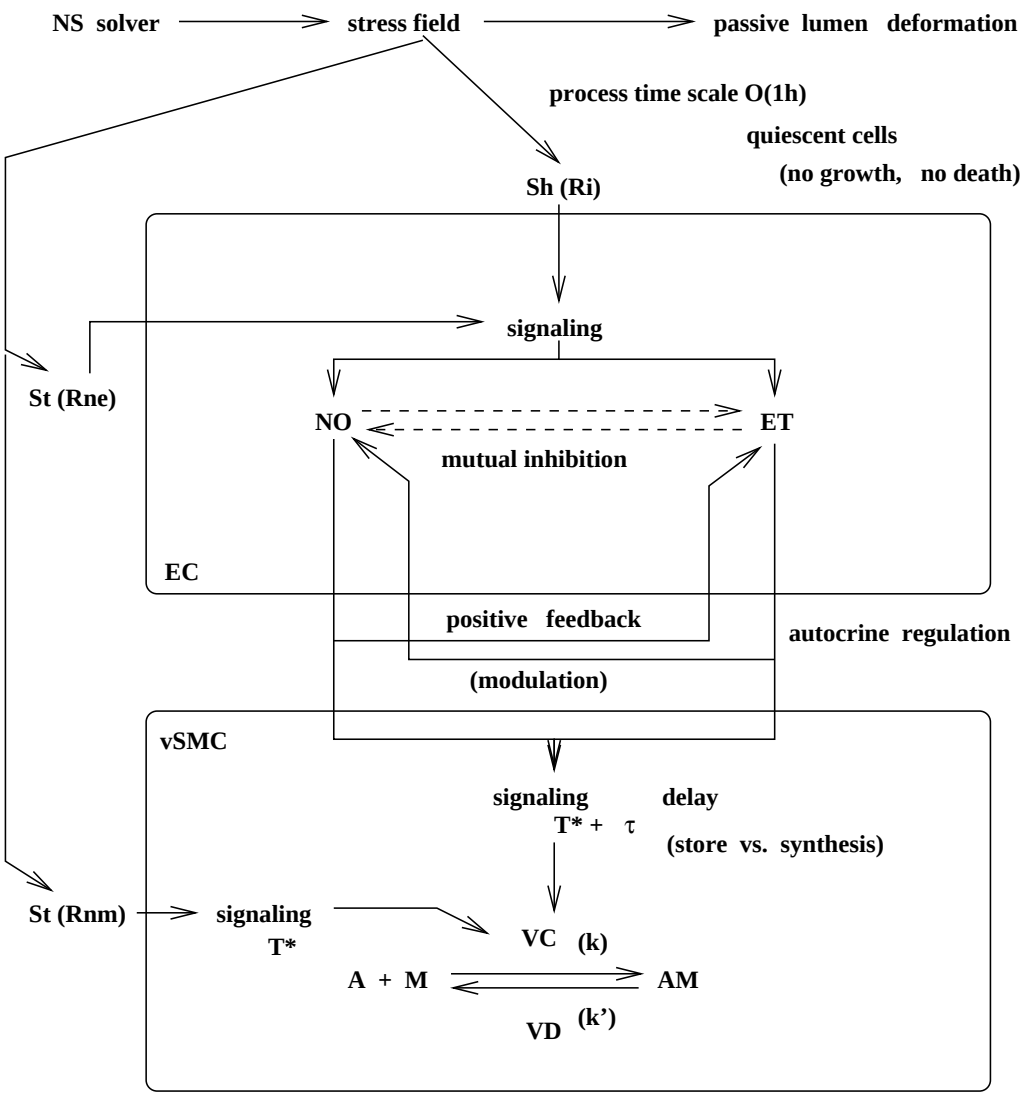
Vasomotor tone and its local control

vasoconstrictors	vasodilators
ET1	NO
TXA2	PGI2
PGF2α	EDHF
Up4A	adrenomedullin
ATP	acetylcholine
5HT	ANP
NPY	

Mechanosensors, mediators, and effectors



Simple compartment-like model of MT



Thanks for attention

coupling

1. fluid solver
2. solid solver
3. tissue reaction solver

validation: non-invasive source = functional imaging