Evaluation of Artery Visualizations for Heart Disease Diagnosis

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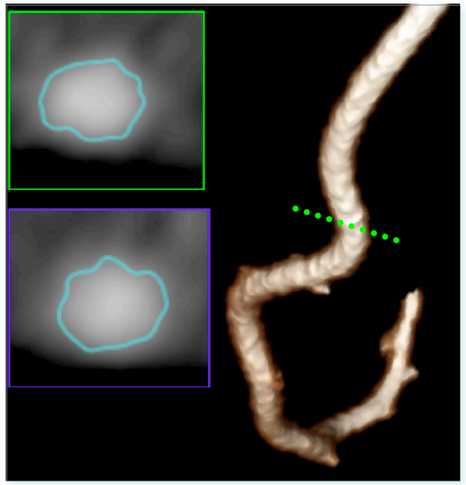
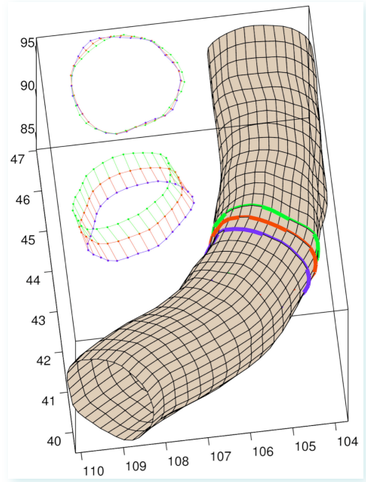
Non-Invasive Diagnosis



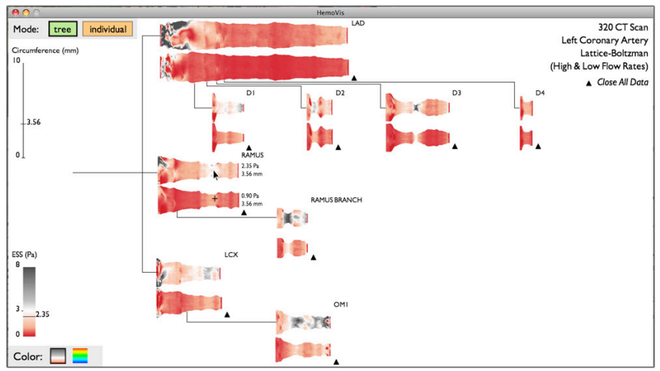


Obtain patient CT data → Segment arteries → Generate patient geometries

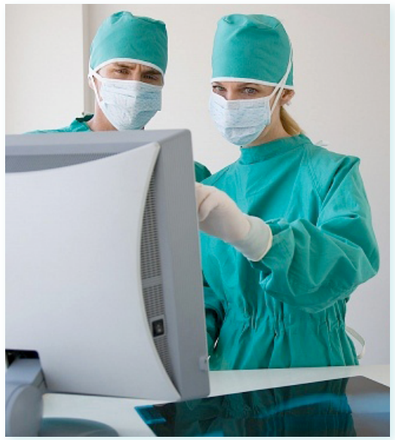
↓

Patient specific blood flow simulation

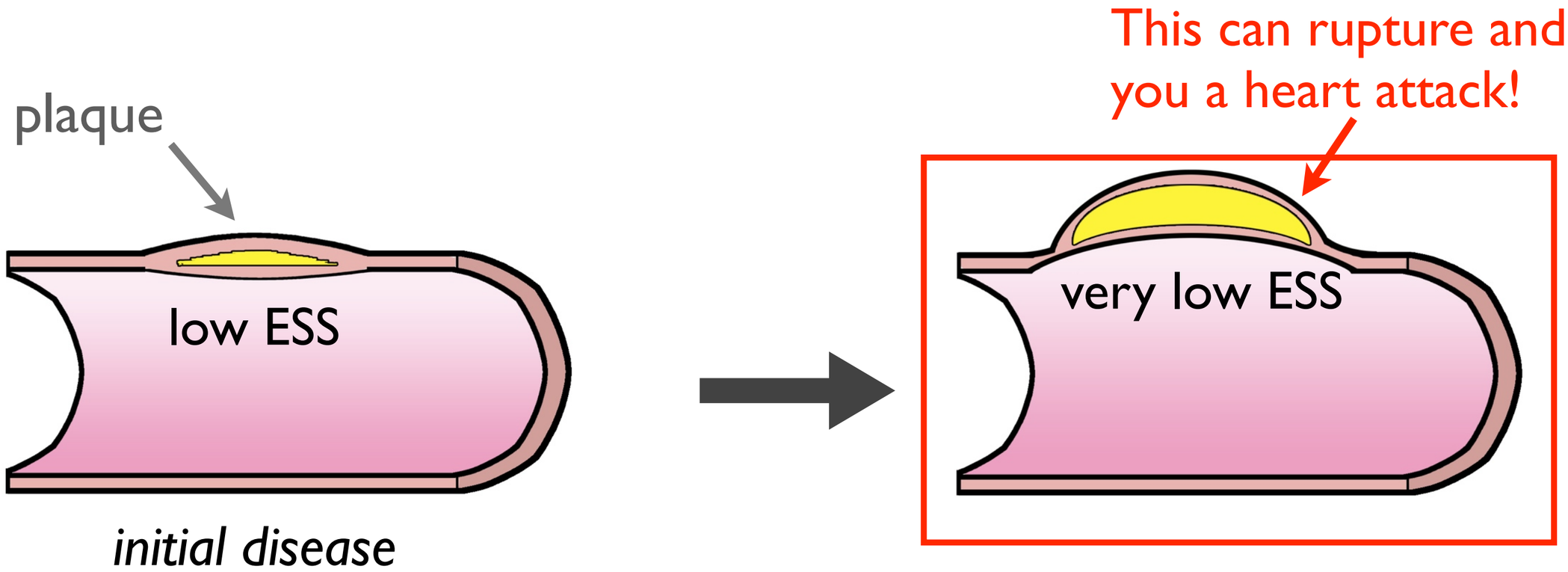
Visualize and analyze data



← Clinical decision



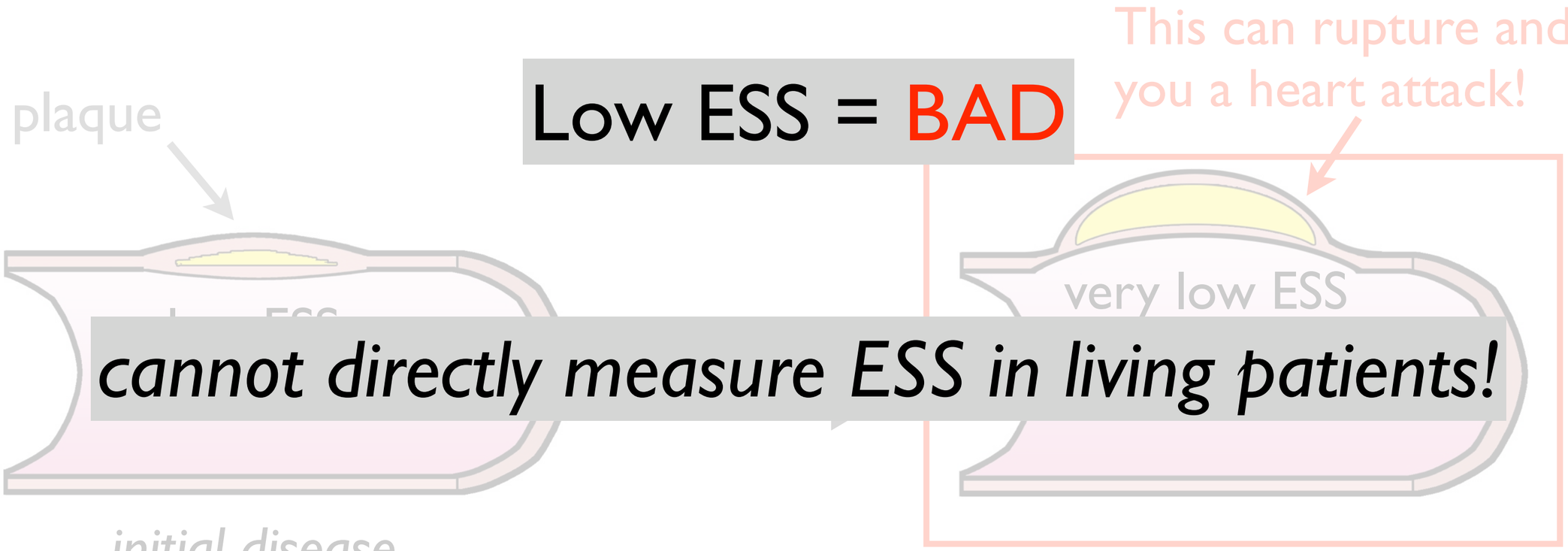
DATA



ESS = endothelial shear stress
(i.e., frictional force from blood flow)

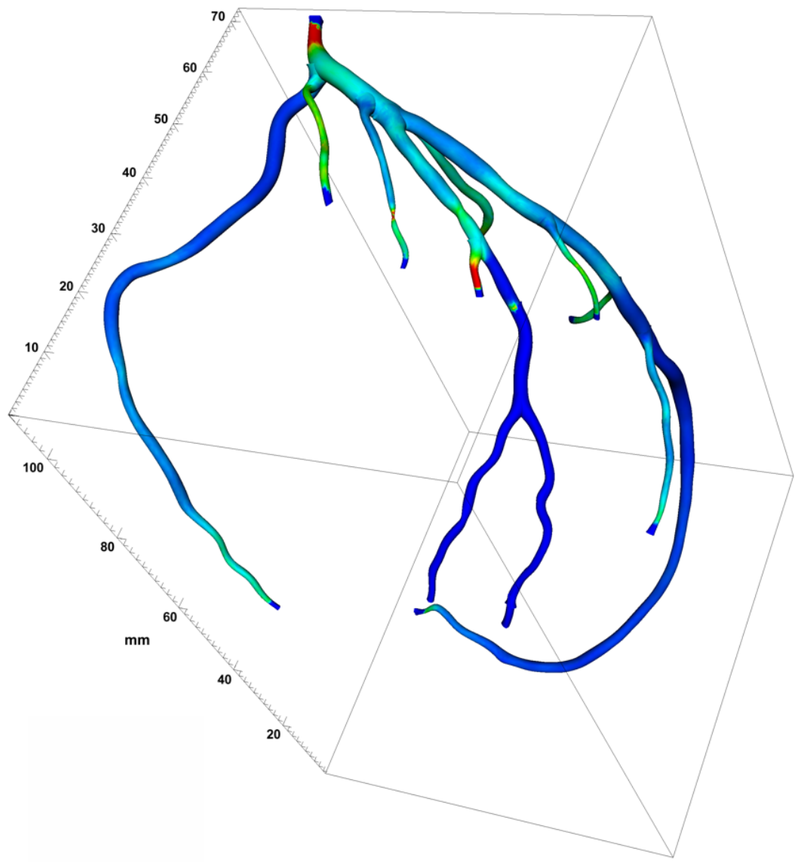
DATA

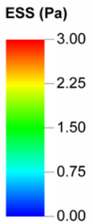
Low ESS = BAD

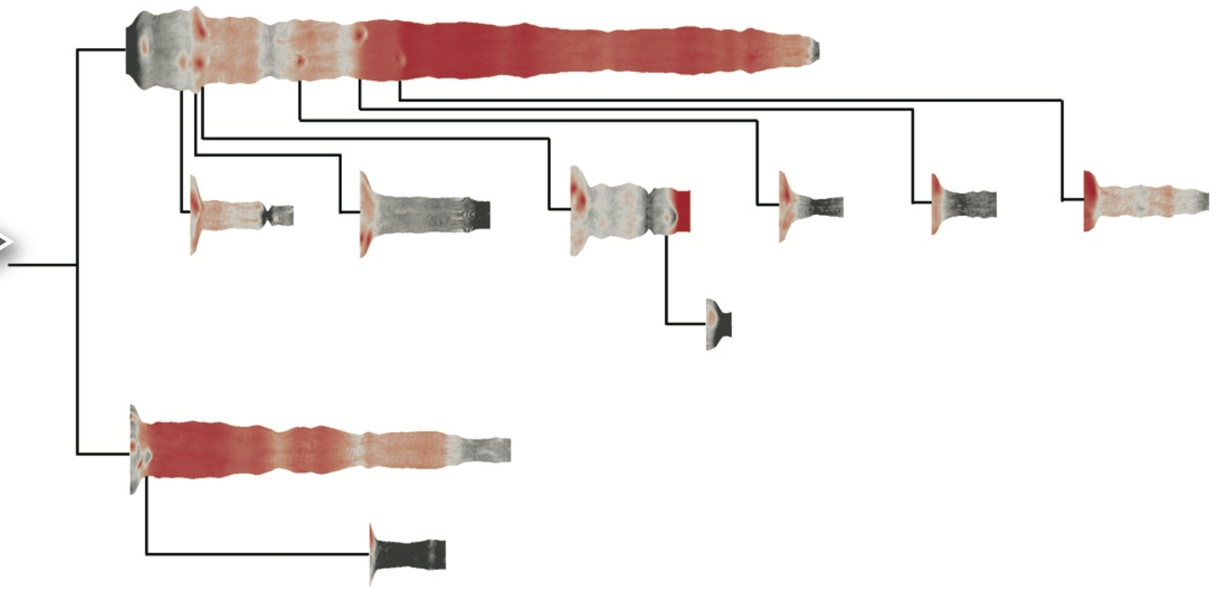


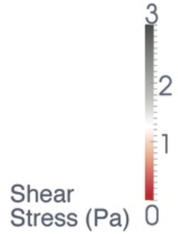
cannot directly measure ESS in living patients!

ESS = endothelial shear stress
(i.e., frictional force from blood flow)


70
60
50
40
30
20
10
100
80
60
40
20
mm


ESS (Pa)
3.00
2.25
1.50
0.75
0.00

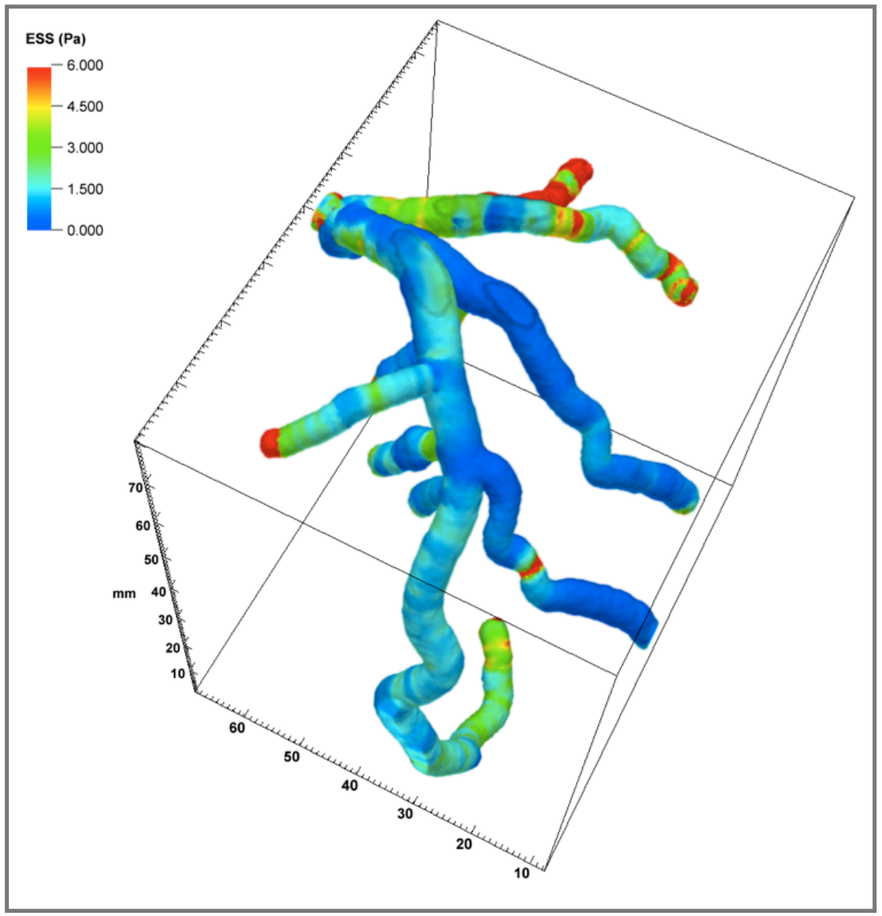



3
2
1
Shear
Stress (Pa)
0

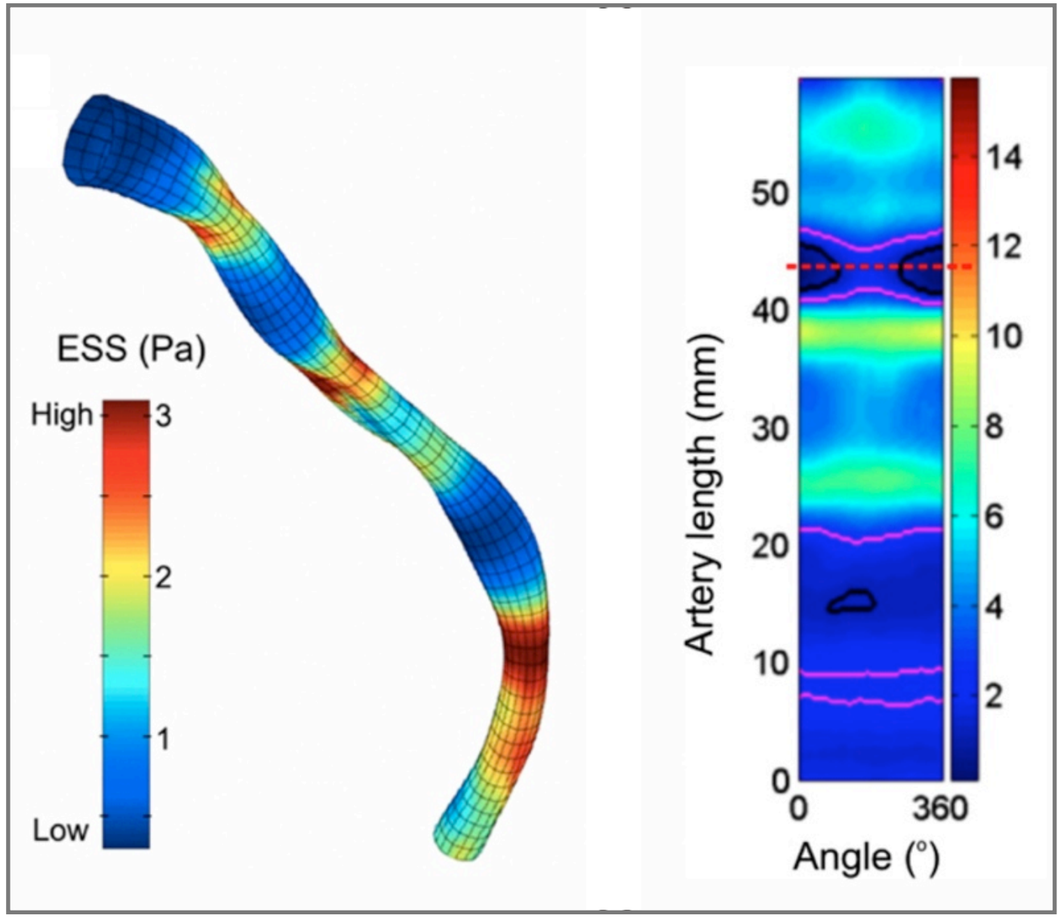
Previous Work

- ESS Vessel Visualization

  [e.g., Forsberg, et al. (2000), Kanitsar, et al. (2002), Museth, et al. (2008), Ropinski, et al. (2009)]



[Rybicki, et al. 2009]

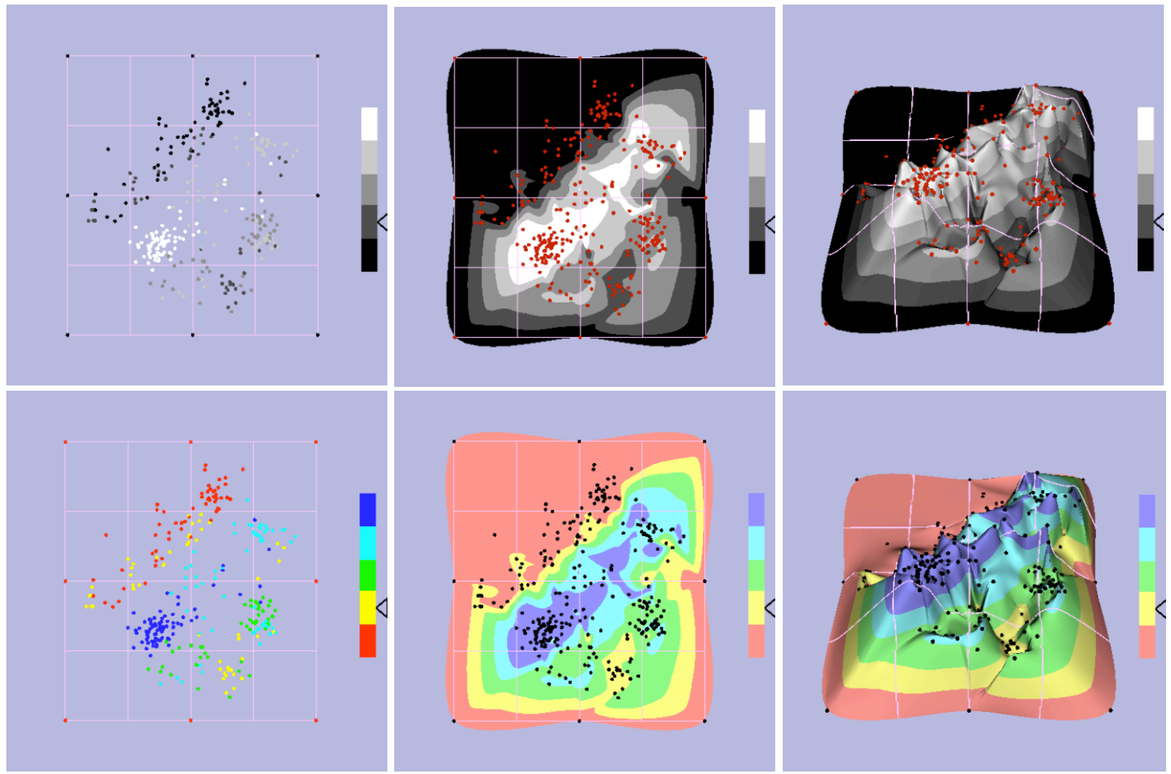


[Chatzizisis, et al. 2007]

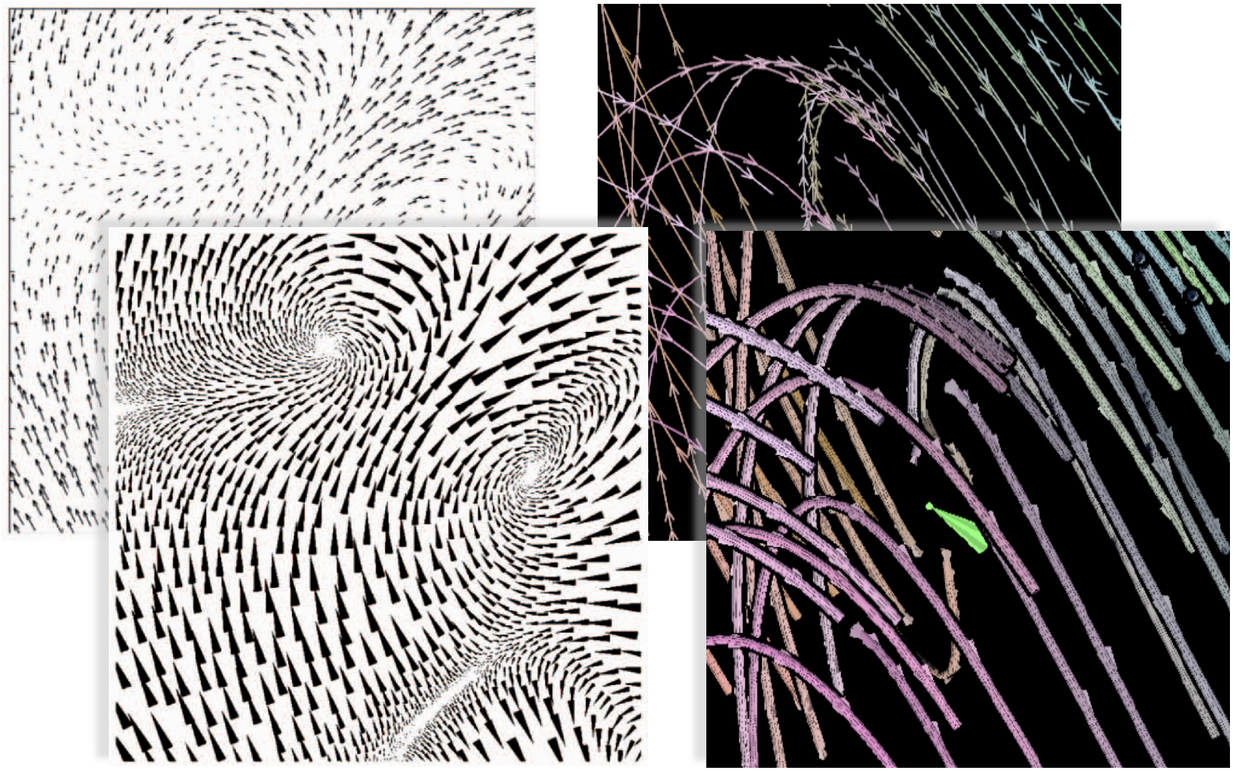
Previous Work

- 2D vs. 3D Evaluation

  [e.g., Cockburn & McKenzie (2002), Laidlaw, et al. (2005), Tory, et al. (2007), Forsberg et al. (2009)]



[Troy, et al. 2007]



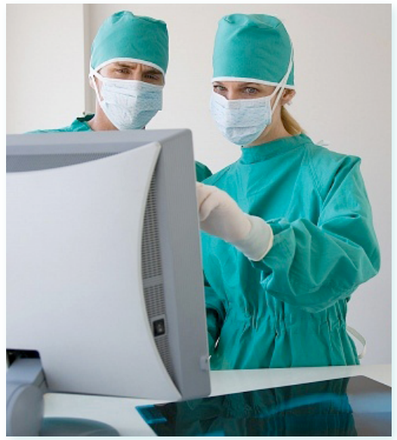
[Laidlaw, et al. 2005]

[Forsberg, et al. 2009]

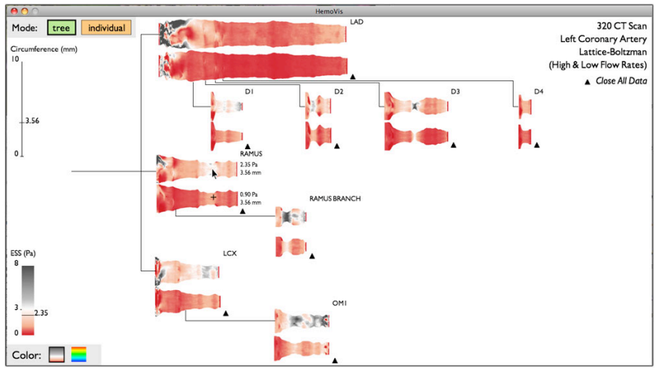
Formative Qualitative Study

- Semi-structured interviews
- 10 medical doctors and researchers
- Brigham & Women's Hospital (Boston, MA)

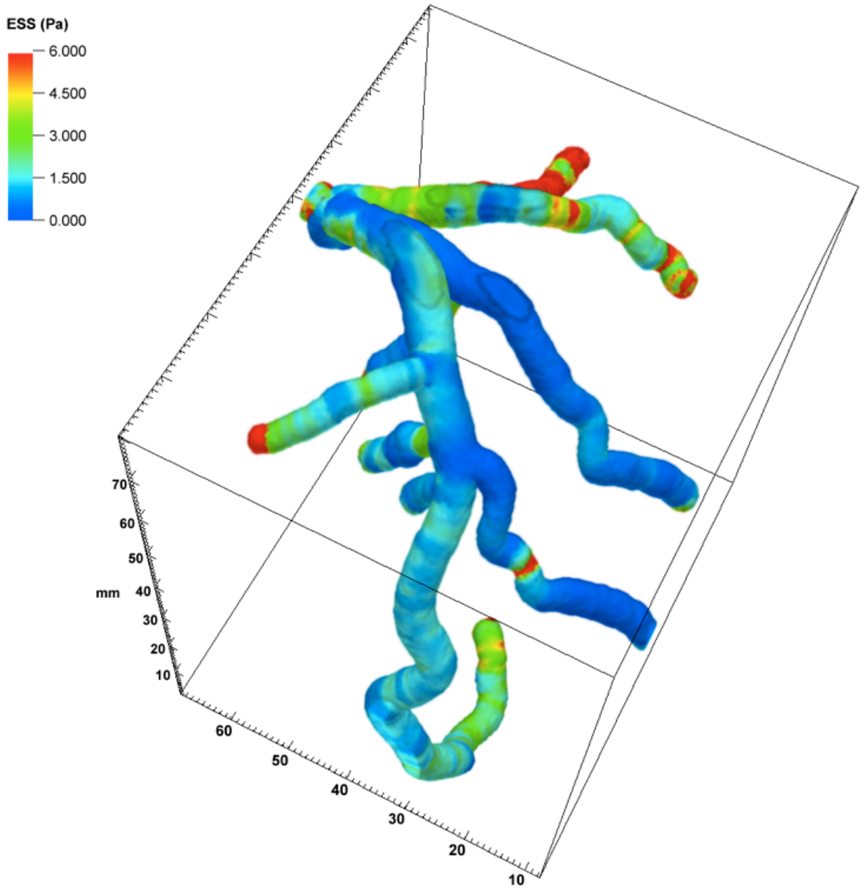
Clinical decision

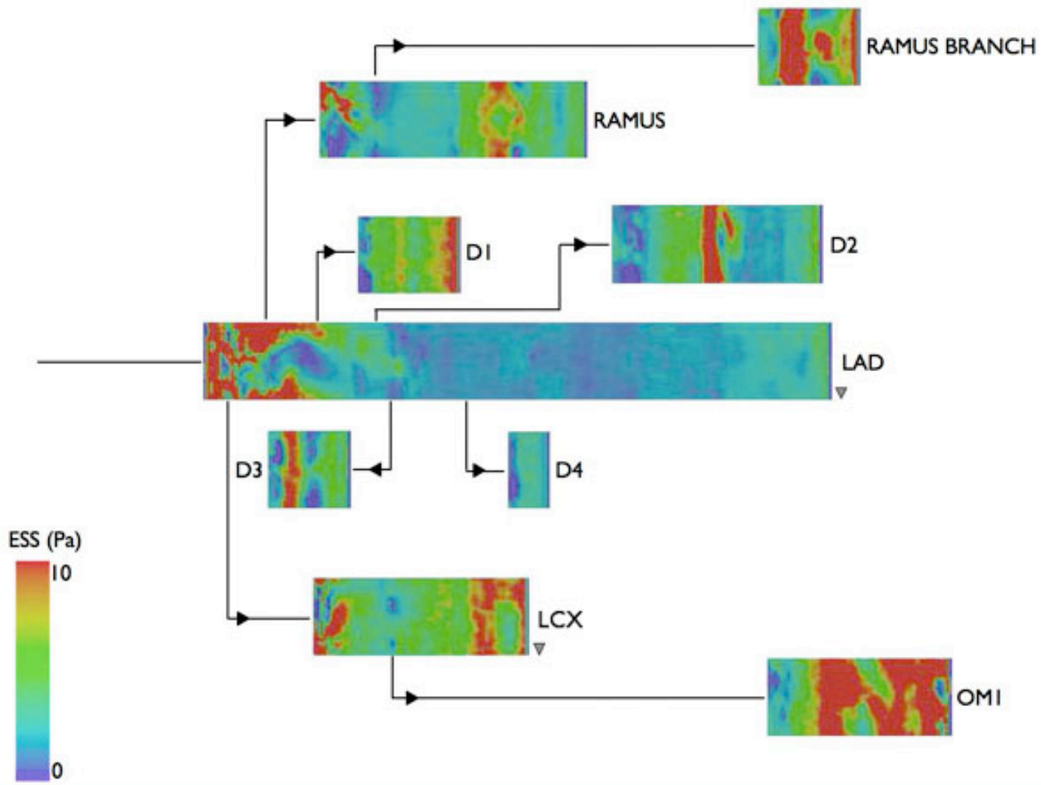


Visualize and analyze data

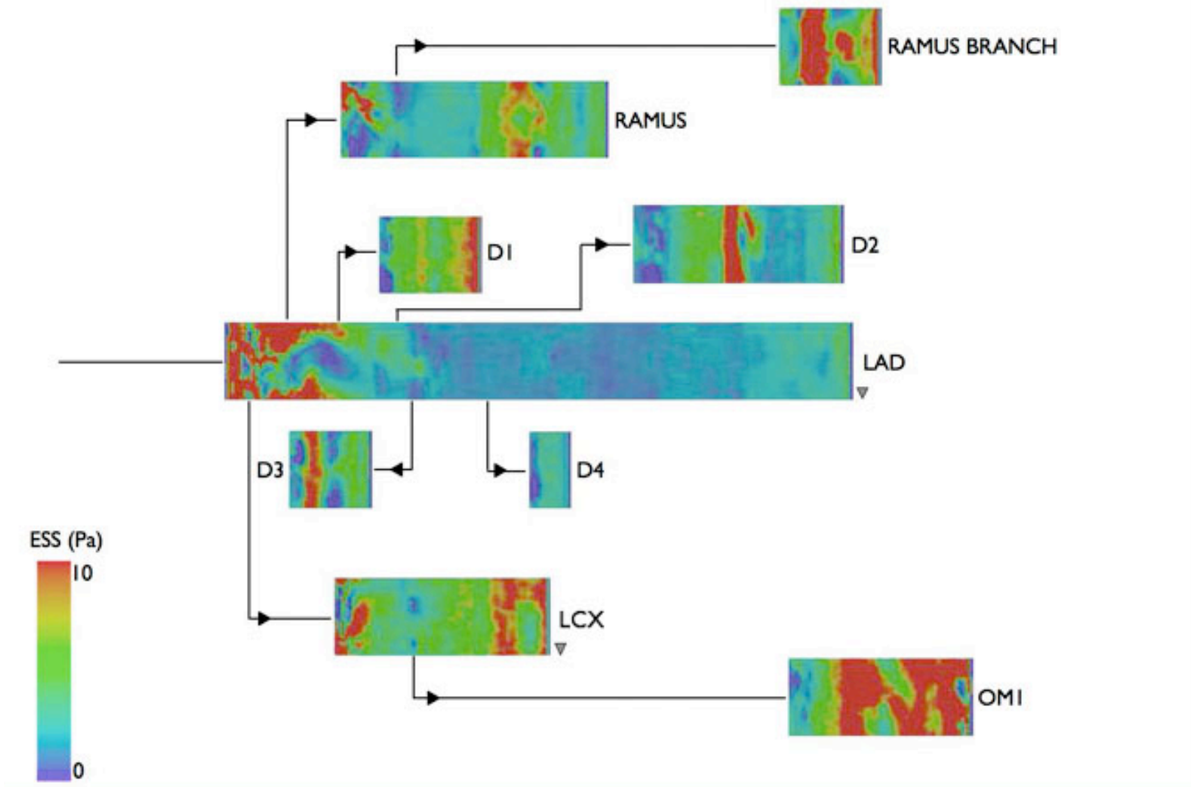


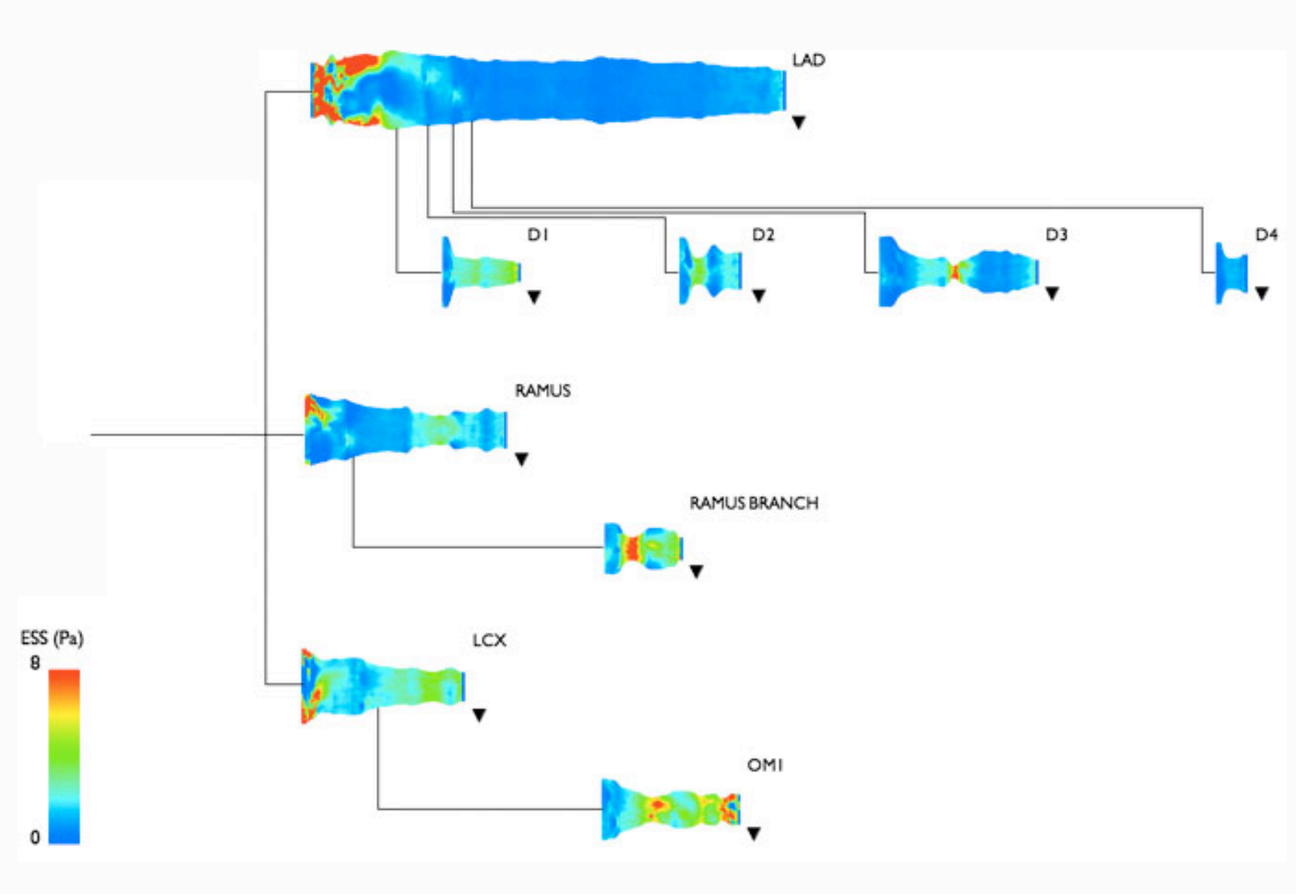
3D


ESS (Pa)
6.000
4.500
3.000
1.500
0.000
mm
70
60
50
40
30
20
10
60
50
40
30
20
10

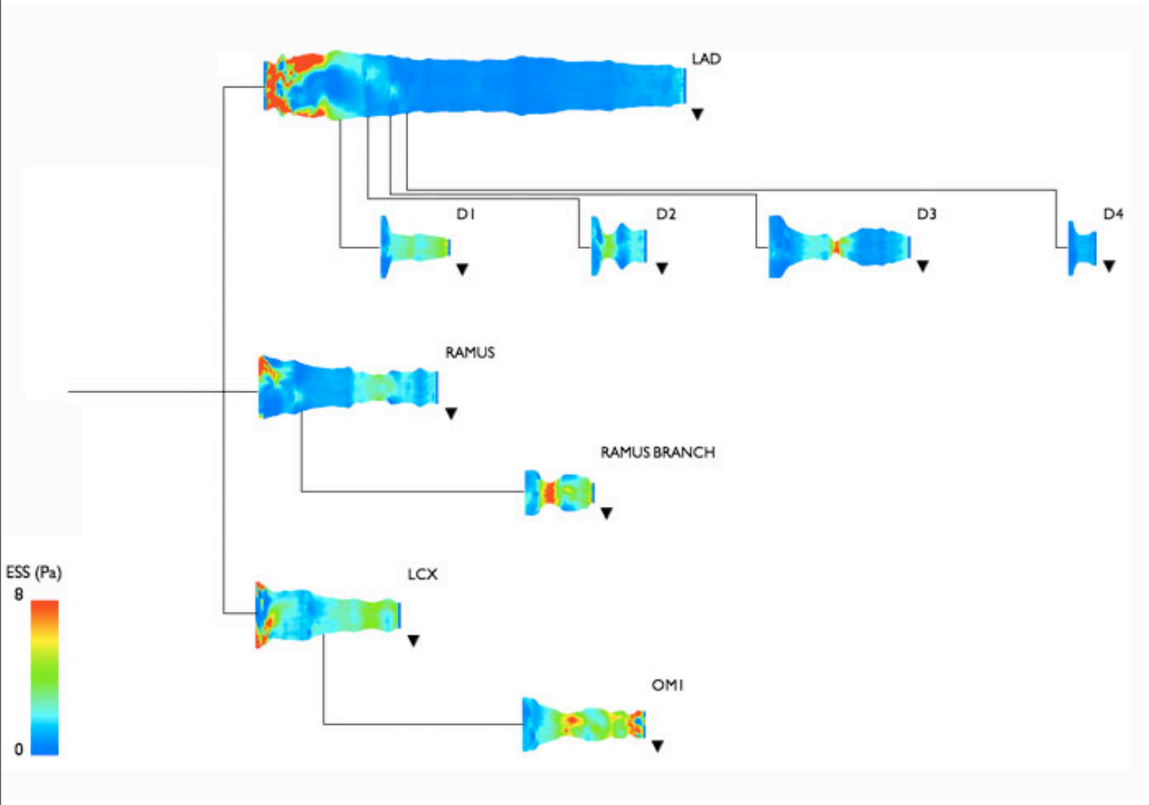

RAMUS BRANCH
RAMUS
D1
D2
LAD
D3
D4
LCX
OM1
ESS (Pa)
10
0

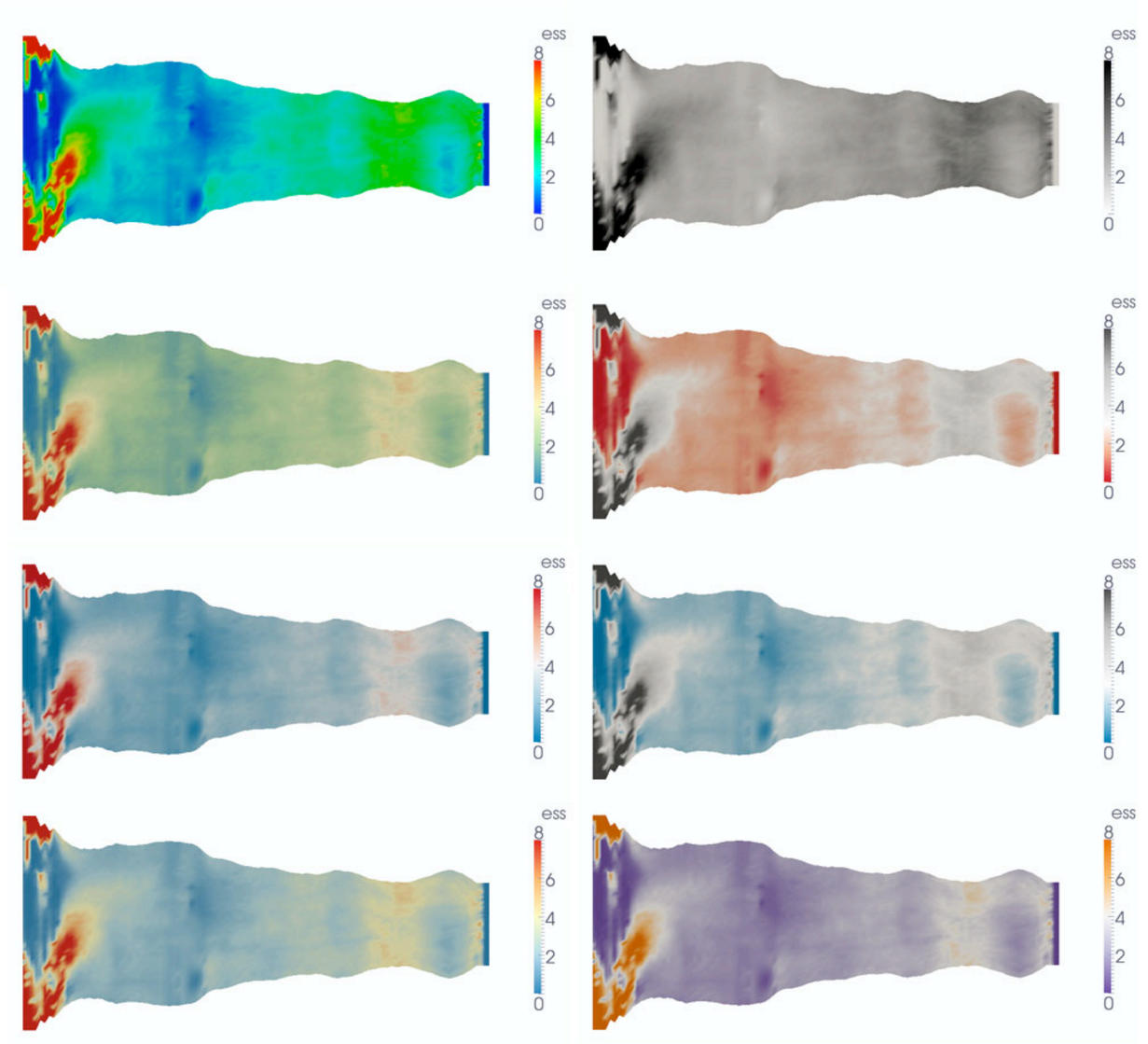
LAYOUT AND PROJECTIONS



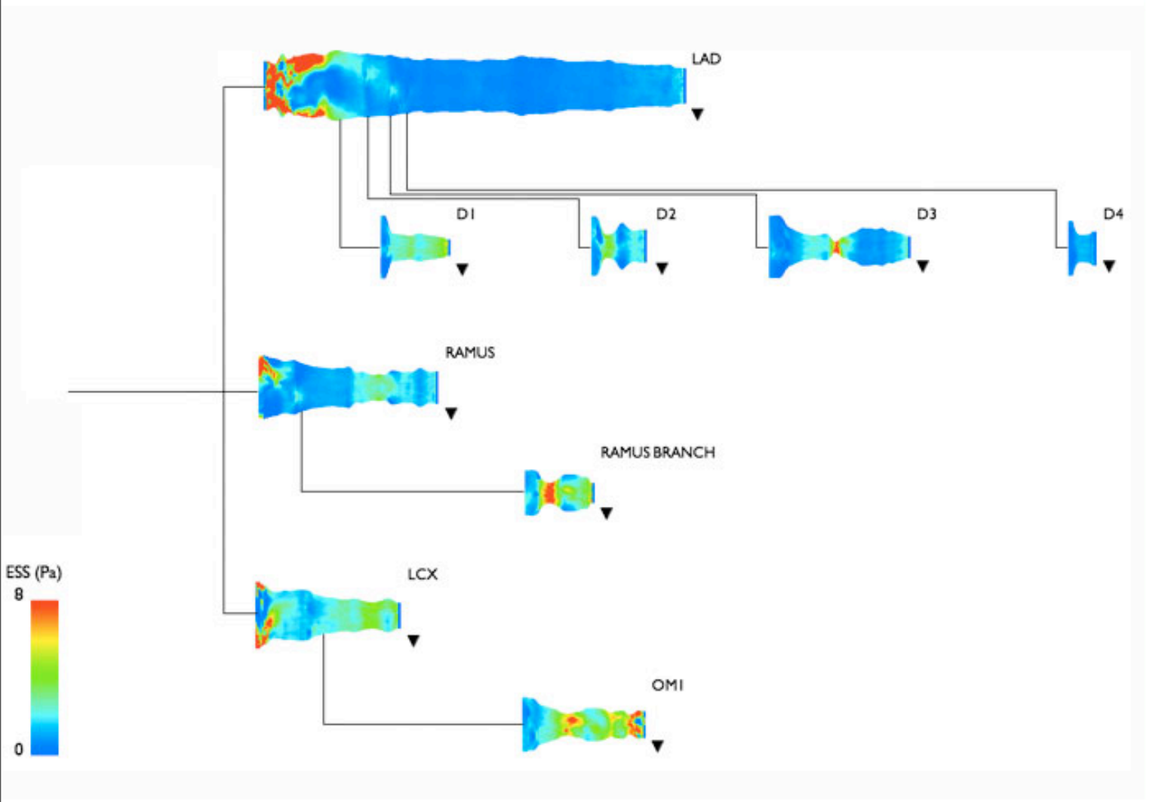


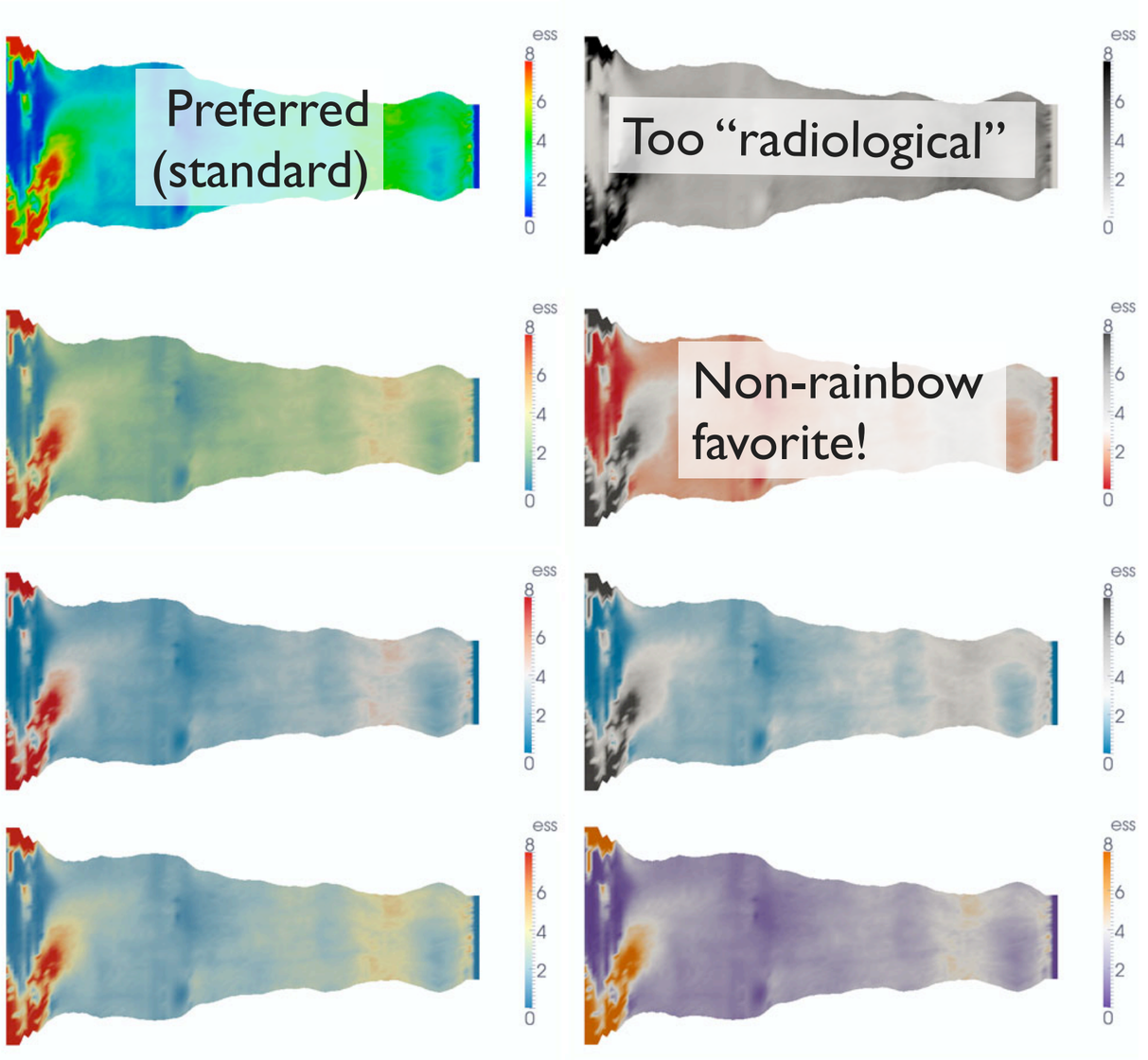
Color



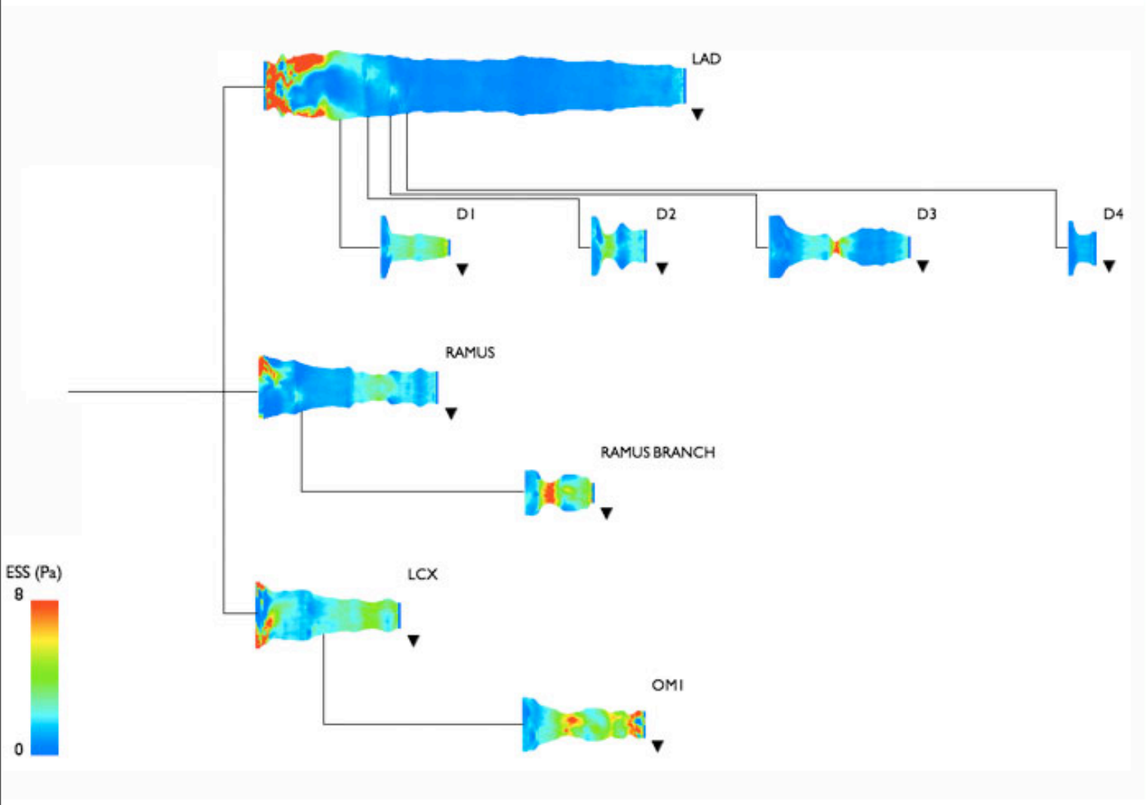


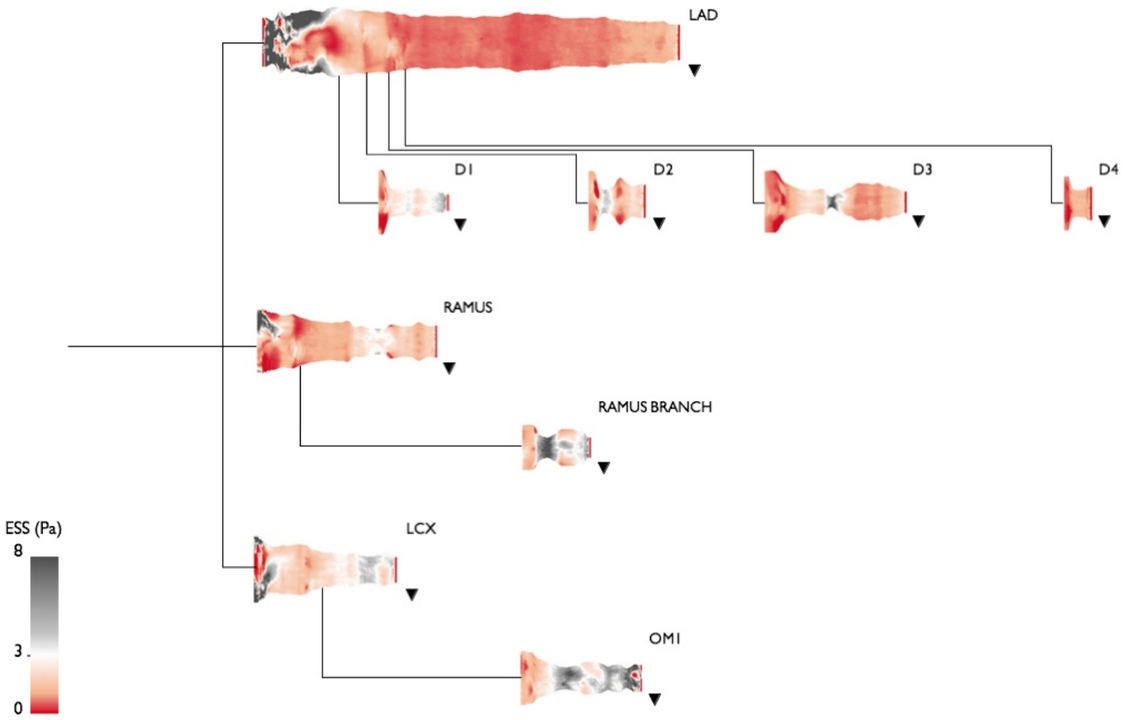
Color


LAD
D1
D2
D3
D4
RAMUS
RAMUS BRANCH
LCX
OM1
ESS (Pa)
8
0


Preferred (standard)
Too “radiological”
Non-rainbow favorite!
ess
8
6
4
2
0

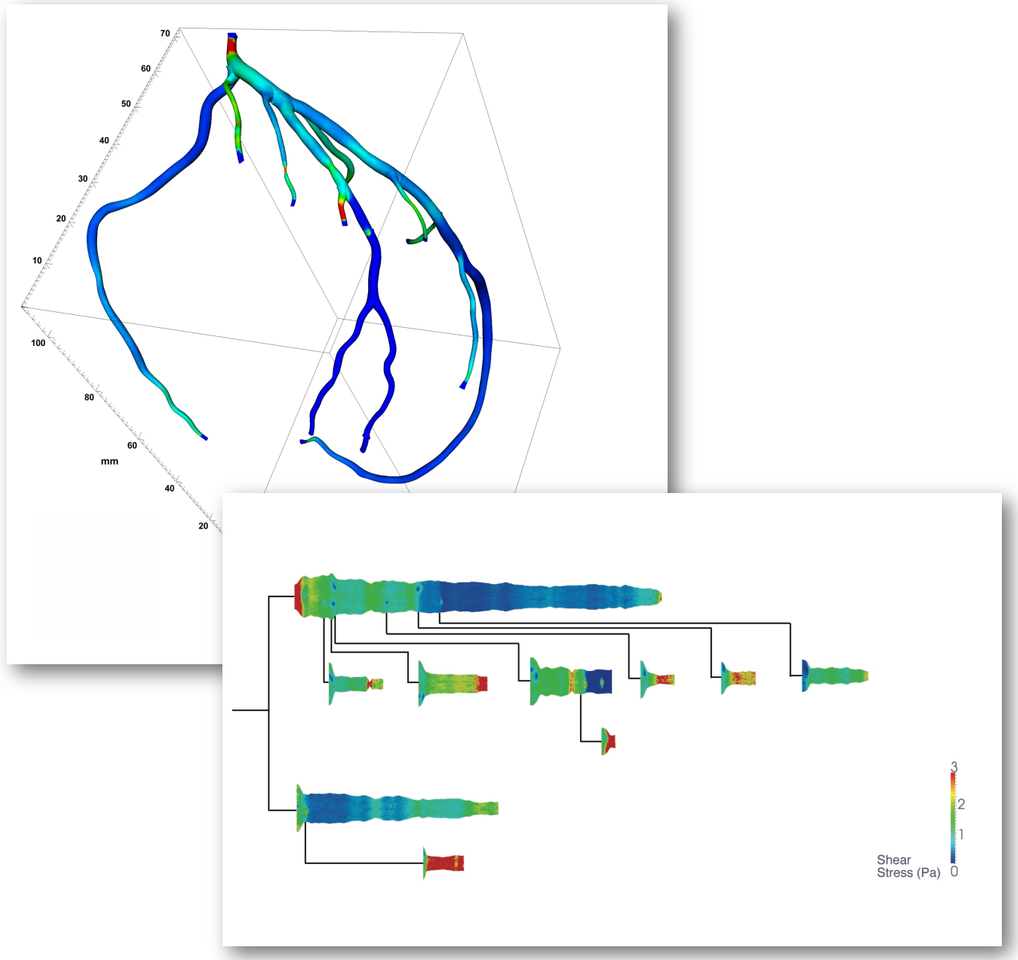
Color


LAD
D1
D2
D3
D4
RAMUS
RAMUS BRANCH
LCX
OM1
ESS (Pa)
8
0

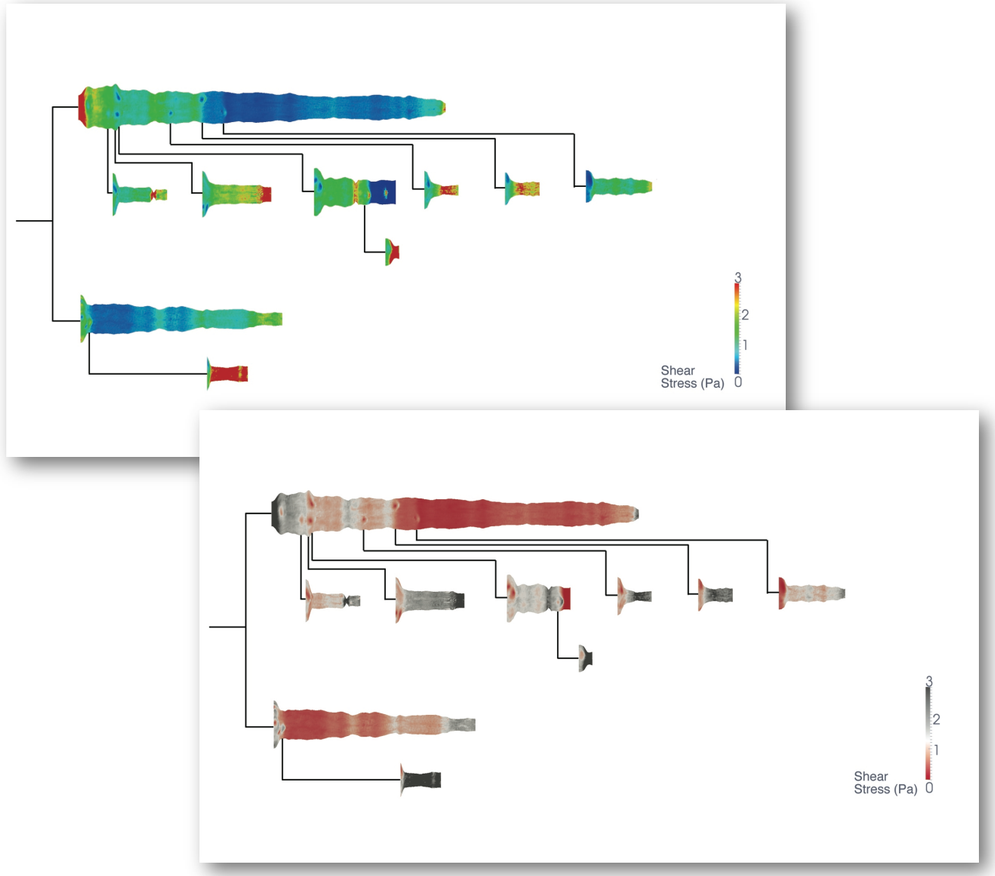

LAD
D1
D2
D3
D4
RAMUS
RAMUS BRANCH
LCX
OM1
ESS (Pa)
8
3
0

Quantitative Study: Goals

3D vs. 2D

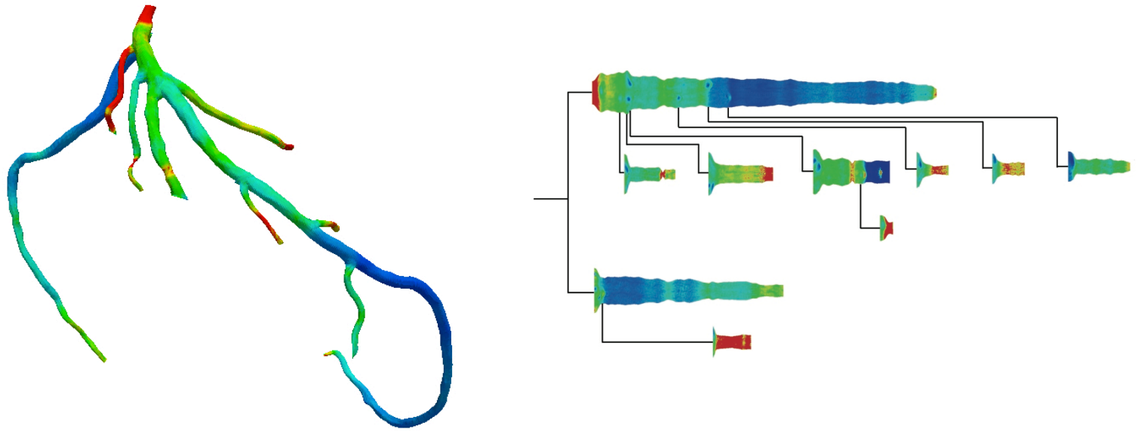


rainbow vs. diverging

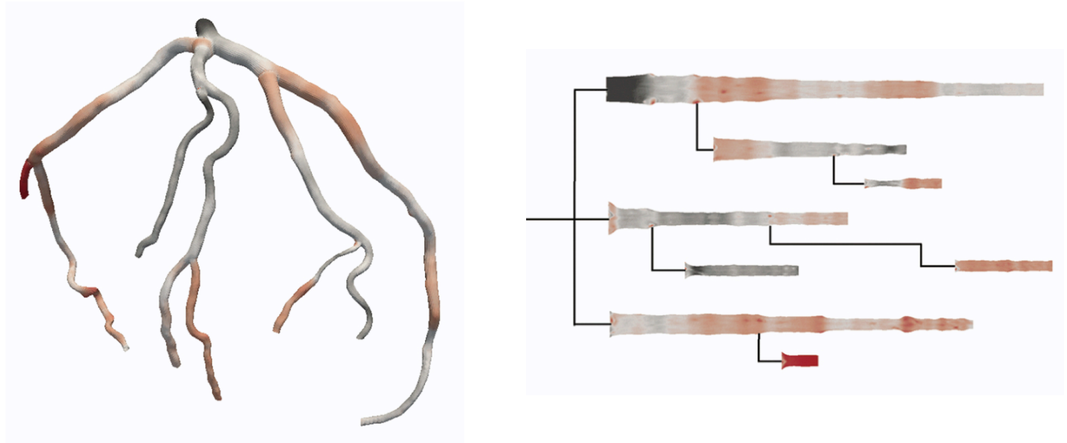


QUANTITATIVE STUDY

- 21 Harvard Medical students (12 women and 9 men)
- Mixed within-subject and between-subject design:
  - *within* = dimensionality of representation (2D or 3D)
  - *between* = color mapping (rainbow or diverging)



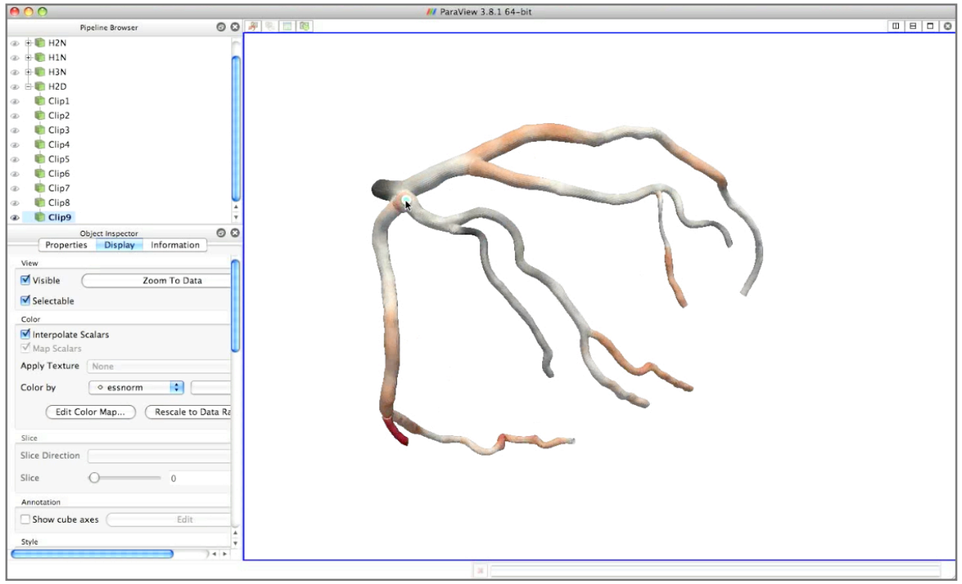
e.g., Participant A

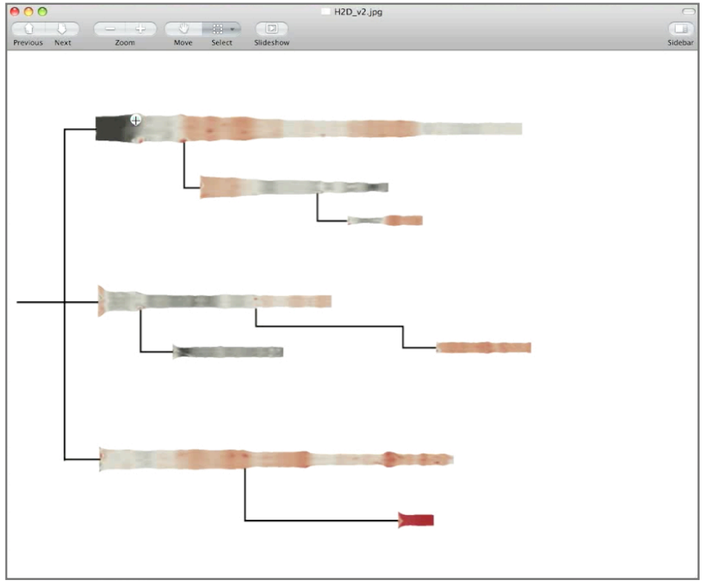


e.g., Participant B

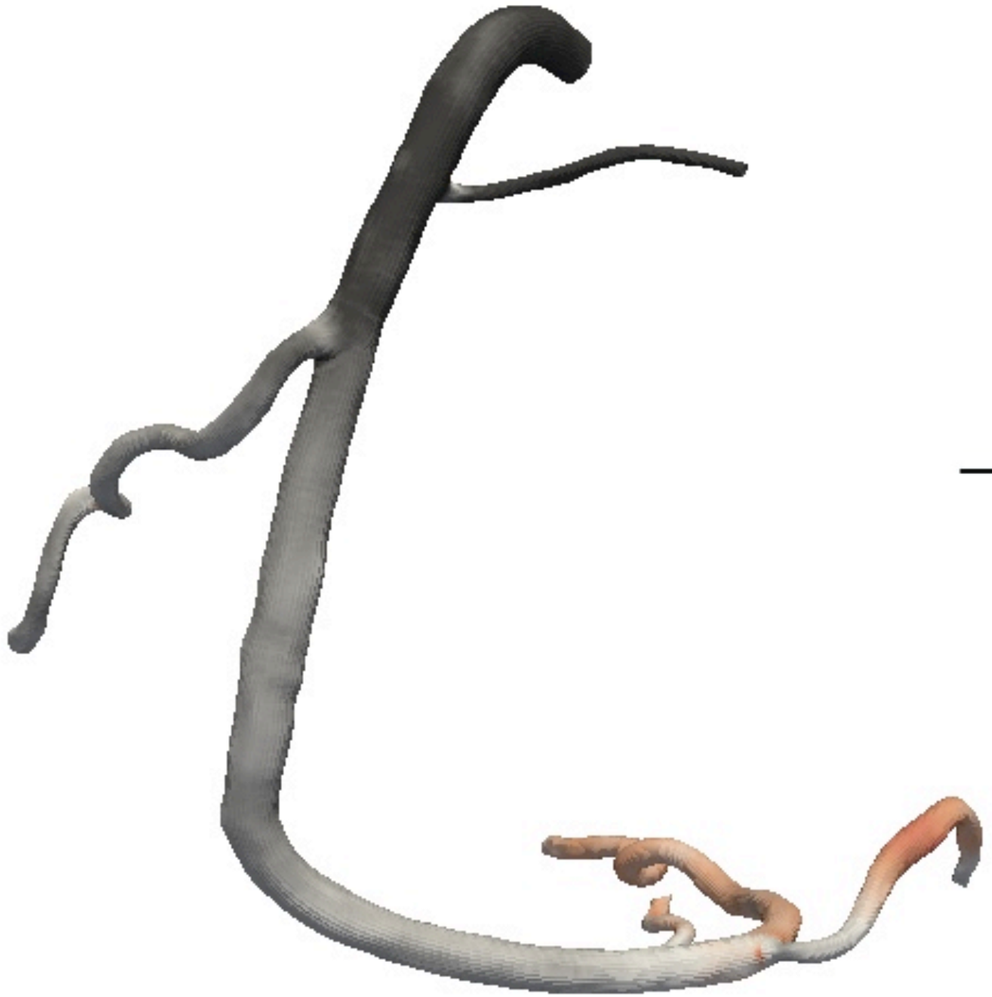
QUANTITATIVE STUDY

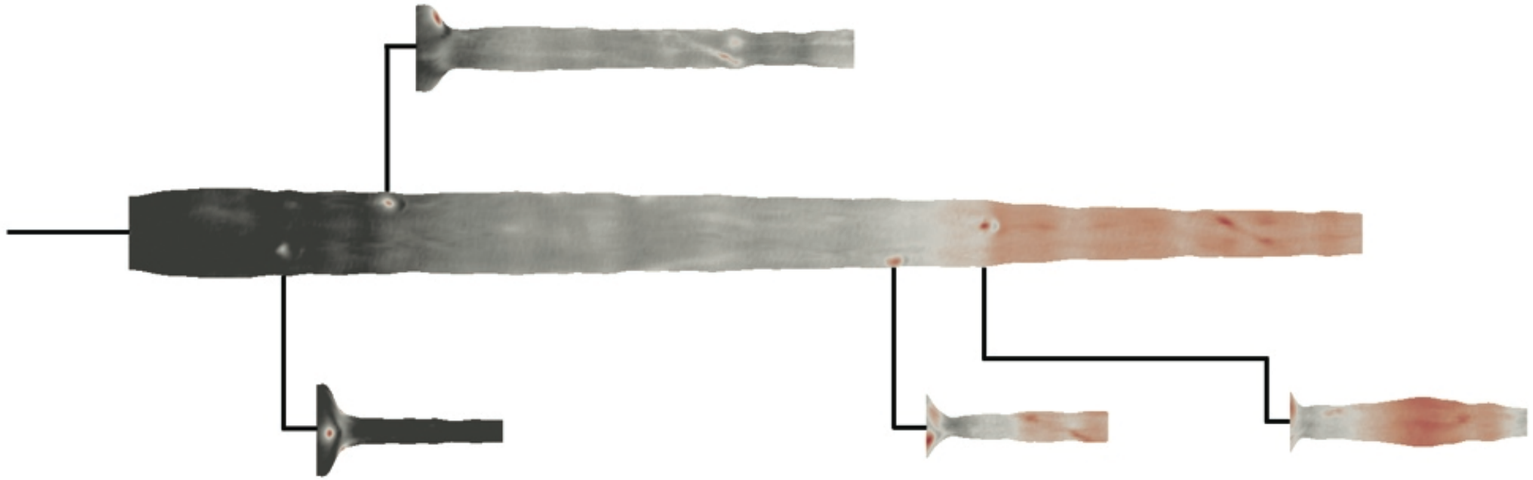
- Dependent measures:
  - fraction of low ESS regions identified
  - number of false positives (i.e., non-low ESS regions identified as low ESS)
  - time to complete a diagnosis



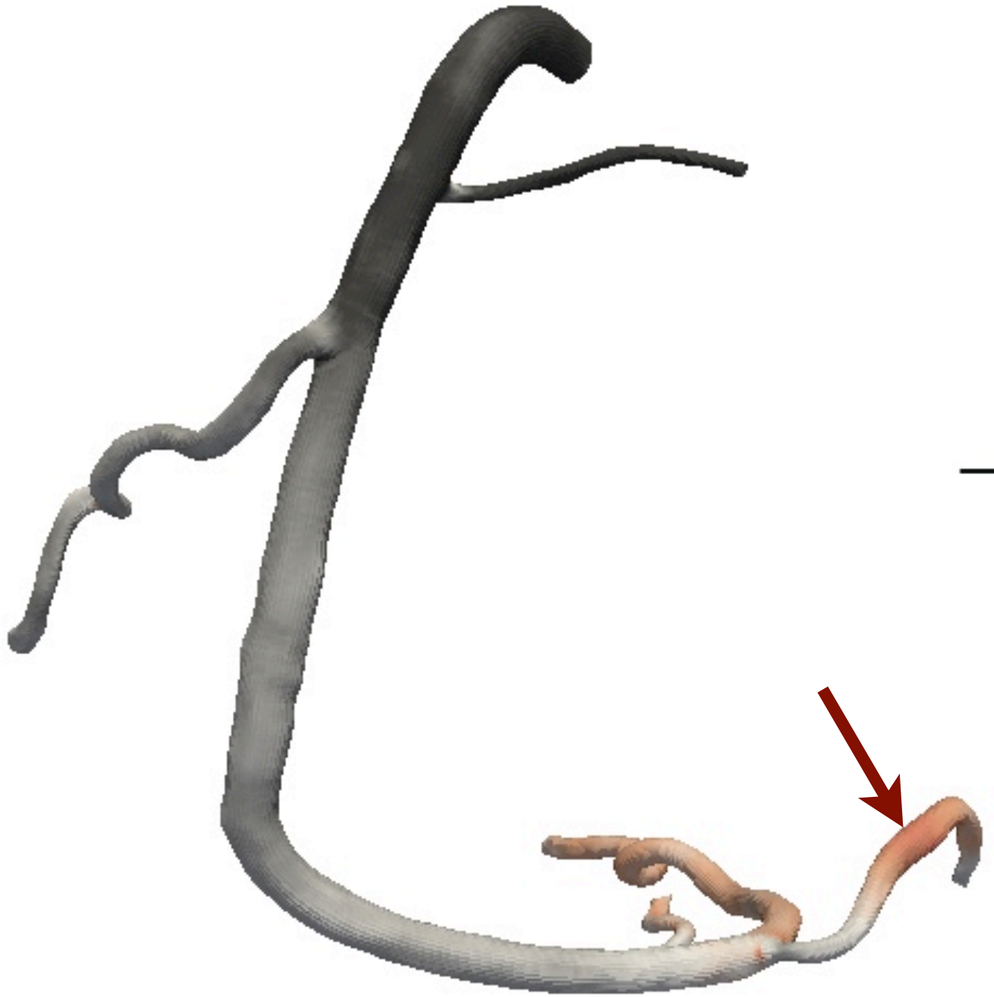


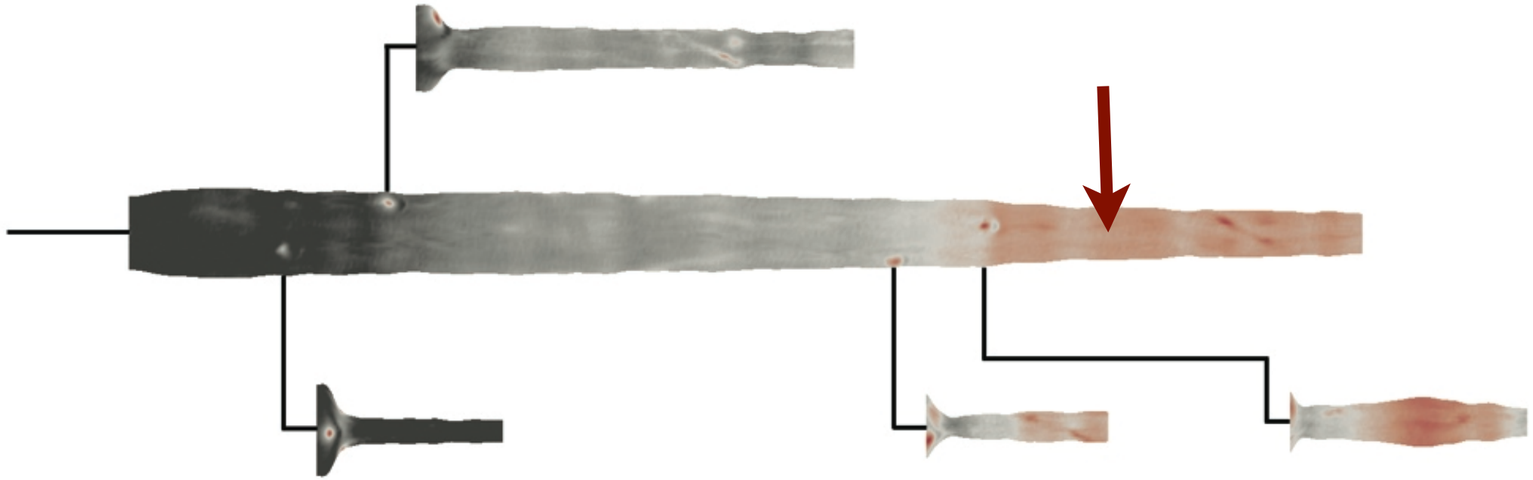
Quantitative Study



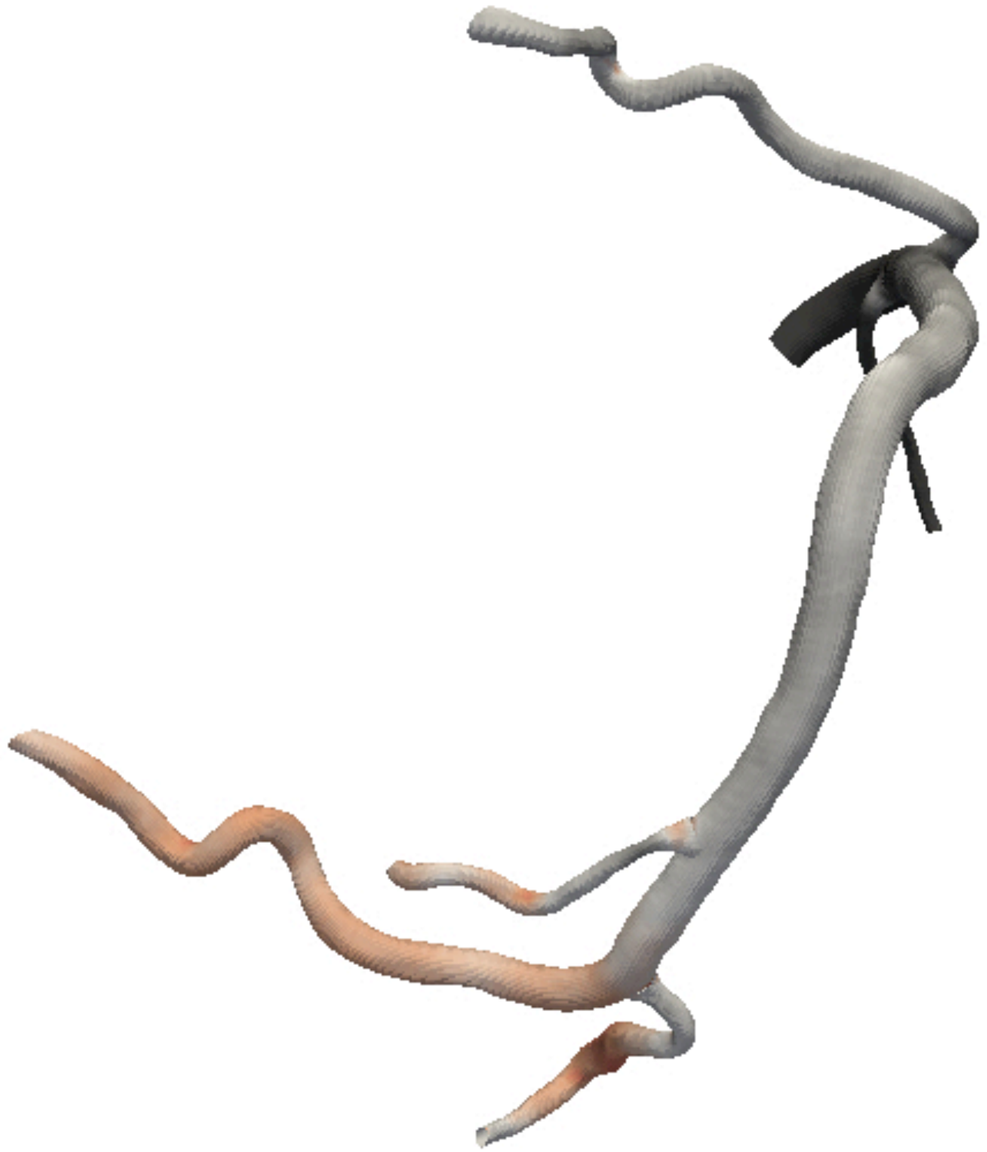


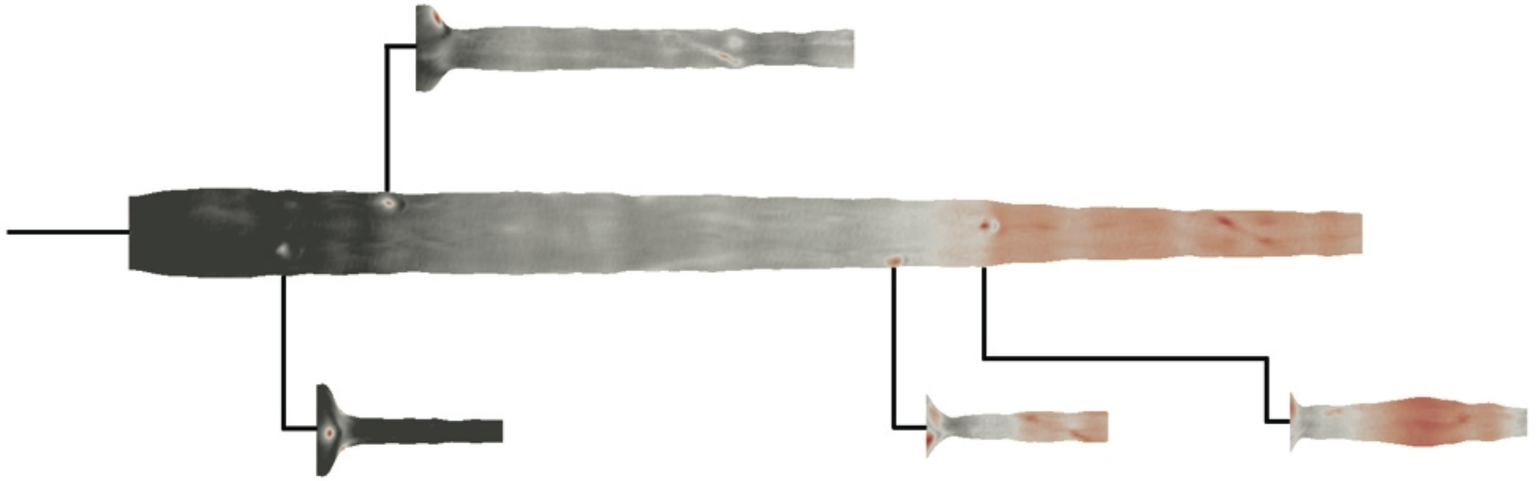
Quantitative Study



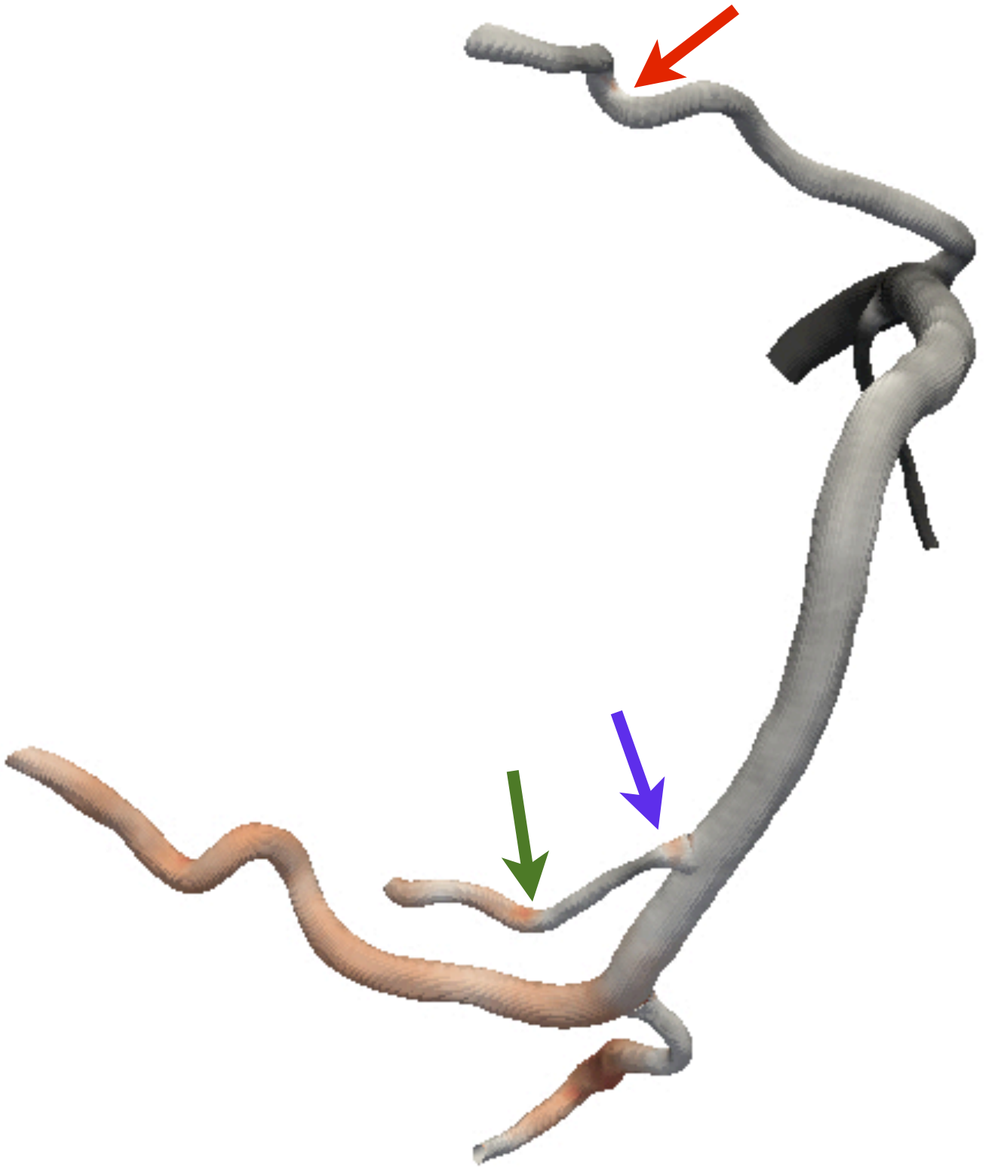


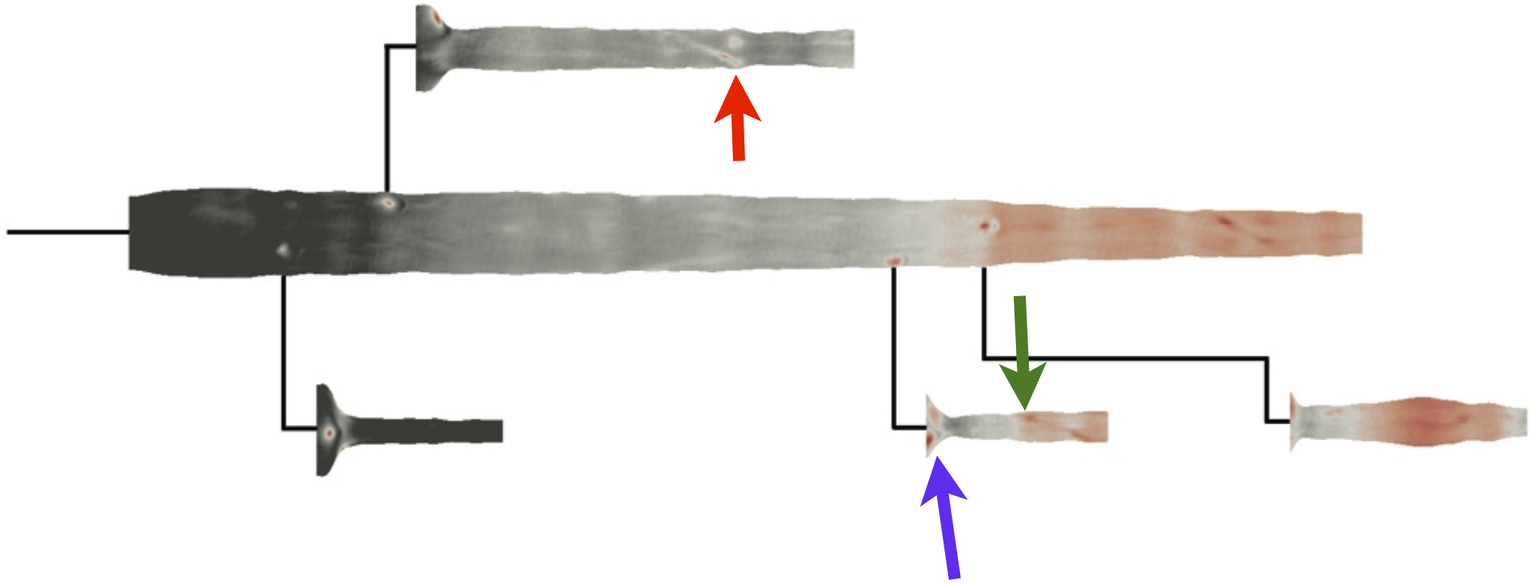
Quantitative Study





Quantitative Study





RESULTS

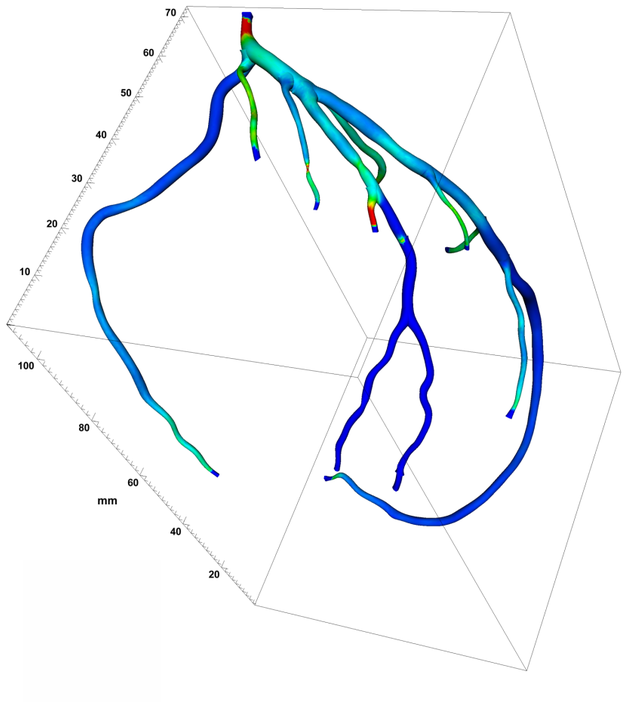
ACCURACY

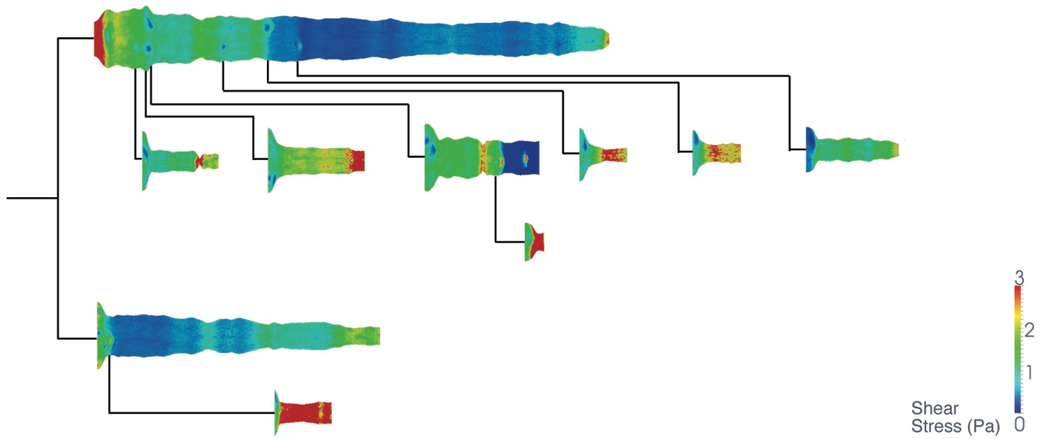
Strong effect of **dimensionality** on accuracy

39%

How many low ESS regions found?

62%





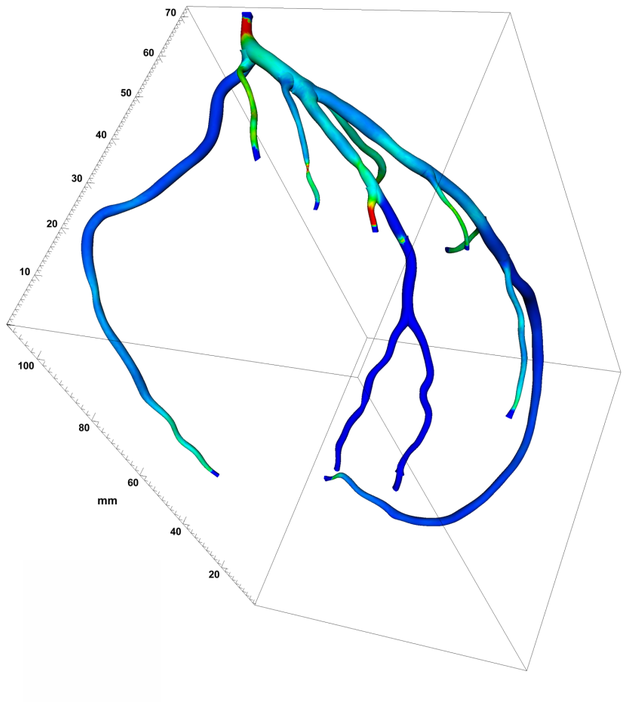
ACCURACY

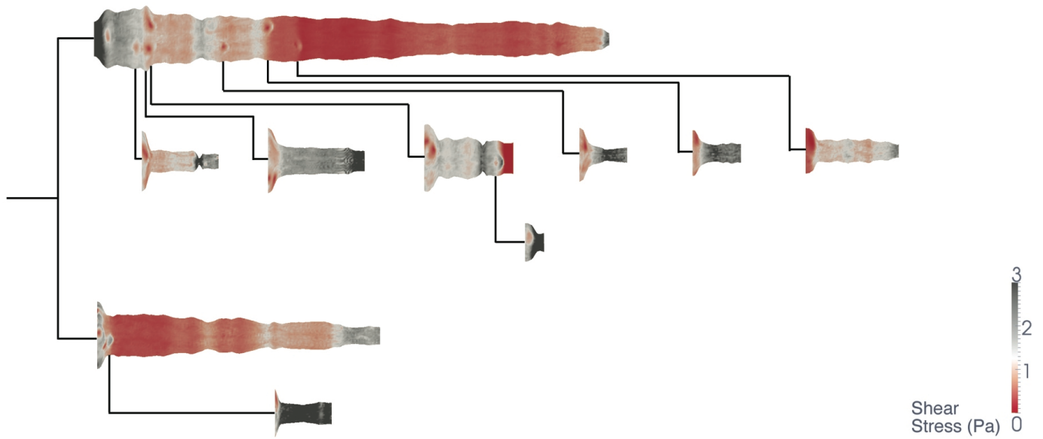
Strong effect of **dimensionality** on accuracy
...as well as **color**

39%

How many low ESS regions found?

91%

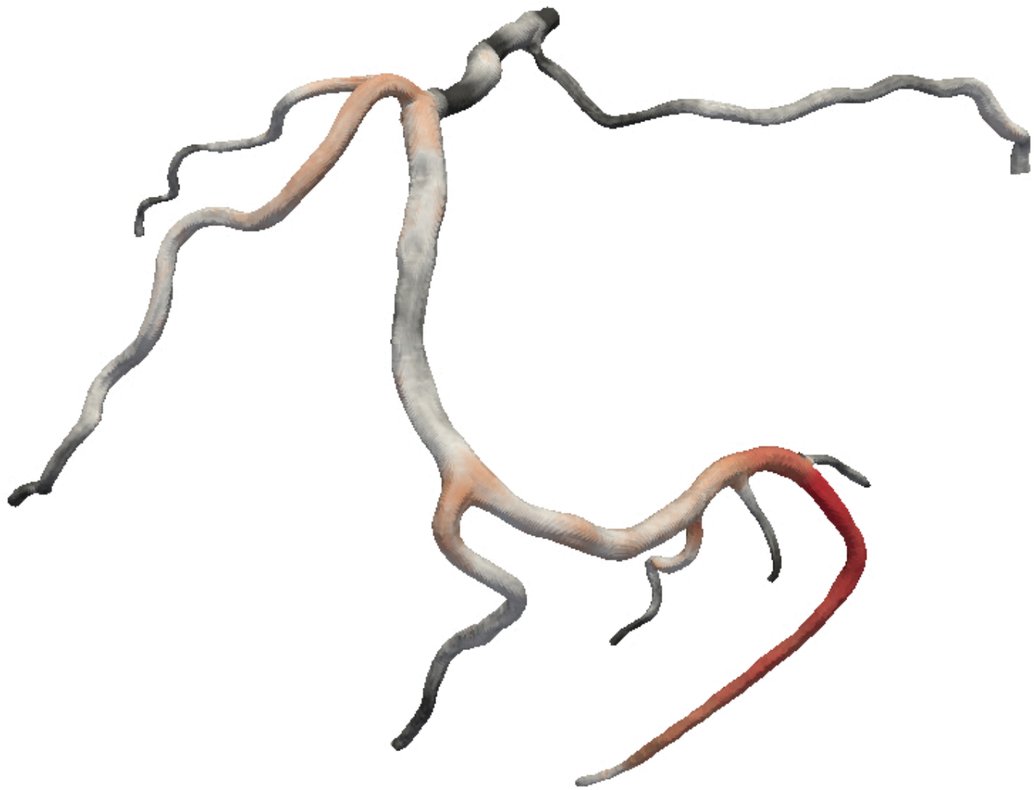




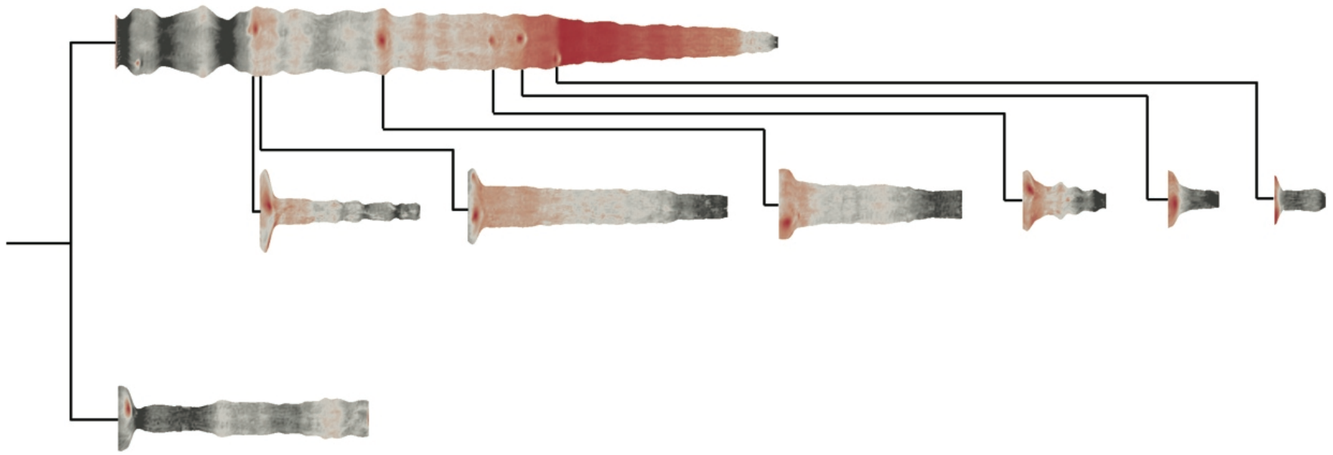
EFFICIENCY

Participants more **efficient** in **2D**.

5.6 sec/region



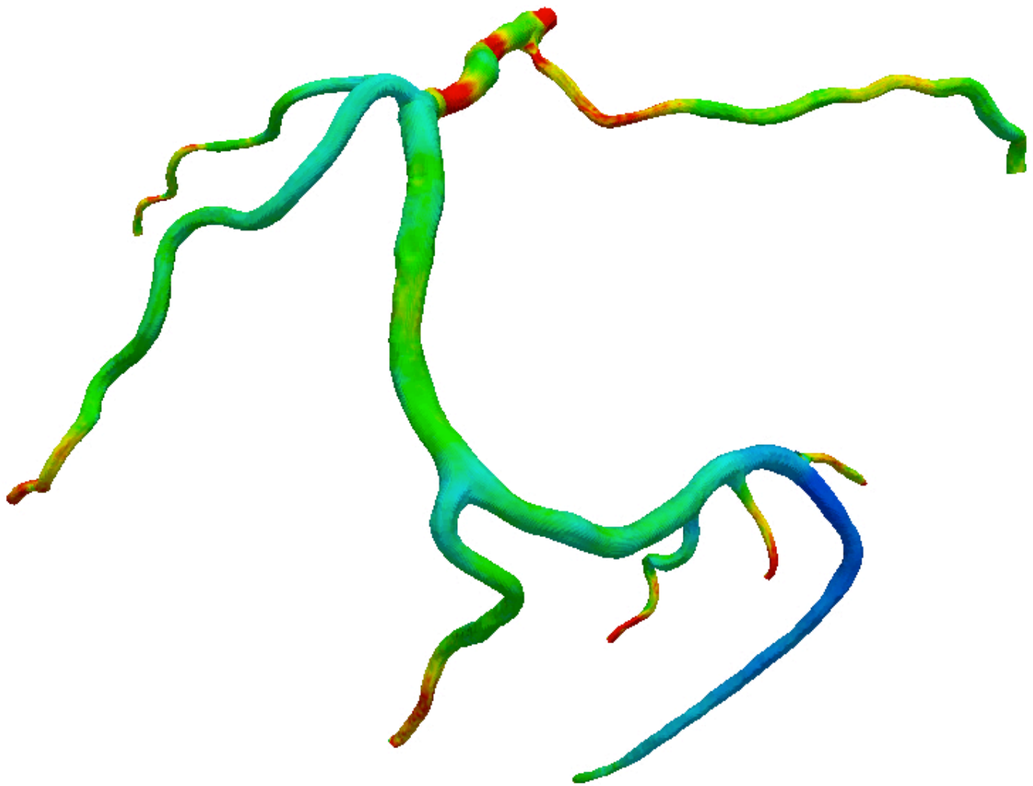
2.4 sec/region



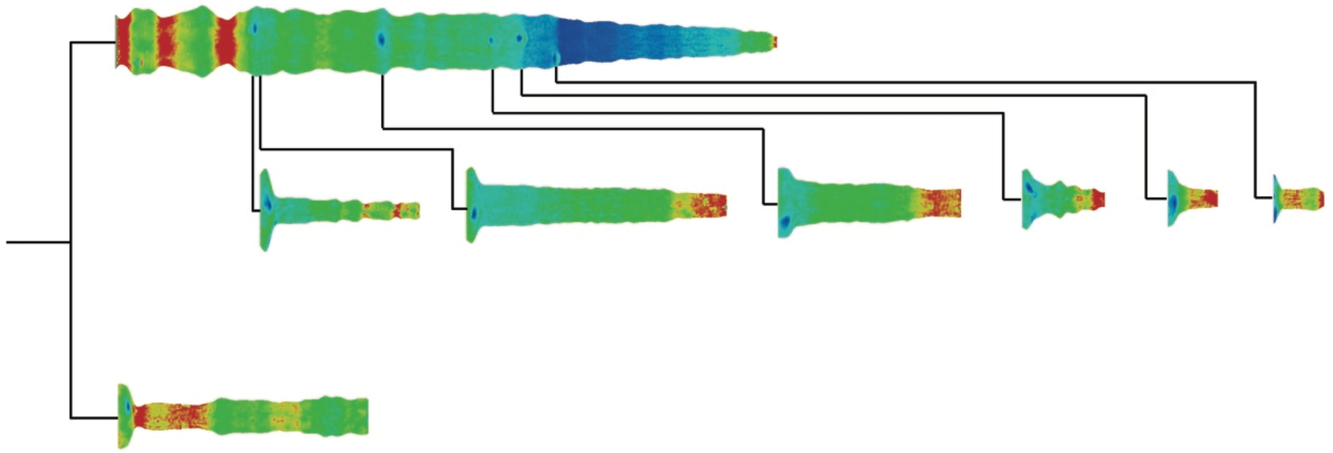
EFFICIENCY

Participants more **efficient** in **2D**.
Rainbow color map has greater effect on efficiency in 3D.

10.2 sec/region



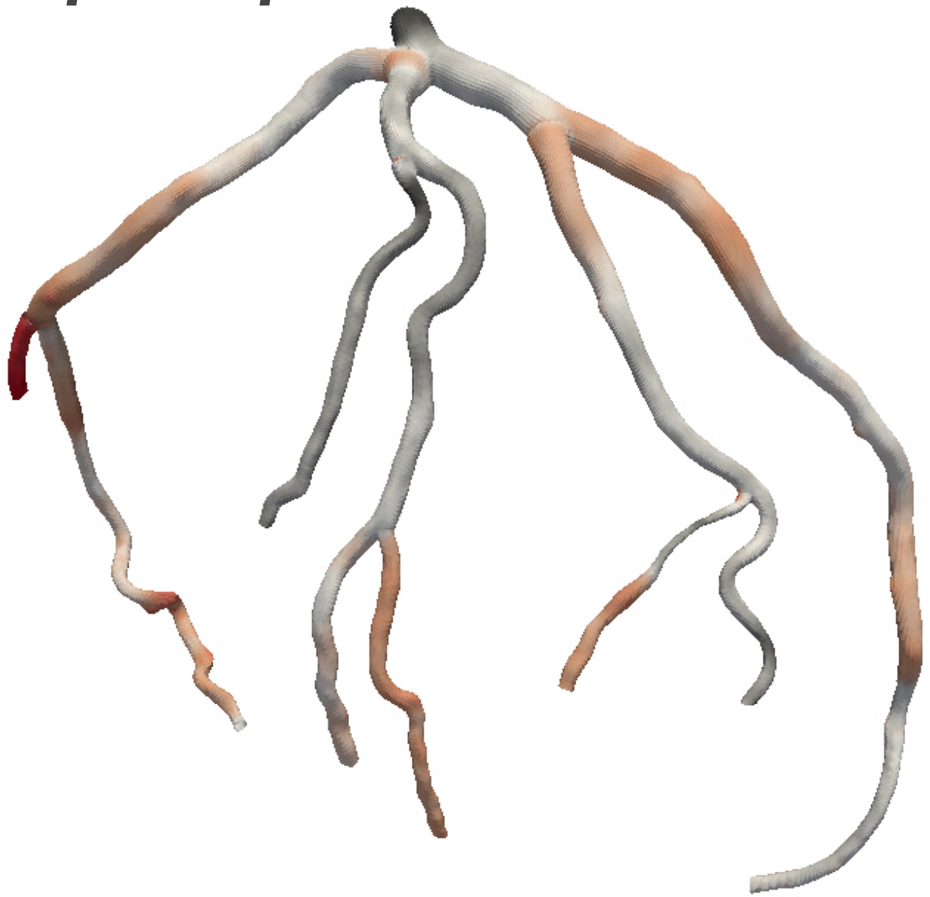
2.6 sec/region

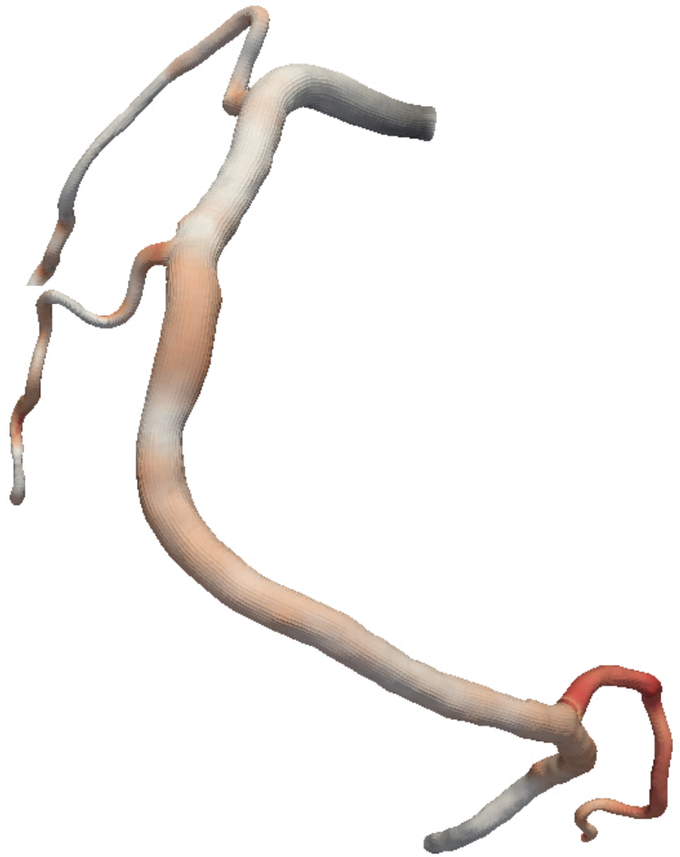


COMPLEXITY

Accuracy decreases with increased data complexity in 3D

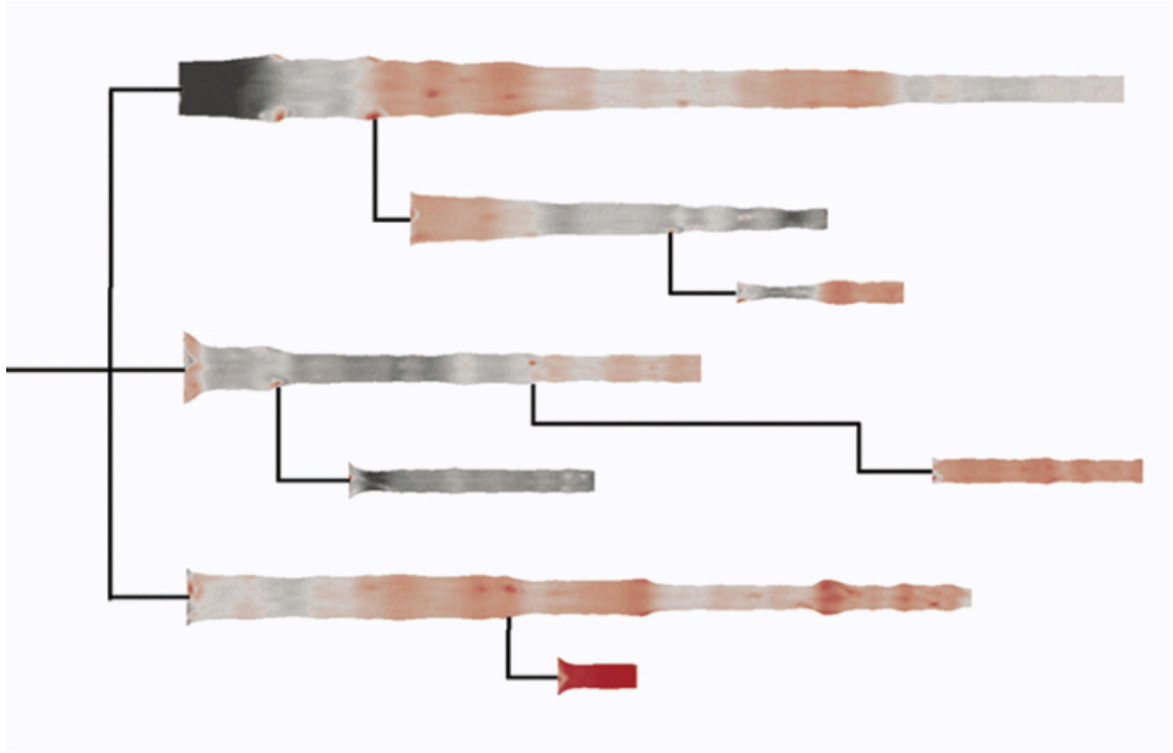
participants less accurate

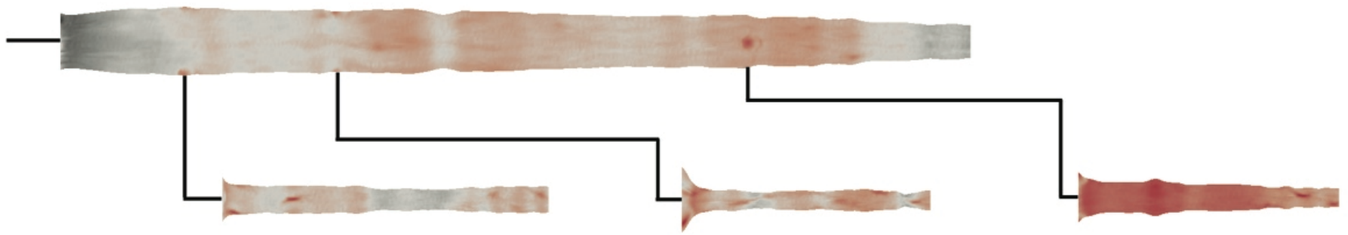




COMPLEXITY

Accuracy decreases with increased data complexity in 3D
(not true in 2D!)



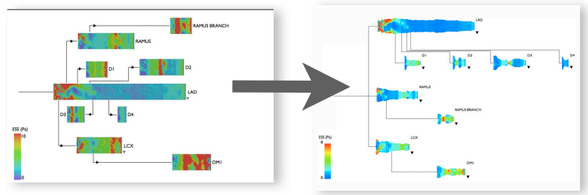


Subjective Responses

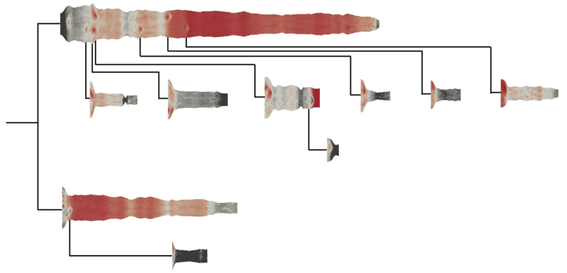
	2D	3D
I found it easy to identify low ESS regions.	✓	✗
I was able to perform the task efficiently.	✓	✗
I am confident I found all the low ESS regions.	✓	✗
I am confident all the places I marked are really low ESS.	–	–

FINDINGS SUMMARY

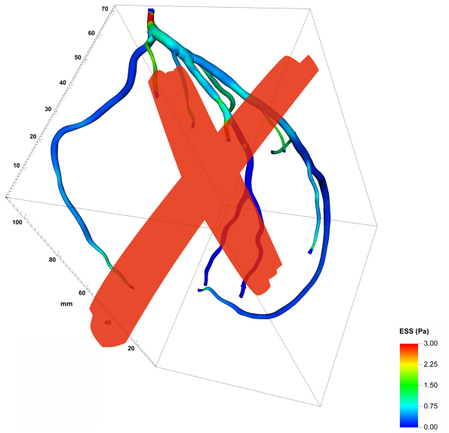
- Domain experts important for design and evaluation



- Even for 3D spatial data, a **2D** representation is
  - more **accurate** for spatial tasks
  - more **efficient** for spatial tasks

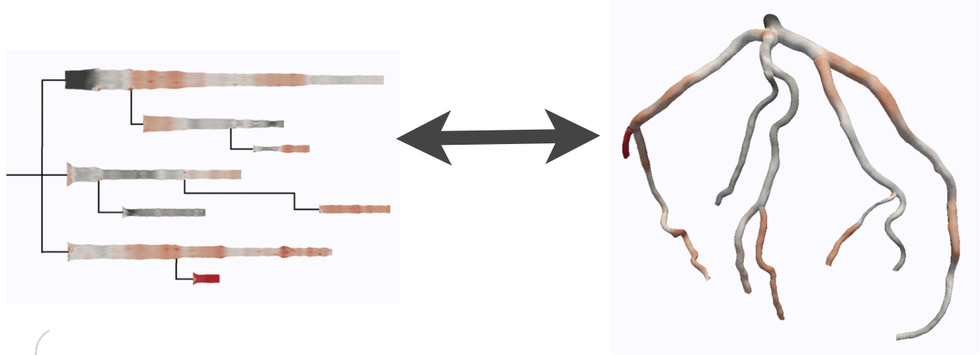


- Rainbow color map
  - is **not accurate** and **not efficient**
  - has adverse effects even greater in 3D

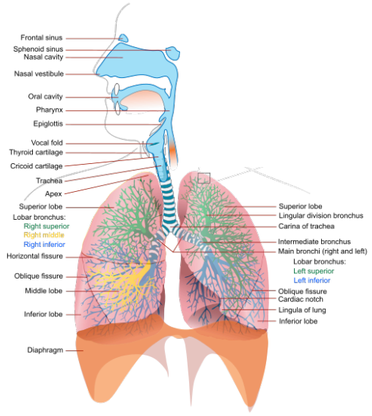


Concluding Remarks

- 3D representation is still essential for surgical planning



- 2D tree diagram applicable to other applications



- Quantitative study convinced our users of good visualization practices