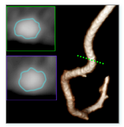
Evaluation of Artery Visualizations for Heart Disease Diagnosis

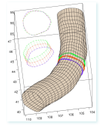
Michelle Borkin,
Krzysztof Gajos, Amanda Peters, Dimitrios Mitsouras,
Simone Melchionna, Frank Rybicki, Charles Feldman,
and Hanspeter Pfister

Harvard School of Engineering & Applied Sciences
Harvard Medical School
Brigham & Women's Hospital

Non-Invasive Diagnosis


Obtain patient CT data


Segment arteries

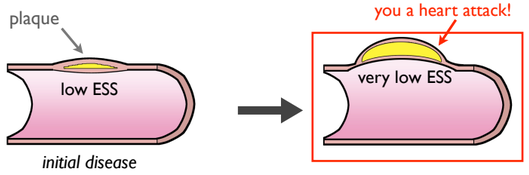

Generate patient geometries

Patient specific blood flow simulation


Visualize and analyze data

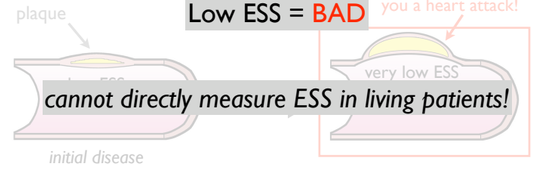

Clinical decision

Data

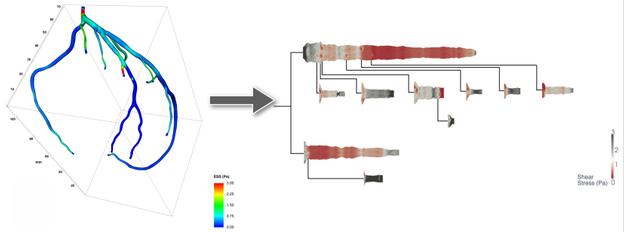


ESS = endothelial shear stress
(i.e., frictional force from blood flow)

Data

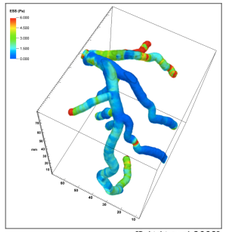


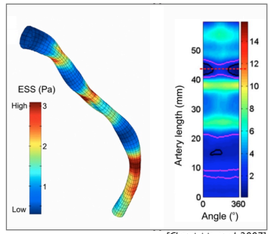
ESS = endothelial shear stress
(i.e., frictional force from blood flow)



Previous Work

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

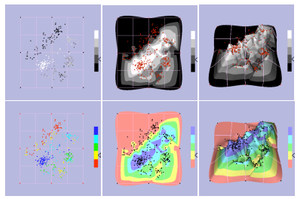

[Rybicki, et al. 2009]

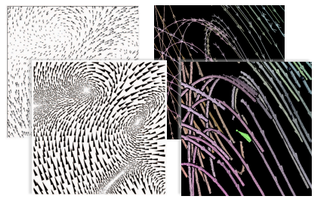


[Chatzizisis, et al. 2007]

Previous Work

- 2D vs. 3D Evaluation
  [e.g., Cockburn & McKenzie (2002), Laidlaw, et al. (2005), Tory, et al. (2007), Forsberg et al. (2009)]

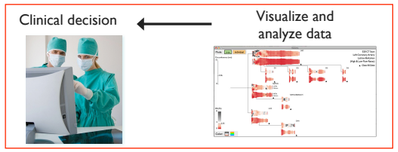

[Troy, et al. 2007]


[Laidlaw, et al. 2005]

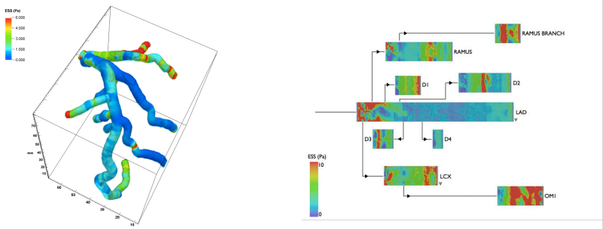
[Forsberg, et al. 2009]

Formative Qualitative Study

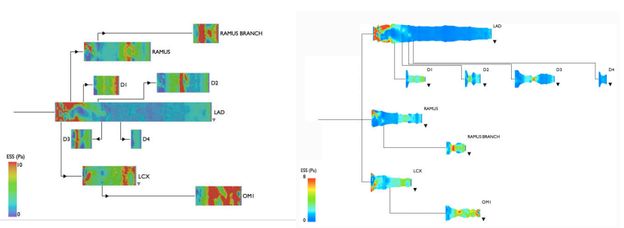
- Semi-structured interviews
- 10 medical doctors and researchers
- Brigham & Women's Hospital (Boston, MA)



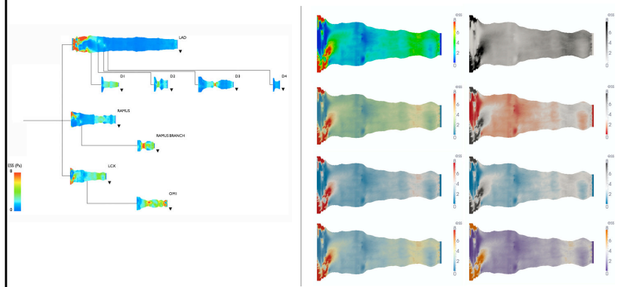
3D



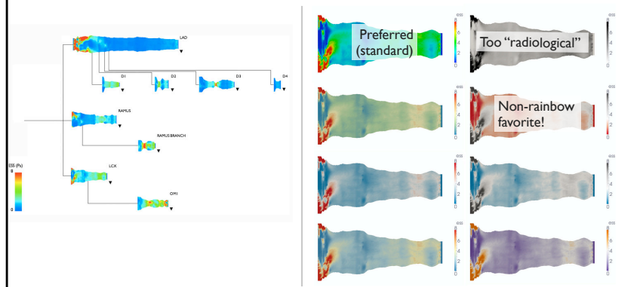
Layout and Projections



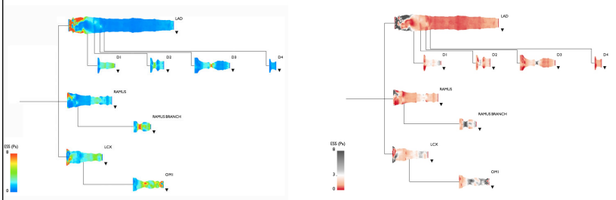
Color



Color

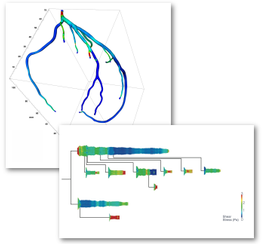


Color

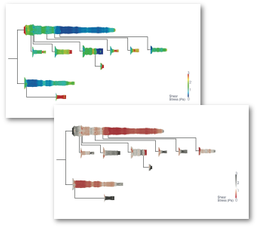


Quantitative Study: Goals

3D vs. 2D

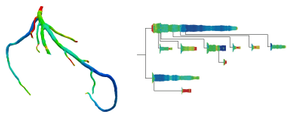


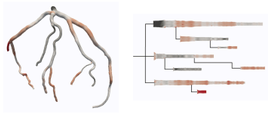
rainbow vs. diverging



Quantitative Study

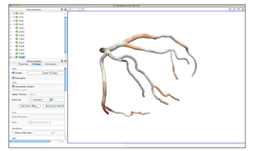
- 21 Harvard Medical students (12 women and 9 men)
- Mixed within-subject and between-subject design:
  - *within* = dimensionality of representation (2D or 3D)
  - *between* = color mapping (rainbow or diverging)

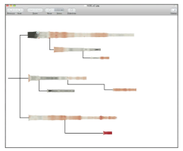

e.g., Participant A


e.g., Participant B

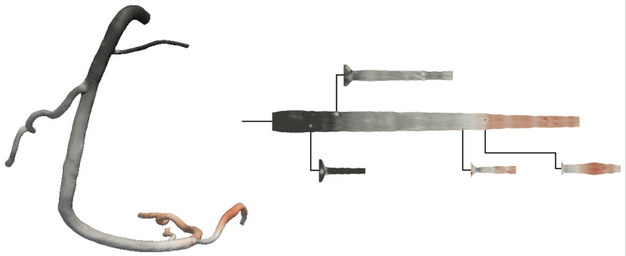
Quantitative Study

- 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

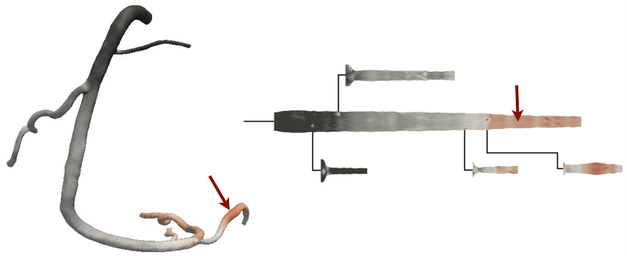




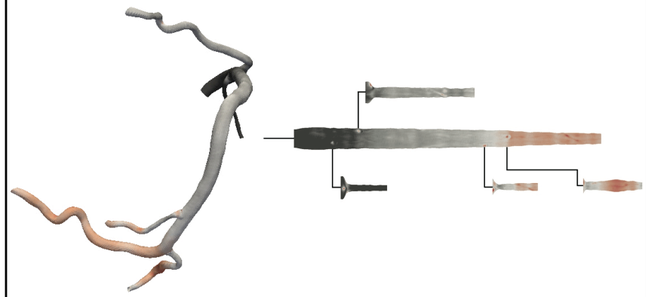
Quantitative Study



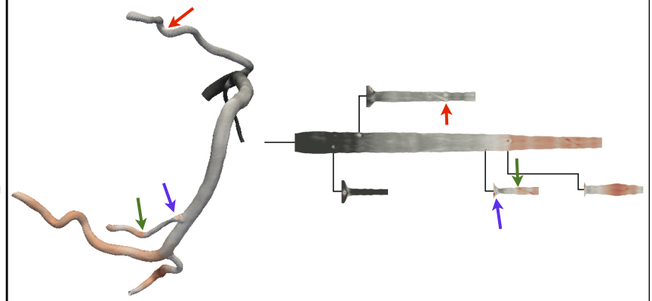
Quantitative Study



Quantitative Study



Quantitative Study

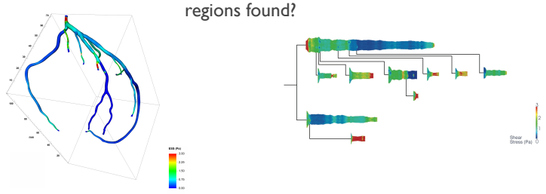


Results

Accuracy

Strong effect of **dimensionality** on accuracy

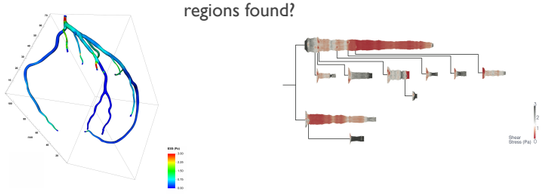
39% How many low ESS regions found? 62%



Accuracy

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

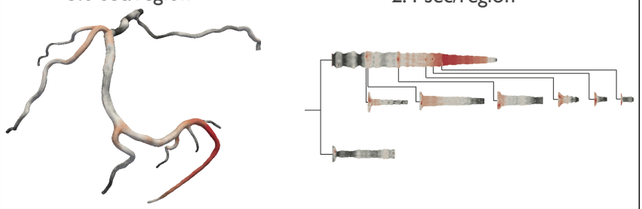
39% How many low ESS regions found? 91%



Efficiency

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

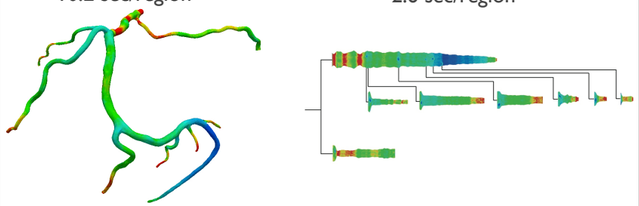
5.6 sec/region 2.4 sec/region



Efficiency

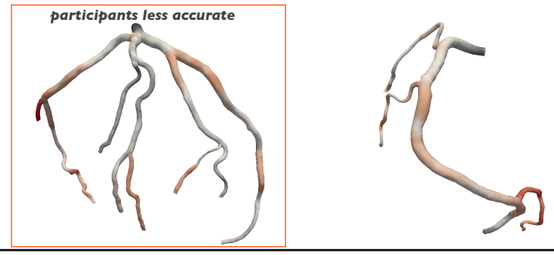
Participants more **efficient** in **2D**.
Rainbow color map has greater effect on efficiency in 3D.

10.2 sec/region 2.6 sec/region



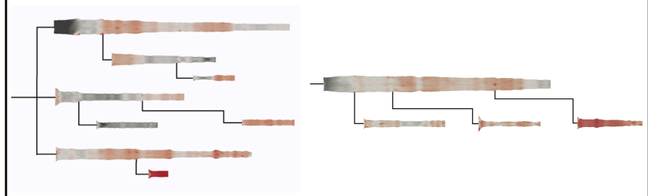
Complexity

Accuracy decreases with increased data complexity in 3D



Complexity

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

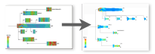


Subjective Responses

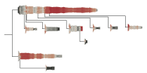
	2D	3D
I found it easy to identify low ESS regions.	✓	✗
I was able to perform the task efficiently.	✓	✗
I am confident I found all the low ESS regions.	✓	✗
I am confident all the places I marked are really low ESS.	–	–

Findings Summary

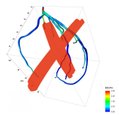
- Domain experts important for design and evaluation



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

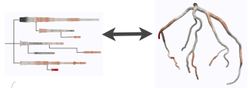


- Rainbow color map
  - is **not accurate** and **not efficient**
  - has adverse effects even greater in 3D

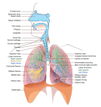


Concluding Remarks

- 3D representation is still essential for surgical planning



- 2D tree diagram applicable to other applications



- Quantitative study convinced our users of good visualization practices