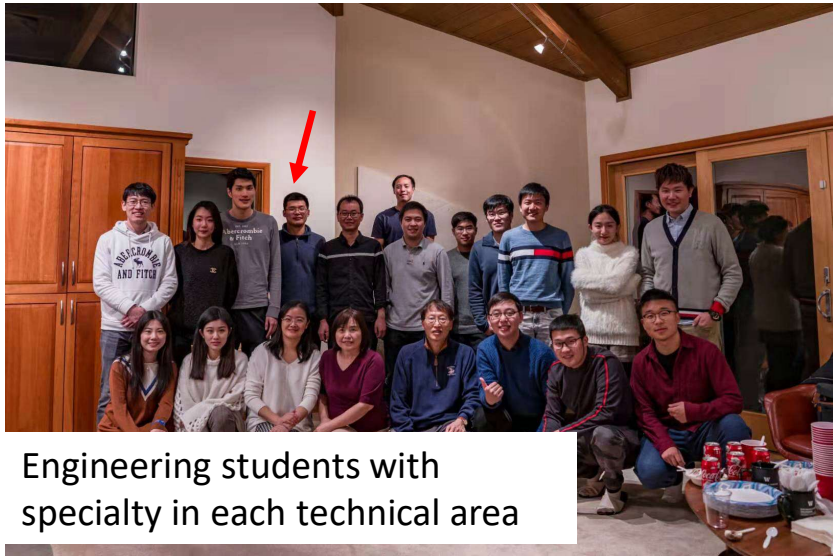
Feature extraction and quantification to explore human vasculature

Li Chen
Department of Electrical and Computer Engineering

UNIVERSITY of WASHINGTON

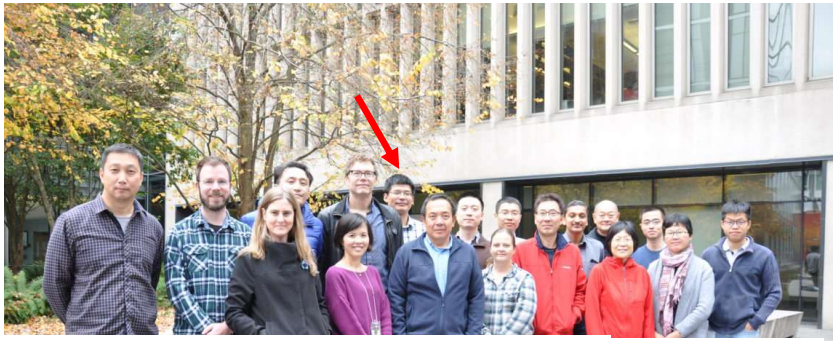
Introduction of myself and my groups

- A 5th year Electrical Engineering PhD student receiving funding from a Radiology lab
- Productive medical researcher with AI/Imaging background
  - 24 publications (13 as first author)



Engineering students with specialty in each technical area

Information Processing Lab
Department of Electrical and Computer Engineering

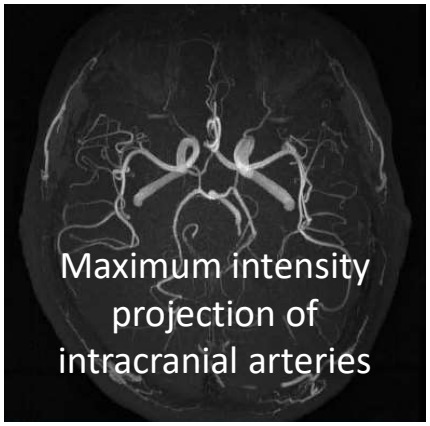


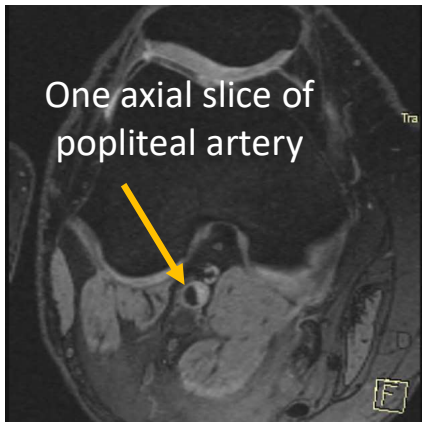
- MR physicists
- Research scientists
- Medical reviewers
- Radiologists
- Neurologists
- Vascular surgeons
- MR operators
- Statisticians

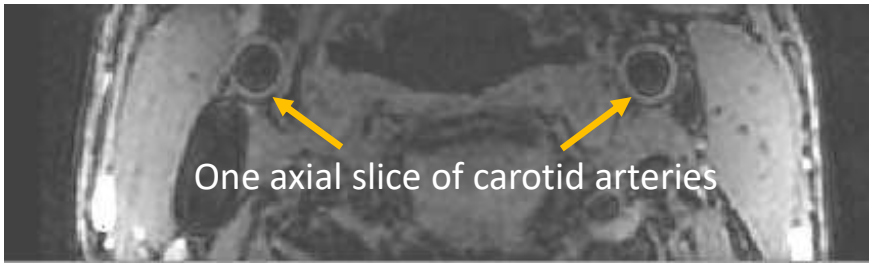
Vascular Imaging Lab
Department of Radiology
UNIVERSITY of WASHINGTON

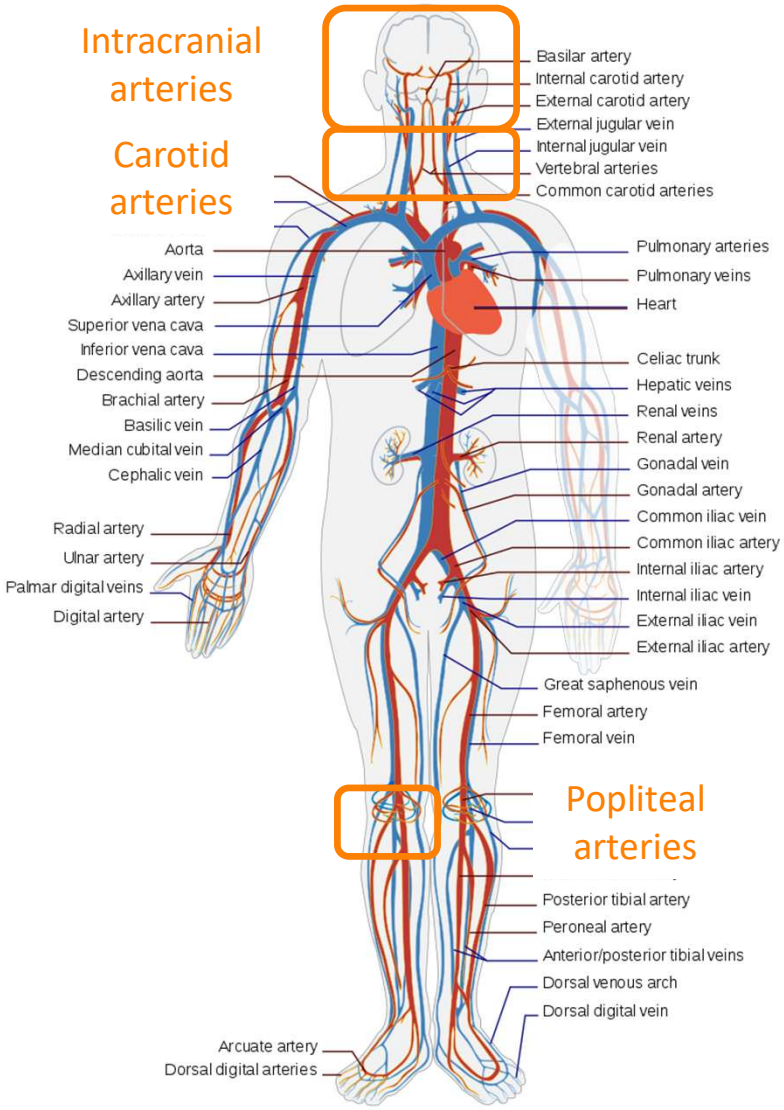
Human vasculature

> A complicated system visualized by Magnetic Resonance Imaging (MRI)







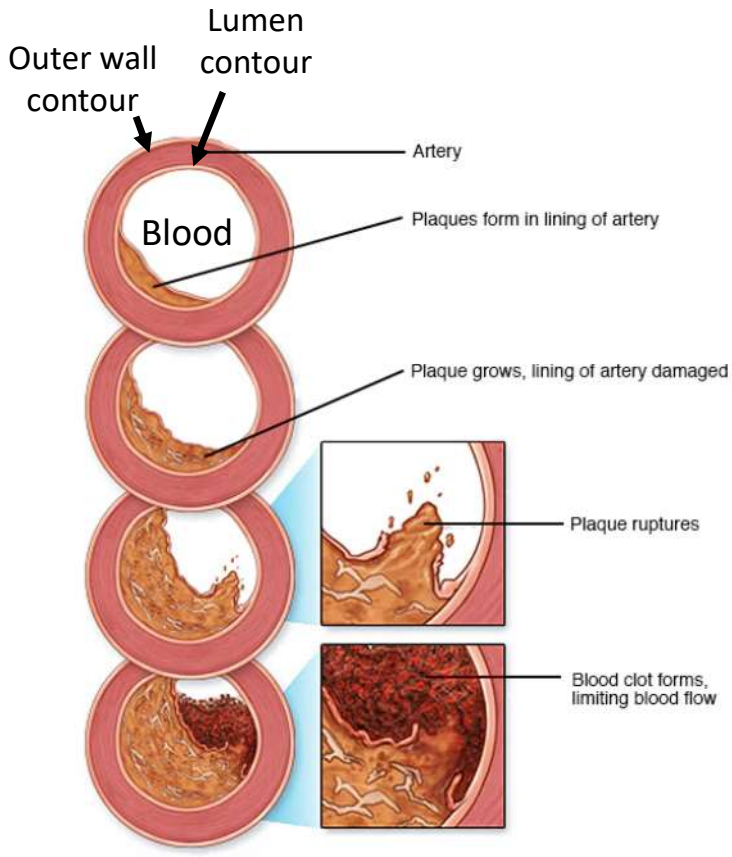


UNIVERSITY of WASHINGTON

Image from Wikipedia: Circulatory_system

Vascular analysis

- Richness of vasculature: blood flow status
- Atherosclerotic plaque: cause of ischemic strokes
- Comprehensive vasculature analysis needed
  - Identify centerlines for structural information
  - Identify vessel wall contours for plaque features
- Automation
  - Unbiased, applicable to large datasets
- Challenging
  - Tiny region, weak signal, limited samples

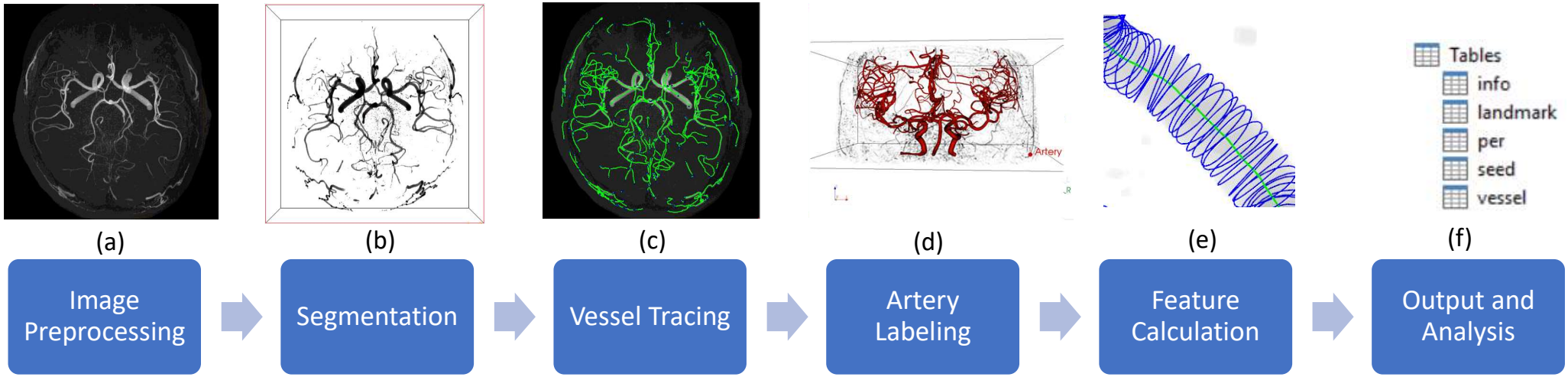


Cross sectional view of an artery with an accumulating plaque

Image from https://www.mayoclinic.org/diseases-conditions/arteriosclerosis-atherosclerosis/symptoms-causes/syc-20350569

iCafe: artery tracing, labeling and quantification

> iCafe: a C++ tool converting 3D MRA images to quantitative vascular map [1]
  - Each artery traced as a radius varying tube [2]
  - Each artery labeled with a certain anatomical type using Graph Neural Network [3]
  - Comprehensive/Regional features useful for quantitative medical research [4]



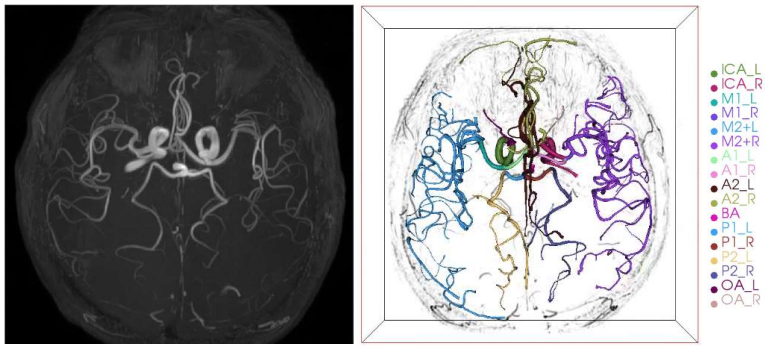
iCafe website: icafe.clatfd.cn

[1] Chen, et. al, Magn Reson Med, 2018.
[2] Chen, et. al, MICAAI CVII-STENT Workshop 2019.
[3] Chen, et. al, MICCAI, 2020.
[4] Chen, et. al. Neurobiology of Aging, 2019.

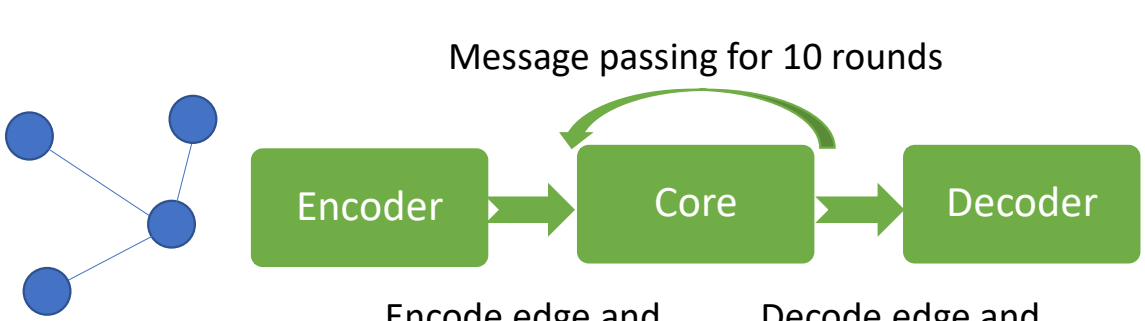
UNIVERSITY of WASHINGTON

Graph neural network for artery landmark labeling

- A message passing graph neural network for node and edge type prediction
- Combine human wisdom with machine knowledge in the hierarchical design of labeling framework



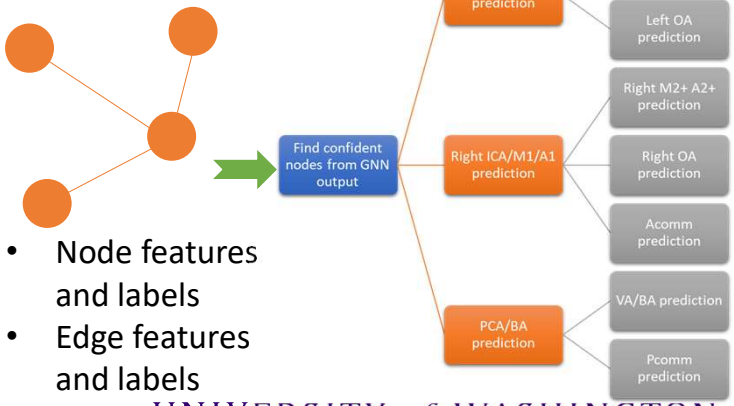
Intracranial arteries: a natural graph with 24 major types



- Node (bifurcation/ending points) features
- Edge (artery) features

Encode edge and node features

Decode edge and node features

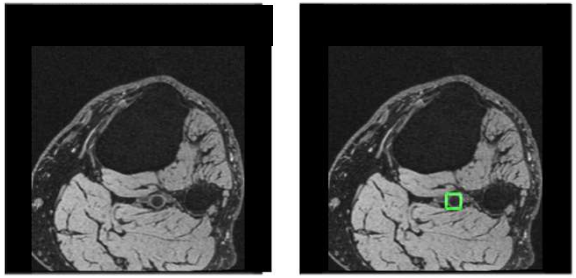


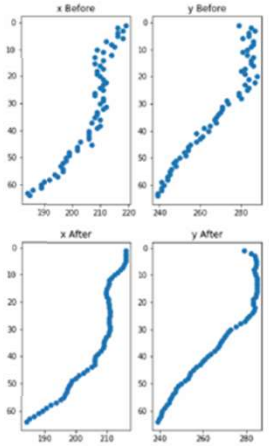
- Node features and labels
- Edge features and labels

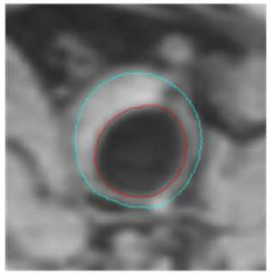
From Chen, et. al, MICCAI 2020

FRAPPE: quantify vessel wall from 3.5 million knee MRI

- Automatically analyze popliteal vessel wall from OAI data* (67 years of human effort)
- Locate artery region (<1% image pixel) along slices accurately [1]
- Segment vessel wall regions continuously and smoothly [2]







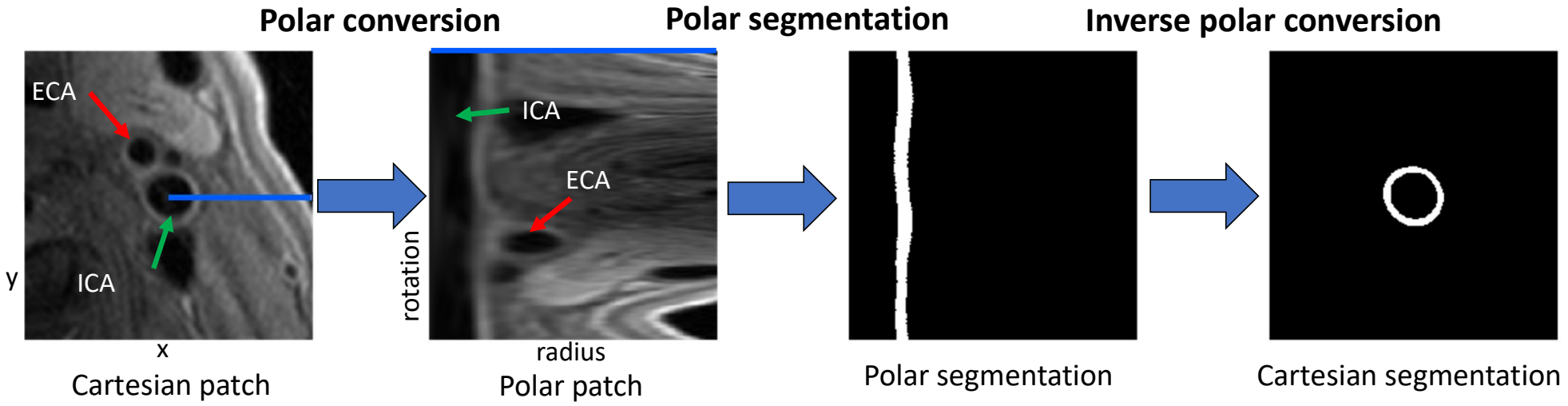
Max wall thickness:
2.62 mm
Mean wall thickness:
1.46 mm
Vessel wall area:
74.49 mm^2
Lumen area:
36.30 mm^2
.....

[1] Chen, et. al, Magn Reson Med, 2020
[2] Chen, et. al, IEEE Access, 2020
* The Osteoarthritis Initiative (OAI) dataset: https://nda.nih.gov/oai

UNIVERSITY of WASHINGTON

Vessel wall segmentation in polar coordinate system

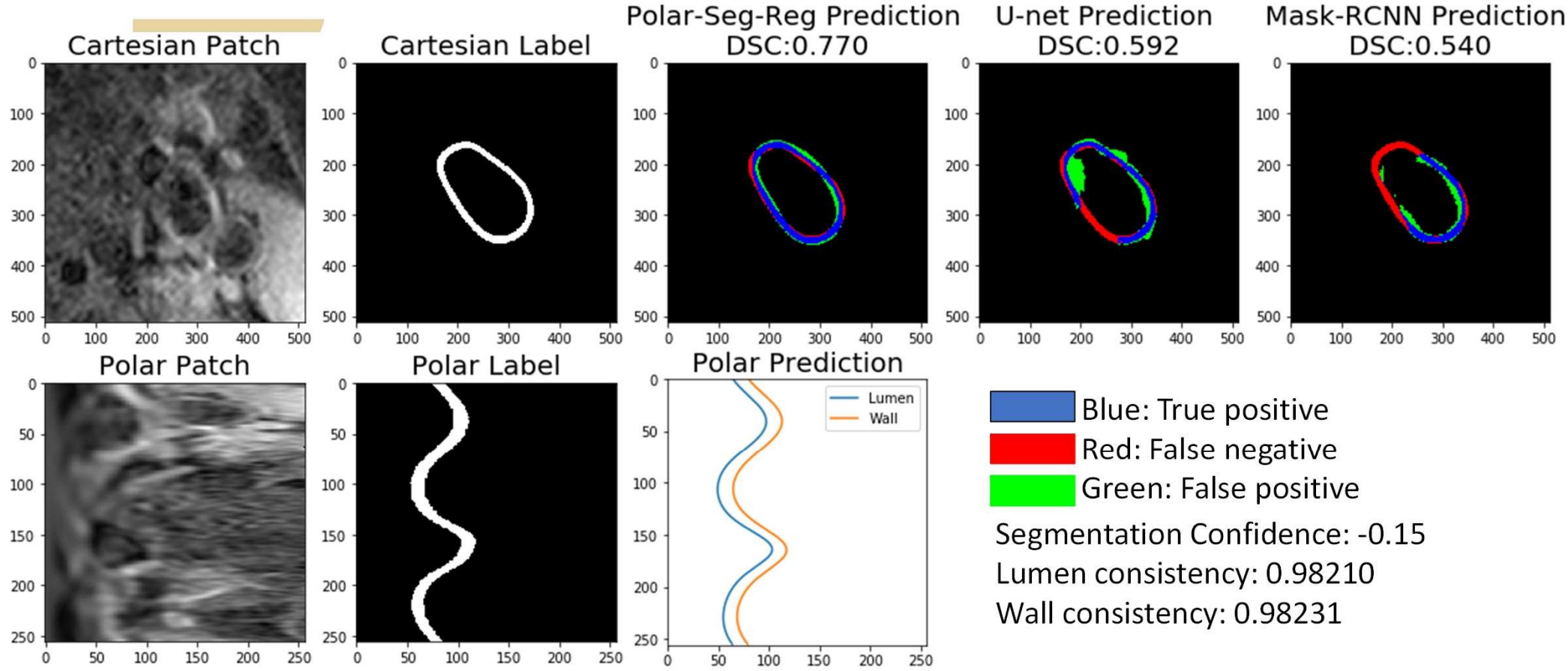
- Benefits of segmenting in polar coordinate system
  - Neighboring arteries (ECA) are quite different from the artery of interest (ICA).
  - Contours are represented as two vertical lines, easy to ensure continuity
- Dual output (segmentation + regression) network for prediction confidence



Example of polar segmentation in a carotid artery

From Chen, et. al, IEEE Access, 2020.

Example of polar segmentation result



Blue: True positive

Red: False negative

Green: False positive

Segmentation Confidence: -0.15

Lumen consistency: 0.98210

Wall consistency: 0.98231

[1] U-Net: Ronneberger, et. al, arXiv, 2015. [2] Mask-RCNN: He, et. al, ICCV, 2017.

Conclusions

- Novel image analysis techniques (iCafe family) on vascular imaging:
  - Quantitative features for medical research
  - Objective review workflow for vascular images
  - Make large population studies/screening feasible
- Artificial intelligence on vascular image analysis
  - Extract subtle patterns not easily describable
  - Data drives models, which are improved with more data
  - Human knowledge and machine knowledge for better models

Acknowledgements

- We acknowledge the contributions from our collaborators.
  - CBIR/CARE II/OAI/CROP investigators
- Thanks for the funding supports from Philips healthcare, National Institute of Health, and American Heart Association.
- We gratefully acknowledge the support of NVIDIA Corporation for donating the Titan GPUs.