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Artificial Intelligence for non-invasive cardiac diagnostics

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Cardiovascular Diseases

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85%[1]

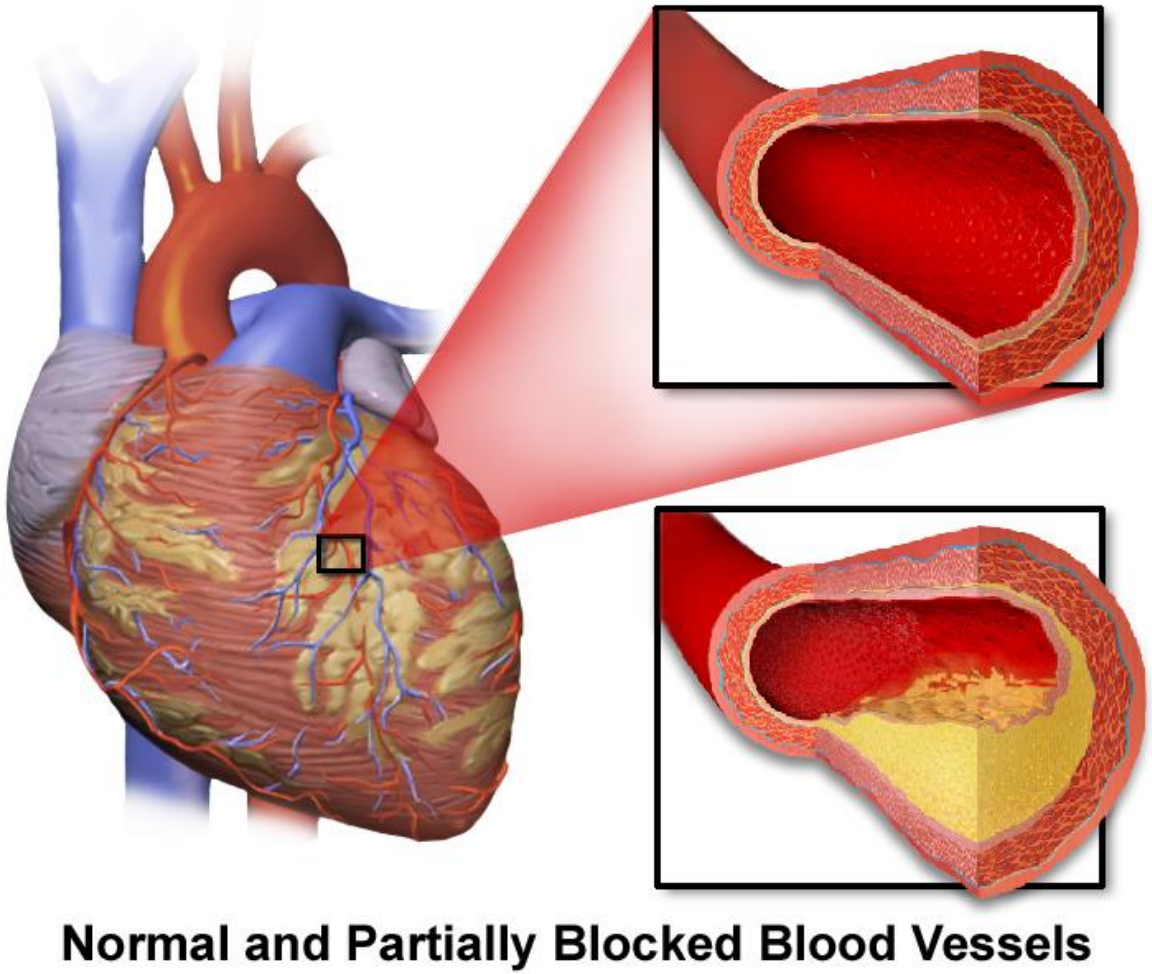
of all CVD are due to heart attacks and strokes

17.9 million[2]

deaths annually

1-2. World Health Organisation – https://www.who.int/news-room/fact-sheets/

Coronary Artery Stenosis



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Fractional Flow Reserve (FFR)

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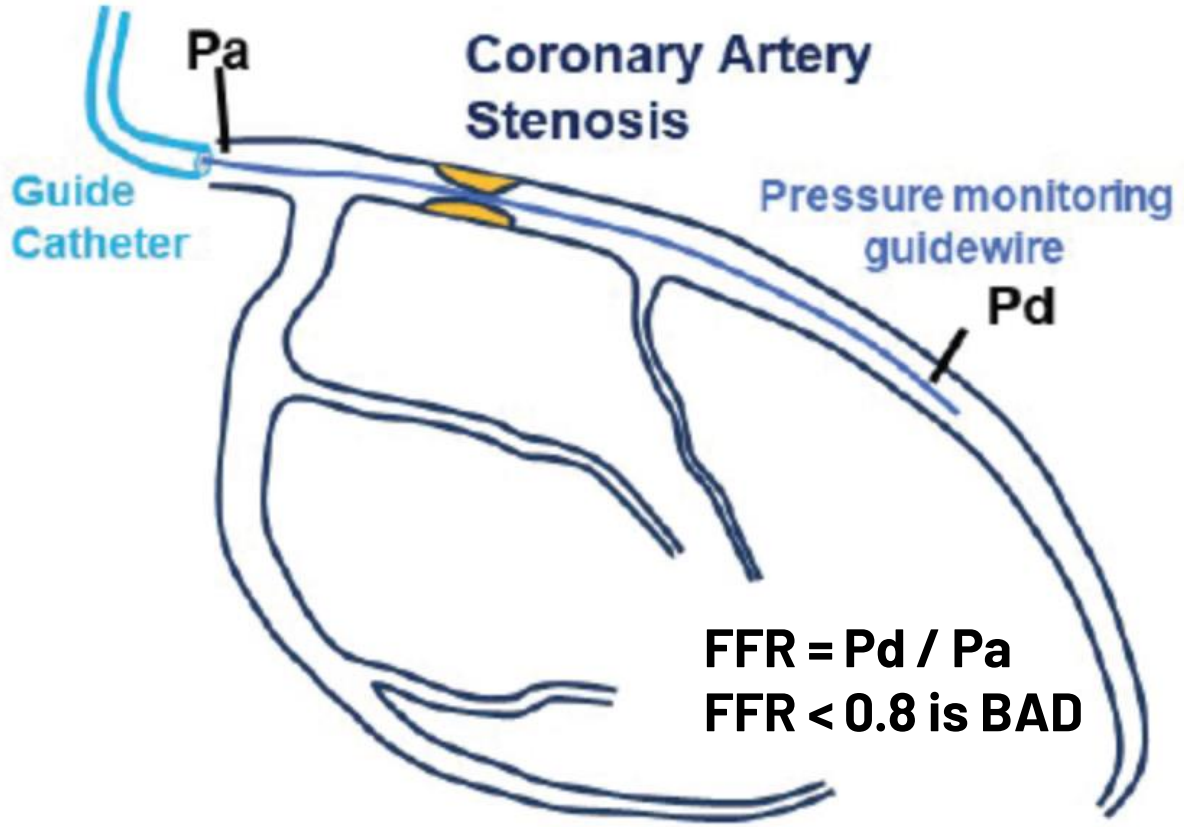

Invasive FFR measurement

Example pressure wire

https://citoday.com/articles/2021-jan-feb/

Challenge: Non-invasive FFR measurment

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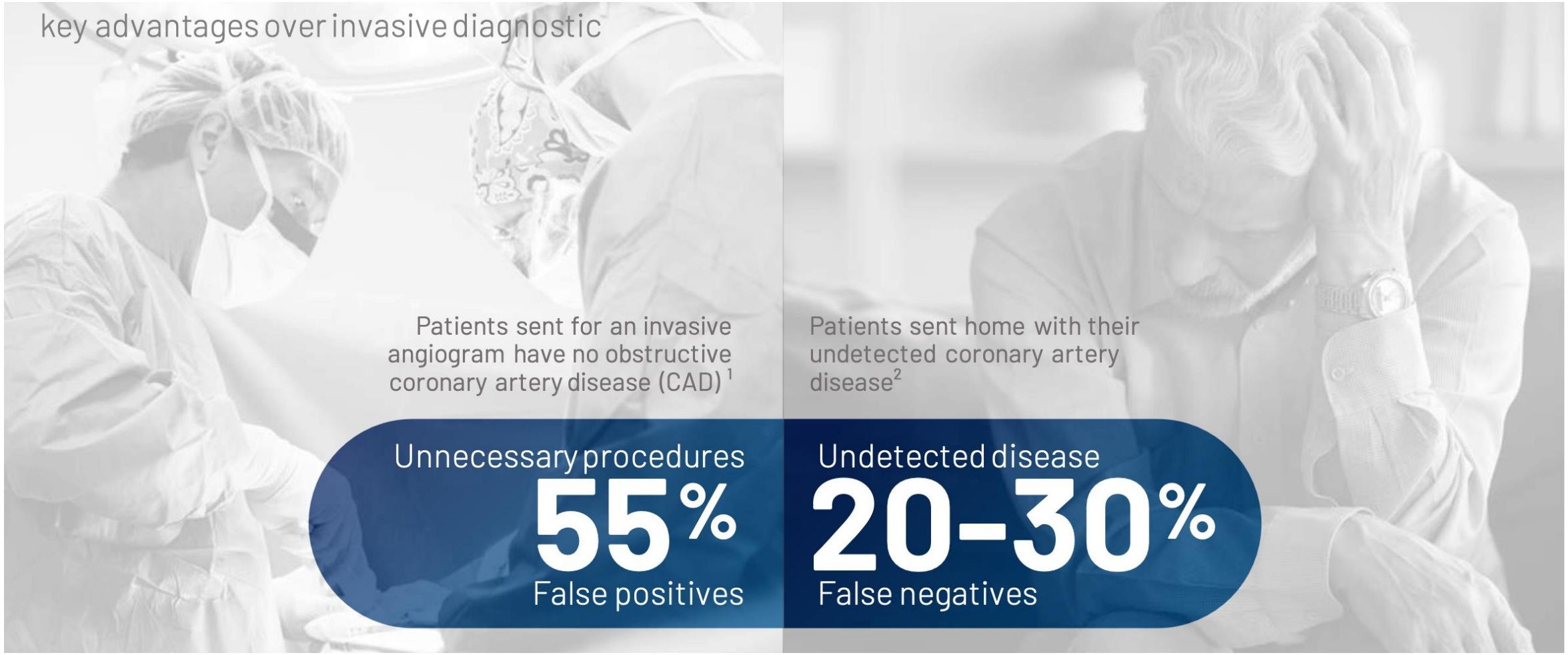

1. Patel, et al. N Engl J Med. 2010. Patel, et al. AHJ 2014. Danad, et al. JAMA Cardiology 2017. 2. Arab-Zadeh, Heart Int 2012. Yokota, et al. Neth Heart J 2018. Nakanishi, et al. J Nucl Cardiol 2018.

Hemolens Diagnostics

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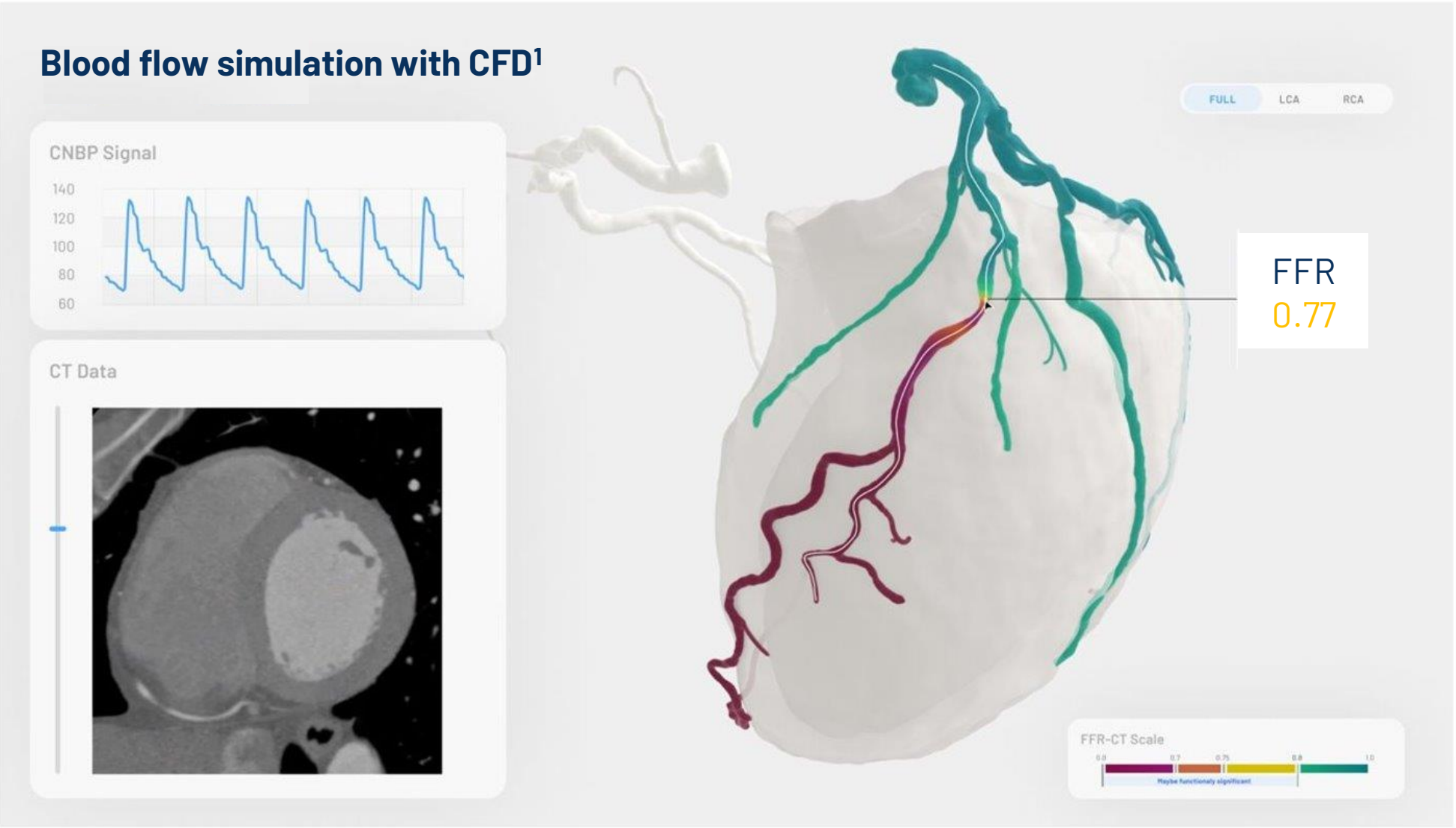
Blood flow simulation with CFD[1]



1. Kosior, A., Mirota, K., & Tarnawski, W. (2019). *U.S. Patent Application No. 16/217,328*

AI R&D in Hemolens Diagnostics

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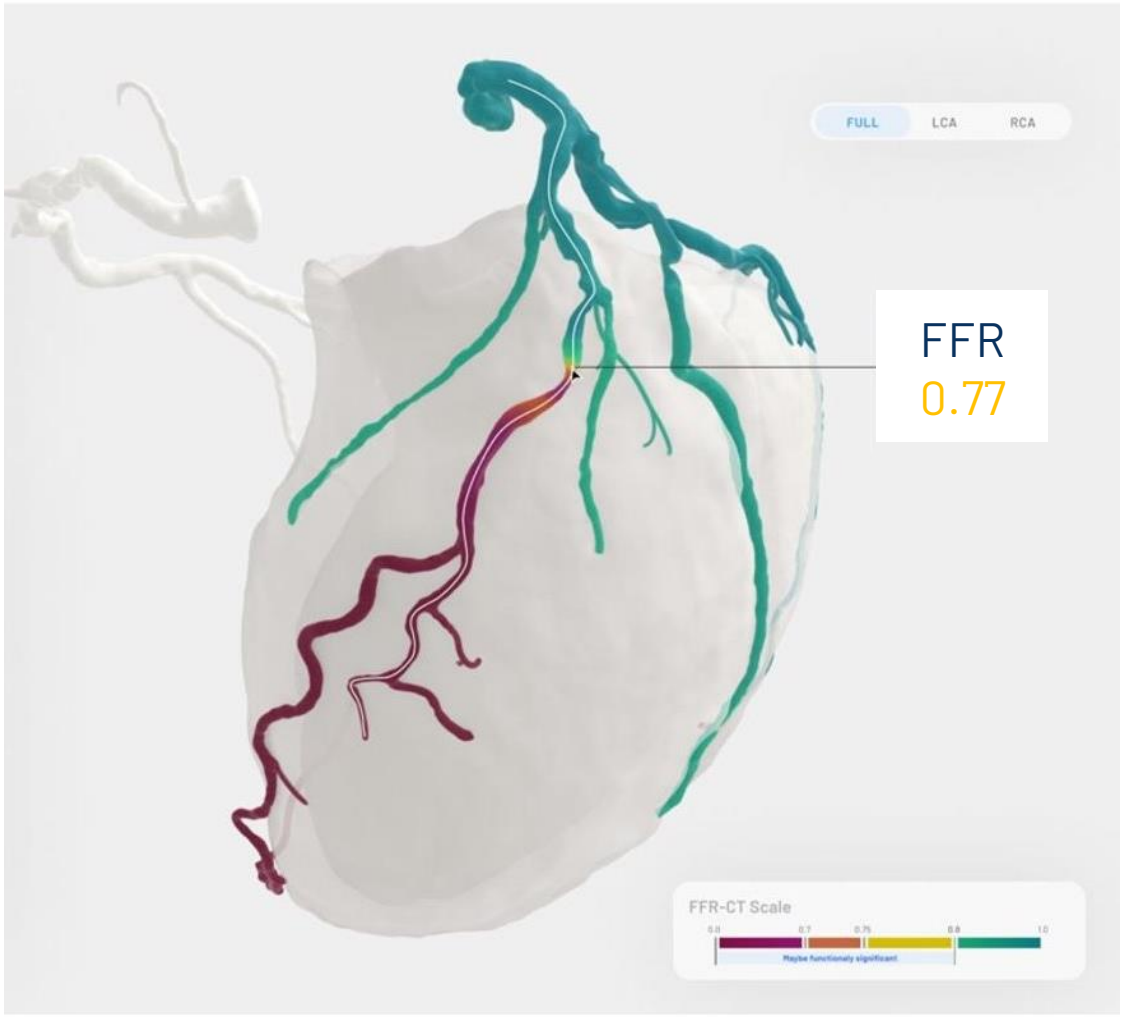

Segmentation:

- Arteries[1],
- Cardiac muscle

Localization:

- Coronary ostia[2]

Computational Geometry:

- Centerline extraction,
- Mesh generation

Challenges:

- FFR estimation with AI[3]

1. Rygiel P., et al. Eigenvector Grouping for Point Cloud Vessel Labeling, GeoMedIA 2023.
2. Gajowczyk M., et al. Coronary Ostia Localization Using Residual U-Net with Heatmap Matching and 3D DSNT, MLMI at MICCAI 2022.
3. Rygiel P., et al. CenterlinePointNet++: A New Point Cloud Based Architecture for Coronary Artery Pressure Drop and vFFR Estimation. MICCAI 2023. Patent pending.

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CenterlinePointNet++: A New Point Cloud Based Architecture for Coronary Artery Pressure Drop and vFFR Estimation

Patryk Rygiel[1], Paweł Płuszka[1], Maciej Zięba[2], Tomasz Konopczynski[1]

1. Hemolens Diagnostics Sp. z o.o.
2. Wroclaw University of Science and Technology

MICCAI 2023

Task: FFR estimation with AI

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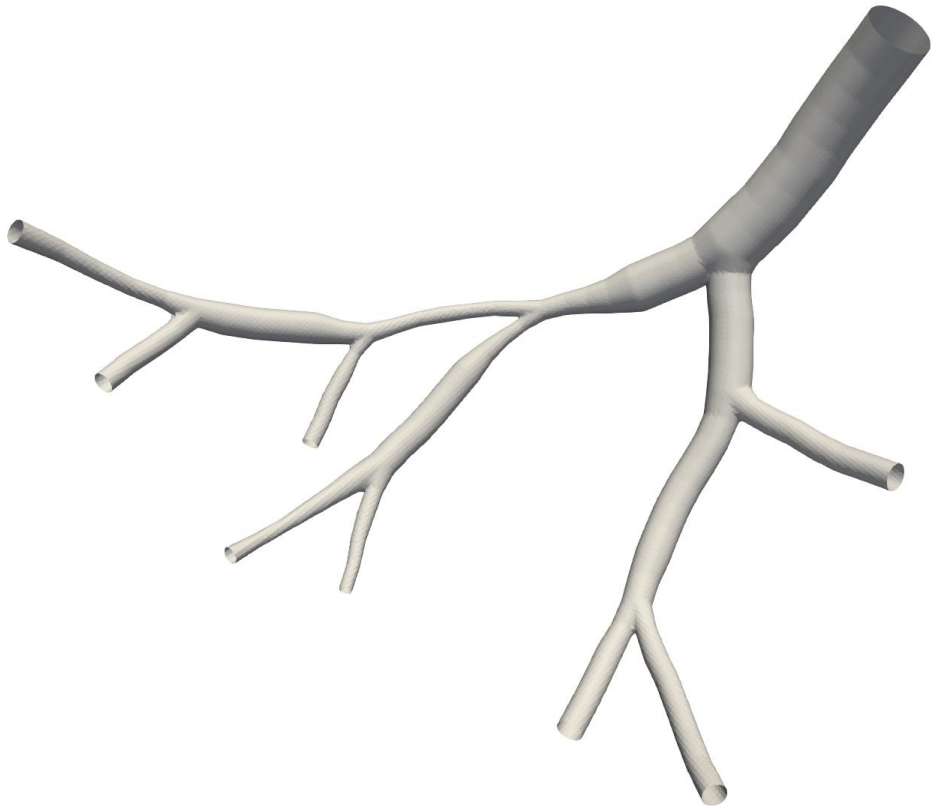
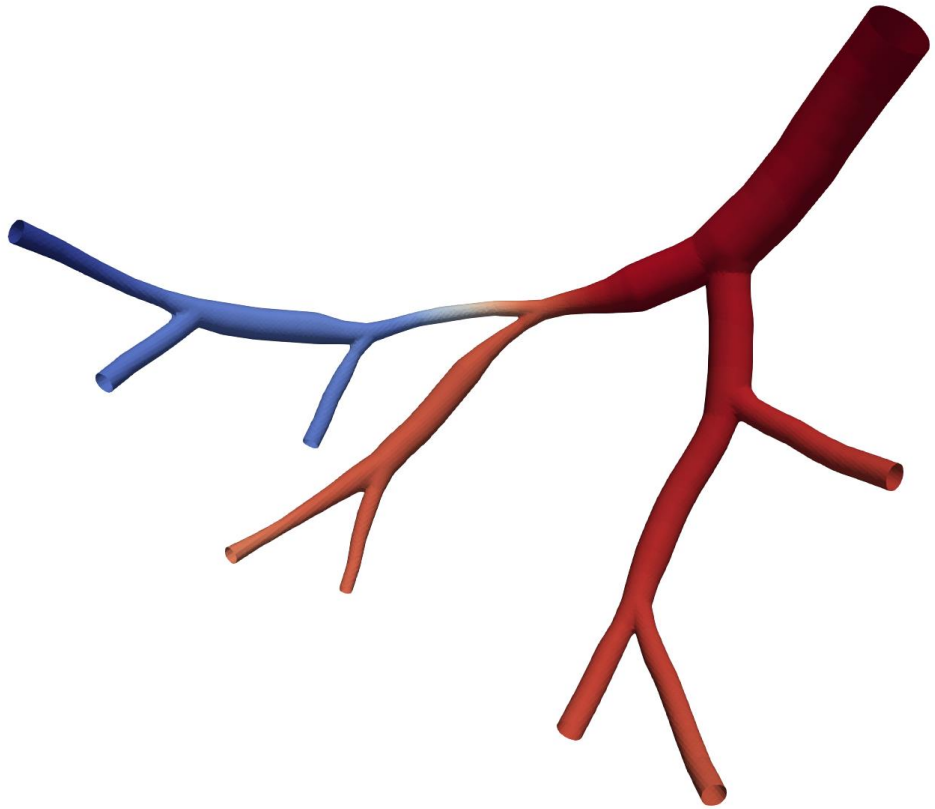


Input mesh + some metadata



FFR estimation

FFR via AI: Siemens

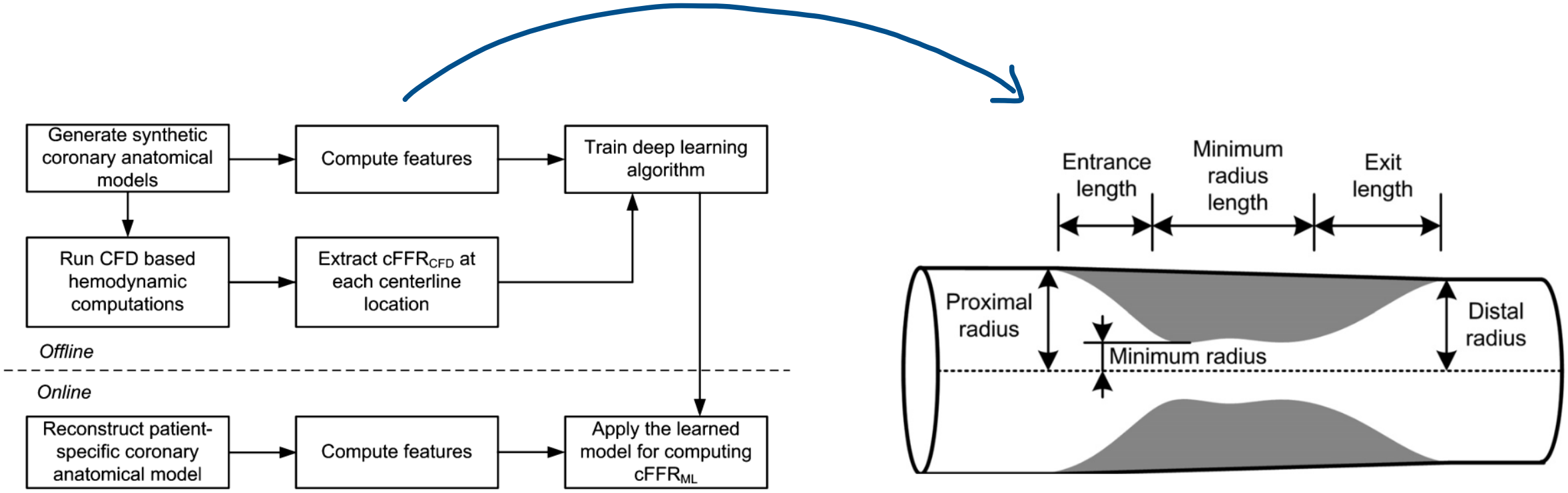
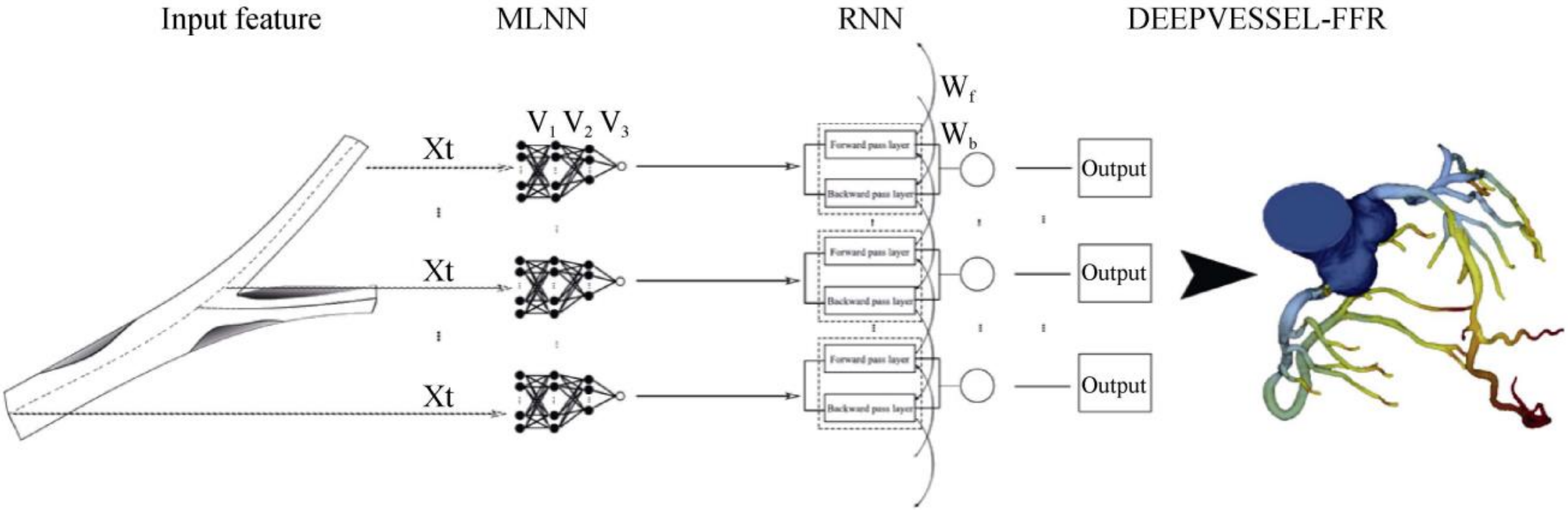


Figure 4.1. Overall workflow of the proposed method.

Lucian Itu et al. "A machine-learning approach for computation of fractional flow reserve from coronary computed tomography", J Appl Physiol 121: 42–52, 2016, doi:10.1152/japplphysiol.00752.2015

FFR via AI: KeyaMedical



Zhi-Qiang WANG et al. "Diagnostic accuracy of a deep learning approach to calculate FFR from coronary CT angiography", Journal of Geriatric Cardiology (2019) 16: 42-48

Our idea – Use of Point Clouds

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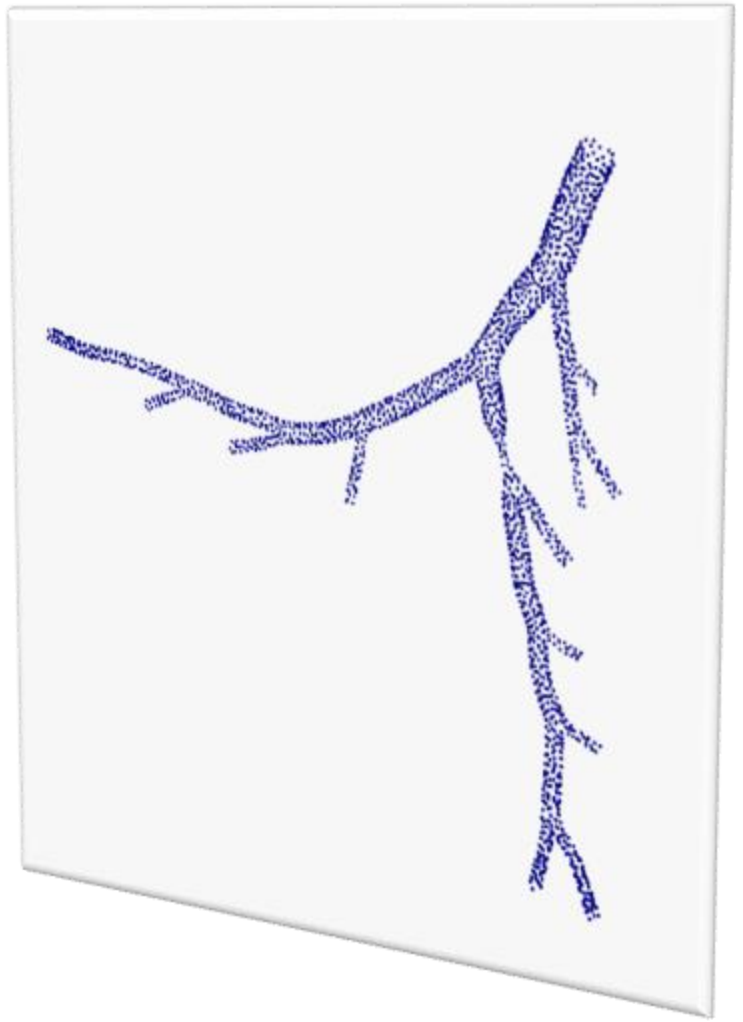
New geometric-based neural network architecture **CenterlinePointNet++** build on top of PointNet++

Multimodal input of **surface point cloud** and a centerline graph

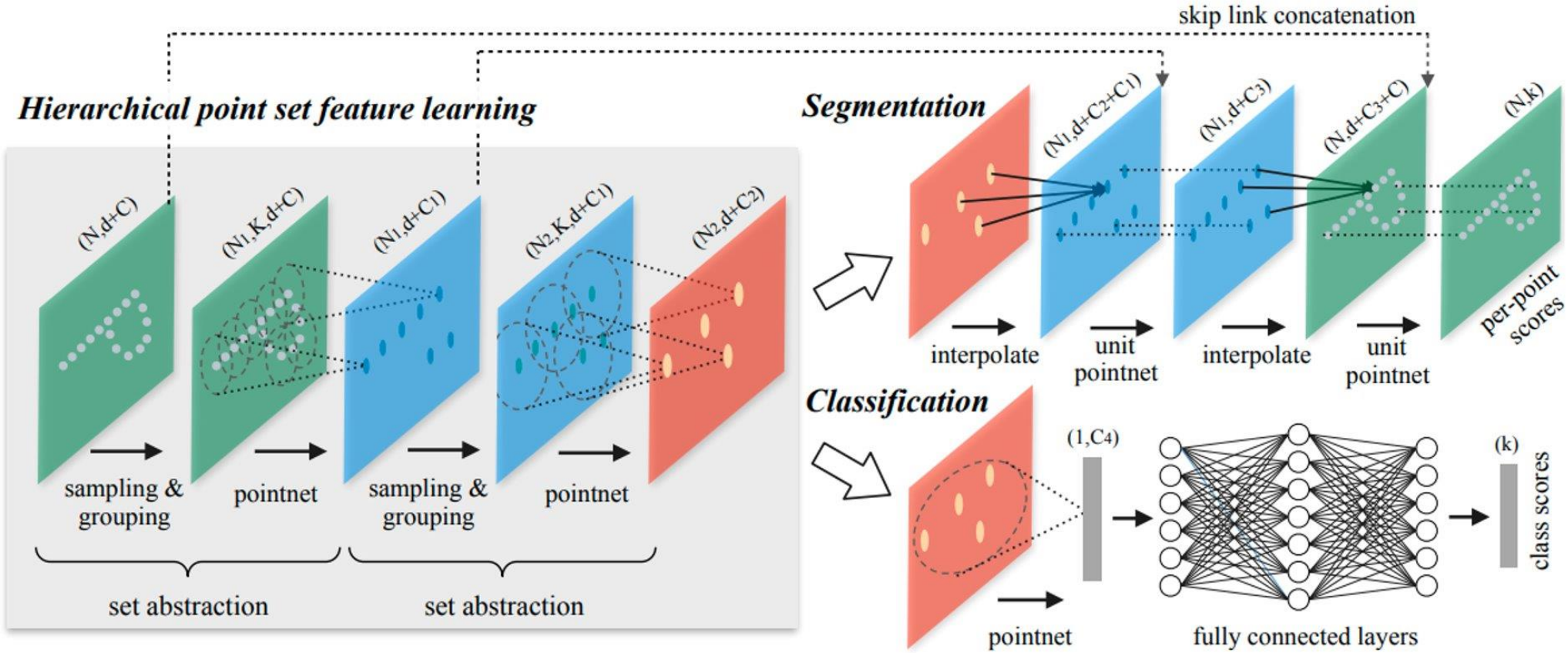
Improvement in the FFR time estimation **from approx. 2h for a CFD simulation to around 15s per coronary artery**

Correlation of 0.93 between CenterlinePointNet++ estimated FFR and a CFD-obtained FFR and **correct diagnosis accuracy of 95%**



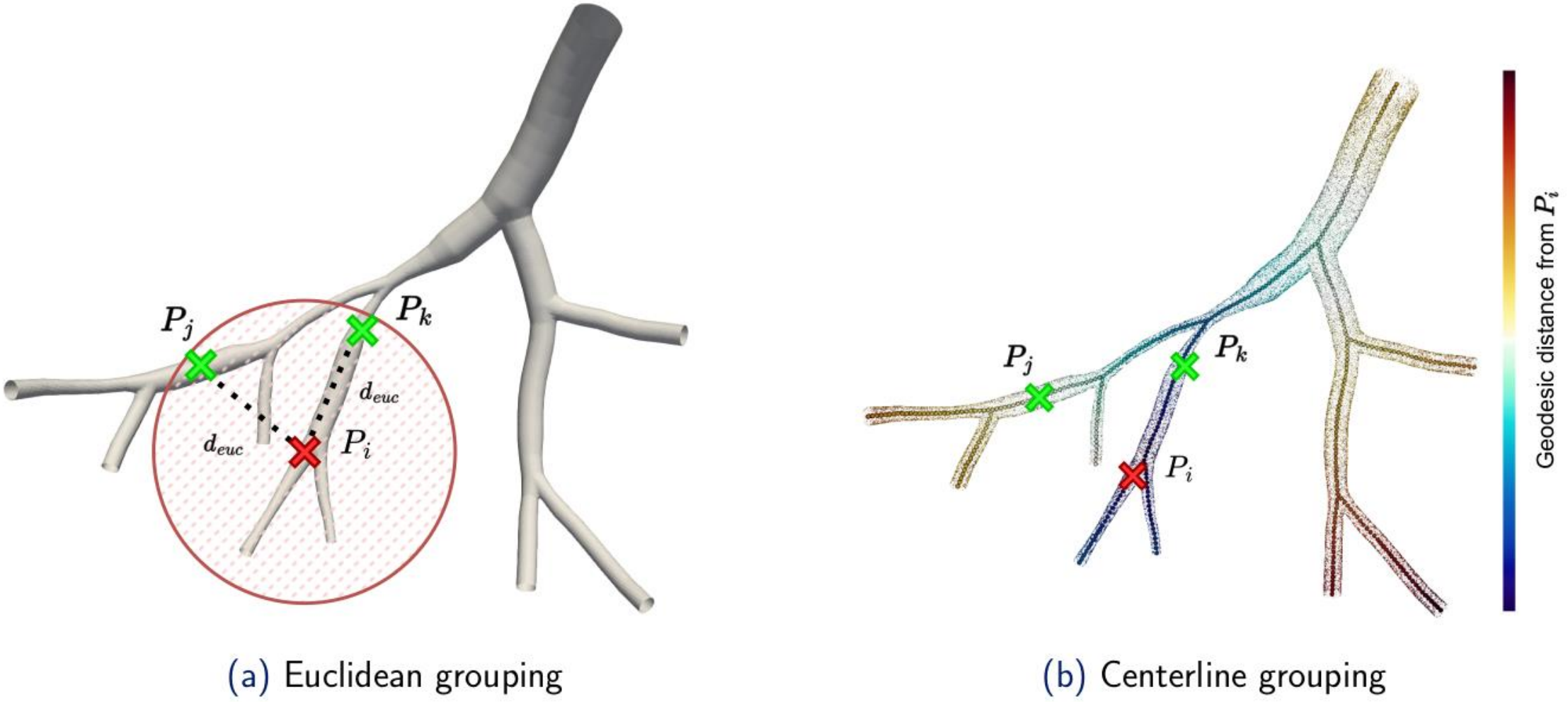
Rygiel P., et al. CenterlinePointNet++: A New Point Cloud Based Architecture for Coronary Artery Pressure Drop and vFFR Estimation. MICCAI 2023.

PointNet++



http://stanford.edu/~rqi/pointnet2/

Centerline grouping



(a) Euclidean grouping

(b) Centerline grouping

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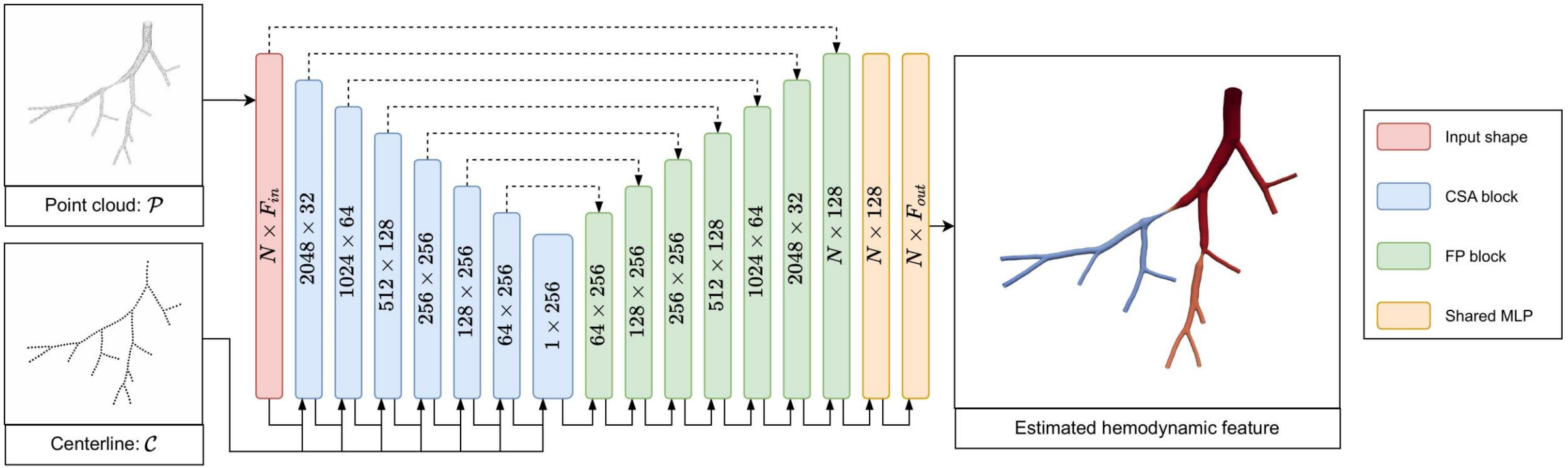
CenterlinePointNet++



Key addition – a novel encoder centerline set abstraction(CSA) block utilizing the centerline grouping procedure

Rygiel P., et al. CenterlinePointNet++: A New Point Cloud Based Architecture for Coronary Artery Pressure Drop and vFFR Estimation. MICCAI 2023.

Experimental data

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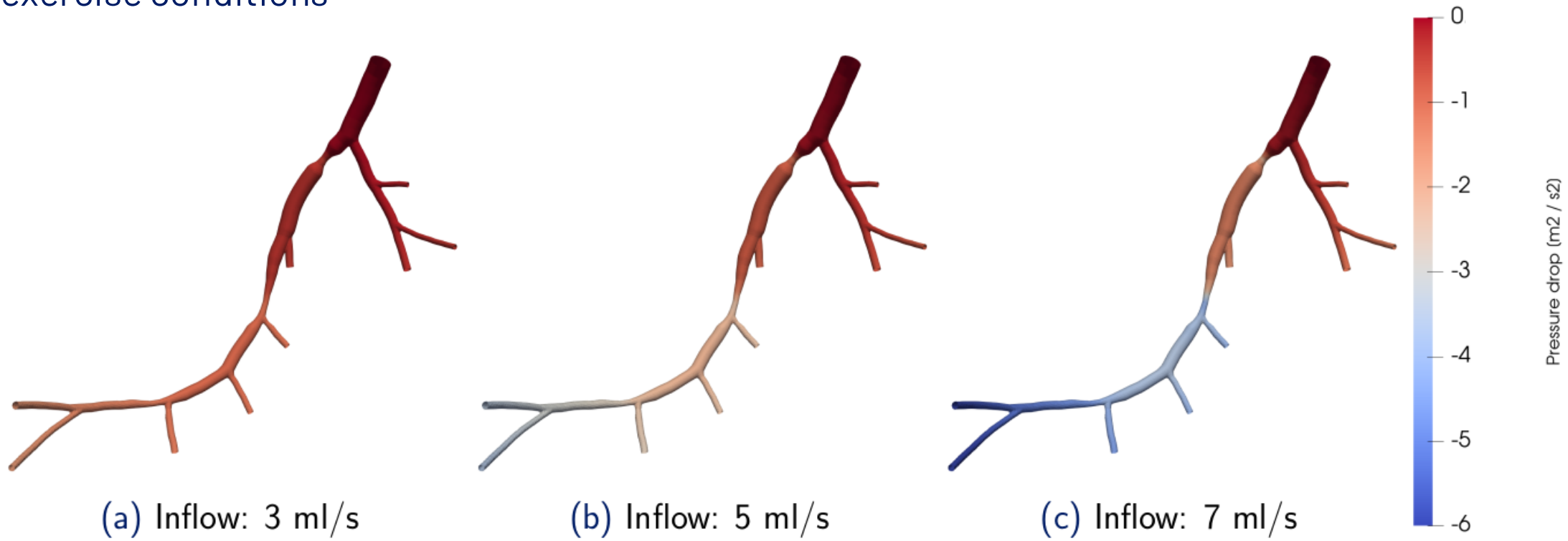
Consists of 1,700 synthetically generated coronary arteries geometries

The GT is a result of a CFD engine designed for blood flow simulation. We sample from a biologically relevant range to simulate a patient under rest, mild exercise and a high-intensity exercise conditions



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Experiments & results

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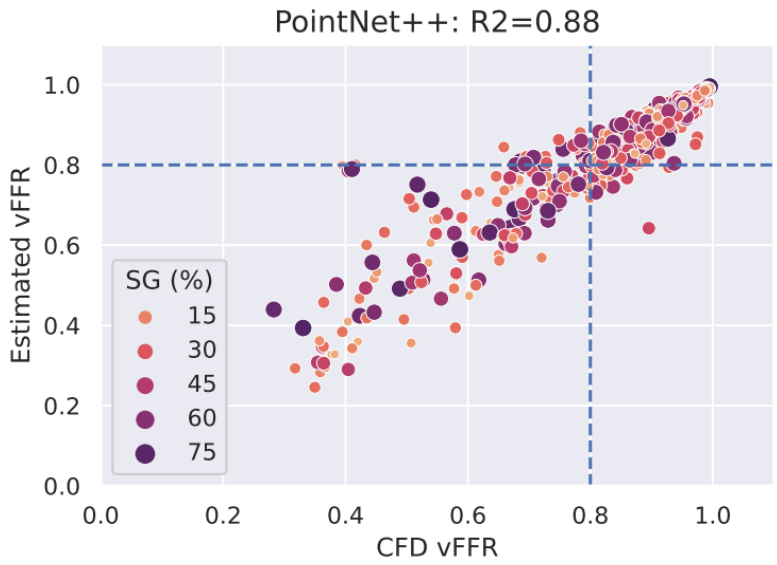
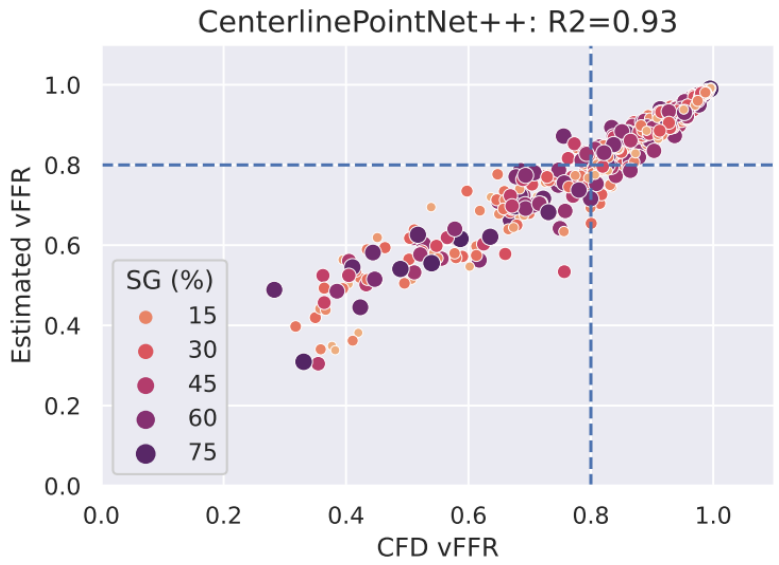
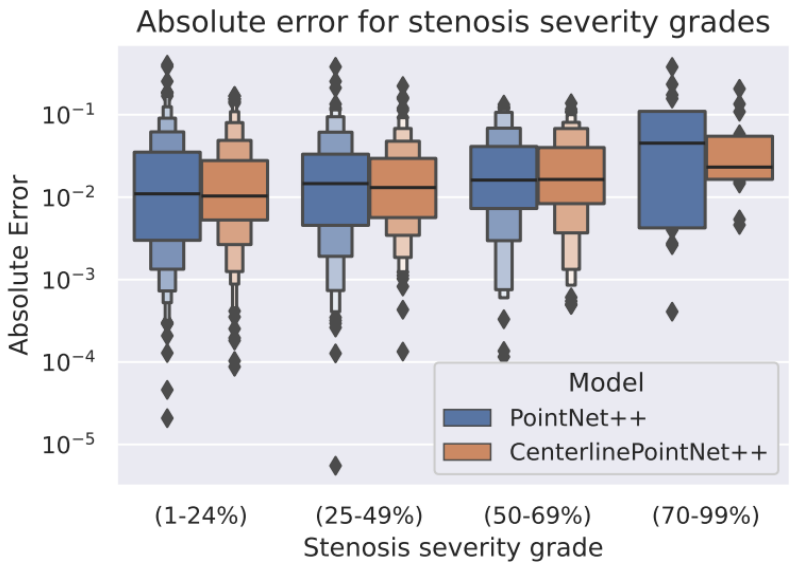
We evaluate estimated vFFR with respect to the stenosis severity grade (SG)

We report the correlation of 0.88 for PointNet++ and 0.93 for CenterlinePointNet++







correct diagnosis accuracy of 95%

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Experiments & results

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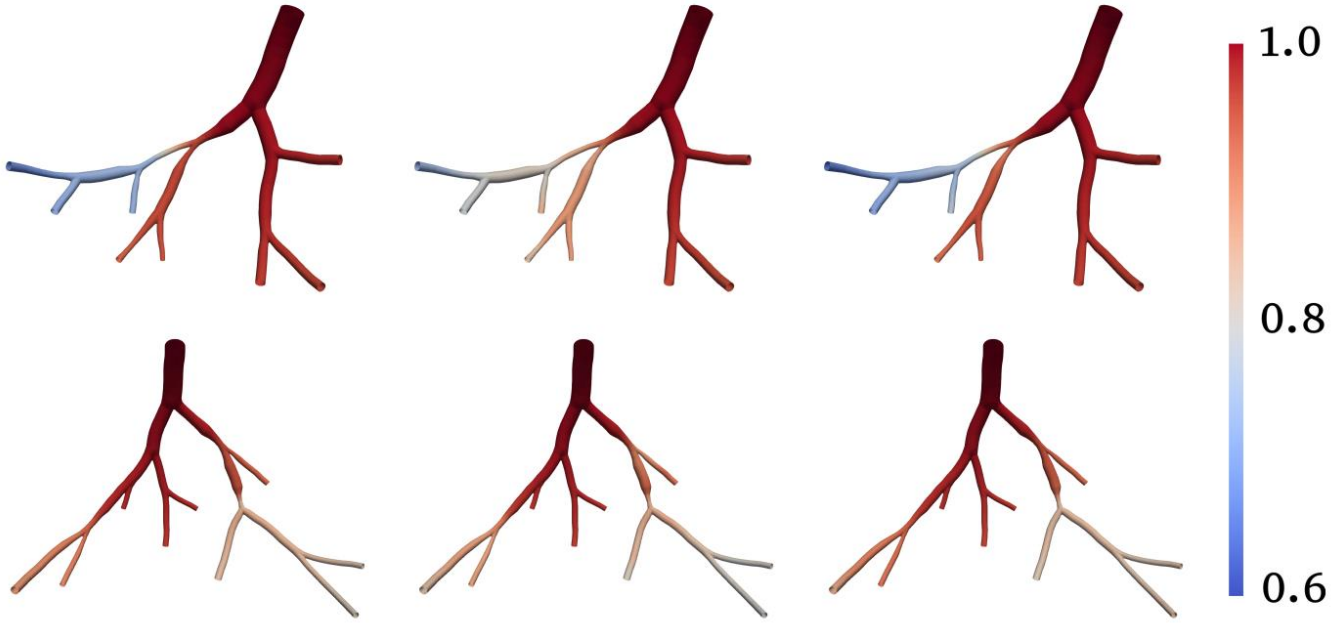
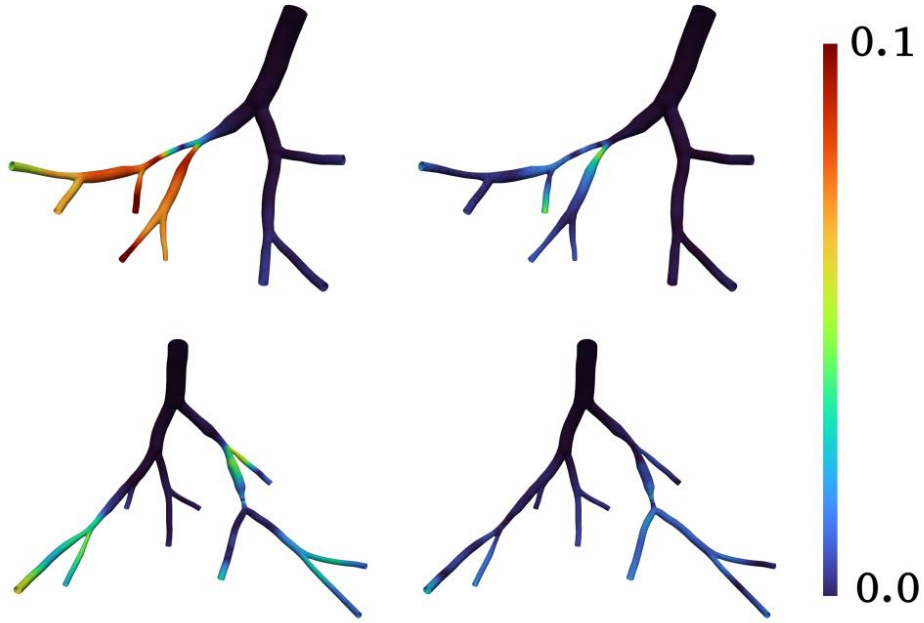
vFFR



CFD (GT) PointNet++ CenterlinePointNet++

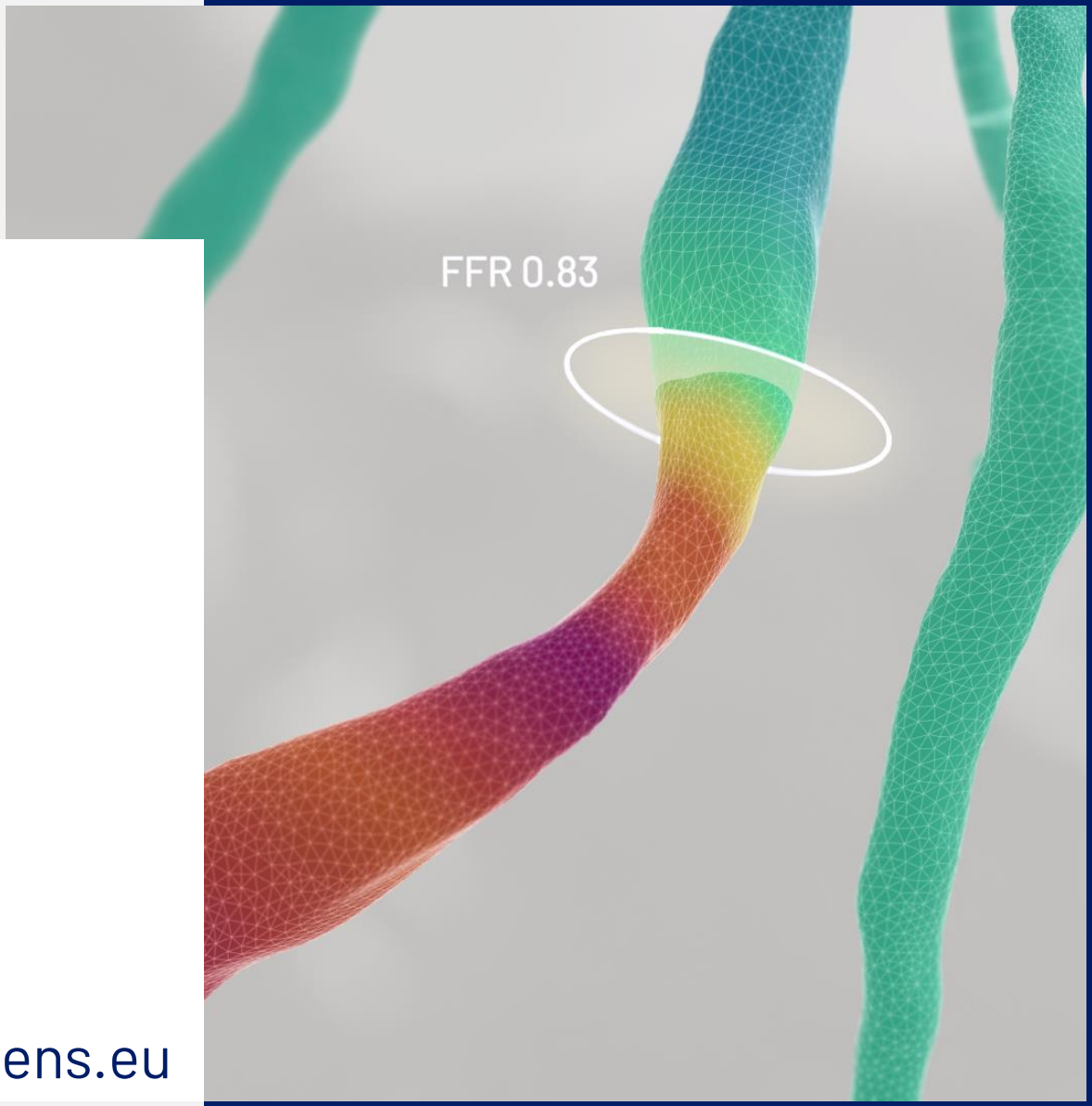
vFFR MAE



PointNet++ CenterlinePointNet++

Rygiel P., et al. CenterlinePointNet++: A New Point Cloud Based Architecture for Coronary Artery Pressure Drop and vFFR Estimation. MICCAI 2023.

HEMOLENS DIAGNOSTICS
to keep you going



Thank you!

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