Role of AI in Cardiac Surgery

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Role of AI in cardiology

Cardiovascular screening

- **Cardiovascular disease** is the primary cause of ***morbidity and mortality*** worldwide. Cardiologists face challenges in ***clinical decision-making*** because of the demands for **better treatment** and the translation of the most recent scientific discoveries into executable strategies.

- The development of ***artificial intelligence (AI)*** in recent decades has allowed **healthcare professionals** to make **more effective** and ***data-driven decisions***.

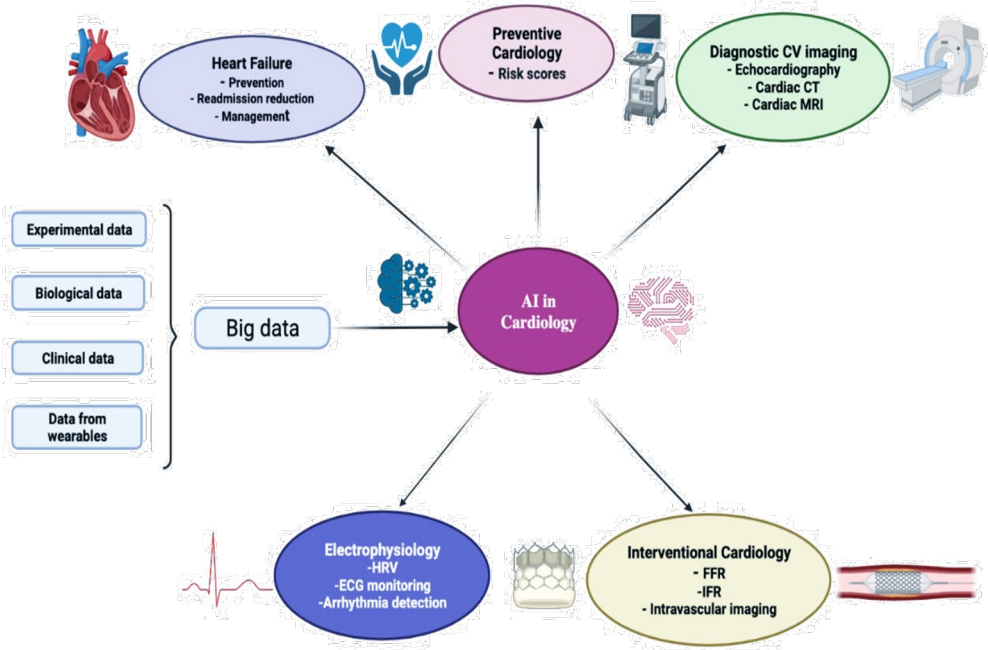
Role of AI in cardiology

Cardiovascular screening

- **AI-based solutions are easily applicable to risk assessment, diagnosis and choice of therapy, procedural guidance, and remote monitoring in CAD patients.**

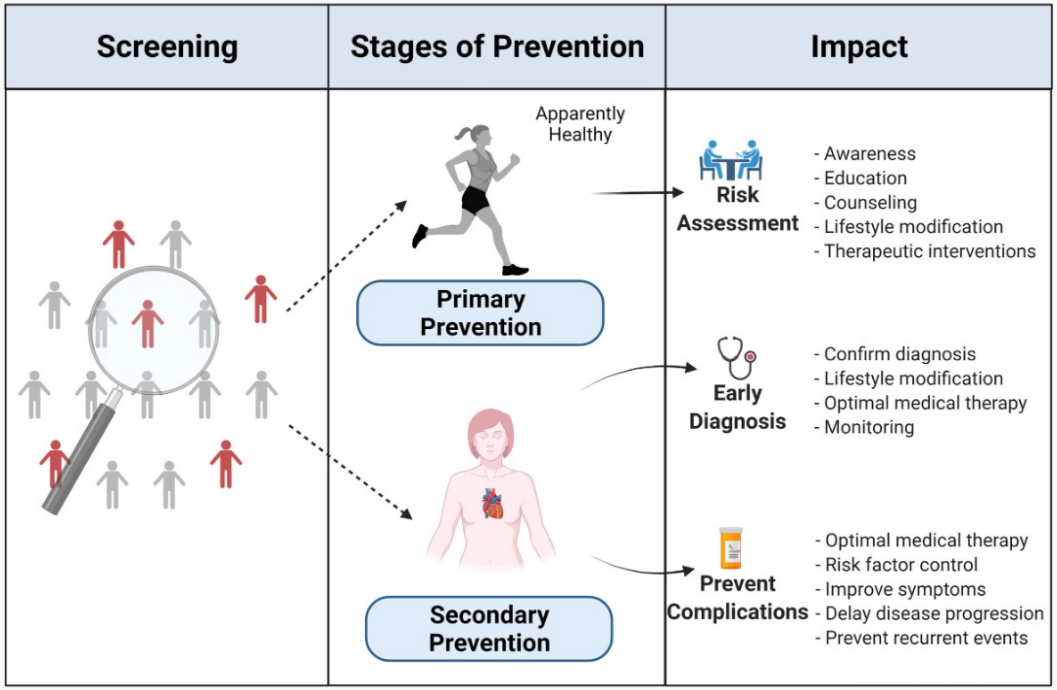
Diagrammatic representation showing the various applications of artificial intelligence in cardiology:

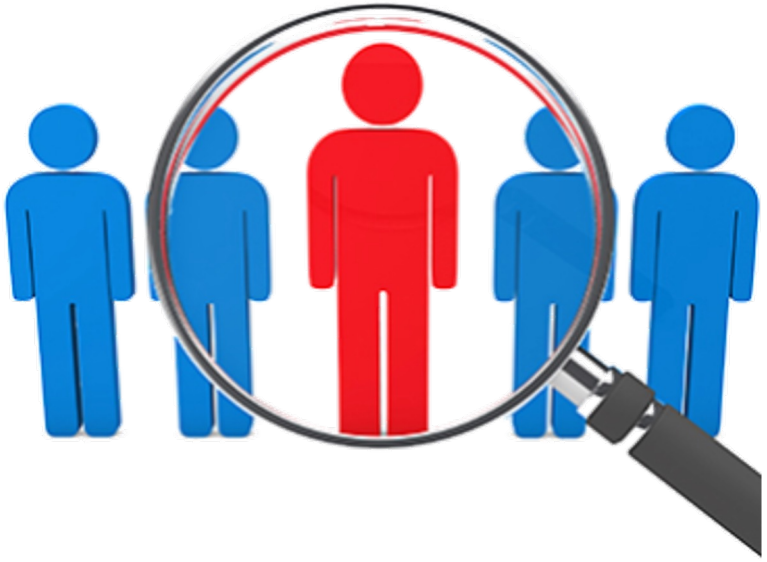
- **Prevention (Risk Score)**
- **Heart Failure**
- **Electrocardiography**
- **Angiography**
- **Cardiac CT and MRI**



Screening of Cardiovascular Disease (CVD)

- Conducting health screenings is a promising strategy for early detection of CVD risk factors with the aim of preventing the onset of CVD or managing CVD for those diagnosed. In particular, ***screenings*** may motivate individuals to seek ***health care*** if they were previously ***unaware of their risk factors***.





System of Cardiovascular Events

Risk assessment is important for different subgroups of CAD patients and guides patient management. In people without known CAD, several tools have been developed and are currently used for the **risk assessment** and **prediction of future cardiovascular event**.

System of cardiovascular events:

- Framingham score, SCORE and SCORE2, as well as the (ACC/AHA) risk tool.
- These tools were derived using traditional statistical methods and show only ***moderate to good discrimination*** in predicting ASCVD outcomes.

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BMJ Open

Use of artificial intelligence to assess the risk of coronary artery disease without additional (non-invasive) testing: validation in a low-risk to intermediate-risk outpatient clinic cohort

Casper G M J Eurlings ,[1,2] Sema Bektas,[2] Sandra Sanders-van Wijk,[3] Andrew Tsirkin,[4] Vasily Vasilchenko,[4] Steven J R Meex,[5,6] Michael Failer,[4] Caroline Oehri,[4] Peter Ruff,[4] Michael J Zellweger,[7] Hans-Peter Brunner-La Rocca[2]

Table 1 Risk class of the thresholds and (expected) prevalence of CAD used for the optimised MPA model, PTP and CAD2 scores

CAD risk classes		MPA model ESC adjusted	PTP score	CAD2 score
Class 1	Very low risk	0%–5%	0%–5%	0%–5%
Class 2	Low risk	5%–70%	5%–15%	5%–15%
Class 3	Medium risk		15%–50%	15%–50%
Class 4	High risk	70%–85%	50%–85%	50%–85%
Class 5	Very high risk	85%–100%	85%–100%	85%–100%

CAD, coronary artery disease; CAD2, CAD consortium clinical; ESC, European Society of Cardiology; MPA, memetic pattern-based algorithm; PTP, pretest probability.

Participants:

Included 696 patients. CAD was defined by a **coronary stenosis > 50%** in at least one coronary vessel in **invasive coronary or CTA**, or having a coronary event within 6 months.

Outcome:

The first cohort validating **pattern-based algorithm (MPA) model** developed in two high-risk populations in a low-risk to **intermediate-risk cohort** to improve risk stratification for non-invasive diagnosis of the presence or absence of CAD.

Reference: validation in a low- risk to intermediate- risk outpatient clinic cohort. BMJ Open 2022;12:e055170. doi:10.1136/ bmjopen-2021-055170.

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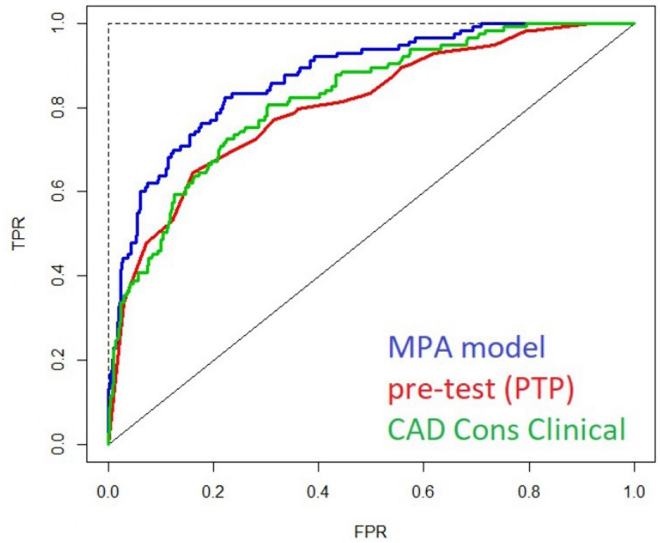


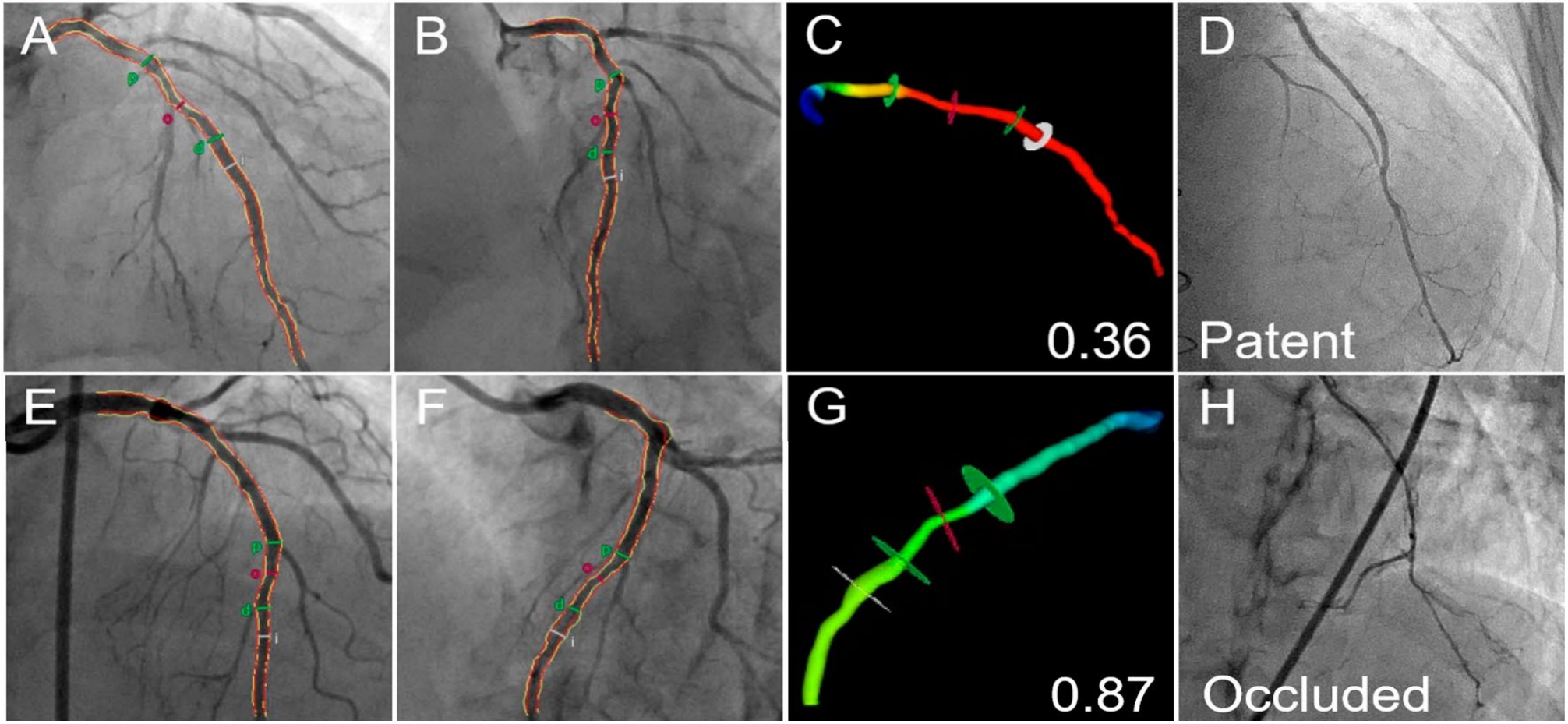
	MPA model ESC adjusted >5%	PTP score >15%	CAD2 score >15%
AuROC	0.87	0.80	0.82
AuROC 95% CI	0.84 to 0.91	0.76 to 0.85	0.79 to 0.85
Sensitivity	82.3%	87.6%	88.5%
Specificity	77.4%	45.6%	50.8%
PPV	41.3%	23.8%	25.8%
NPV	95.8%	95.0%	95.8%
FPR	22.6%	54.4%	49.2%

Conclusion:

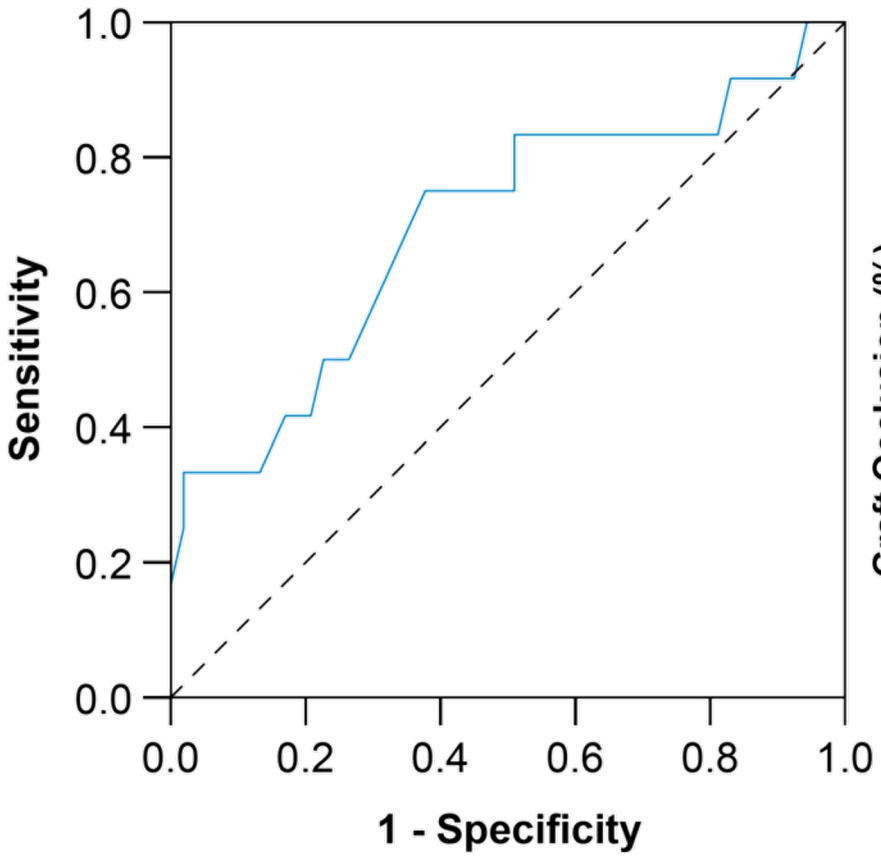
In this **low - risk** to **intermediate - risk** population, the **MPA model** provides a good **risk stratification** of presence or absence of **coronary artery disease (CAD)** with a better ROC compared with **traditional risk scores**. The results are promising but need prospective confirmation.

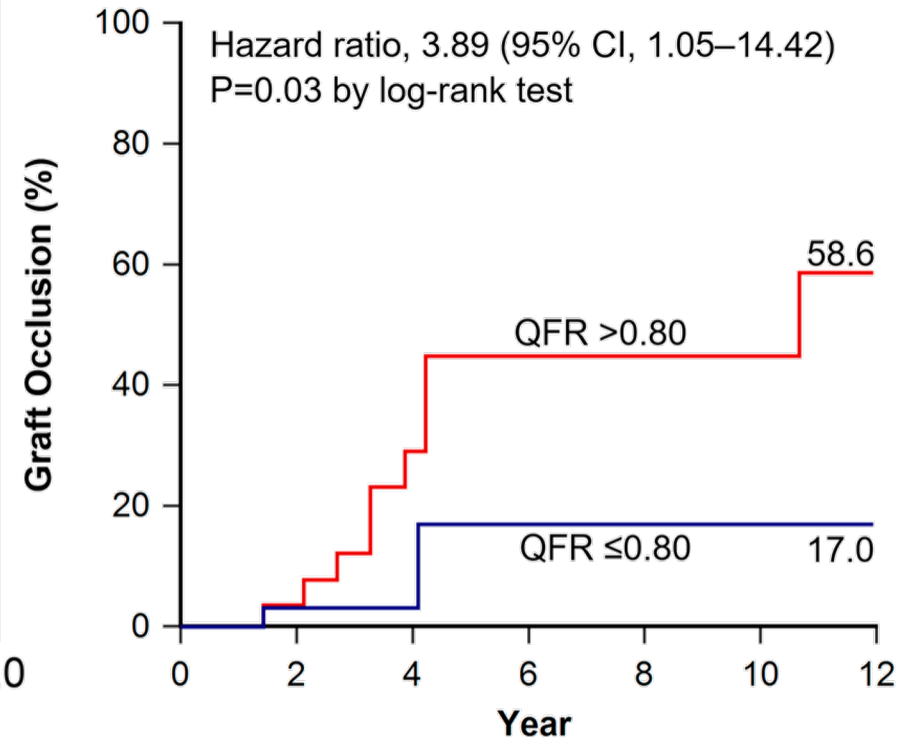
Reference: validation in a low- risk to intermediate- risk outpatient clinic cohort. BMJ Open 2022;12:e055170. doi:10.1136/ bmjopen-2021-055170.

AI Analysis in Graft Patency



Discriminatory Power of AI to Predict Graft Occlusion

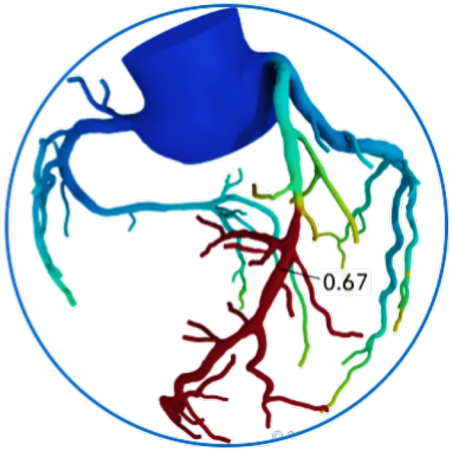




CT FFR (AI & CFD)

- The path to **diagnosing coronary artery disease (CAD)** hasn't always been clear or reliable.
- The pathway begins with a CCTA. If the physician sees disease, the CCTA images are sent to **computational center**, where **AI algorithms**, **computational fluid dynamics** and trained analysts create the **FFRCT Analysis**.
- This personalized model of a patient's coronary arteries provides **functional information** about each blockage.

+



The IMPACT

PATIENTS

The CT+FFRCT pathway will:

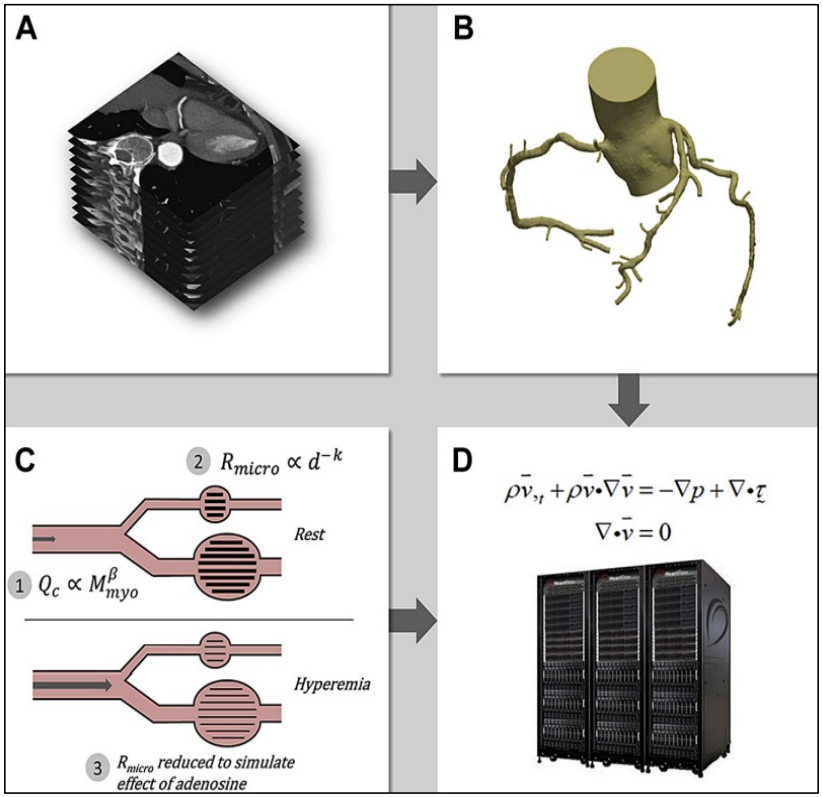
- Provide a clearer picture of their heart health
- Help explain symptoms, providing peace of mind
- Minimize hospital visits necessitated by repetitive cardiac testing
- Limit testing-related radiation exposure

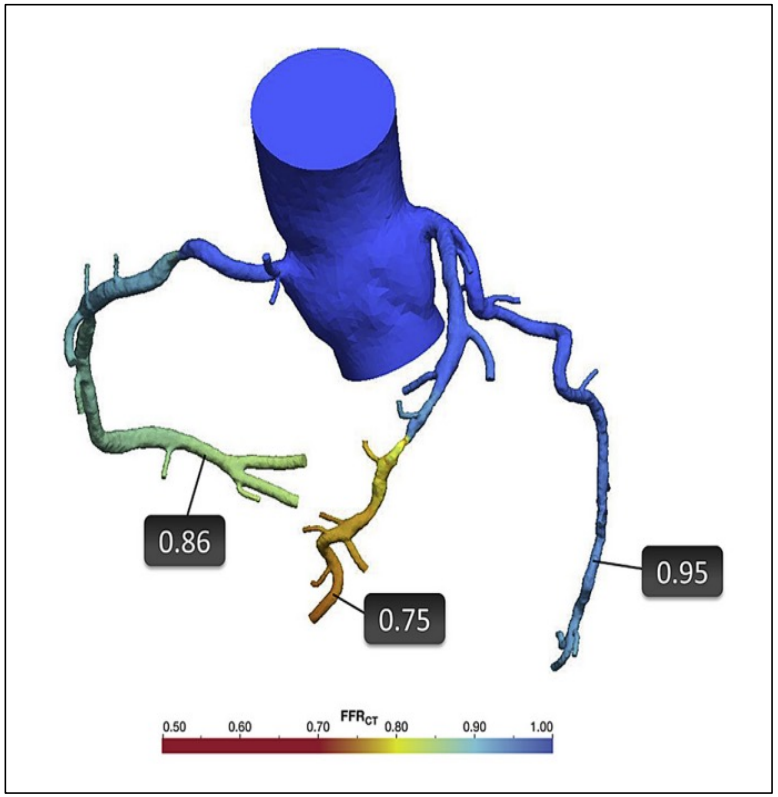
PHYSICIANS

The CT+FFRCT pathway will:

- Provide the highest diagnostic accuracy
- Diagnose CAD that can be missed by stress tests
- Reduce diagnostic Cath labs not resulting in revascularization

Routine coronary computed tomography angiography data are received. A quantitative 3-dimensional anatomic model is generated.





PRECISE Trial Rewrites the Patient Pathway

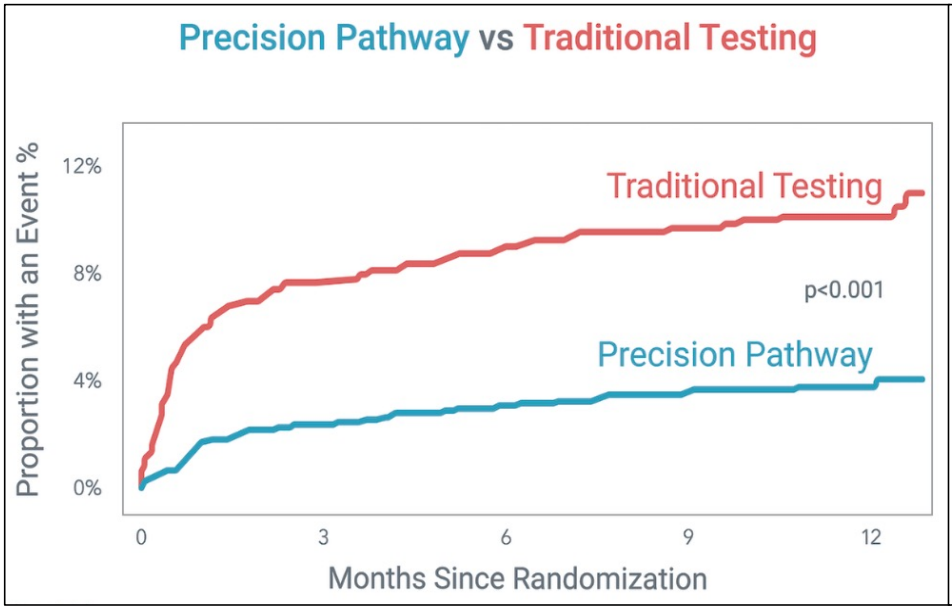
Helping physicians get the right patient, the right care at the right time.

This image is not an accurate representation of the HeartFlow product

دانشگاه علوم پزشکی و خدمات بهداشتی، درمانی ایران

1-Year Primary Endpoint Results

The Precision Pathway, centered around CCTA + FFRCT, achieved its primary endpoint by significantly reducing the composite of all-cause death, nonfatal MI, or catheterization without obstructive disease relative to Traditional Testing at 1 year.



Precision Pathway compared to Traditional Testing:

65
Global Sites

2,103
Patients

Adjudicated
Core Lab, CEC[2]

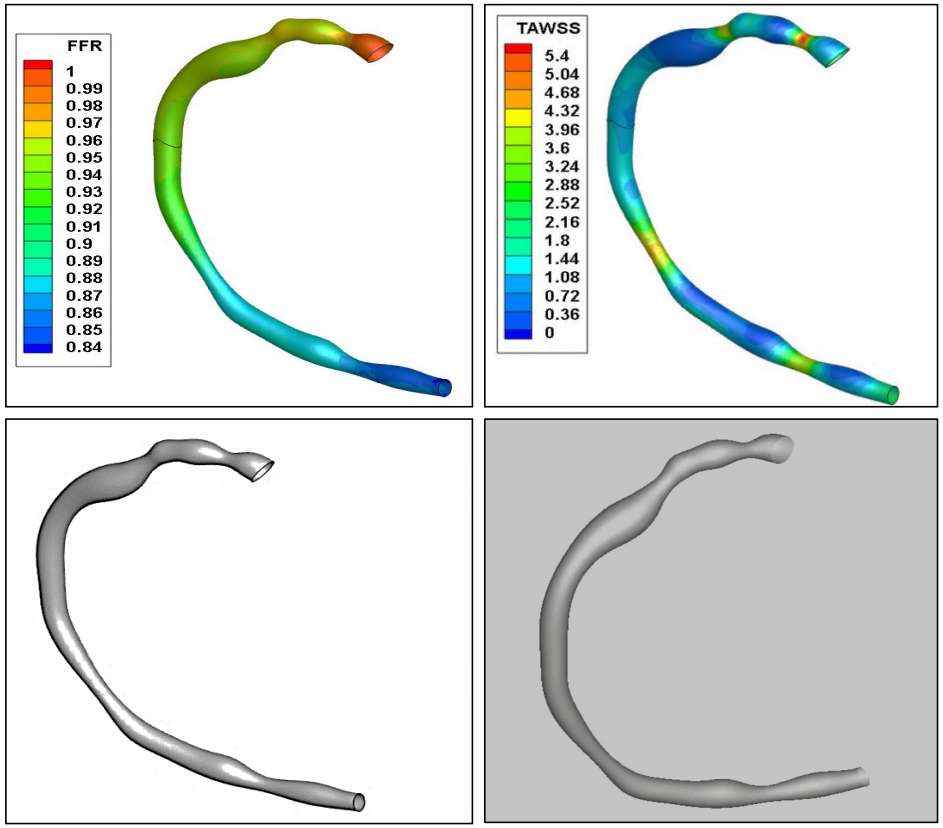
Precision Pathway	Traditional Testing
Risk scoring to defer testing for low-risk patients.[3]	**Functional testing** (stress nuclear and stress echo) and **Invasive Coronary Angiography** (ICA).
CCTA with selective FFR_{CT}[4] for elevated risk patients.	

Mathematical Equations

Hemodynamic Parameters:

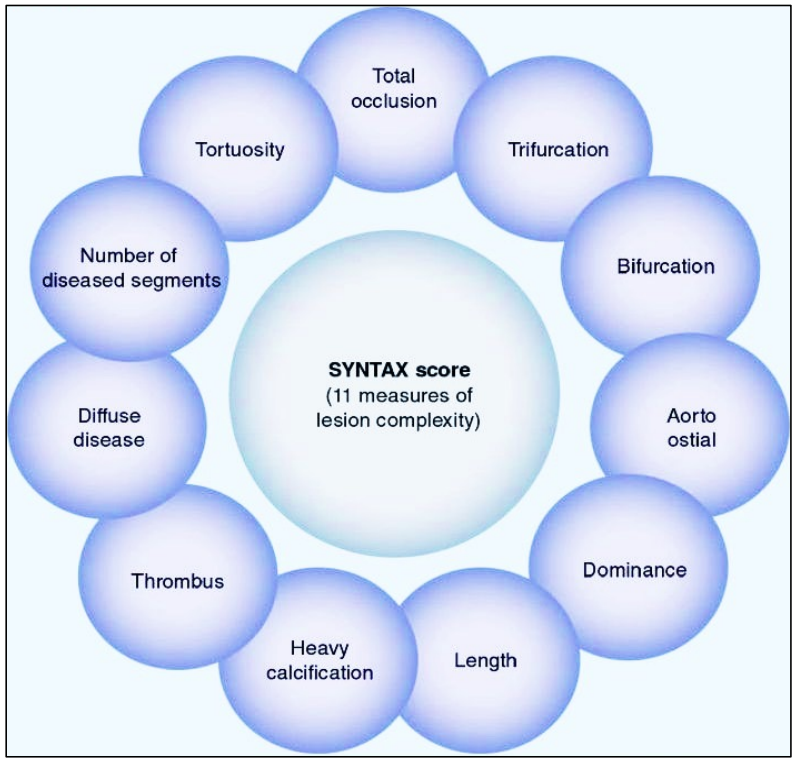
- Wall Shear Stress (WSS)
- Fractional Flow Reserve (FFR)
- Index of Microvascular Resistance (IMR)

Wall shear stress (WSS) and other hemodynamic parameters play a **fundamental role** in the development of atherosclerosis in the coronary arteries. **High WSS** causes the **rupture of fatty plaques** and Low WSS increases atherosclerosis.

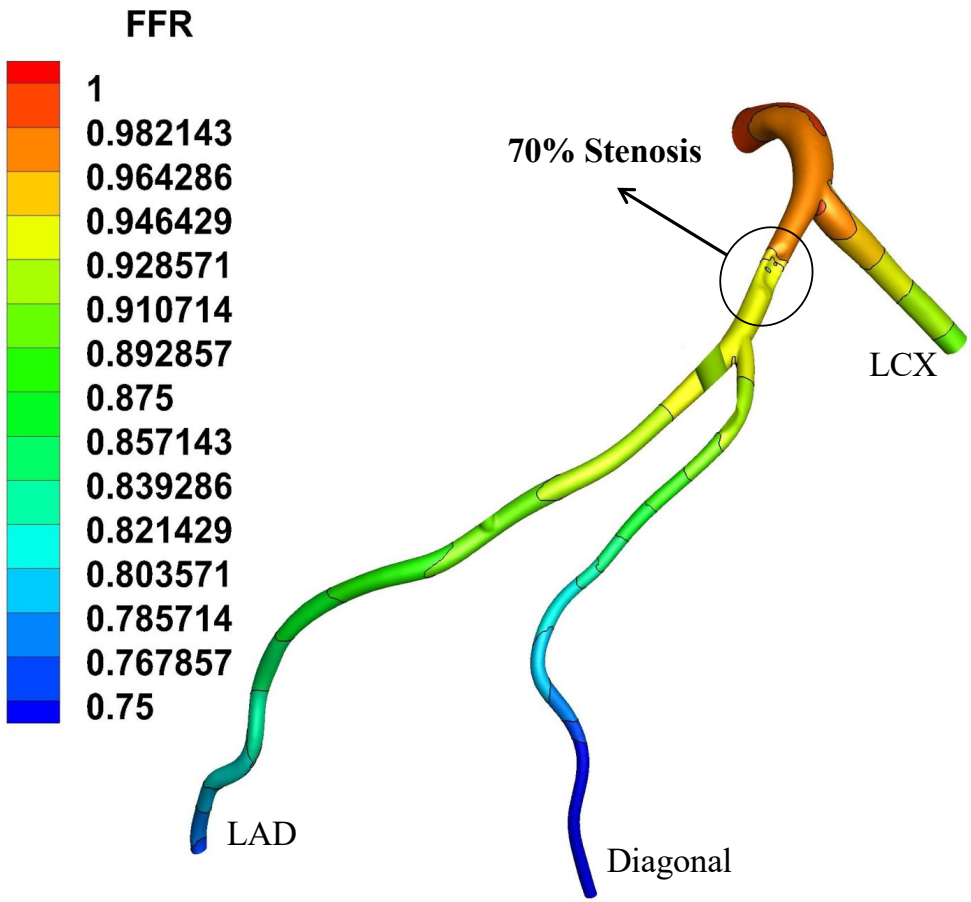


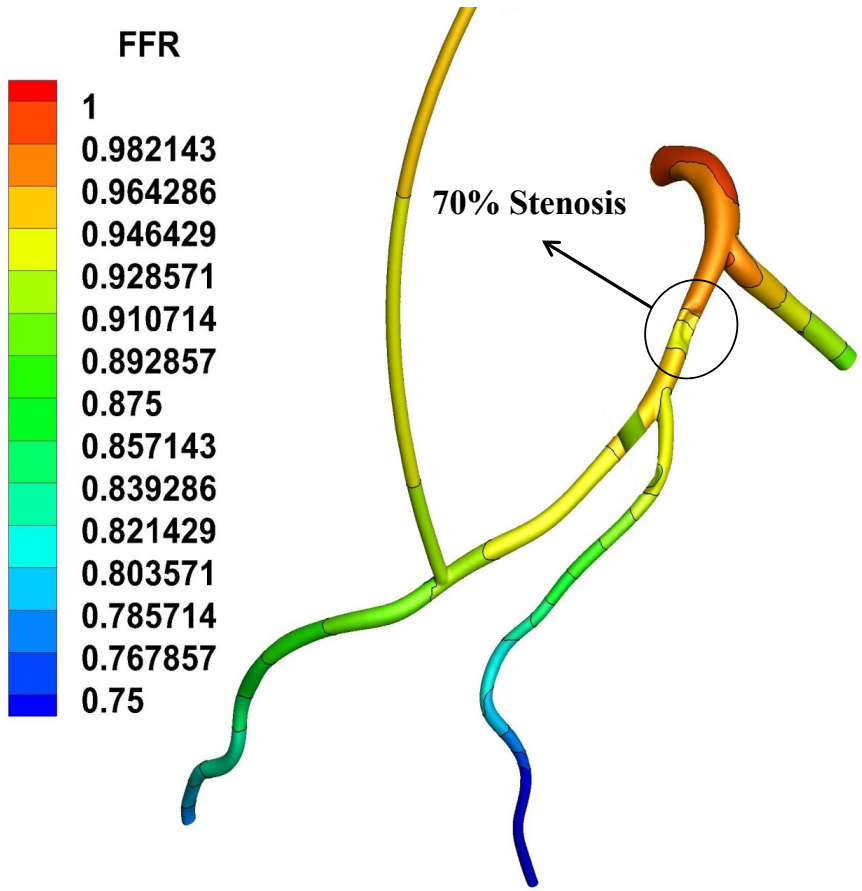
Functional Syntax Score (FSS)

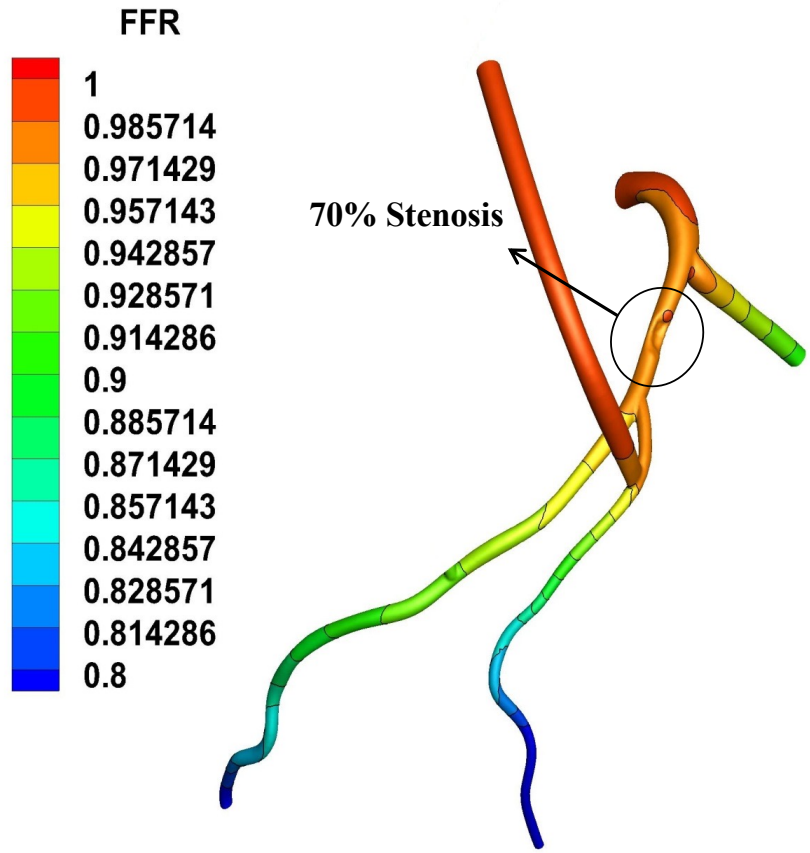
- Anatomical Synergy Between PCI With TAXUS and CABG Surgery (SYNTAX) Score combined with clinical characteristics play a decisive role when deciding on the revascularization strategy.
- SYNTAX Score with functionally significant lesions (FFR ≤0.8) was associated with improved clinical outcomes.
- Functional SS (FSS) integrates SS and FFR (SS is only calculated in vessels with low FFR), thereby providing both anatomic and functional information.
- Compared with SS, FSS had better discriminant ability in predicting clinical outcomes.

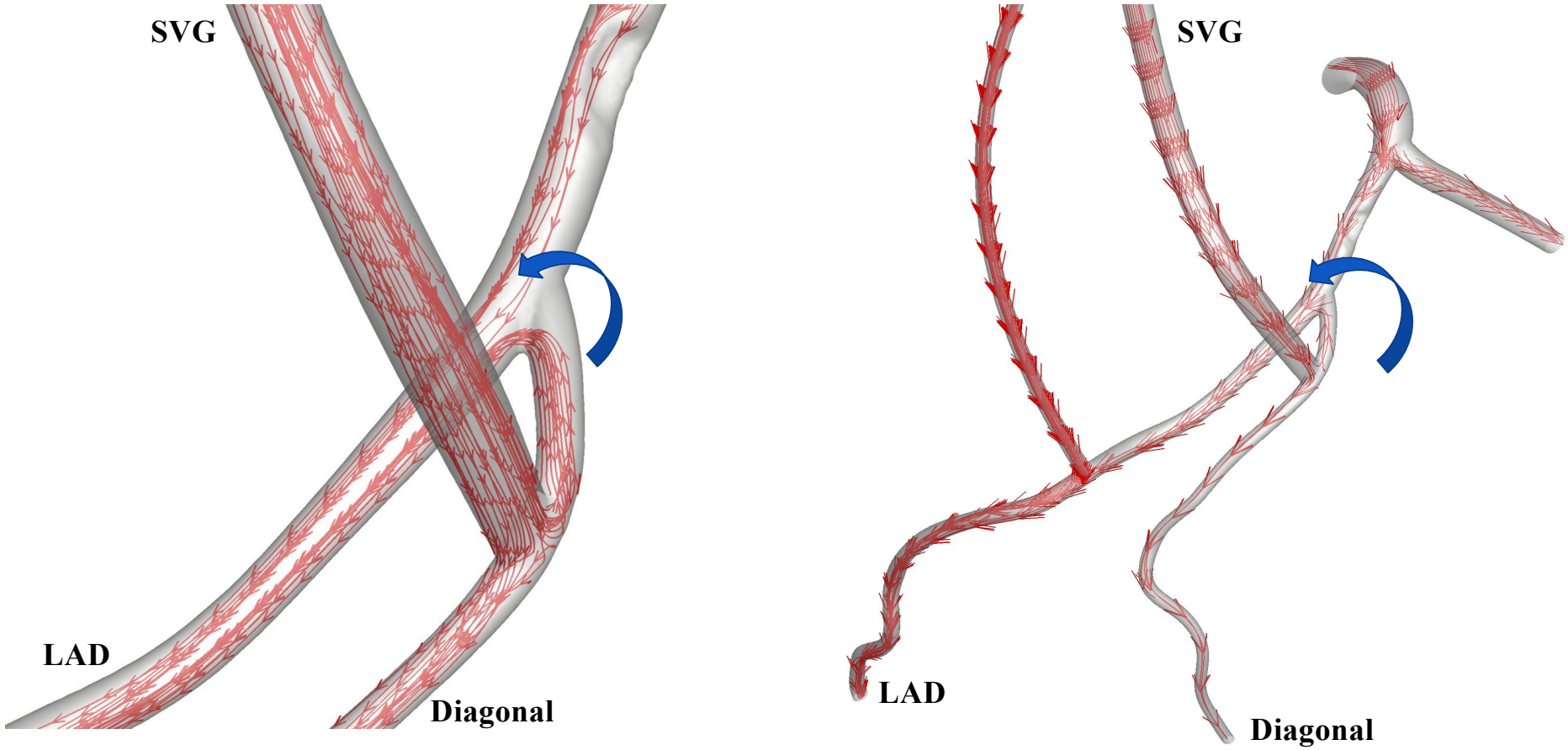


Model. 2


FFR
1
0.982143
0.964286
0.946429
0.928571
0.910714
0.892857
0.875
0.857143
0.839286
0.821429
0.803571
0.785714
0.767857
0.75
70% Stenosis
LCX
LAD
Diagonal


FFR
1
0.982143
0.964286
0.946429
0.928571
0.910714
0.892857
0.875
0.857143
0.839286
0.821429
0.803571
0.785714
0.767857
0.75
70% Stenosis

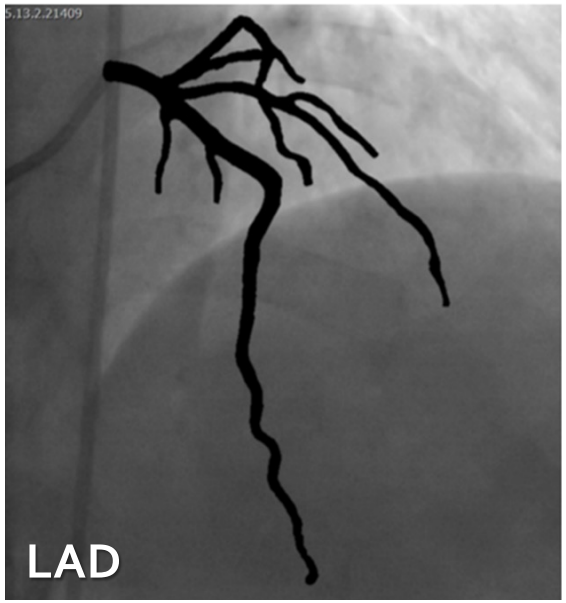

FFR
1
0.985714
0.971429
0.957143
0.942857
0.928571
0.914286
0.9
0.885714
0.871429
0.857143
0.842857
0.828571
0.814286
0.8
70% Stenosis

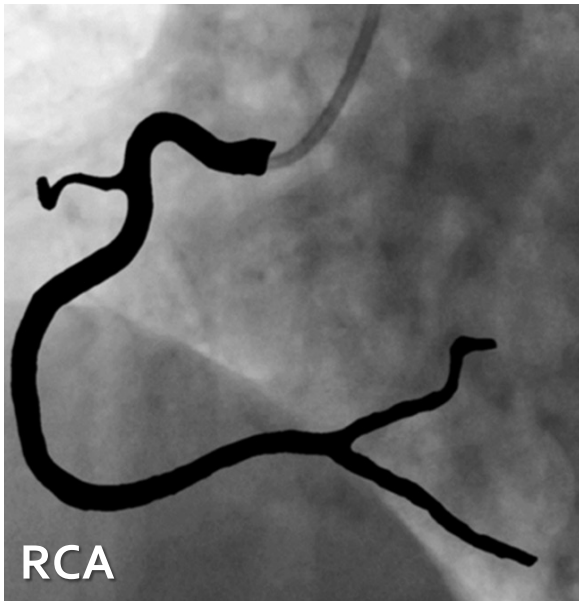

SVG
LAD
Diagonal
SVG
LAD
Diagonal

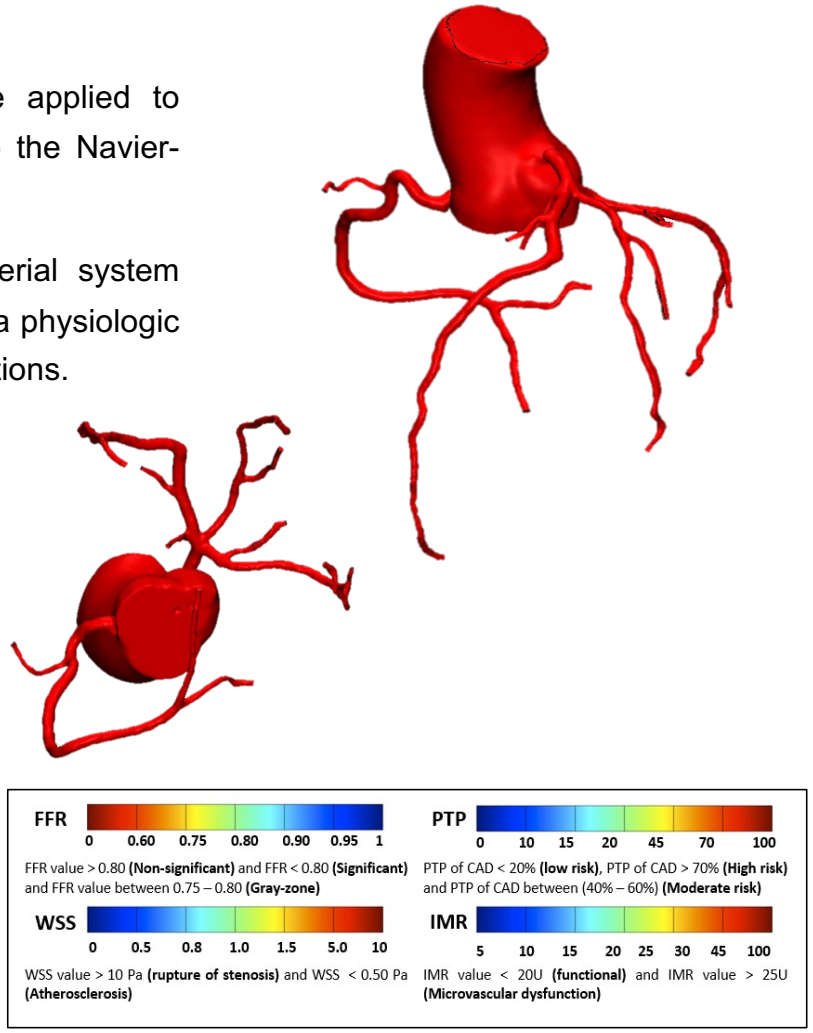
Virtual Angiography

Virtual angiography software is a newer imaging post-processing technique applied to coronary CTA data and uses computational fluid dynamics (CFD) according to the Navier-Stokes equations to generate pressure drop.

This involves creation of an anatomic 3D model of the entire coronary arterial system according to semiautomatic segmentation of the volumetric CTA data, as well as a physiologic model according to patient-specific inflow and outflow boundary condition assumptions.







Anatomical and Physiological Assessment

Result:

- LIMA on LAD is **patent.**
  - ✓ LAD occluded **(NiFFR = 0.00)**, Filled via LIMA with poor distal run off.
- SVG conduit on D is **occluded.**
  - ✓ Diagonal is patent with good distal run off.
- SVG conduit on OM2 is **patent.**
  - ✓ LCX occluded **(NiFFR = 0.00)**, Filled via SVG with good distal run off.
- SVG conduit on PDA is **patent.**
  - ✓ RCA occluded **(NiFFR = 0.00),** Filled via SVG with good distal run off.
- Index of microvascular resistance is 25 U, microvascular is functional.
- Residual functional syntax score post CABG is 19 (<24), therefore medical treatment under observation recommended.