FFR CT : STATE OF THE ART IN THE EVALUATION OF CORONARY ARTERY DISEASE

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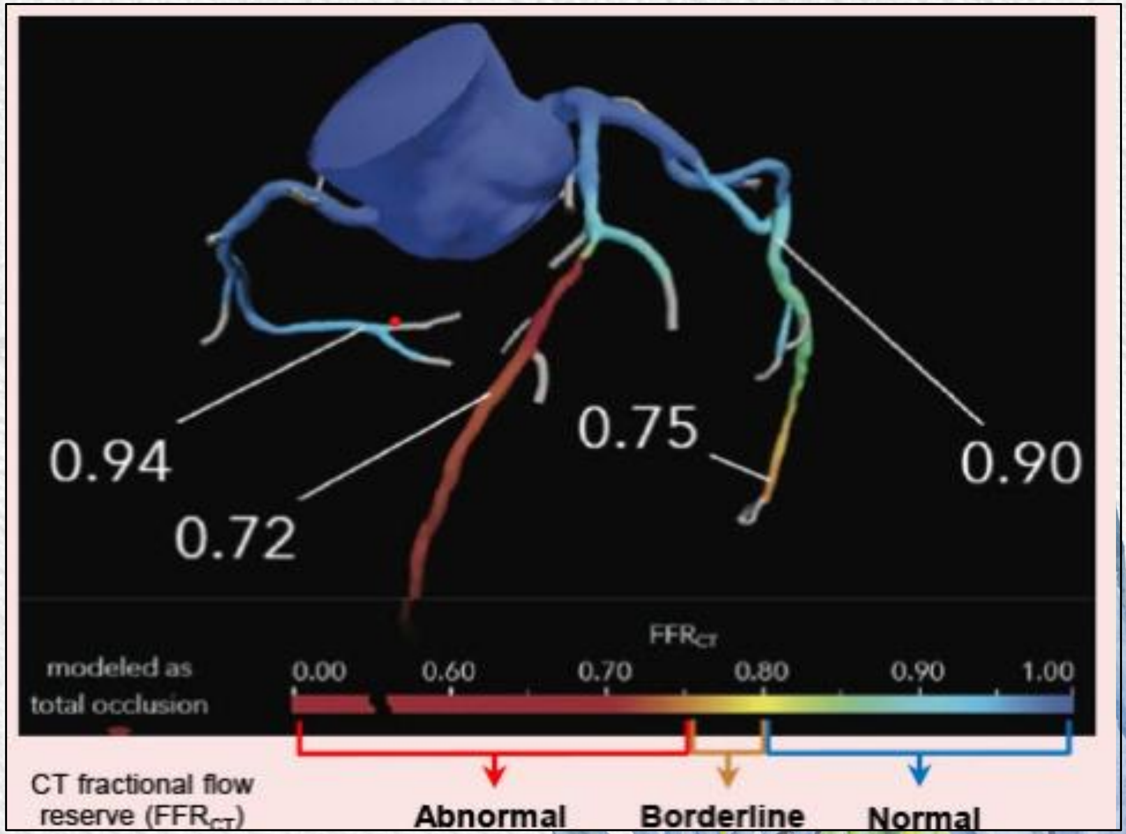
INTRODUCTION TO CT-FFR

Definition:Non-invasive physiological simulation technique that models coronary blood flow dynamics from CT angiography.

Calculates the ratio of maximum blood flow distal to a stenosis to the theoretical maximum flow without disease.

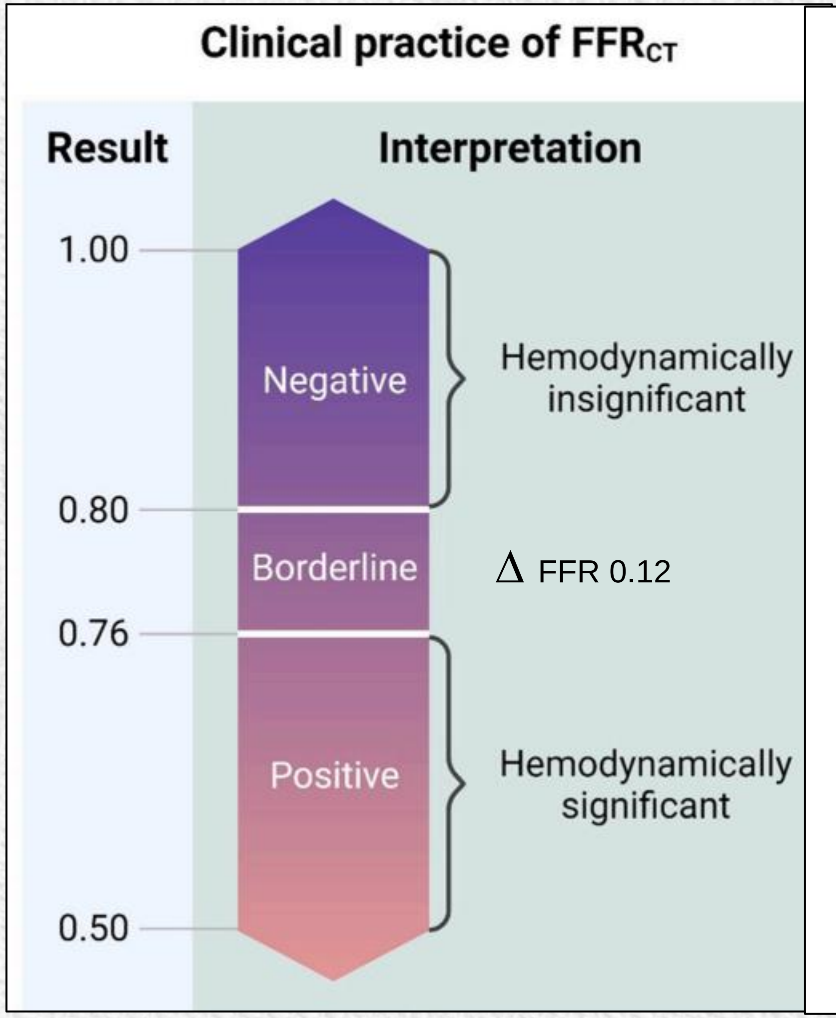
It uses Computational Fluid Dynamics (CFD) or Machine Learning algorithms.

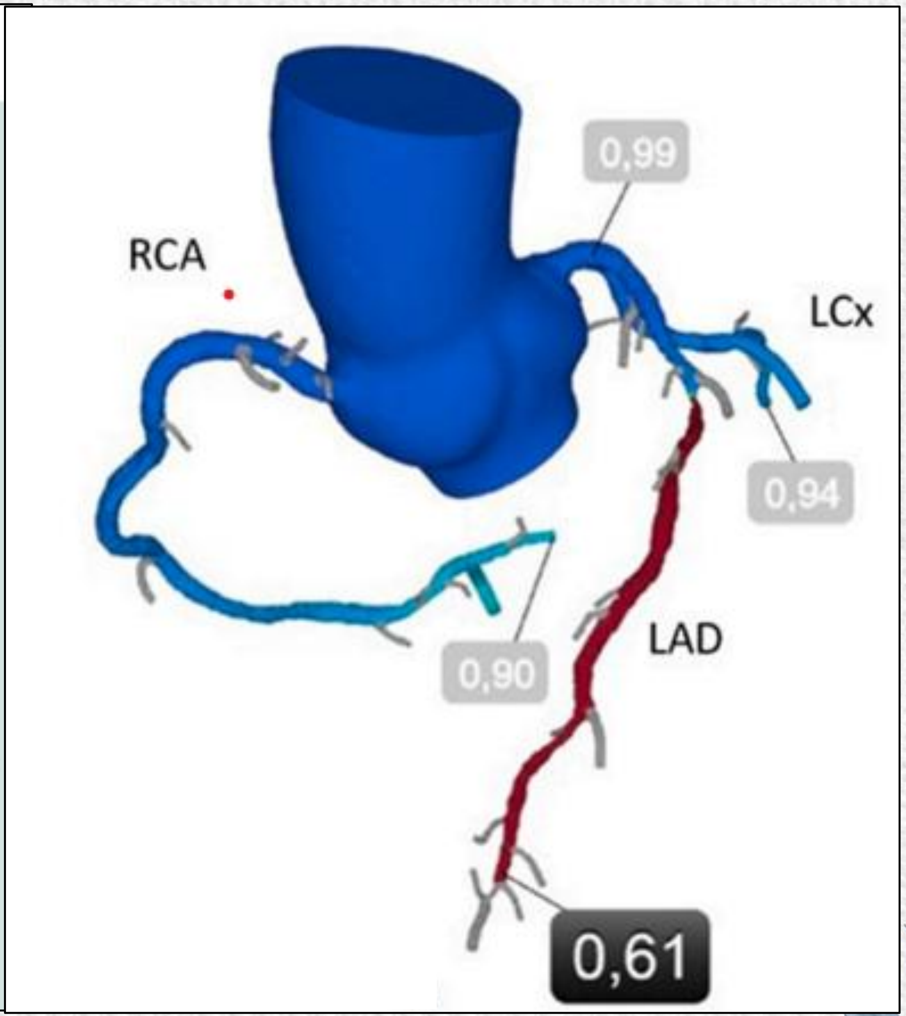
Interpretation Values →



Liangbo Hu et al., Computed Tomography-Derived Fractional Flow Reserve: Developing A Gold Standard for Coronary Artery Disease . **Rev. Cardiovasc. Med. 2024; 25(10): 372**

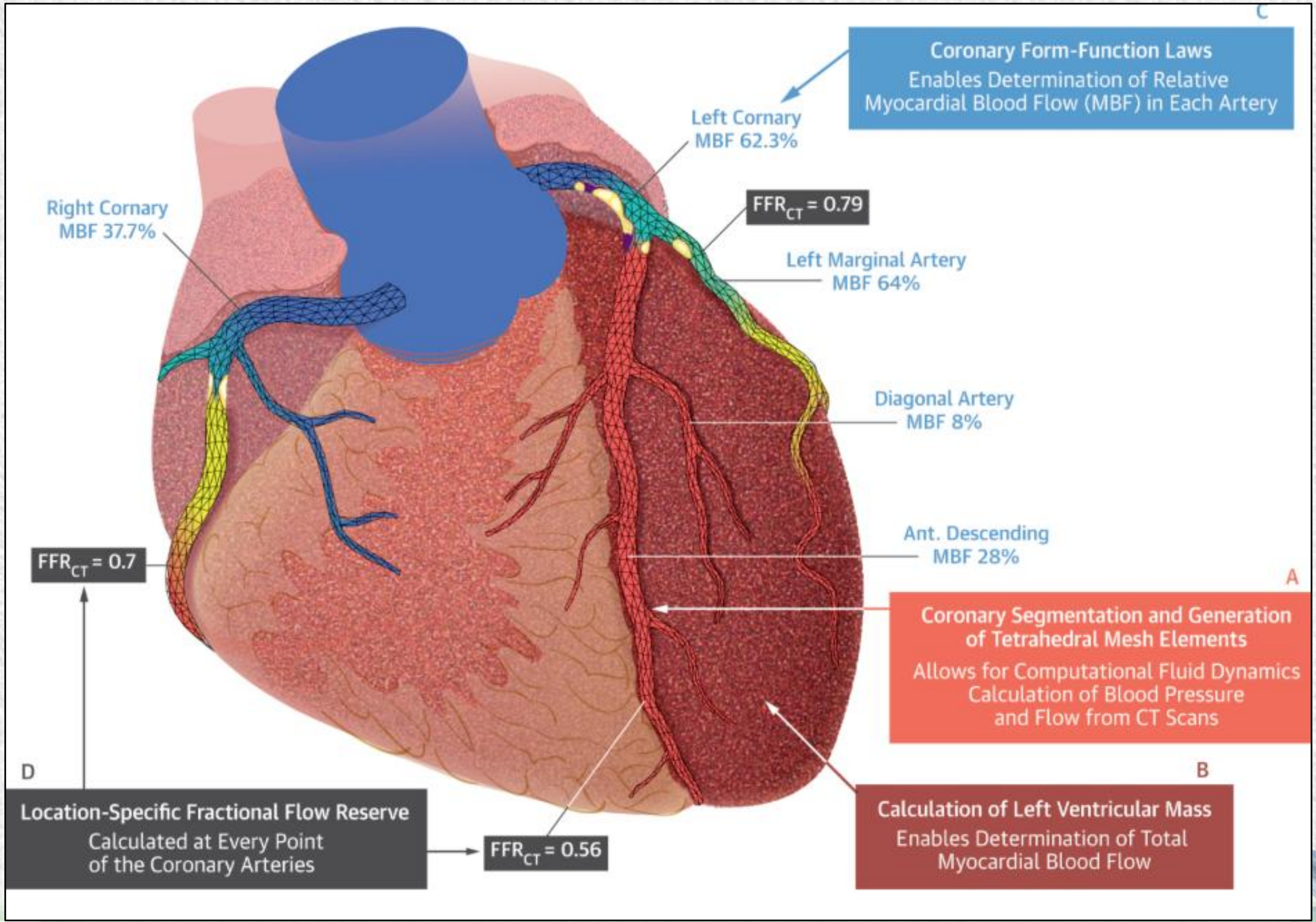
INTRODUCTION TO CT-FFR





Waheed A et al., CT derived fractional flow reserve: Part 2 – Critical appraisal of the literature, Journal of Cardiovascular Computed Tomography, j.jcct.2025.05.241

INTRODUCTION TO CT-FFR



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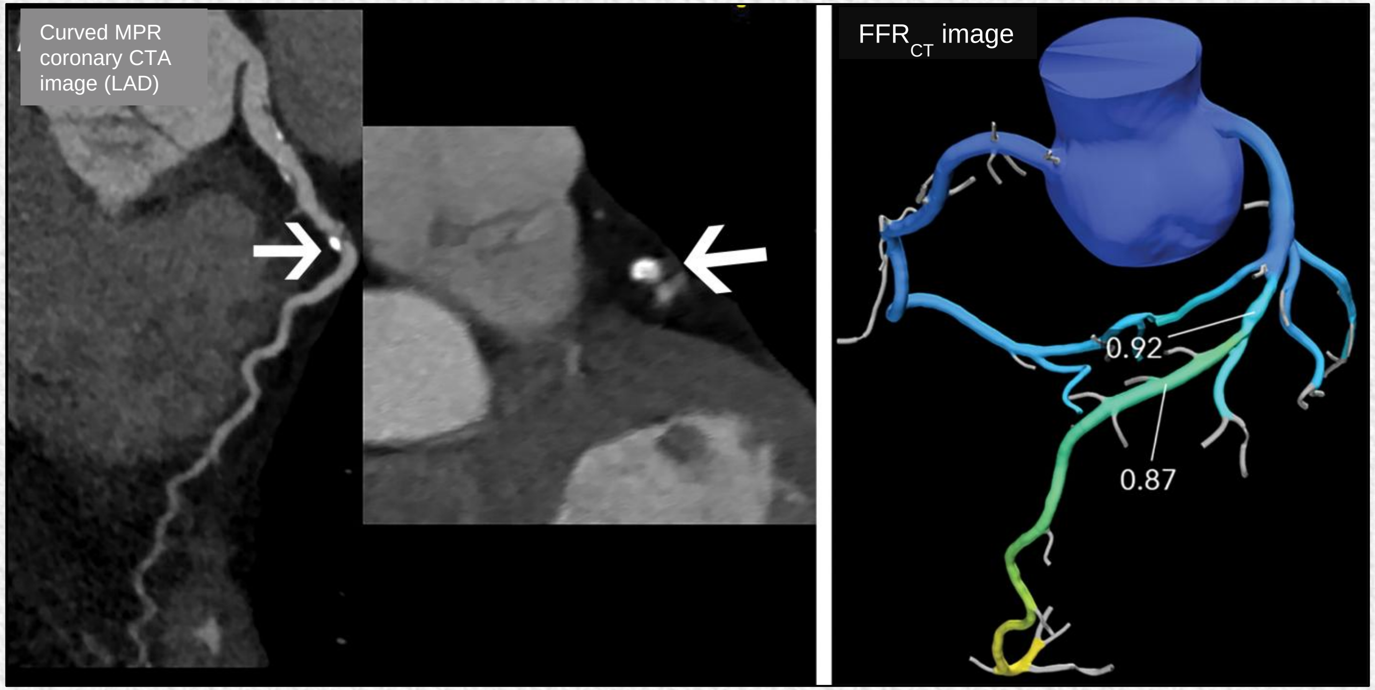
CLINICAL APPLICATIONS AND INDICATIONS

Evaluation of Intermediate Stenosis (50-90%)

Helps determine the actual hemodynamic significance of the injury.
Guide to decisions on revascularization vs. medical therapy.
CAD-RADS 2.0 recommends CT-FFR for CAD-RADS 3 and 4a stenoses.

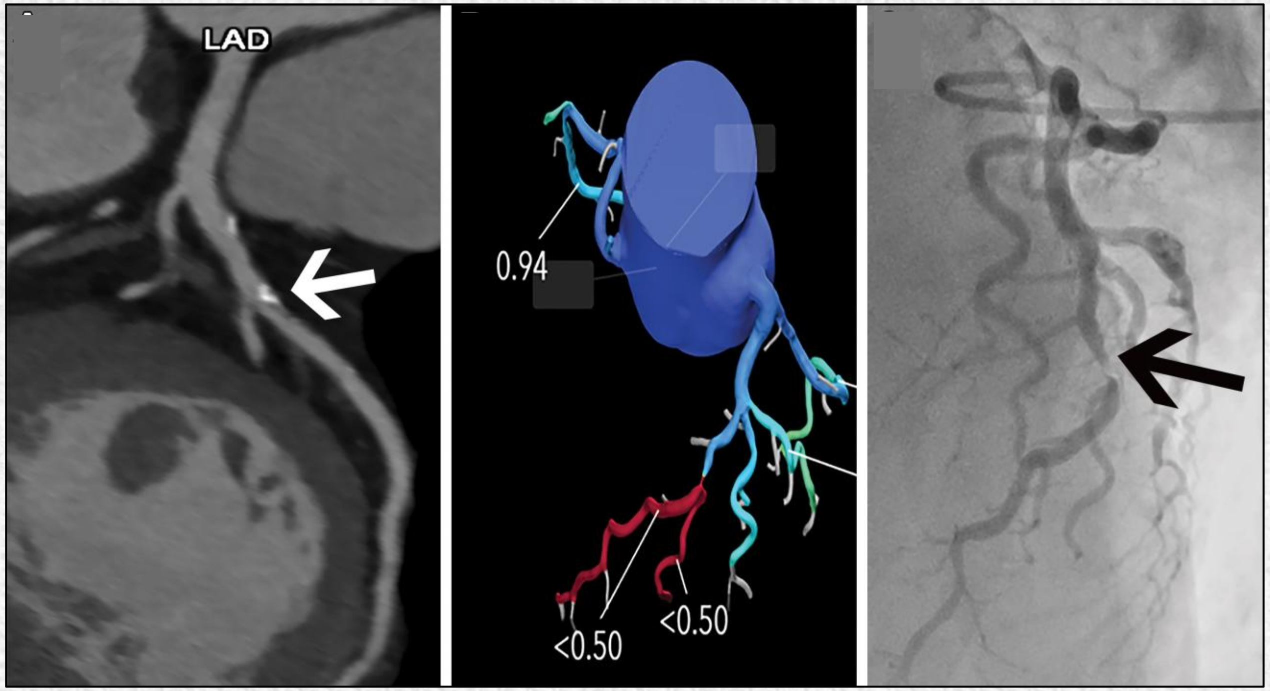


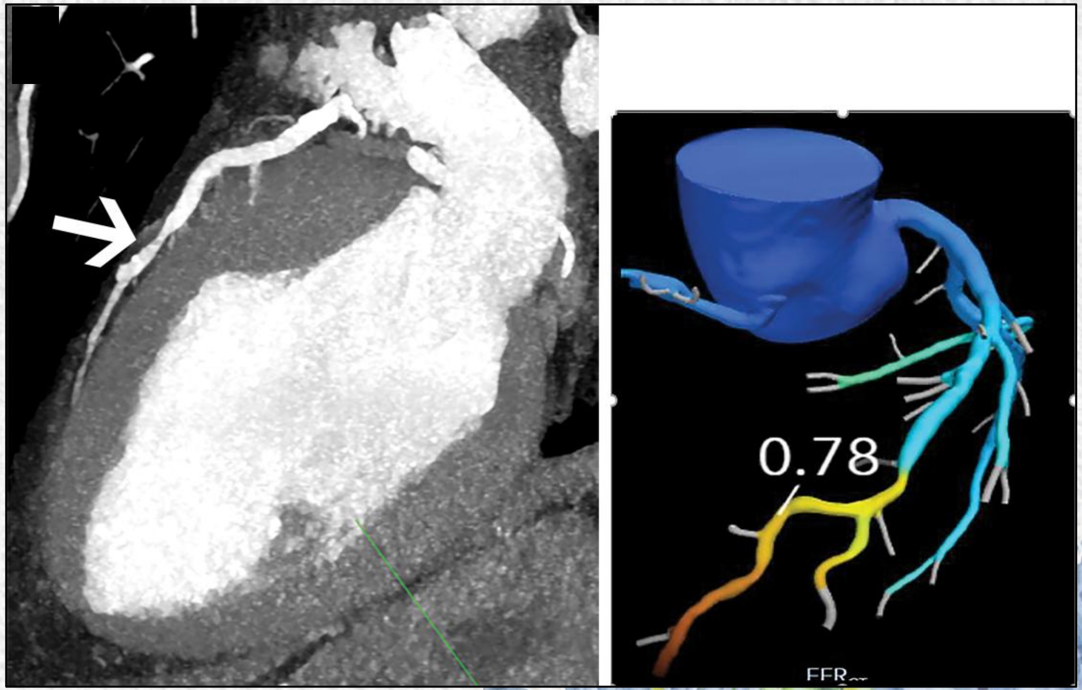
Rajiah et al. CT Fractional Flow Reserve: A Practical Guide to Application, Interpretation, and Problem Solving. Radiographics. 2022 Mar-Apr;42(2):340-358.

CLINICAL APPLICATIONS AND INDICATIONS

Pre-procedural Planning (PCI/CABG):

Sheath/catheter selection, optimal stent lengths, fluoroscopic angles.
Precise phenotyping of CAD, tailoring revascularization strategies.





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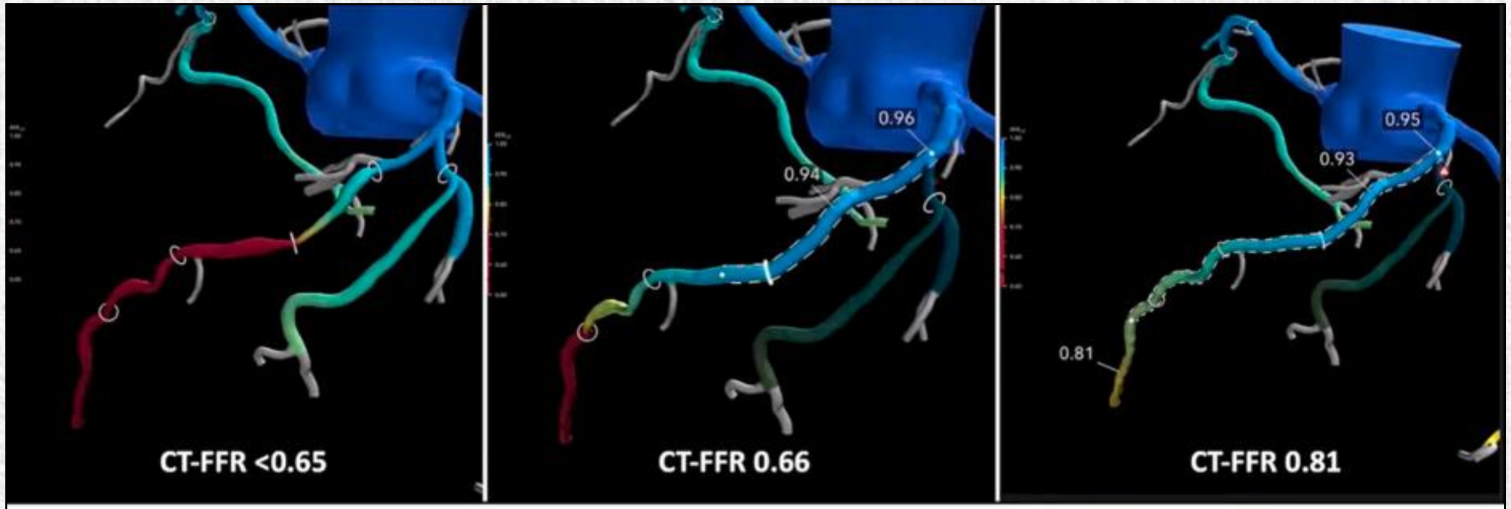
CLINICAL APPLICATIONS AND INDICATIONS

Pre-procedural Planning (PCI/CABG):

Virtual stenting planner



Baseline CT-FFR Physiologically Diffuse CAD	Virtual Stenting from Proximal to Mid LAD *Minimal CT-FFR improvement*	Virtual Stenting from Proximal to Distal LAD (80 mm) *Sub-optimal increase in CT-FFR - 0.81*

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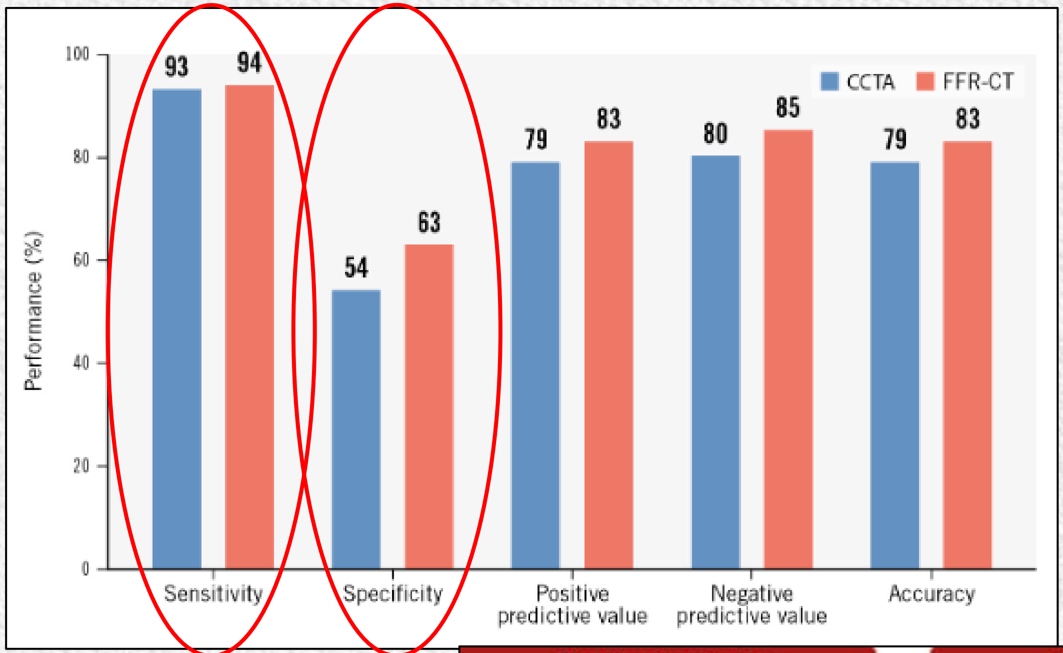
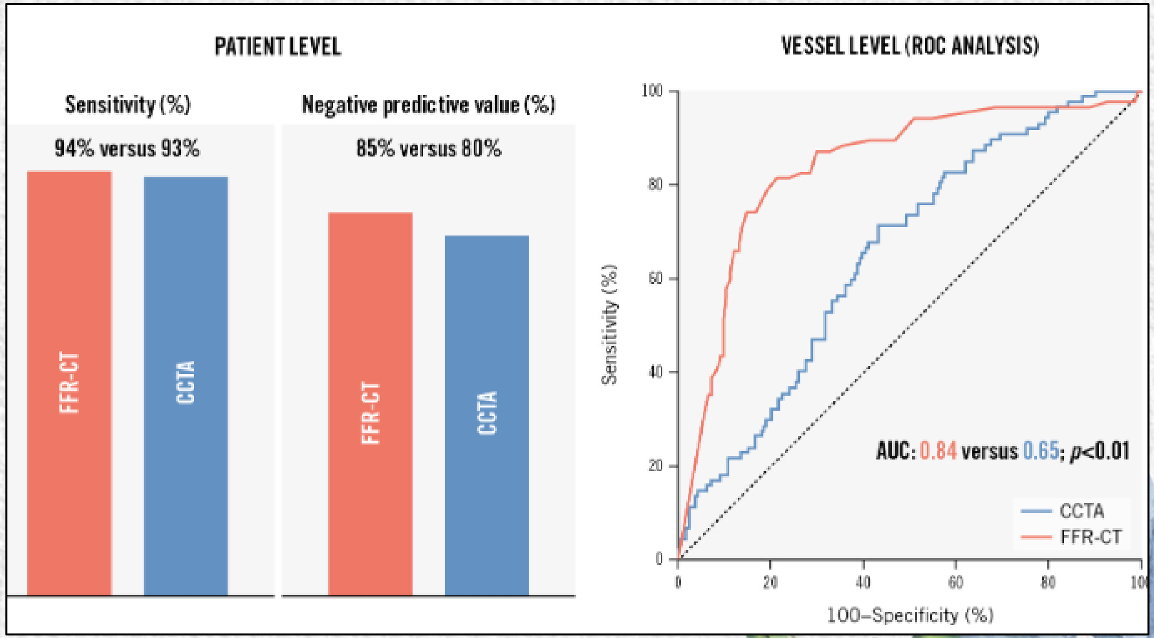
CLINICAL APPLICATIONS AND INDICATIONS

ACS:

In high-risk NSTE-ACS: Diagnostic precision superior and greater ability to rule out hemodynamically significant stenoses to CT angiography (sensitivity 94%, specificity 63% at the patient level).





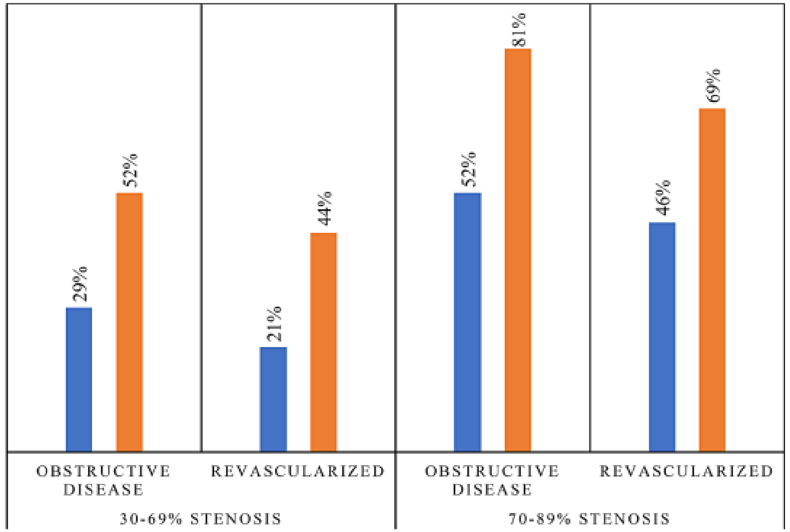
Study location/timeline	Patient population	Study objectives
4 European centres 2019-2022 (stopped at 2/3 of the sample size)	164 high-risk ACS patients Median hs-TnT level: 5.3 (IQR 1.8-18.6) × URL	Capacity of FFR-CT and CCTA to rule out significant lesions (patient and vessel level) assessed by a core laboratory

Meier et al. Usefulness of FFR-CT to exclude haemodynamically significant lesions in high-risk NSTE-ACS. **EuroIntervention 2025;21:73-81**

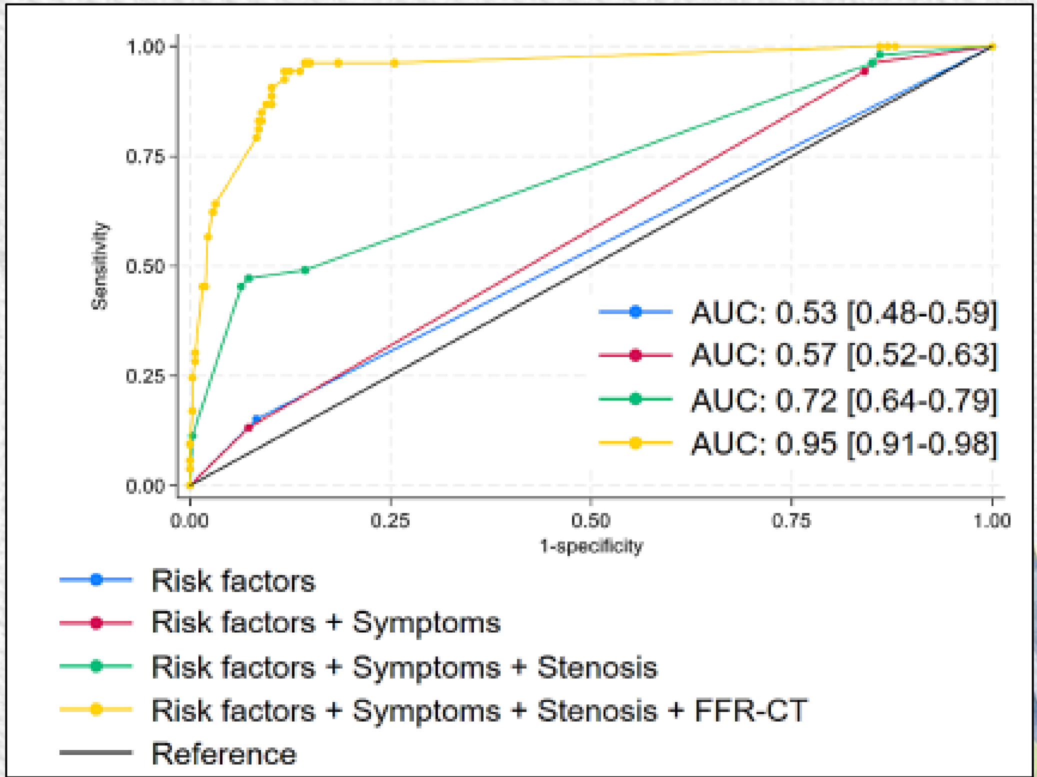
CLINICAL APPLICATIONS AND INDICATIONS

Stable Chest Pain:

Effective tool that minimized the number of invasive procedures and increased the revascularization.
FFRCT has been associated with a better over all diagnostic precision and a higher sensitivity than perfusion imaging with SPECT and magnetic resonance.

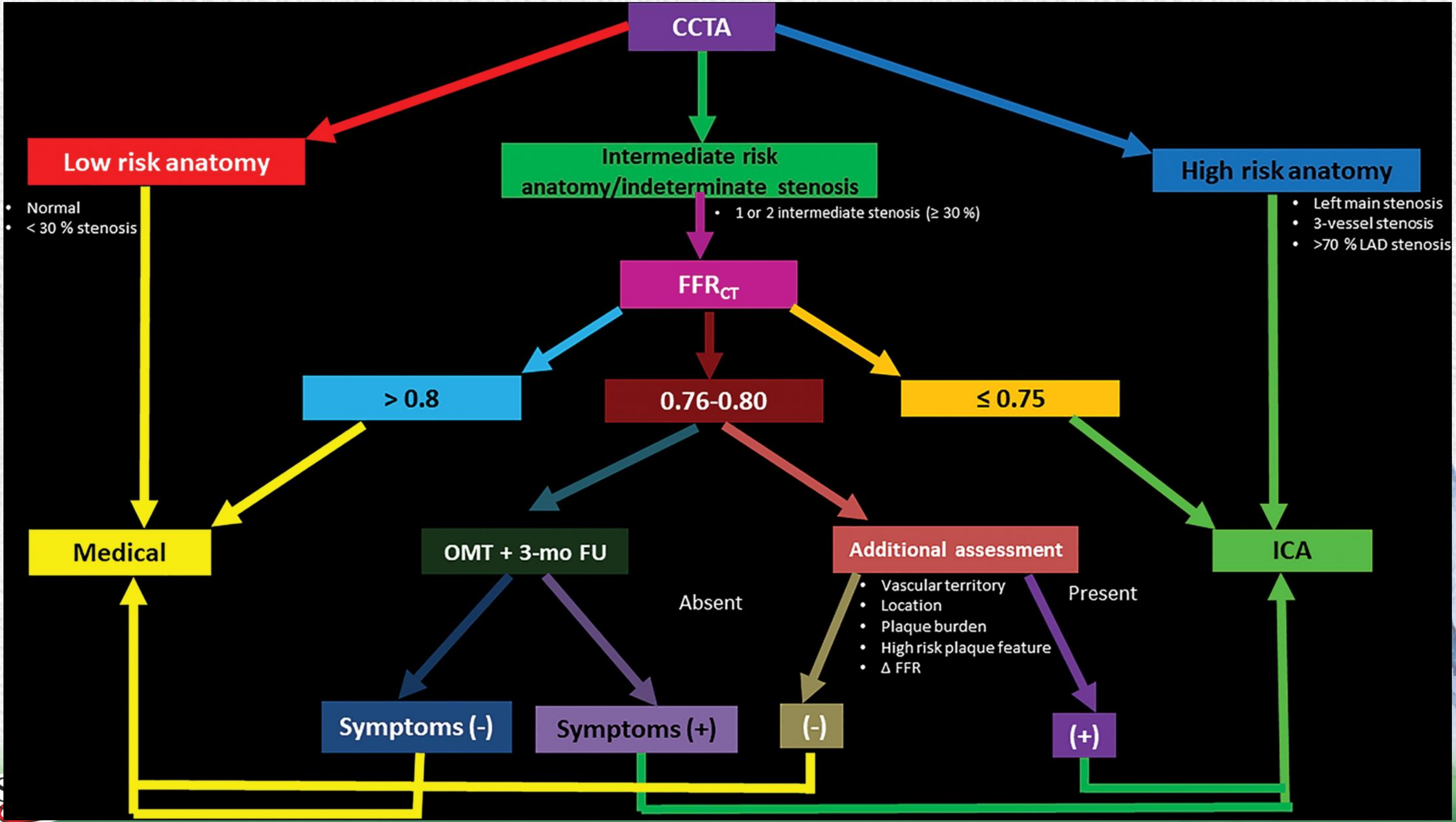


CTA	Ref	Ref	Ref	Ref
FFR_{CT}	2.61 (1.11, 6.15)	2.92 (1.59, 7.34)	3.77 (1.49, 9.54)	3.21 (1.34, 7.68)
P-value	0.028	0.023	0.005	0.009



Thangavel S et al. Selective FFRCT testing in suspected stable angina in clinical practice - initial experiences. Int J Cardiovasc Imaging 2024 Oct;40(10):2213-2220

CLINICAL APPLICATIONS AND INDICATIONS



DIAGNOSTIC ACCURACY AND PROGNOSTIC VALUE

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Comparative Performance vs. CT FFR and CT Angiography:

Diagnostic Metric	CT-FFR (Per Patient)	Coronary CT Angiography (Per Patient)	CT-FFR (Per Vessel)	Coronary CT Angiography (Vessel)
Sensitivity	89% (IC 95%: 85-92%)	93% (Meta-analysis)	85% (IC 95%: 82-88%)	88% (Meta-analysis)
Specificity	71% (IC 95%: 61-80%)	32% (Meta-analysis)	82% (IC 95%: 75-87%)	46% (Meta-analysis)
Precision	~84% (DISCOVER-FLOW)	~59% (DISCOVER-FLOW)	N/A	N/A
	81% (NXT)	53% (NXT)	N/A	N/A
PPV (Positive Predictive Value)	83% (from SCASEST)	79% (from SCASEST)	67% (from SCASEST)	56% (from SCASEST)
NPV (Negative Predictive Value)	85% (from SCASEST)	80% (from SCASEST)	92% (from SCASEST)	92% (from SCASEST)

FFRCT : its ability to significantly increase the specificity of coronary CT angiography in the evaluation of CAD.
Superior diagnostic performance of FFRCT compared with anatomic interpretation by coronary CT angiography alone.

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Zhuang et al. Computed tomography angiography-derived fractional flow reserve (CT-FFR) for the detection of myocardial ischemia with invasive fractional flow reserve as reference: systematic review and meta-analysis. Eur Radiol. 2023 Feb;30(2):712-725

CLINICAL EVIDENCE

Year	Study	Comparison	Patients	Findings
2011	DISCOVER FLOW	FFR ct vs CCTA	103 p	↑ Specifity
2012	De FACTO	FFR CT vs CCTA	252 p	↑ Sensibility intermediate lesions
2014	NXT	FFR CT vs CCTA	254 p	↑ Specifity
2015	PLATFORM	For an invasive treatment, CTA and FFR ct	584 p	↓ Incidence NO CAD. ↓ Costs.
2016	RIPCORD	FFR CT vs CCTA	200 p	↑ Specifity (1/3 Changes strategy)
2017	PACIFIC	FFR ct vs CCTA, SPECT and PET	208 p	↑ Specifity vs CCTA, SPECT and PET PET > in discrimination intention to analysis

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CLINICAL EVIDENCE

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ReASSESS (2018)
- FFR ct vs SPECT
- 143 p
- = Accuracy for ischemia
- ↑ Sensibility FFRct
- ↑ Specifity SPECT

ADVANCE (2018)
- FFR CT vs CCTA
- 5083 p
- 2/3 changes treatment strategy with FFrct

SYNTAX III REVOLUTION (2019)
- FFR CT vs CCTA
- 223 p
- Enfermedad multivaso
- 1/4 changes treatment strategy with FFrct

ADVANCE DK (2022)
- FFR CT vs CCTA
- 3 years FU

TARGET (2023)
- FFR ct in situ
- ↓ p. stable CAD undergoing ICA wo NOCAD.
- No difference in MACE at 1 year compared with standard care.

ADVANCE ED (2024)
- FFR ct vs CRM, stable arterial disease
- Costs analysis
- ↓ innecesary procedures.

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COMPARISON OF DIFFERENT CT FFR SUPPLIERS AND PRODUCTS

Company/Organization	Production	Characteristic	Individuals Sensitivity (%)	Individuals Specificity (%)	Vessels Sensitivity (%)	Vessels Specificity (%)	Approval
HeartFlow	FFRCT	Primary 3D-CFD	86	79	84	86	FDA (2014)
Siemens	cFFR	On-site	87	86	—	—	Cooperate with HeartFlow (2017)
Toshiba	CT-FFR	Reduced 3D-CFD	77.8	76.8	—	—	—
RuiXin	RuiXin-FFR	Multi-layer deep learning	87	88	—	—	MDR (2023), NMPA (2021)
United Imaging	uCT-FFR	AI computing	89	91	—	—	NMPA (2024)
Shukun Technology	Shukun-FFR	AI computing	96.2	93.1	83.6	96.3	NMPA (2023)
YueYing	MaiYing®esFFR	3D-CFD	—	—	—	—	NMPA (2022)
KeYa	CT-FFR	3D-CFD	93.6	88.2	93.9	90.4	FDA (2022), NMPA (2020), CE (2018),
Affiliated Jinling Hospital, Medical School of Nanjing University	CT-FFR	Fully automatic, on-site	84	81	—	—	Under testing (2024)

Waheed A et al., CT derived fractional flow reserve: Part 1 – Critical appraisal of the literature, Journal of Cardiovascular Computed Tomography, j.jcct.2025.05.241

IMPACT ON CLINICAL MANAGEMENT AND CARE PATHWAYS

Reduction of Unnecessary ACI:

Patients with normal CT-FFR can be safely deferred from ACI.

In high-risk NSTE-ACS, it can avoid more than 60% of unnecessary invasive evaluations. Increase in optimal medical therapy.

Optimization of Treatment Strategies:

More precise decisions regarding revascularization vs. medical therapy, especially in intermediate stenoses.

In situ CT-FFR improves patient selection for ACI.

Profitability Considerations:

Historically, slow and expensive post-processing.

Savings potential by avoiding costly ACI.

Higher costs for CT-FFR (£2,102-£3,913 per patient) vs. conventional stress imaging (£1,411-£2,148).

Profitability varies depending on the system and the comparative diagnostic pathway.

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CLINICAL GUIDELINES AND RECOMMENDATIONS

	Recommendations for the Use of CT-FFR	Contraindications/Situations Not Recommended
Society for Cardiovascular Computed Tomography (SCCT) / CMS CAD-RADS 2.0 / 2021 (CMS Coverage Guide)	Defines the hemodynamic relevance of stenoses. Reasonable and necessary in intermediate-risk patients with acute or stable chest pain and 40%-90% stenosis on coronary CT angiography.	Previous prosthetic valves or bypass grafts, Bare-metal stents, Post-heart transplant, recent MI (<30 days), Pacemaker/defibrillator, Stenosis >90% or <40% does not require FFRct.

Vrints et al. 2024 ESC Guidelines for the management of chronic coronary syndromes: Developed by the task force for the management of chronic coronary syndromes of the European Society of Cardiology (ESC) Endorsed by the European Association for Cardio-Thoracic Surgery (EACTS). European Heart Journal, Volume 45, Issue 36, 21 September 2024, Pages 3415–3537

Cury et al. CAD-RADS™ 2.0 – 2022 Coronary Artery Disease-Reporting and Data System: An Expert Consensus Document of the Society of Cardiovascular Computed Tomography (SCCT), the American College of Cardiology (ACC), the American College of Radiology (ACR), and the North America Society of Cardiovascular Imaging (NASCI) JACC: Cardiovascular Imaging Volume 15, Number 11

LIMITATIONS, CHALLENGES AND PRACTICAL CONSIDERATIONS

ADVANTAGES
Allows anatomical and functional evaluation in a single test.
No need for additional testing for patients.
No need for additional contrast.
No need for additional radiation.
Assesment of lesion specific ischemia.
May prevent unnecessary invasive coronary angiograms.
Determine physiological pattern of disease and focal pressure gradients.
Using virtual stenting tools can guide revascularization strategies.

DISADVANTAGES
Not useful for distal lesions. (Best for prox and mid vessels).
Not useful for vessels with stents.
Lees reliable with extensive calcifications.
Highly dependent on image quality.
Additional cost and reimbursement can be challenging.
Offsite analysis challenges usage in urgent settings.

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FUTURE DIRECTIONS

Emerging Technologies and Algorithms.

AI/Deep Learning: Will improve accuracy, reduce times, overcome limitations (artifacts, calcification).

On-site solutions: Streamline clinical workflows.

Expansion of Clinical Indications.

Randomized controlled trials in high-risk populations to assess impact on hard endpoints and cost-effectiveness.

Objective: Minimize unnecessary invasive procedures, optimize patient outcomes.

AI-Clinical Convergence:AI-powered CT-FFR as an indispensable tool in precision cardiology.

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EXECUTIVE SUMMARY / CONCLUSIONS

CT-FFR: Noninvasive evaluation of CAD, deriving physiological information from coronary CT angiography.

Strong evidence from indexed journals and trials: Superior accuracy and prognostic value.

Overcomes the limitation of CT Angiography: Anatomy does not always correlate with functional ischemia.

Invasive Gold Standard (FFR) vs. Noninvasive CT-FFR: Closing the Gap.

Benefits: Reduces unnecessary invasive procedures, optimizes revascularization, improves outcomes.