Mesure de la pression endocoronaire et l'imagerie: Pourquoi faut il une approche "virtuelle"?

Eric Van Belle,

Lille University Hospital

Heart & Lung Institute

DIU cardiologie interventionnelle

FACULTE DE MEDECINE

Instituts thématiques Inserm

Institut national de la santé et de la recherche médicale

Functional testing and intravascular imaging for lesion assessment

Recommendations	Class	Level
When evidence of ischaemia is not available, FFR or iwFR are recommended to assess the haemodynamic relevance of intermediate-grade stenosis.	I	A

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

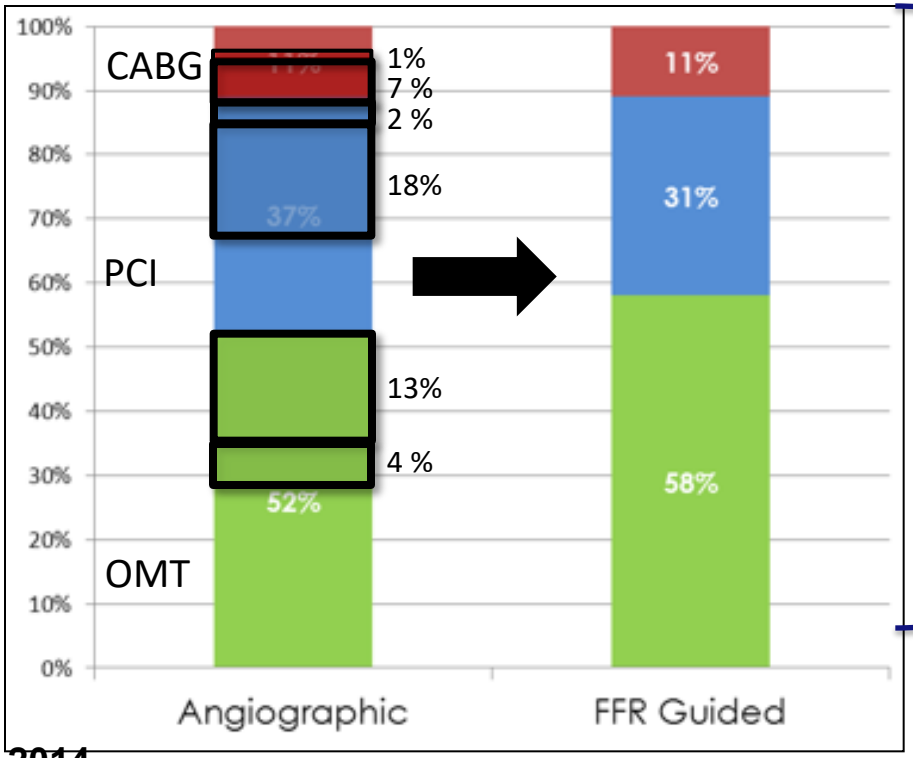
R3F

American Heart Association.

Outcome Impact of Coronary Revascularization Strategy Reclassification With Fractional Flow Reserve at Time of Diagnostic Angiography

Insights From a Large French Multicenter Fractional Flow Reserve Registry

Eric Van Belle, MD, PhD; Gilles Rioufol, MD, PhD; Christophe Pouillot, MD;



43% of patients changed therapy with FFR guidance

Van Belle et al. Circulation 2014

JACC
JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY

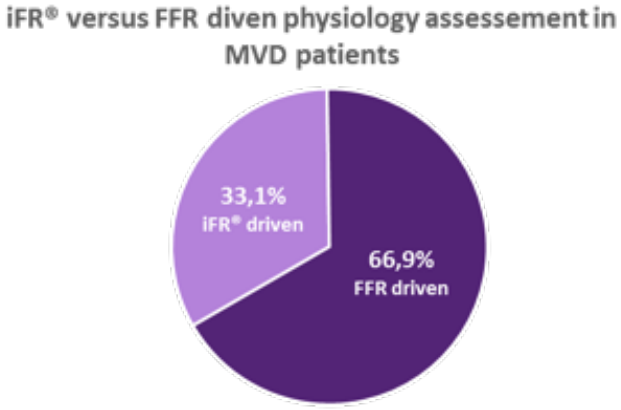
Impact of Routine Invasive Physiology at Time of Angiography in Patients With Multivessel Coronary Artery Disease on Reclassification of Revascularization Strategy

Results From the DEFINE REAL Study

Eric Van Belle, MD, PhD,[a] Robert Gil, MD, PhD,[b] Volker Klauss, MD,[c] Mohammed Balghith, MD,[d] Martijn Meuwissen, MD, PhD,[e] Jérôme Clerc, MD,[f] Bernhard Witzenbichler, MD,[g] Miha Cercek, MD,[h] Marios Vlachojannis, MD,[i] Irene Lang, MD,[j] Philippe Commeau, MD,[k] Flavien Vincent, MD,[a] Luca Testa, MD, PhD,[l] Wojciech Wasek, MD, PhD,[m] Nicolas Debry, MD,[a] Stephan Kische, MD, PhD,[n] Gabriele Gabrielli, MD,[o] Gennaro Sardella, MD, PhD[p]

JACC: CARDIOVASCULAR INTERVENTIONS VOL. 11, NO. 4, 2
FEBRUARY 26, 2018:354–65

Reclassification according to the number of vessel investigated

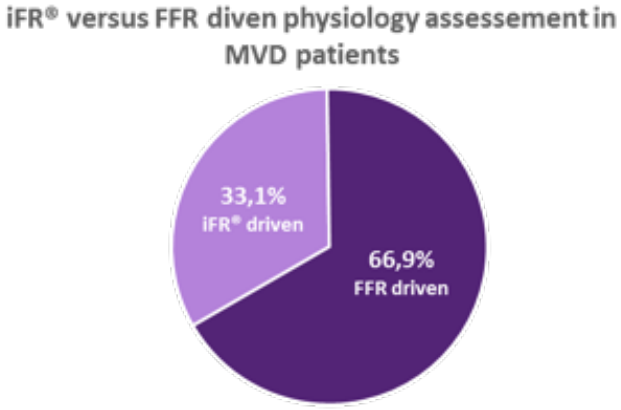


iFR : 1.9 vessels
FFR: 1.6 vessels

Van Belle *et al.*

Routine Invasive Physiology in MVD

Reclassification according to the number of vessel investigated

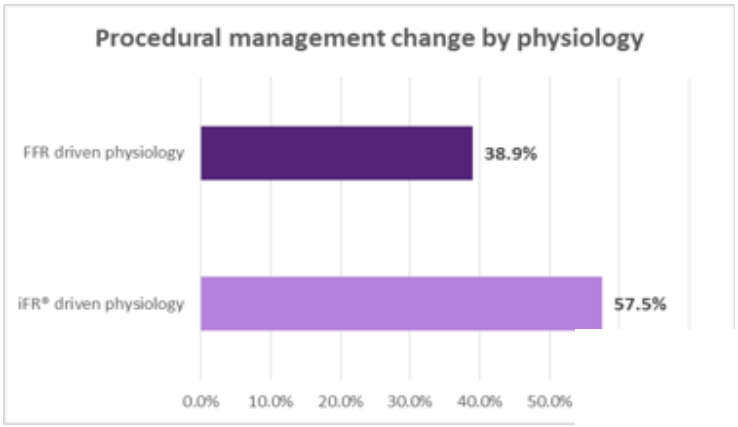


iFR : 1.9 vessels
FFR: 1.6 vessels

P=0.0001

FFR: 1.6 vessels

iFR : 1.9 vessels



Van Belle *et al.*
Routine Invasive Physiology in MVD

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Multivessel PCI Guided by FFR or Angiography for Myocardial Infarction

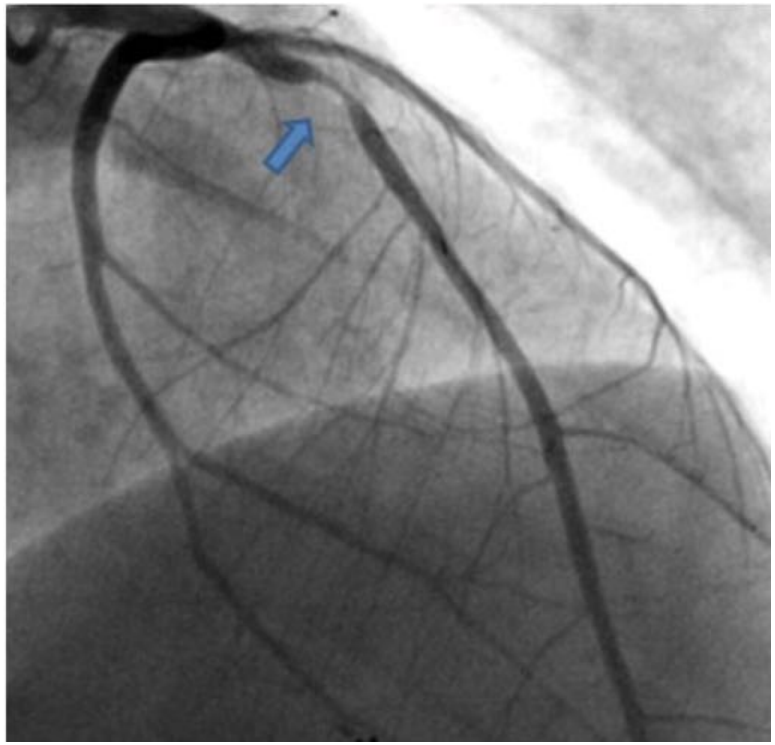
Etienne Puymirat, M.D., Ph.D., Guillaume Cayla, M.D., Ph.D., Tabassome Simon, M.D., Ph.D., Philippe G. Steg, M.D., Gilles Montalescot, M.D., Ph.D., Isabelle Durand-Zaleski, M.D., Ph.D., Alicia le Bras, M.D., Romain Gallet, M.D., Ph.D., Khalife Khalife, M.D., Jean-François Morelle, M.D., Pascal Motreff, M.D., Ph.D., Gilles Lemesle, M.D., Ph.D., Jean-Guillaume Dillinger, M.D., Ph.D., Thibault Lhermusier, M.D., Ph.D., Johanne Silvain, M.D., Ph.D., Vincent Roule, M.D., Ph.D., Jean-Noel Labèque, M.D., Grégoire Rangé, M.D., Grégory Ducrocq, M.D., Ph.D., Yves Cottin, M.D., Didier Blanchard, M.D., Anaïs Charles Nelson, N.D., Bernard De Bruyne, M.D., Ph.D., Gilles Chatellier, M.D., and Nicolas Danchin, M.D., for the FLOWER-MI Study Investigators*

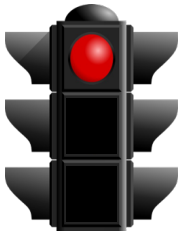
Initial plan:
To perform FFR of non-culprit at the time of the initial PCI in all patients

Actaal plan
<5% of patients had FFR of additional non culprit during the index angiography

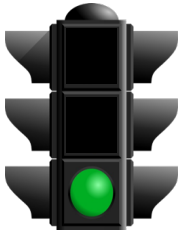
Performing pressure wire measurments in patients with MVD is very rare

A simple case!



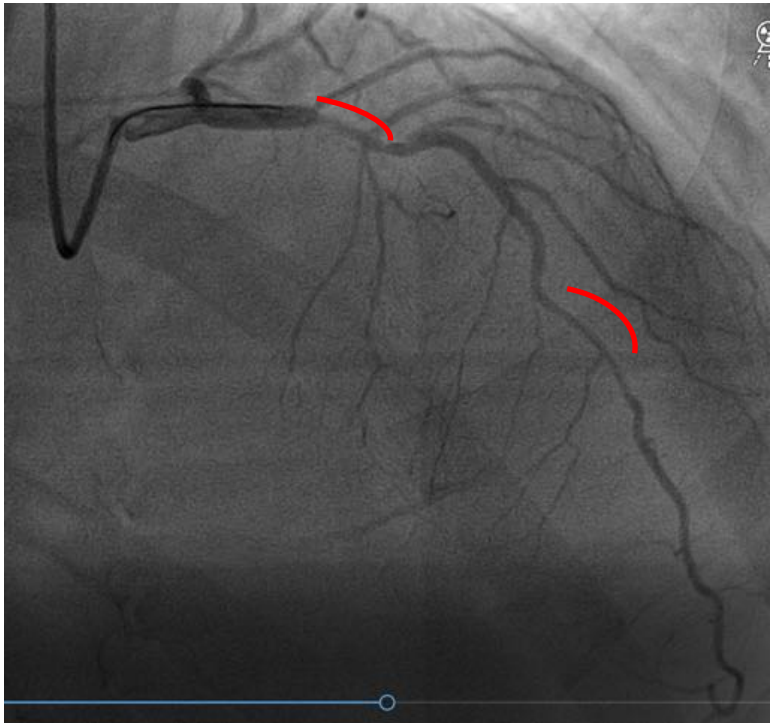


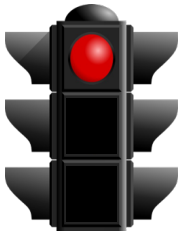
Traitement medical
FFR > 0.81
iFR > 0.89



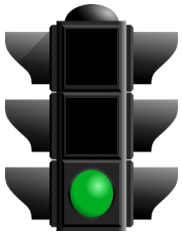
Angioplastie
FFR ≤ 0.80
iFR ≤ 0.89

Amore complexe case!





Traitement medical
FFR > 0.81
iFR > 0.89

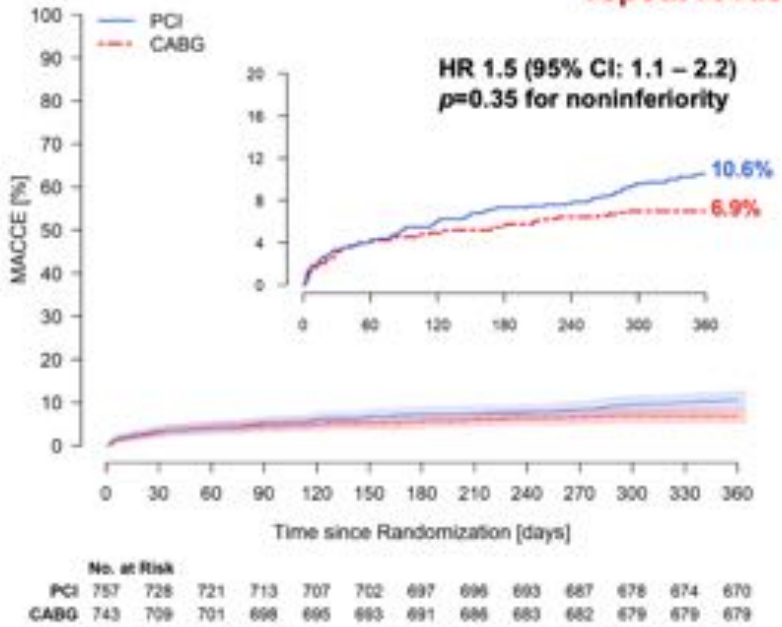


Angioplastie
FFR ≤ 0.80
iFR ≤ 0.89

FAME 3

Primary Endpoint

MACCE (Death, MI, stroke or repeat revascularization) at 1 Year

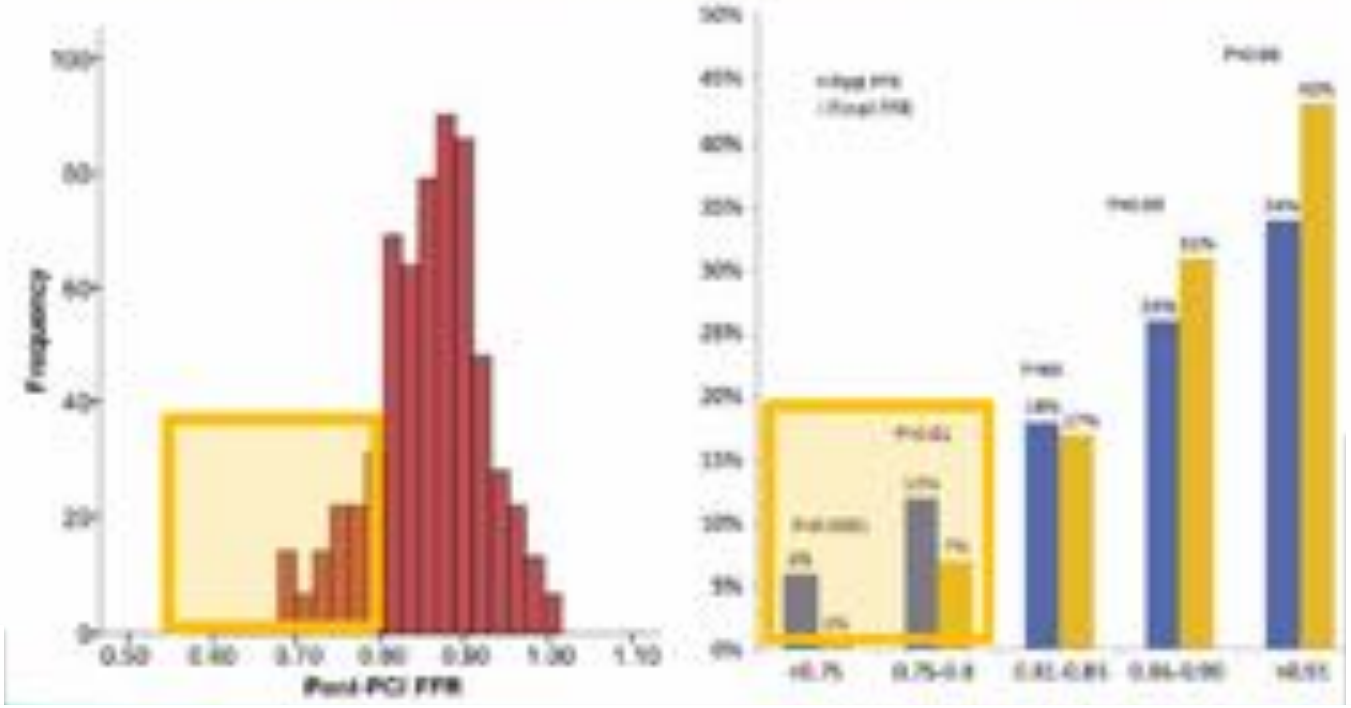


Procedural Characteristics

Variable	PCI (n=757)
% Lesions FFR measured	82%
FFR>0.80	24%
Staged procedure	22%
Number of stents	3.7±1.9
Total stent length	80 mm
Intravascular imaging	12%
FFR measured after PCI	60%

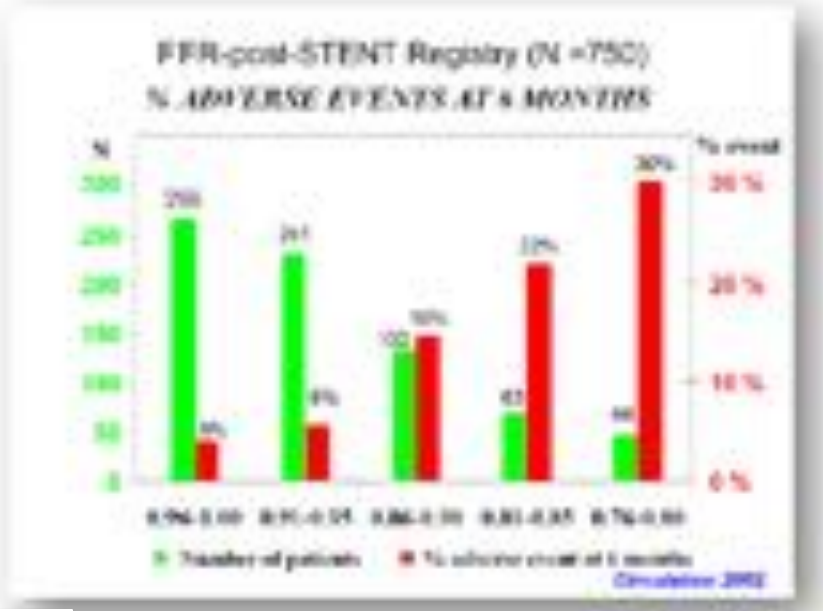
Variable	CABG (n=743)
FFR measured prior to CABG	10%
# of distal anastomoses	3.4±1.0
Multiple arterial grafts	25%
LIMA	97%
Off-Pump surgery	24%

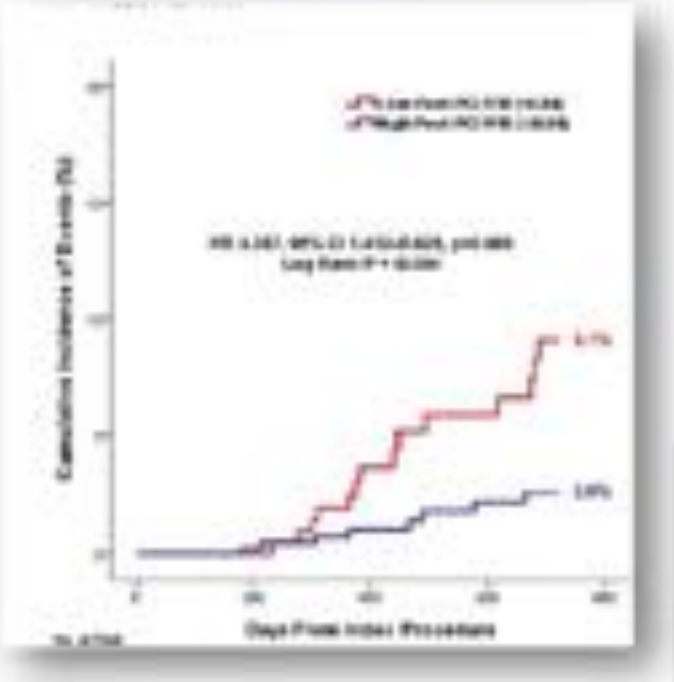
Post PCI ischemia based on FFR ≤0.80 occurs in 10-20% of cases



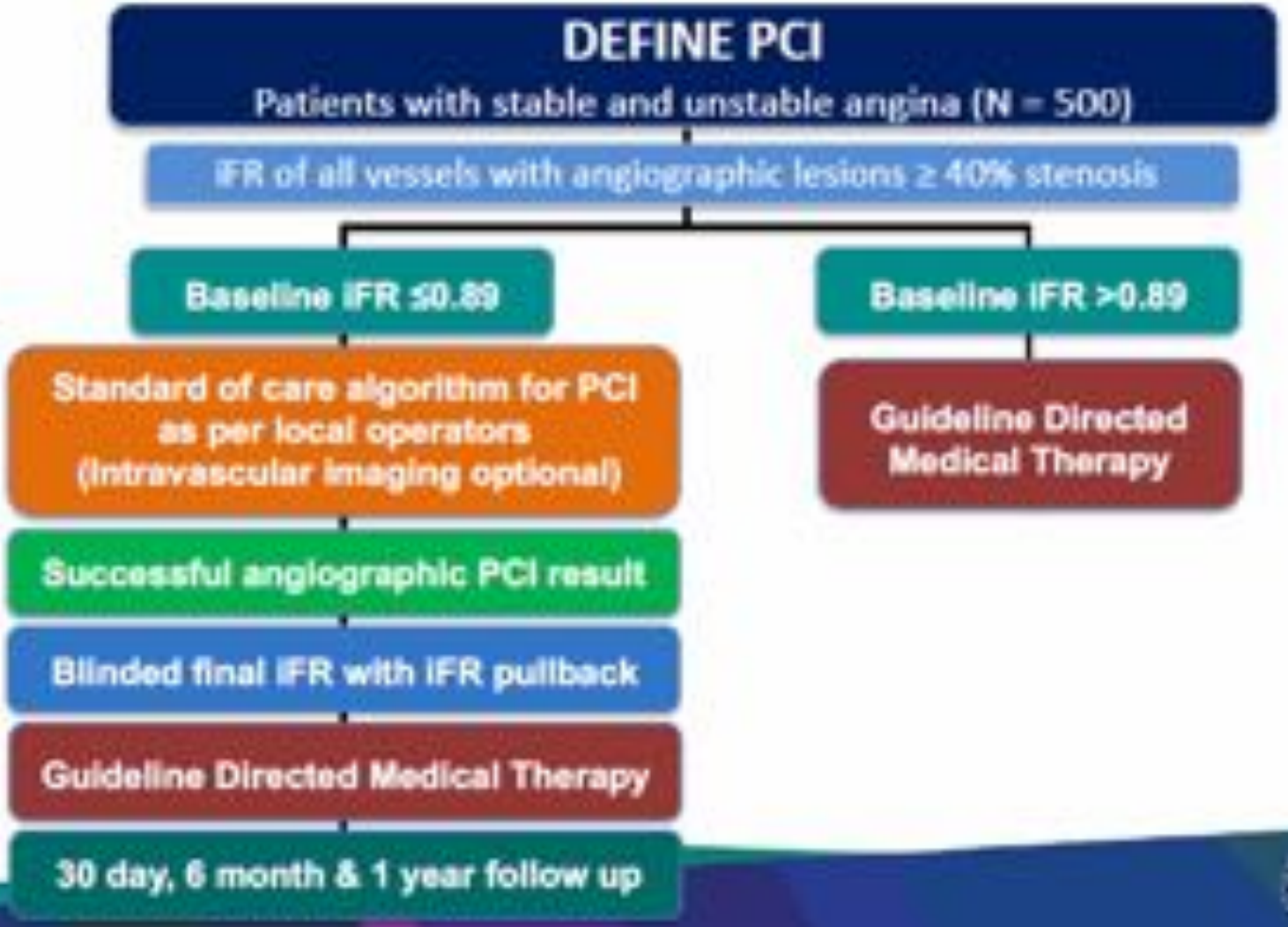
Lee JM., et al. J Am Coll Cardiol Intv. 2018;11:1099–108.
Agarwal SK, et al. J Am Coll Cardiol 2016;9:1022–31.

Low post-PCI FFR is related to adverse events





Pijls N, et al. *Circulation*. 2002;105:2950-54.
Lee JM, et al. *J Am Coll Cardiol Intv*. 2014;11:1999–2009.


DEFINE PCI
Patients with stable and unstable angina (N = 500)
iFR of all vessels with angiographic lesions ≥ 40% stenosis
Baseline iFR ≤0.89
Baseline iFR >0.89
Standard of care algorithm for PCI as per local operators (Intravascular imaging optional)
Guideline Directed Medical Therapy
Successful angiographic PCI result
Blinded final iFR with iFR pullback
Guideline Directed Medical Therapy
30 day, 6 month & 1 year follow up

DEFINE PCI

Primary Study Endpoint

480 Patients with Angiographically Successful PCI and qualified iFR pullbacks

24% Residual Ischemia (112 patients with Post PCI iFR≤0.89)

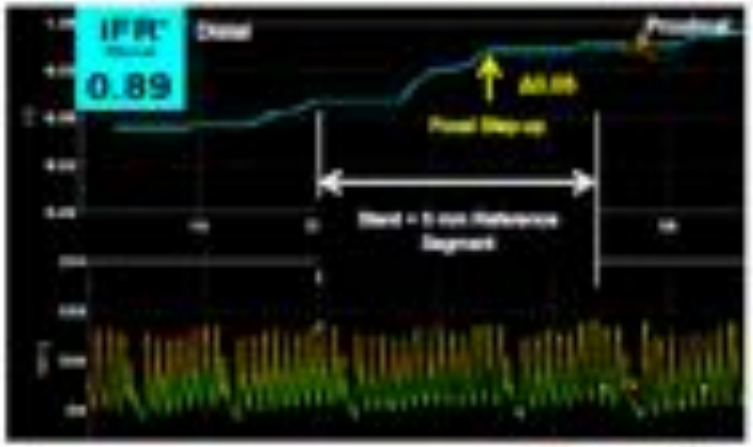
■ Post iFR≤0.89 ■ Post iFR>0.89

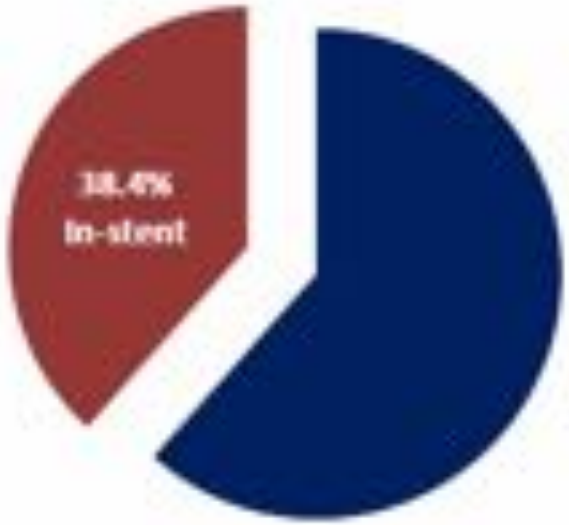
Focal defined as step-up of ≥0.03 units in < 15 mm segment
Diffuse defined as > 15 mm segment

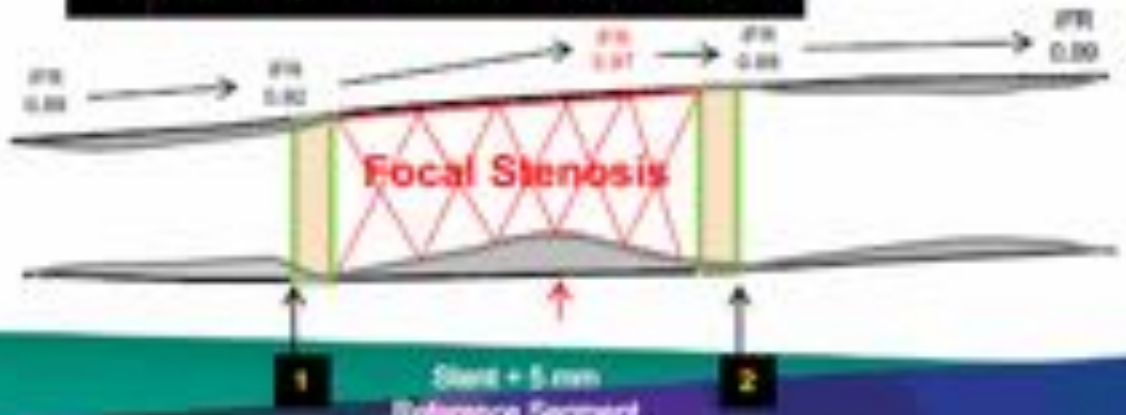
DEFINE PCI

Focal Residual Pressure Gradient in-stent

Among the 93 vessels with focal disease, there were 146 segments (stent, proximal or distal) that had significant residual pressure gradients



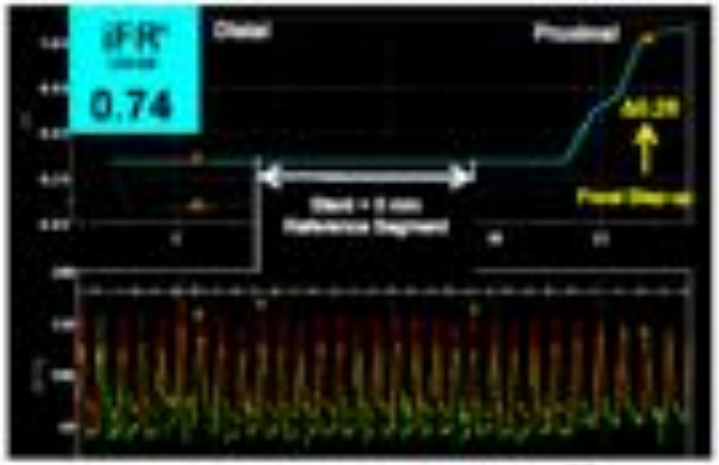


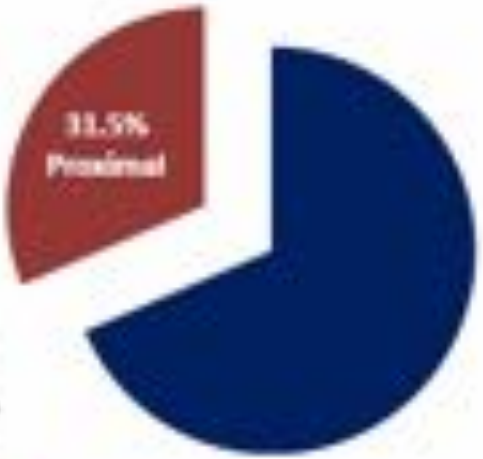


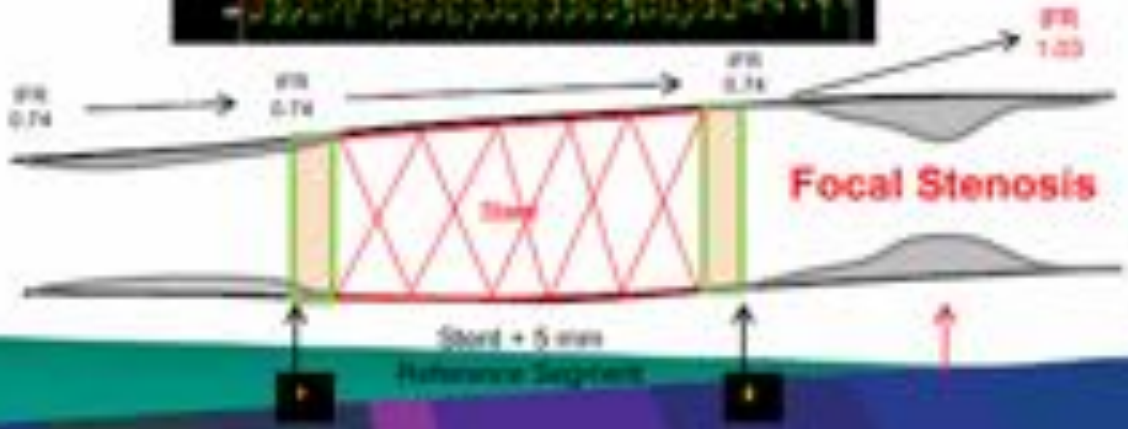
DEFINE PCI

Focal Residual Pressure Gradient Prox to stent

'Physiologic miss' occurred in 31.5% of focal lesions proximally



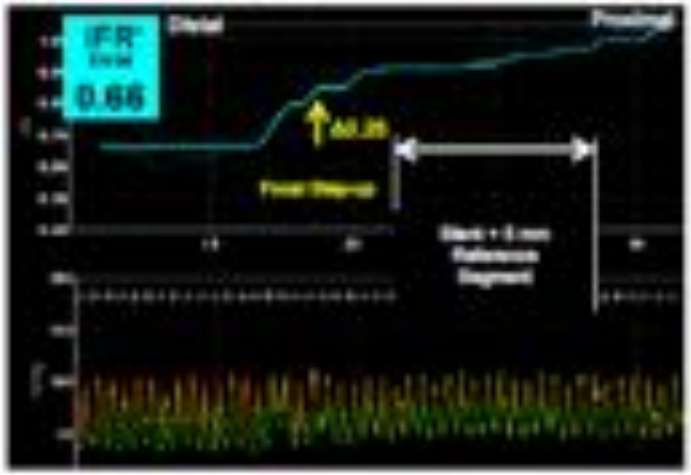


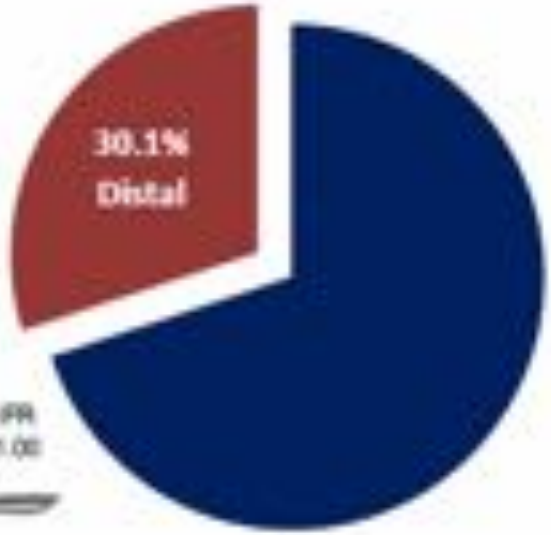


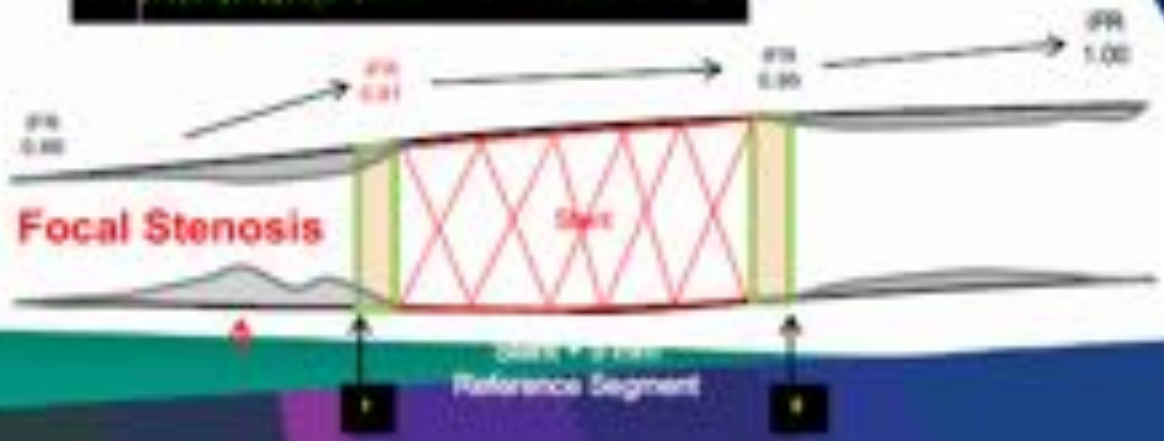
DEFINE PCI

Focal Residual Pressure Gradient Distal to stent

'Physiologic miss' occurred in 30.1% of focal lesions distally







In 10-20% of cases a vessel remains ischemic after an an oppropriate PCI

In 2/3 of the cases this « ischemic » vessel post PCI is due to a « missed » focal lesion

In patients with multivessel PCI 30-50% of patients have « incomplete » coronary revascularization

ESC European Society of Cardiology

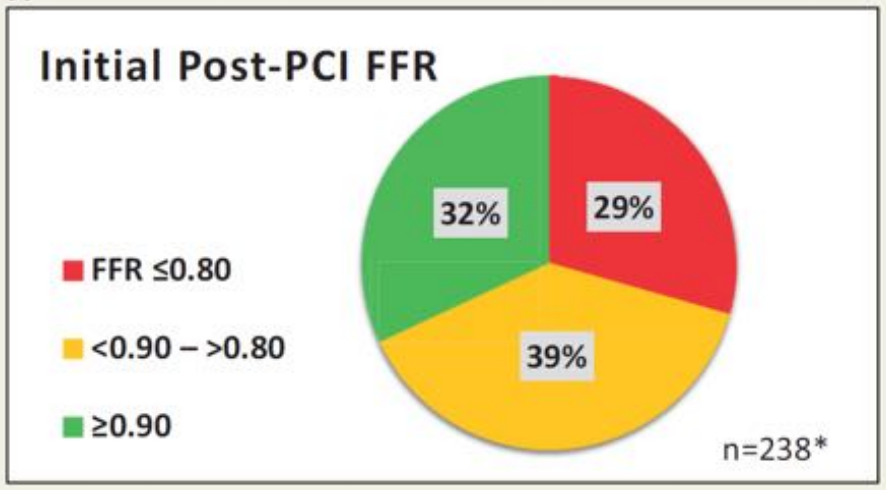
European Heart Journal (2021) **42**, 4656–4668
doi:10.1093/eurheartj/ehab449

FASTTRACK CLINICAL RESEARCH
Interventional cardiology

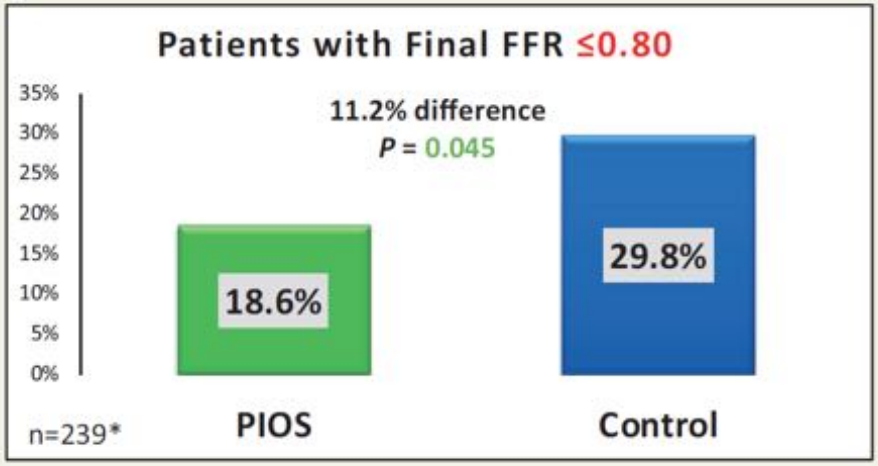
Post-stenting fractional flow reserve vs coronary angiography for optimization of percutaneous coronary intervention (TARGET-FFR)

Damien Collison [1,2*], **Matthaios Didagelos** [1],

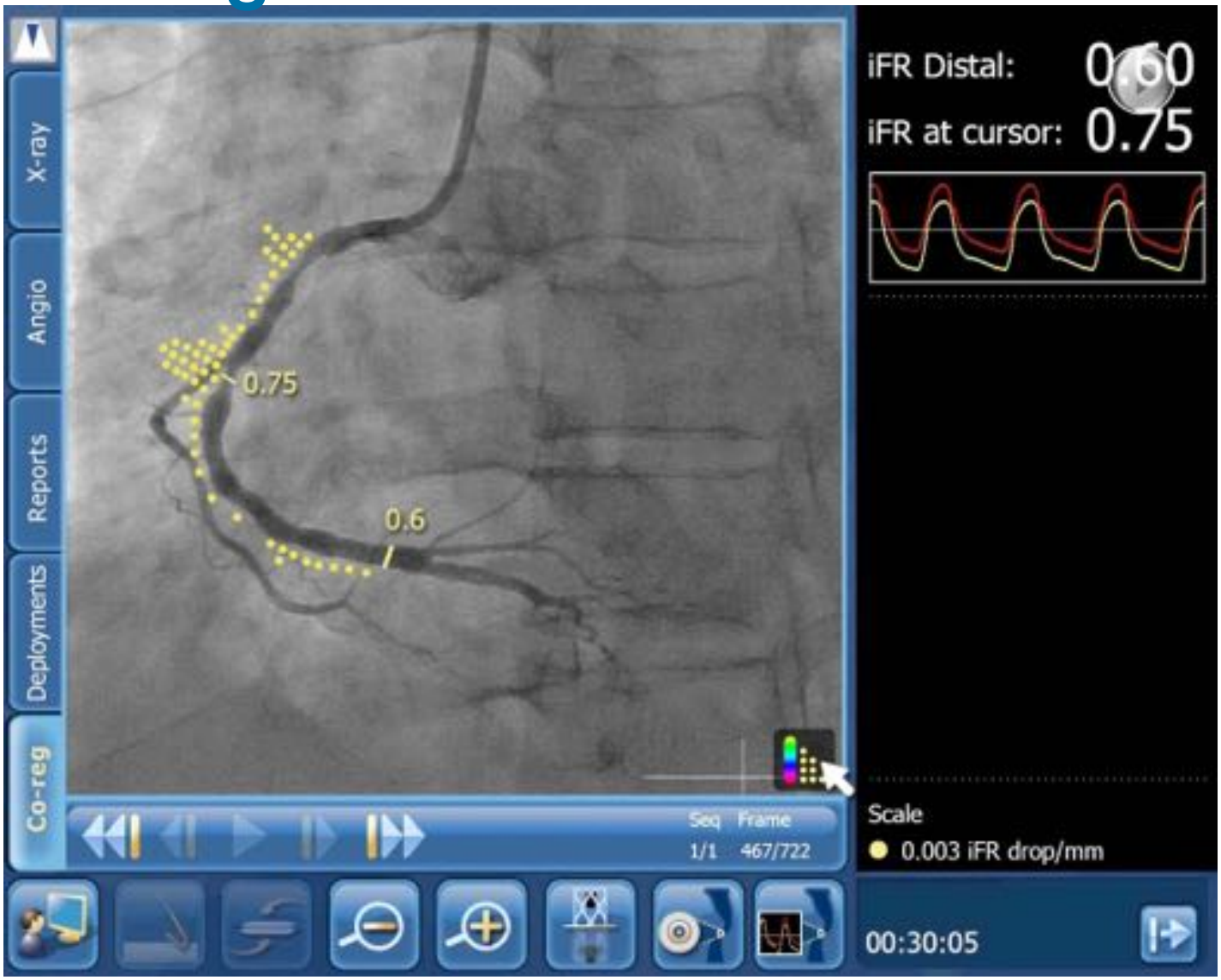
A



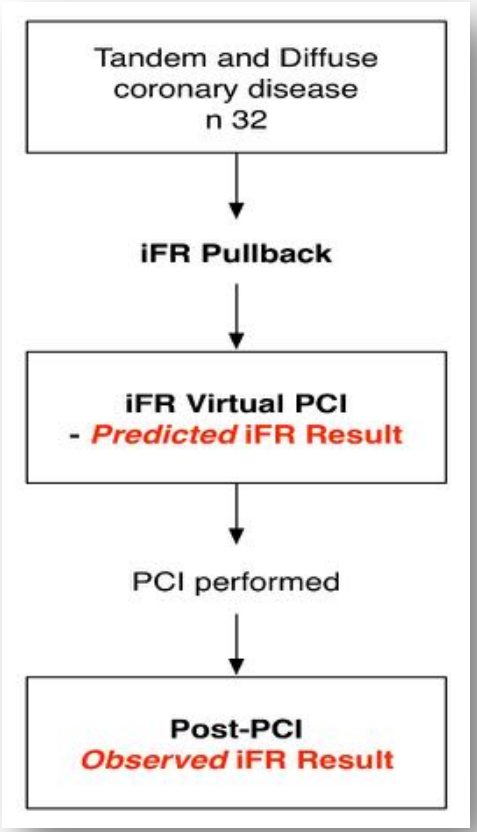
D



iFR Co-registration et Virtual PCI



iFR Pullback Study

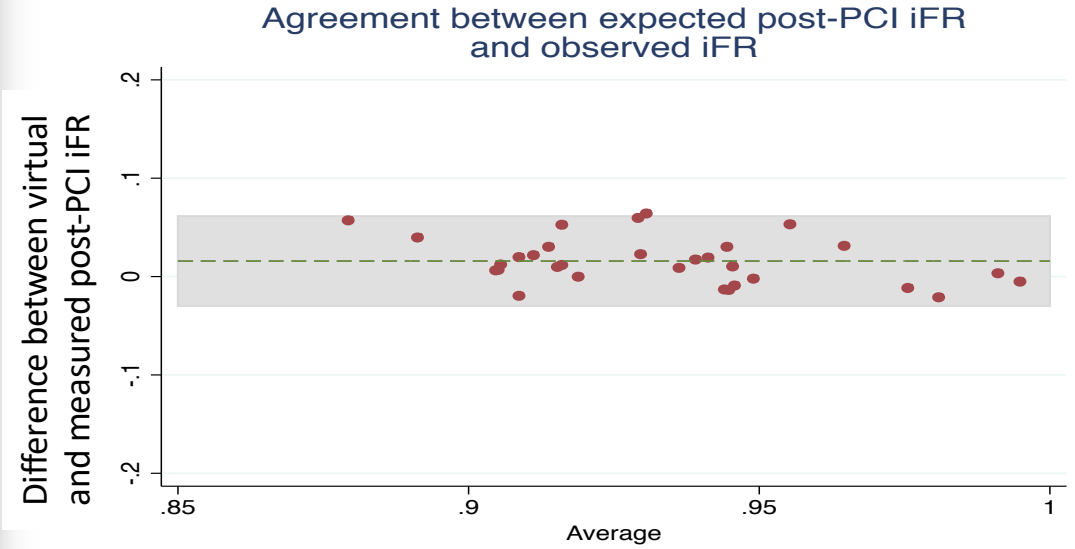


Pre-PCI iFR: 0.78 ± 0.03

Predicted iFR: 0.94 ± 0.01

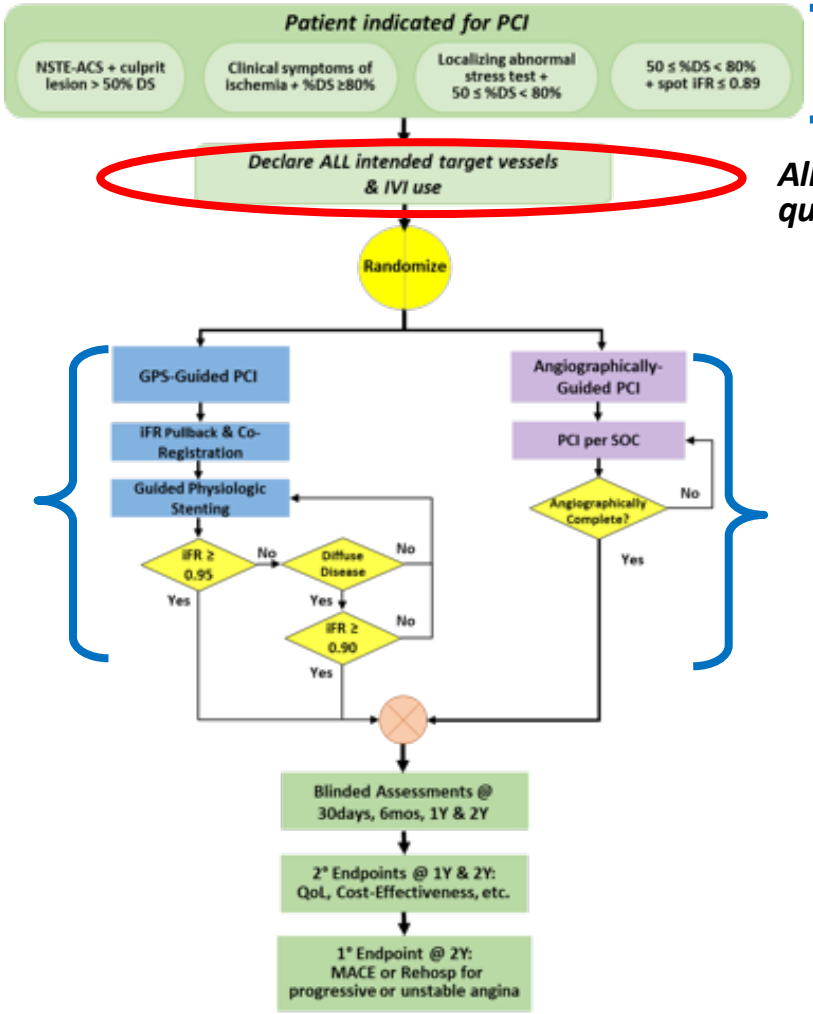
Observed iFR: 0.93 ± 0.03

p=0.48



Nijjer SS, Davies J et al *JACC: Cardiovascular Interventions*. 2014;7:1386–1396

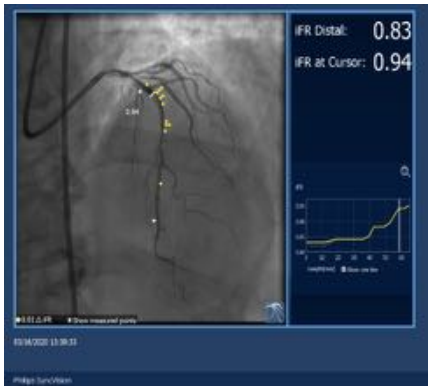
DEFINE GPS Flow



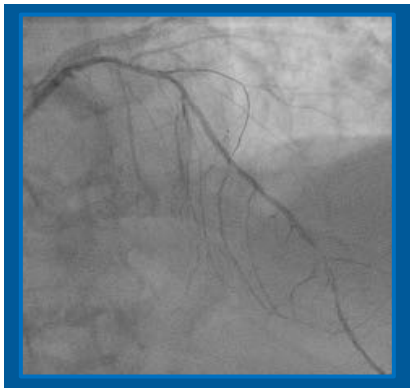
Aligned with Guideline Recommendations for PCI

All vessels to undergo PCI must be qualified prior to randomization

Physiology-Guided PCI



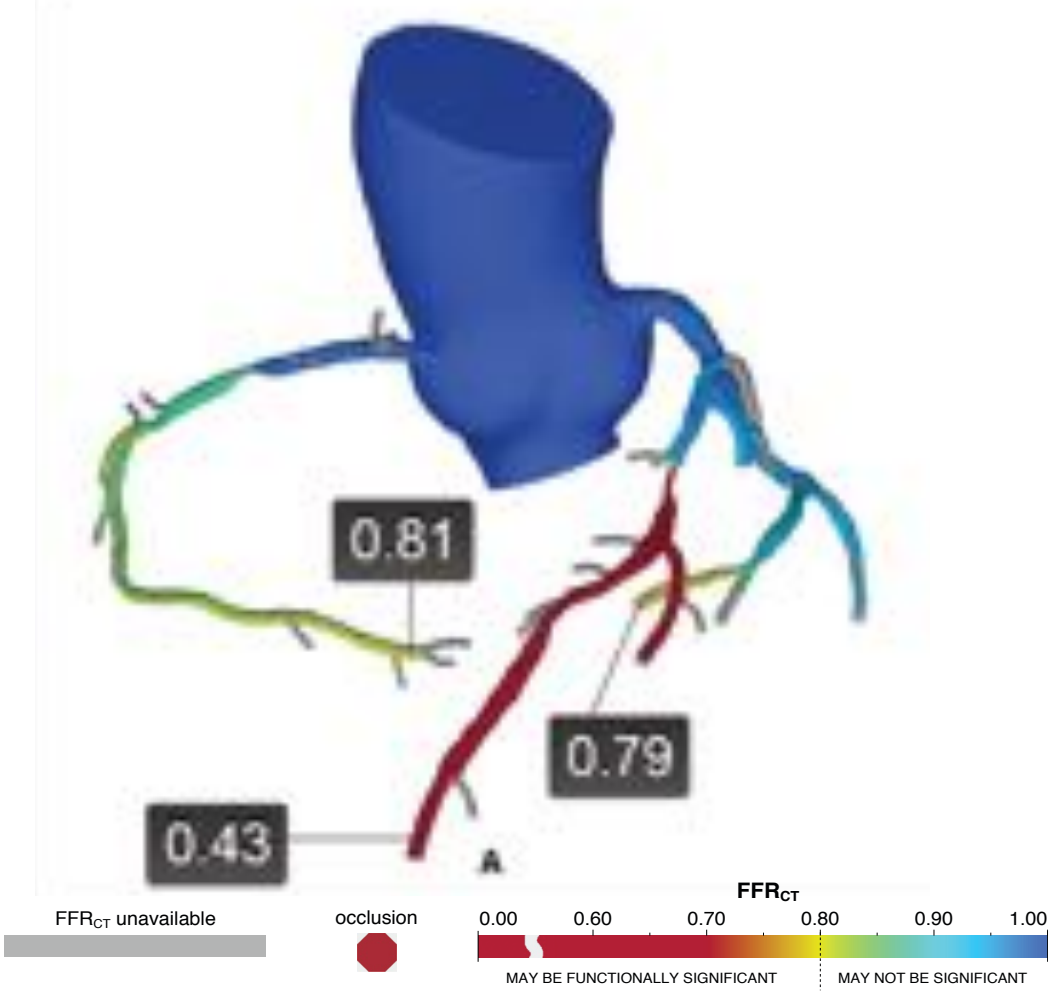
Standard of Care PCI



Further virtualization to « estimate » the pressure drop

Using CT to provide FFR

Multi-vessel narrowings, but functional ischemia in only a single vessel
Clinician determined that only a single stent was required



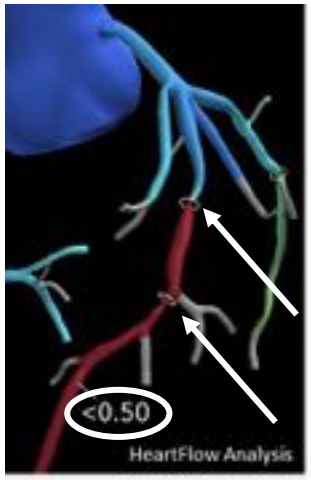
2019 euroPCR

Benefits of Obtaining information for planning With noninvasive FFR_{CT} prior to Invasive Evaluation- The BOWIE study

Eric Van Belle, MD PhD, Luis Raposo MD, Sergio Bravo Baptista MD PhD, Flavien Vincent, MD PhD, Sina Porouchani MD, Alessandro Cosenza MD, Campbell Rogers MD, Jonathon Leipsic MD

What is FFR_{CT} Planner*?

Pre-procedure evaluation of alternate treatment strategies to optimize coronary flow



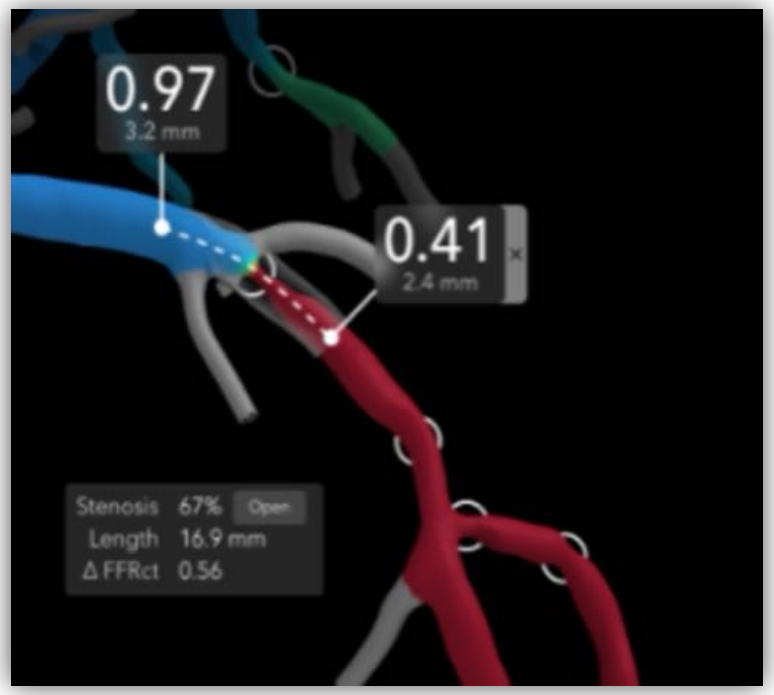
?

- Real-time non-invasive interactive tool
- Explore different clinical scenarios by virtually removing stenoses
- Assess resulting FFR_{CT} value(s) from any scenario

Van Belle et all JACC Imaging 2021

FFR_{CT} Planner* Virtual PCI

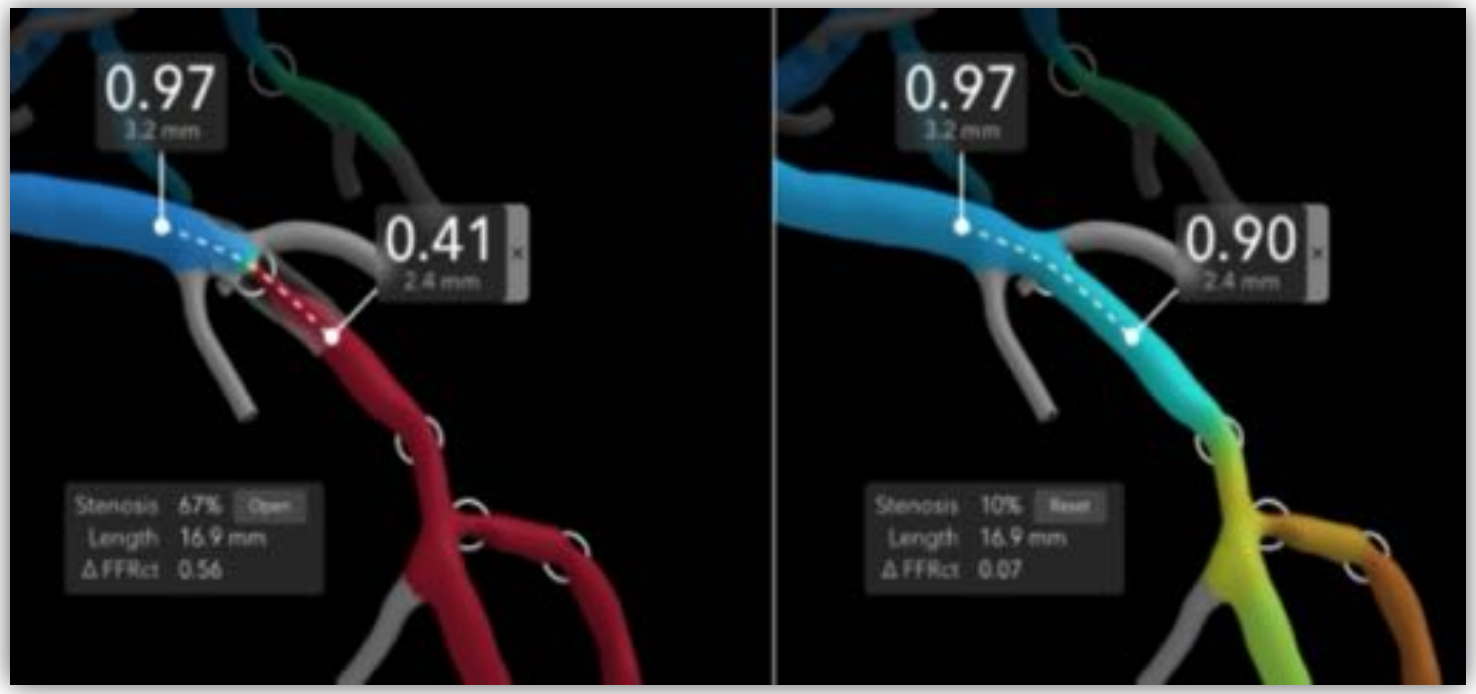
Real-time FFR_{CT} Recalculation



Van Belle et all JACC Imaging 2021

FFR_{CT} Planner* Virtual PCI

Real-time FFR_{CT} Recalculation



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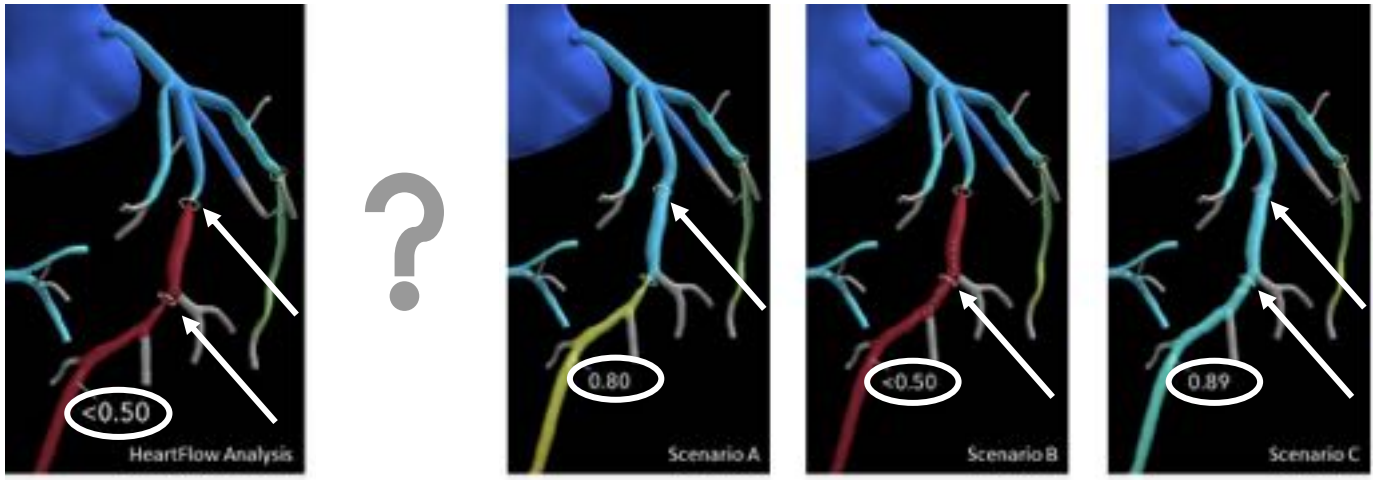
What is FFR_{CT} Planner*?

Pre-procedure evaluation of alternate treatment strategies to optimize coronary flow



- Real-time non-invasive interactive tool
- Explore different clinical scenarios by virtually removing stenoses
- Assess resulting FFR_{CT} value(s) from any scenario

*Not yet commercially available, pending Regulatory Review

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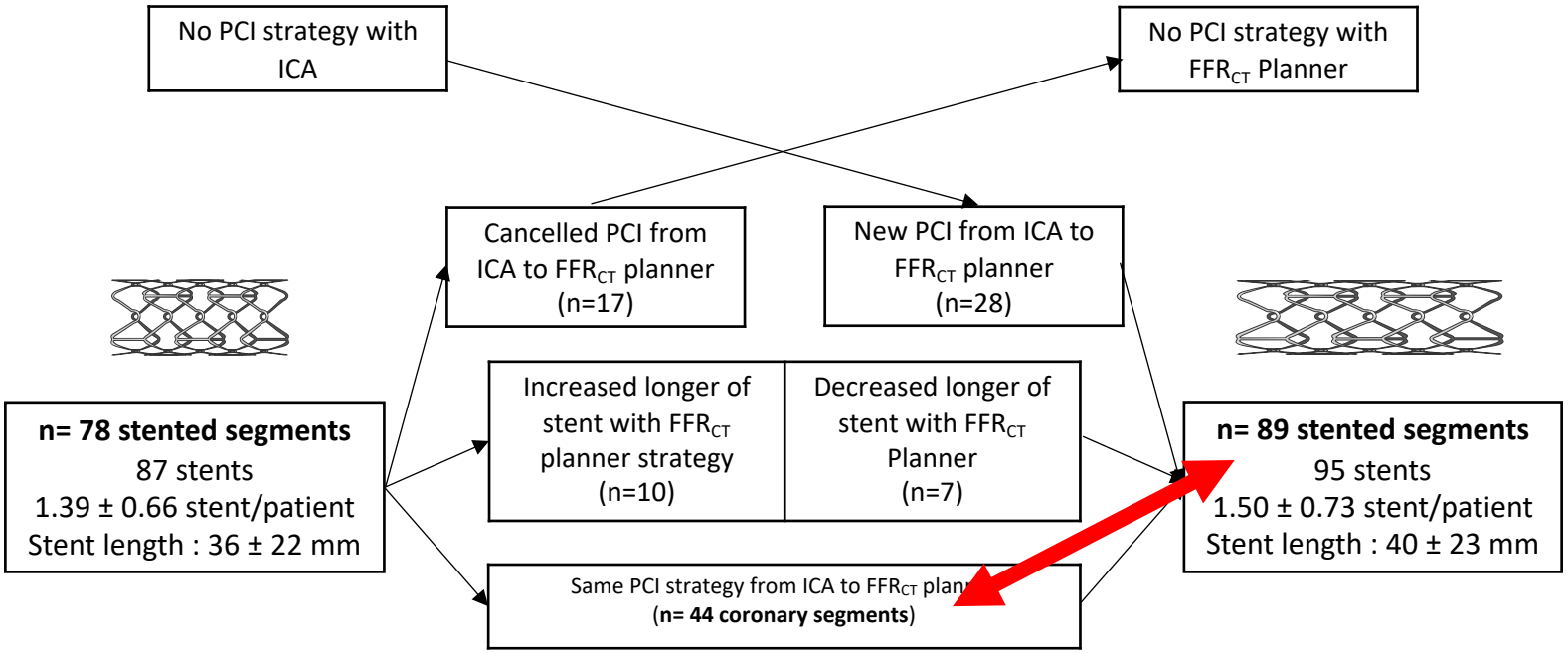
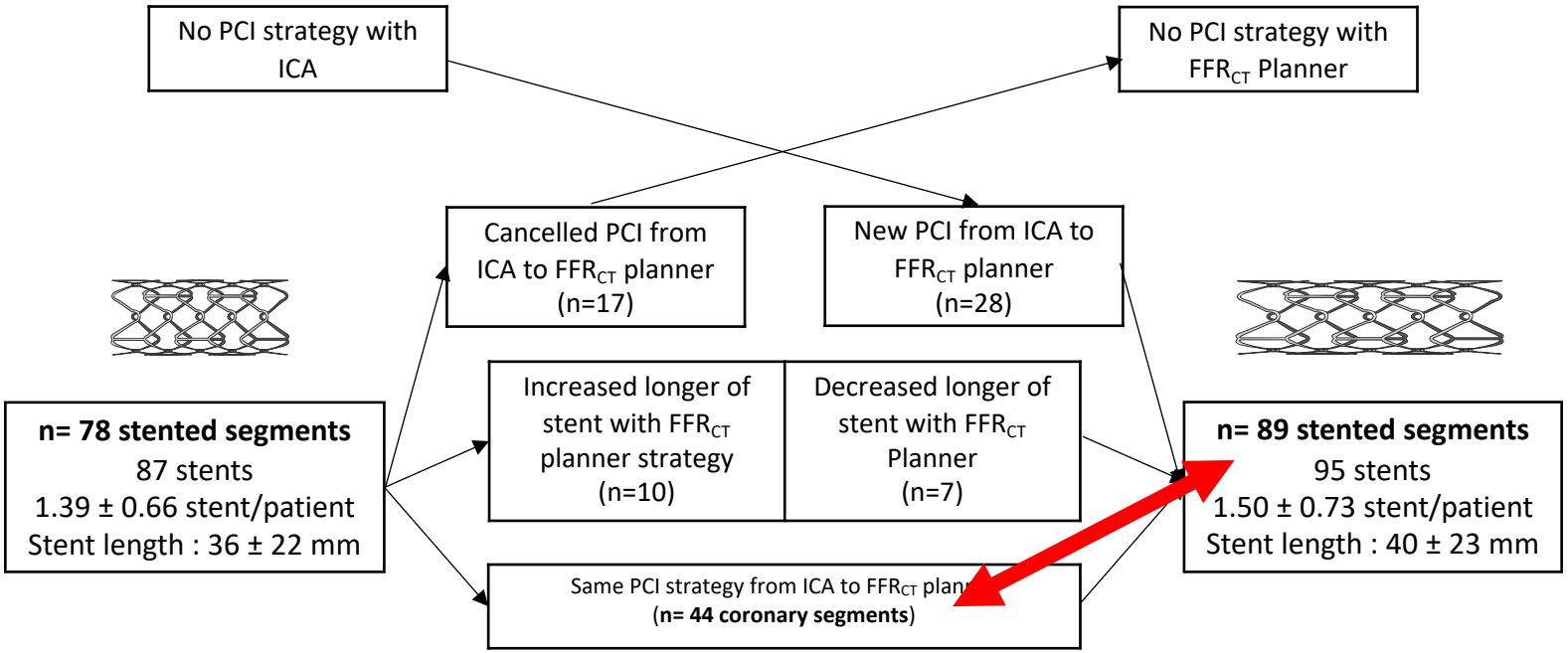


Van Belle et all JACC Imaging 2021



Change of strategy in 51% of cases

Van Belle et all JACC Imaging 2021

Quantitative Flow Ratio (QFR)

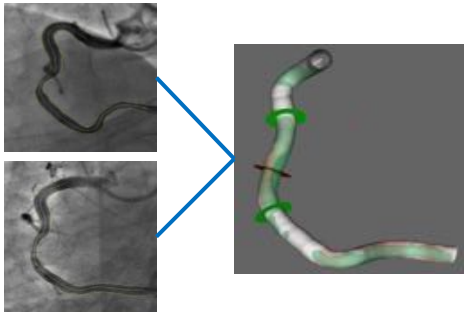
Standard Angiogram

Data Transmission System

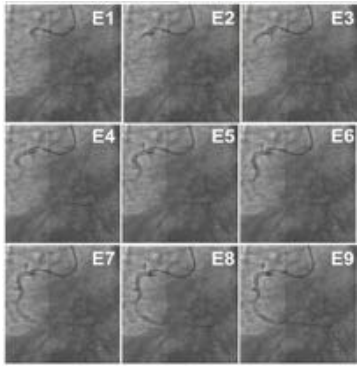
Two image runs with angle difference ≥25°

AngioPlus System

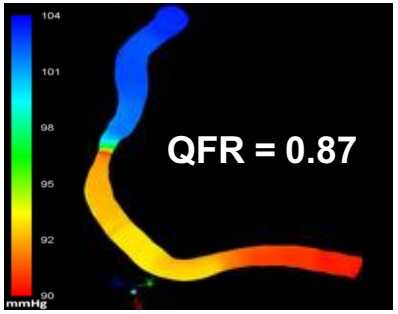
3D Reconstruction



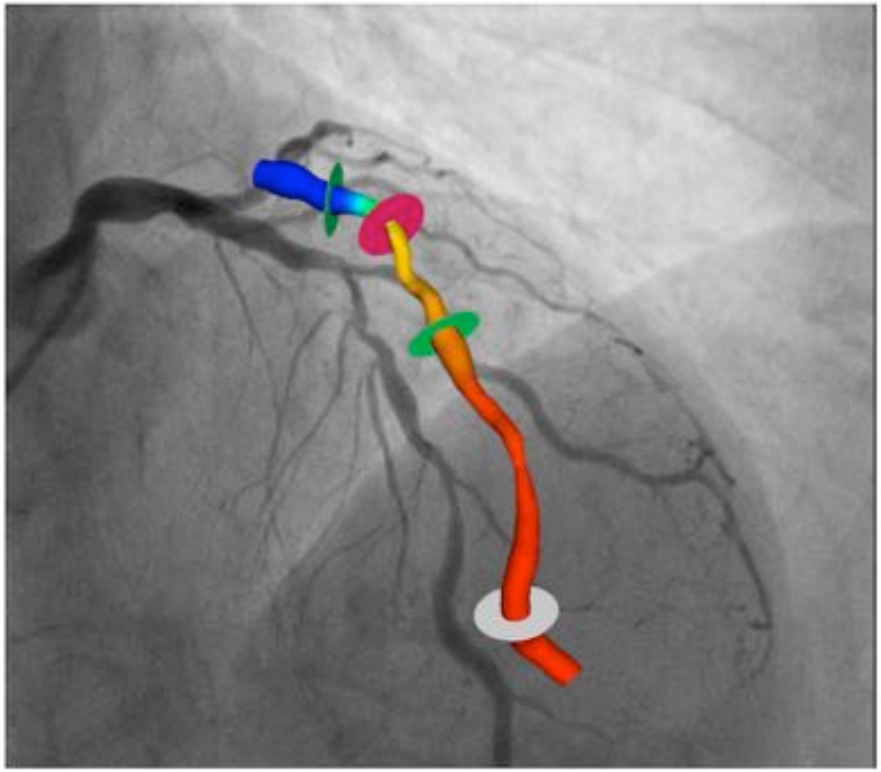
Modified Frame Count



QFR



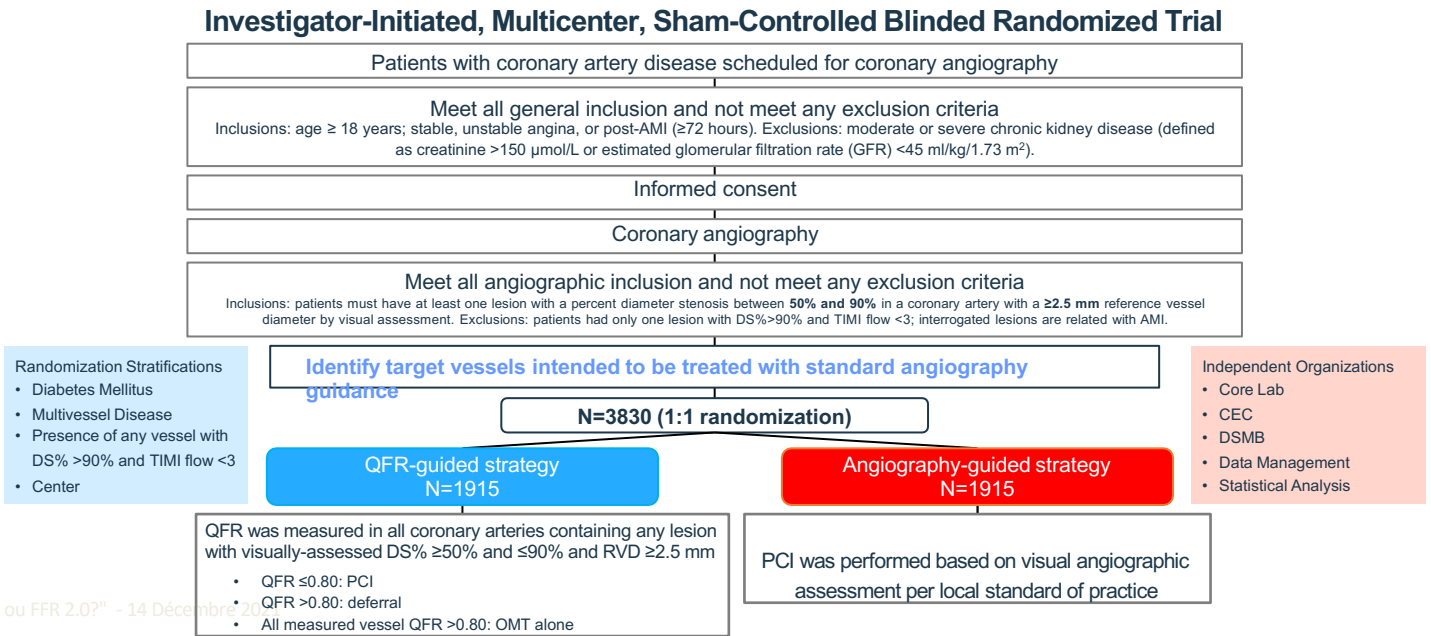
Without Inducing Hyperemia



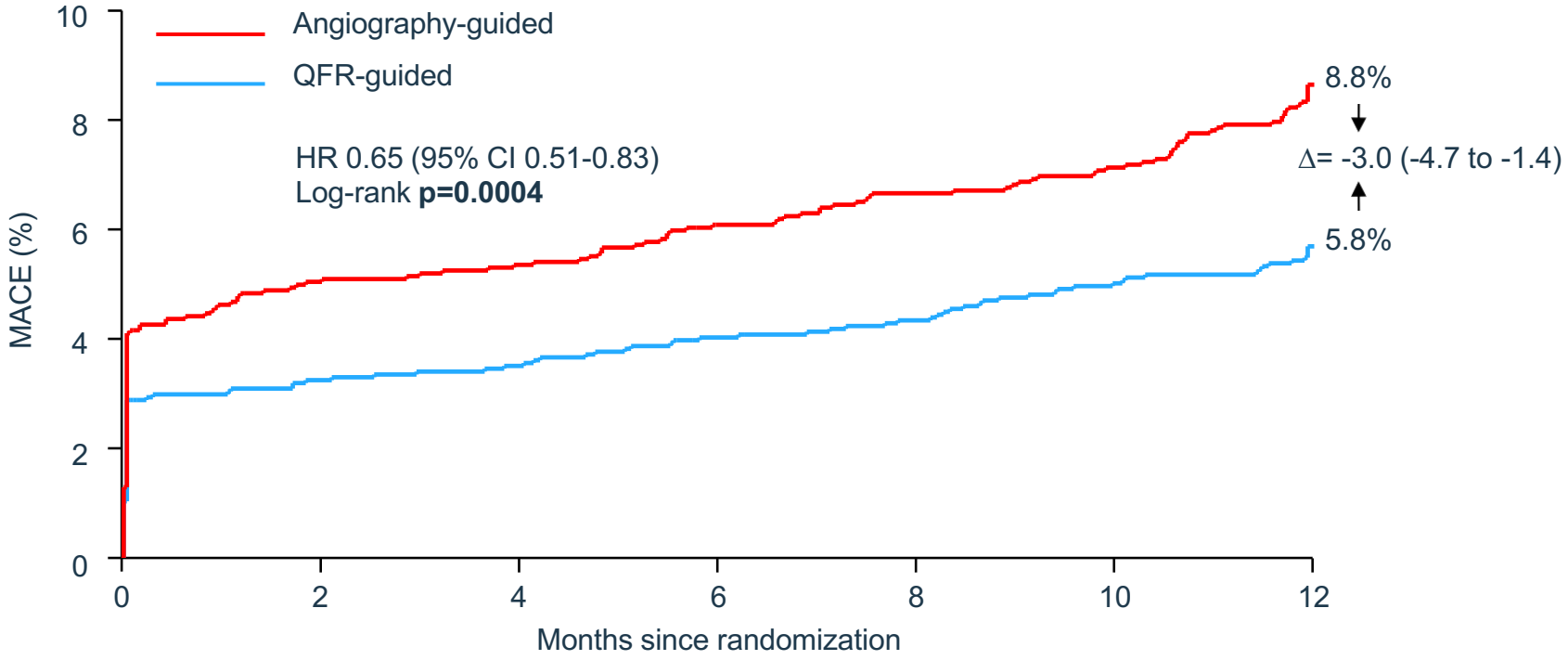
Study Design

Angiographic quantitative flow ratio-guided coronary intervention (FAVOR III China): a multicentre, randomised, sham-controlled trial

Bo Xu*, Shengxian Tu*, Lei Sang*, Zening Jin, Bo Yu, Guosheng Fu, Yujie Zhou, Jian'an Wang, Yundai Chen, Jun Pu, Liangfong Chen, Xinkai Qu, Junqing Yang, Xuebo Liu, Lijun Guo, Chengxing Shen, Yaojun Zhang, Qi Zhang, Hongwei Pan, Xiaogang Fu, Jian Liu, Yanyan Zhao, Javier Escaned, Yang Wang, William F Fearon, Kefei Dou, Ajay J Kirtane, Yongjian Wu, Patrick W Serruys, Weixian Yang, William Wijns, Changdong Guan, Martin B Leon†, Shubin Qiao*†, Gregg W Stone†; FAVOR III China study group‡



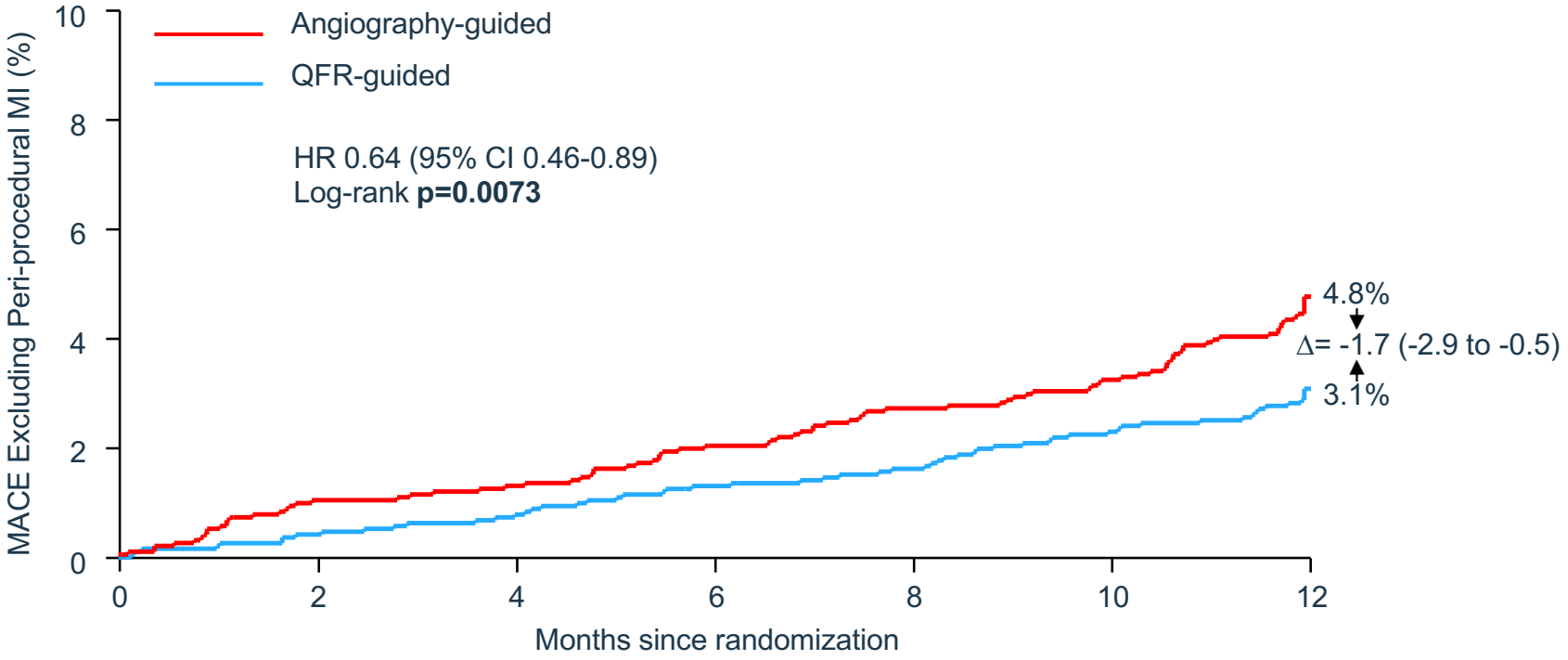
Primary Endpoint (ITT)



No. at risk

QFR-guided	1913	1845	1840	1828	1821	1809	1795
Angiography-guided	1912	1804	1798	1783	1770	1762	1732

Major Secondary Endpoint (ITT)



No. at risk

QFR-guided	1913	1900	1894	1881	1874	1862	1846
Angiography-guided	1912	1883	1877	1862	1847	1839	1808

FAVOR III Europe Japan

- Stable angina pectoris or evaluation of secondary stenosis after MI
- Coronary stenosis of 40-90% by visual estimate

↓

1:1 randomization of 2000 patients

↓ ↓

QFR guiding | **FFR guiding**

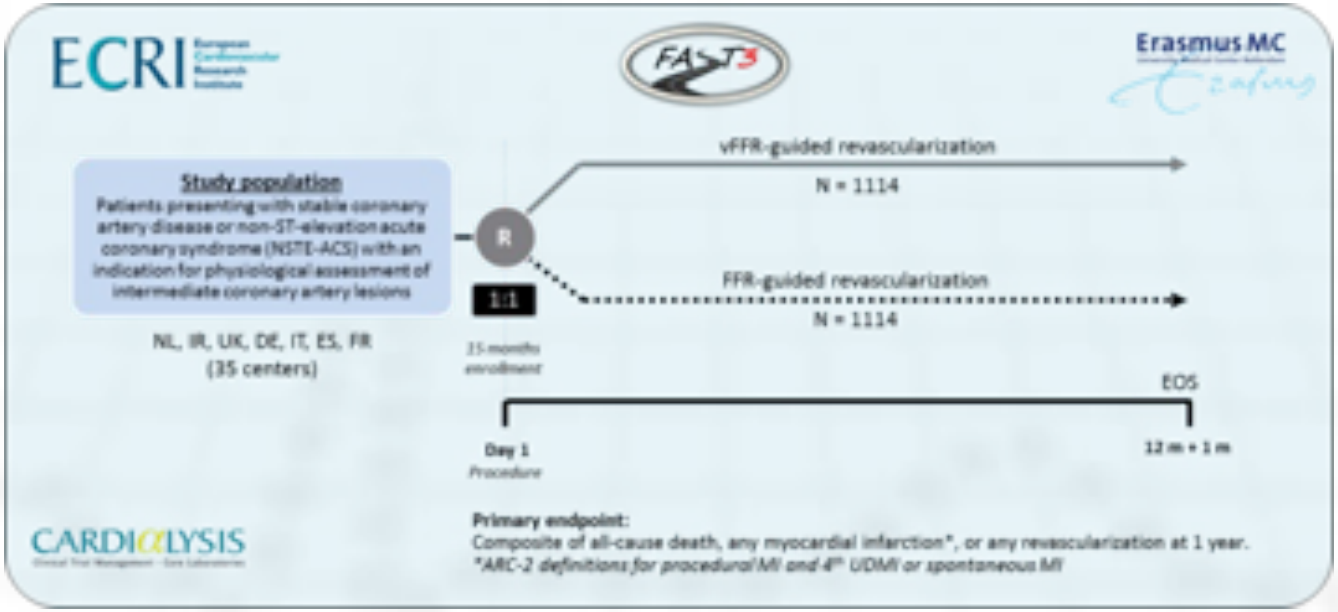
↓ ↓

Primary endpoint: One year PoCE for non-inferiority

Two-year follow-up | Only clinical follow-up

favor@clin.au.dk

Study flow chart



Summary 1

- ✓ Invasive pressure wire (FFR/iFR) is the "gold standard" for the detection of ischemic territory vessels.
- ✓ In patients with MVD, investigation of every vessel with lesion > 30% is critical to propose the best treatment option.
- ✓ Despite its benefit extensive one shot physiology investigation is difficult to achieve with invasive methods (in Flower MI only 5% of patients had complete FFR investigation at time of PCI).

Summary 2

- ✓ Recent studies haves shown that 20-25% vessel territories remain ischemic after an apparently appropriately conducted PCI:
  - ✓ Once the procedure is "finished" it is difficult to correct (TARGET FFR)
  - ✓ Pre-procedural pullback-derived pressure coronary mapping"
  - ✓ Combined to
  - ✓ virtual PCI"

    would be key to improve the clinical outcome of our coronary patients, in particular those with MVD.

➔ These approaches are difficult to achieve in most patients with current invasive technics

Perspective

- ✓ The recent clinical outcome study FAVOR 3 china demonstrated the benefit of the angio-based QFR versus Angiography alone in patients referred for PCI
- ✓ Additional studies will further define the role of these "virtual approaches" in patient workflow:
  - ✓ Virtual PCI (based on iFR) versus angiography: DEFINE-GPS
  - ✓ Clinical outcome studies for "Angio-based-FFR" versus FFR: FAVOR 3 Europe-Japan, FAST 3
  - ✓ Added value of FFR-CT on top CT-scan: The CROISSANT study

Thank you for your attention!

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QCM 1

- Dans le cadre de la prise en charge d'un infarctus transmural par angioplastie primaire chez un patient multitronculaire, vous faites la FFR des vaisseaux non-coupables:
- A) Oui, dans la même procédure
- B) Oui, dans la même procédure (mais pas la nuit)
- C) Oui, je remet le patient sur la table pour une nouvelle coronarographie (et un FFR) quelques jours plus tard.
- D) jamais

Perspective

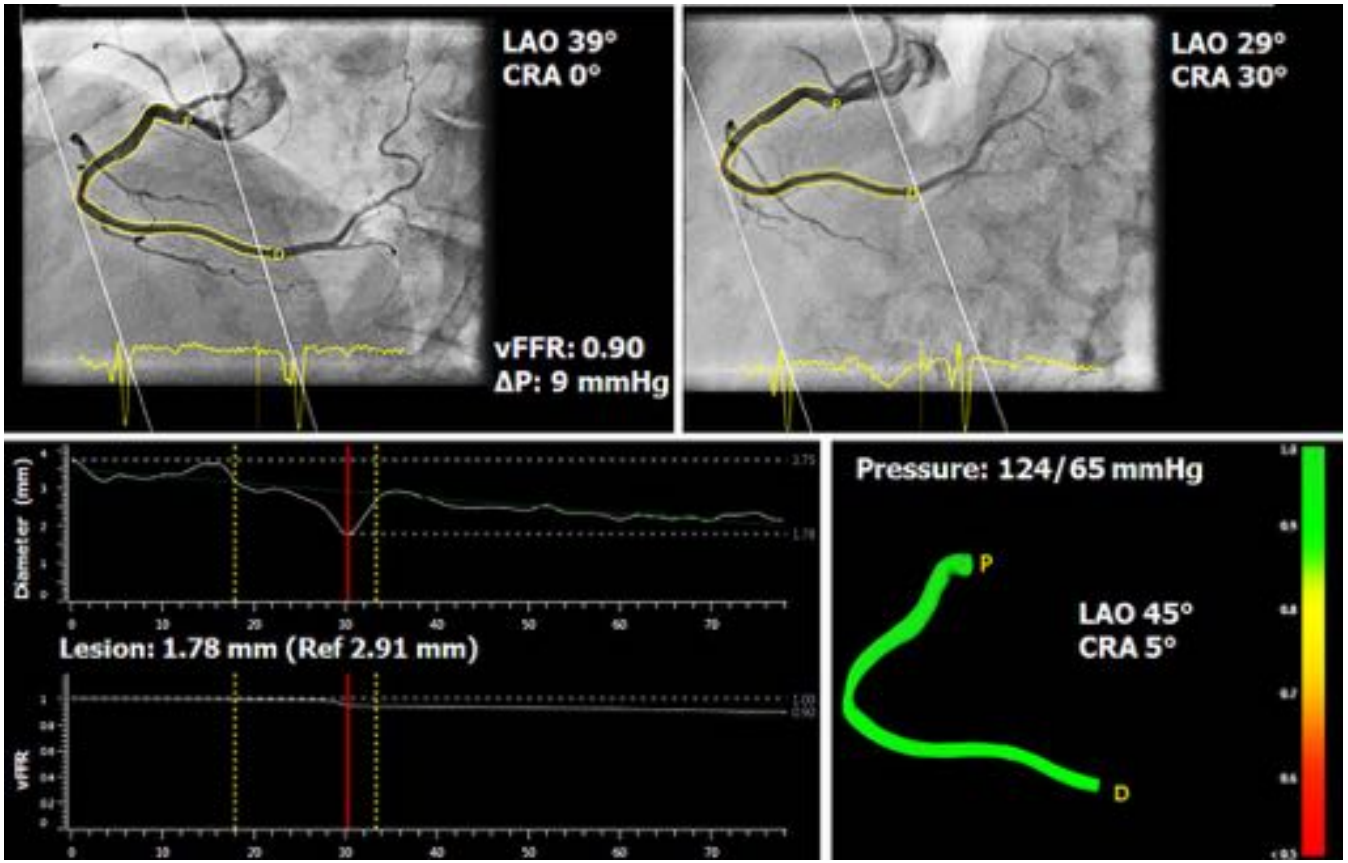
- ✓ Virtualization of coronary pressure drop using computational fluid dynamics derived from imaging (CT-scan or angiography) has a strong potential to provide a more complete picture of pressure drop in all coronary arteries in a single investigation.

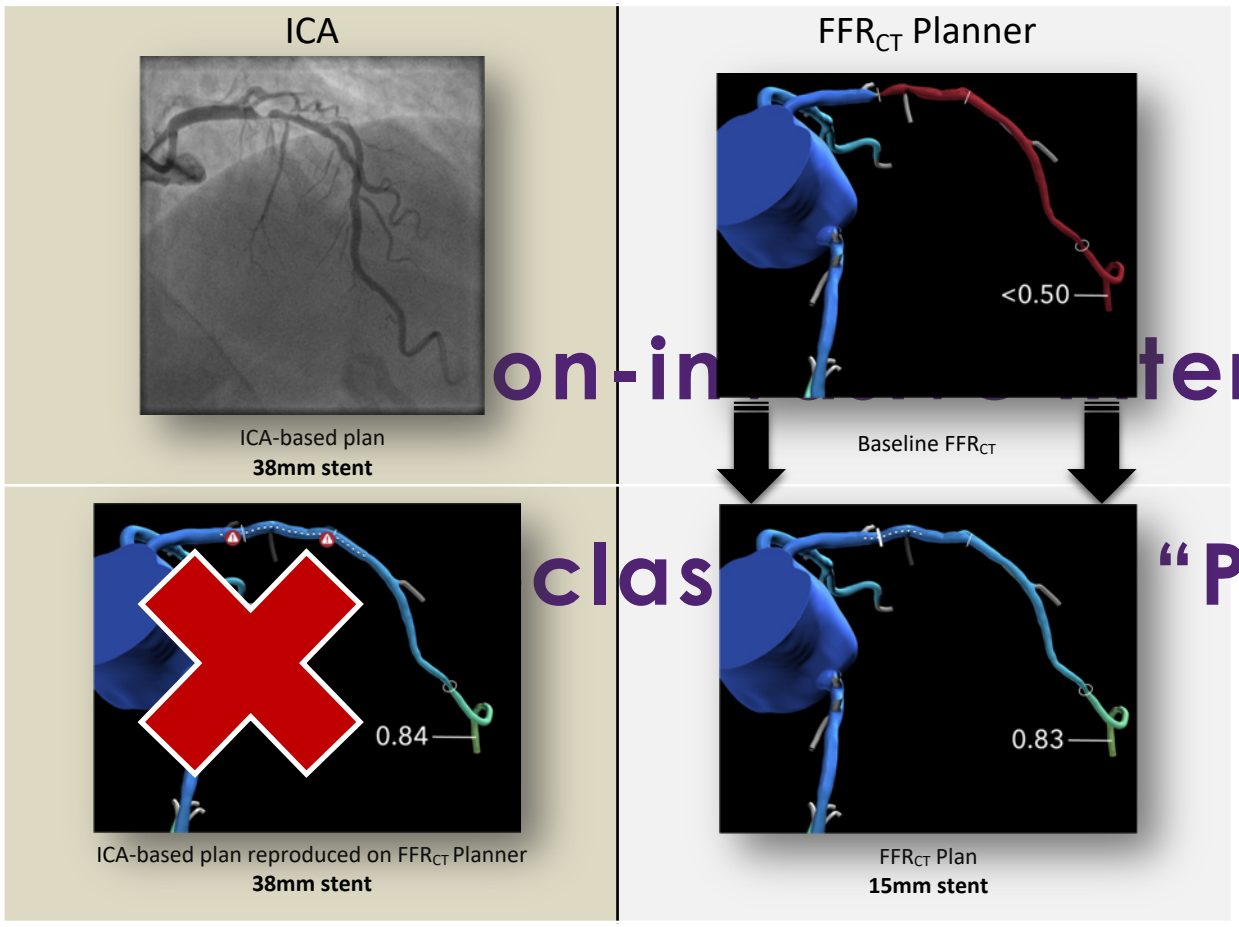
- ✓ It has also the potential to test different PCI scenario and to predict the final "FFR" of these scenario: Virtual PCI

Virtual FFR based on Agngiography

Required:

- **2 contrast filled angiograms**
- **Orthogonal views: ≥30 degrees**
- **Invasive aortic pressure**

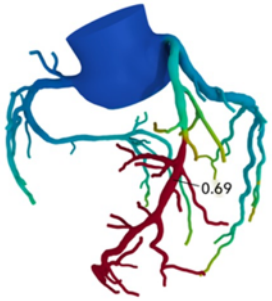




Reduced stent length using FFR$_{CT}$ Planner strategy yielded similar physiologic result as ICA-based plan

FFR_{CT} Planner Core Components

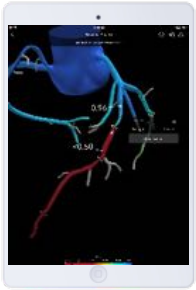
1 **Starts with the HeartFlow Analysis**



Interactive Mobile Platform 2

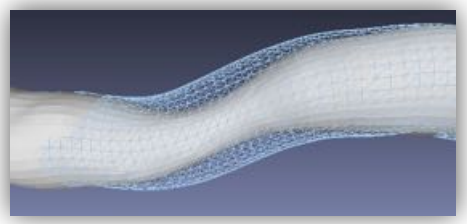
- iOS, interactive viewer

HeartFlow Planner



3 **Ideal Geometry**

- Contains a second anatomic model representing the "ideal" vessel

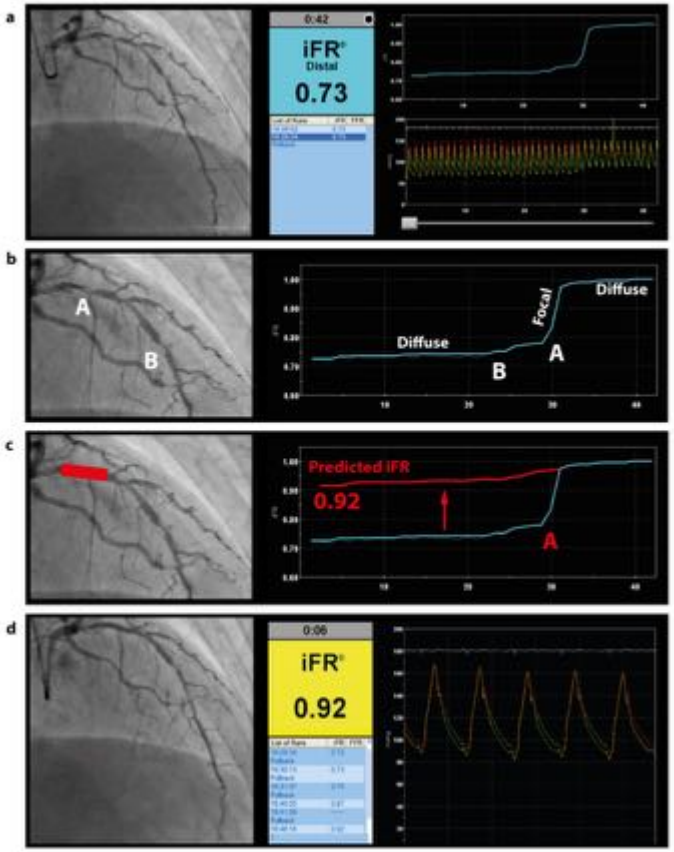


Real-time FFR_{CT} calculation 4

- Modified vessel combined with updated physiology

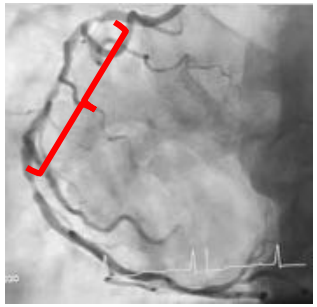
*Not yet commercially available, pending Regulatory Review

iFR et lésions en série

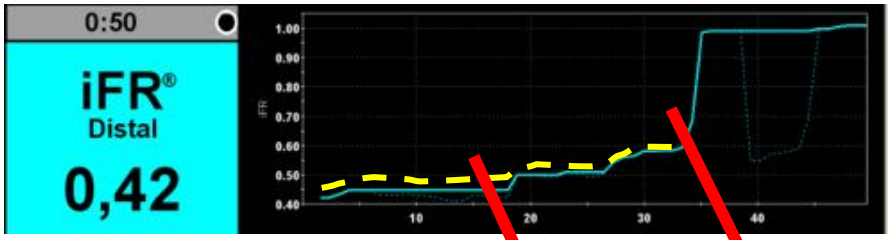


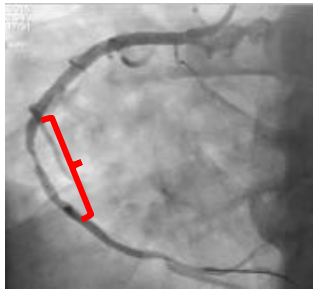
- Nombre et extension des sténoses n'impactent pas significativement le flux basal
- La perte de charge hémodynamique due à une lésion est spécifique à cette lésion uniquement
  - ✓ « Absence » de cross-talk entre les lésions en série
- Le changement du profil hémodynamique après angioplastie devient donc prévisible

iFR pull-back

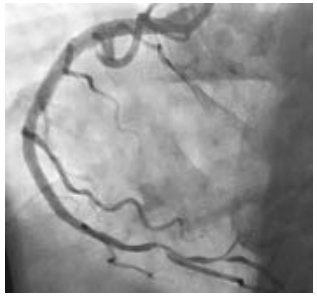


Profil de la perte de charge

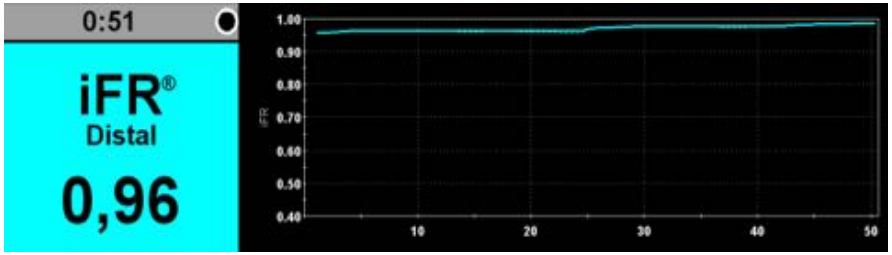


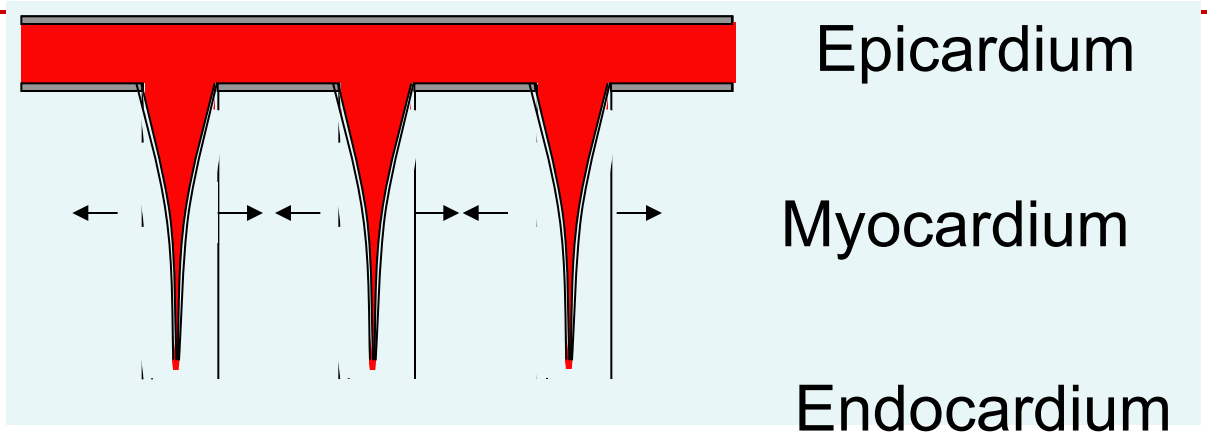


Perte de charge résiduelle
après 1er stenting

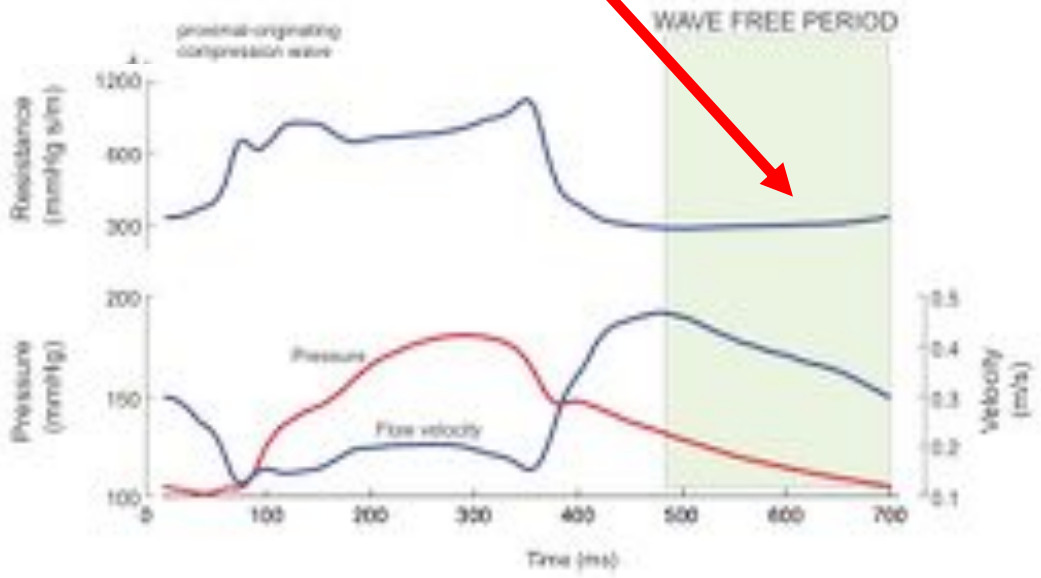


Profil hémodynamique
normal





Distal pressure falling



Homme, 78 *ans*

Bon état général

ATCD IDM inferieur (10 ans) – CD occluse connue non revascularisée

Hospitalisé pour NSTEMI avec décompensation cardiaque.

ETT : FEVG conservée avec séquelle inférieure.

Anticoagulation efficace pour une fibrillation atriale.

Fonction rénale normale. Pas de diabète.

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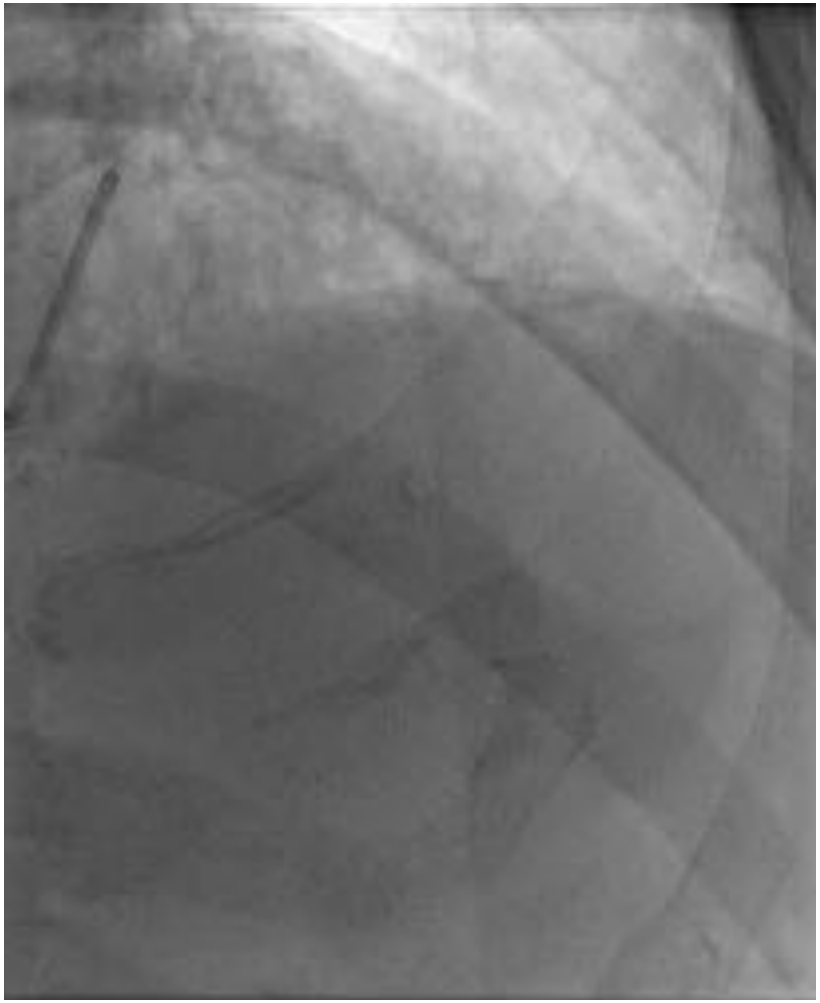

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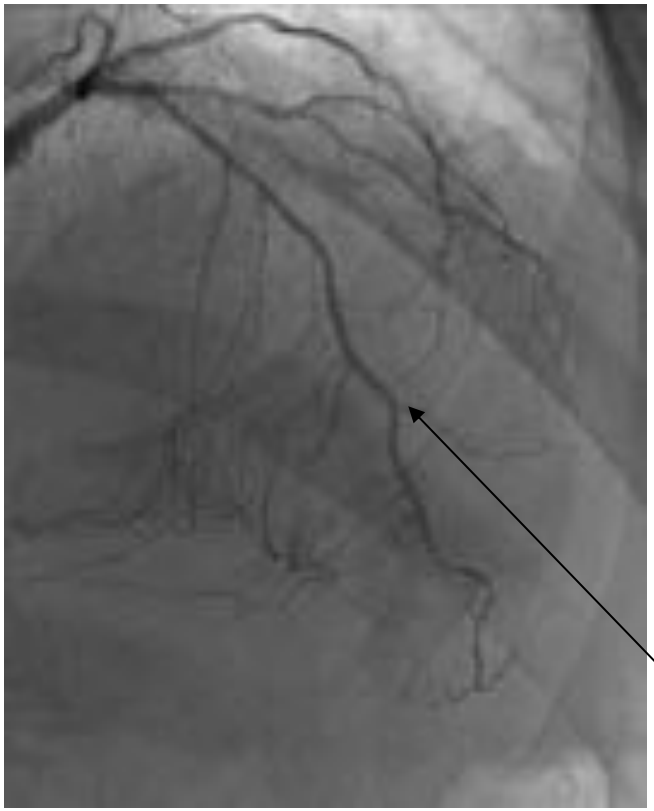

Zone de mesure avec le guide de pression

Evaluation physiologique sur l'IVA

FFR à 0,74
iFR à 0,69

Vaisseau physiologiquement très ischémique

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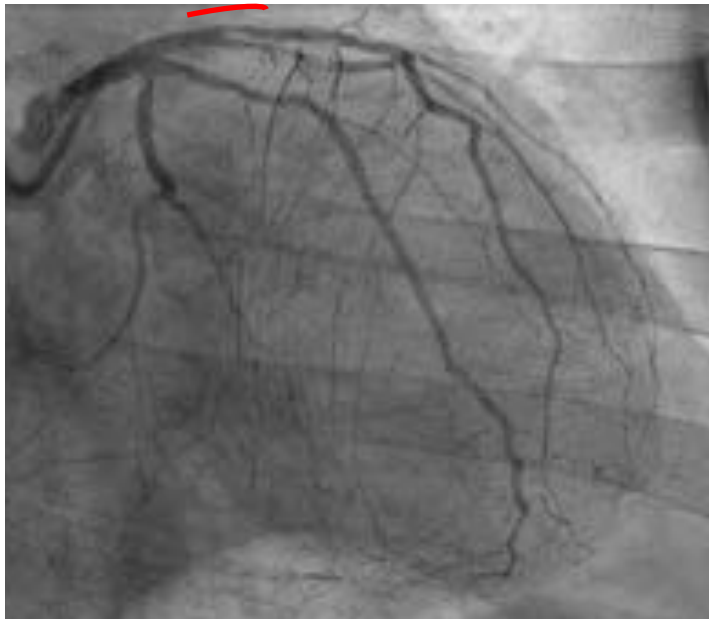

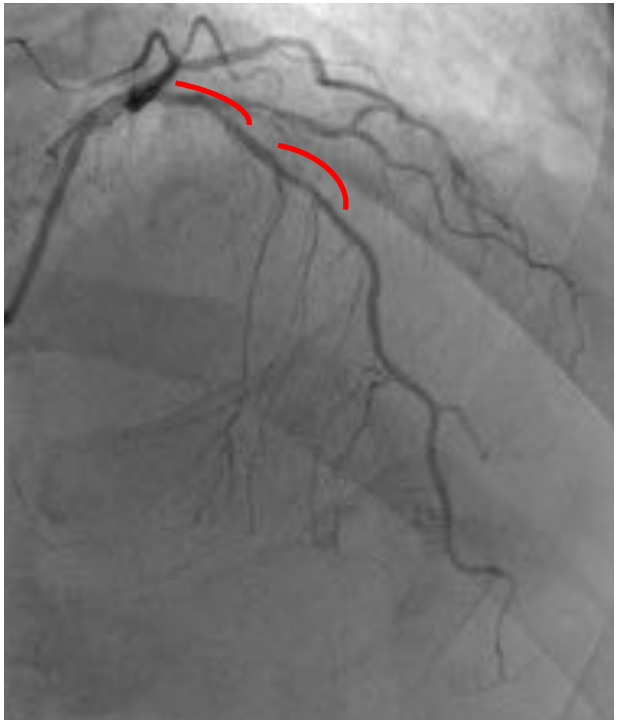

Angiographiquement :

Lésions relativement diffuses avec 2 zones distinctes

↓

Quelle stratégie de revascularisation ?

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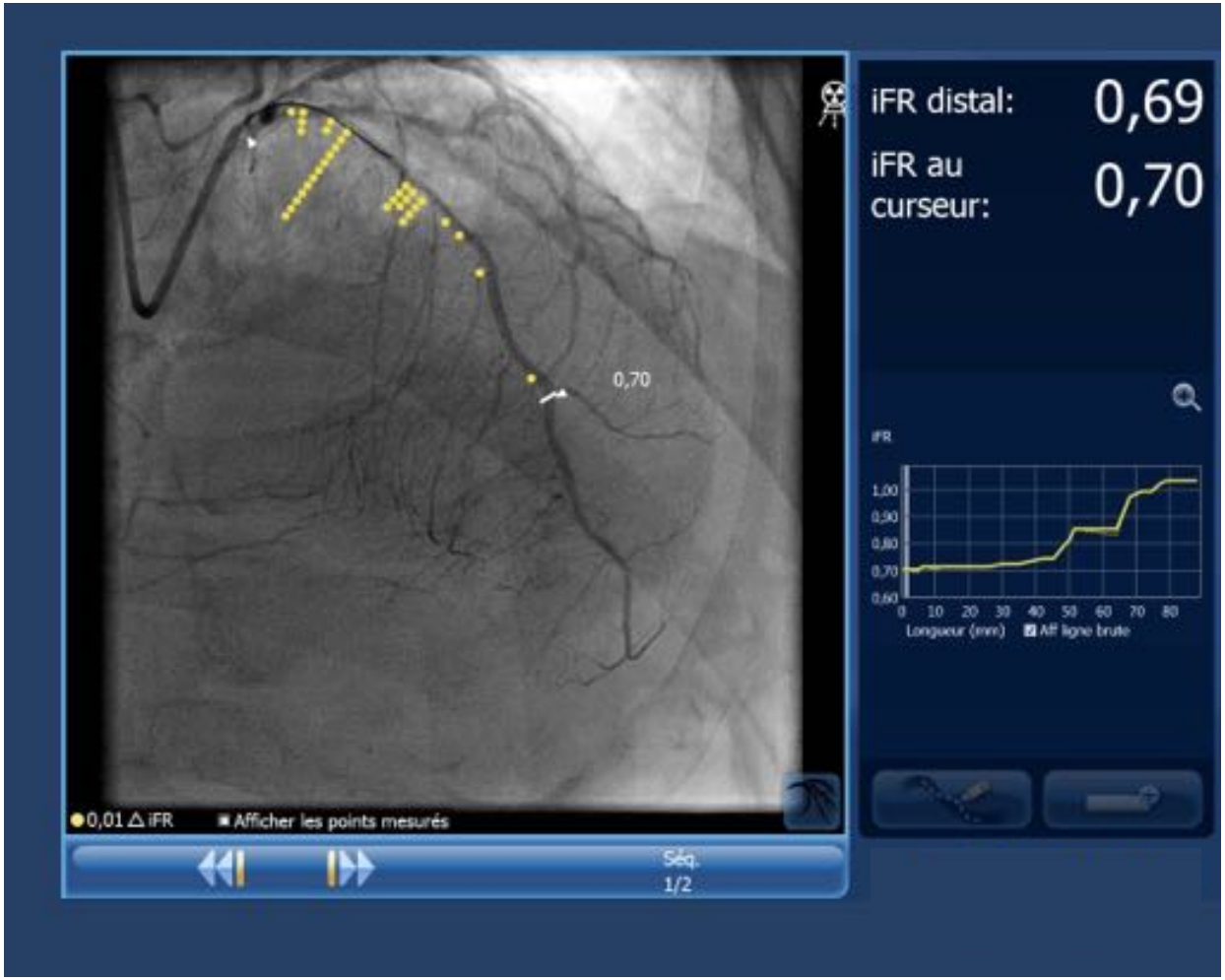

iFR pull back

Perte de charge bien repartie entre les 2 lésions

Pour amener iFR >.9 nécessité de traiter les 2 lésions

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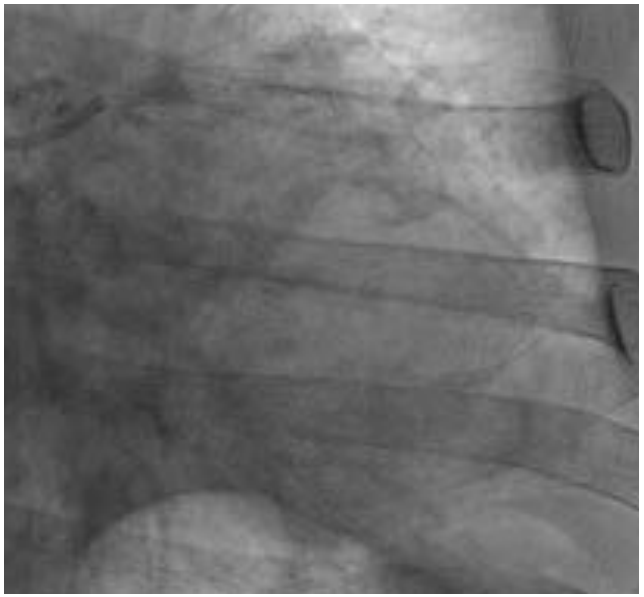
2 stents actifs 2,75*28mm et 3,5*28mm
POT à 3,75mm, Side vers la diagonale et POT final.



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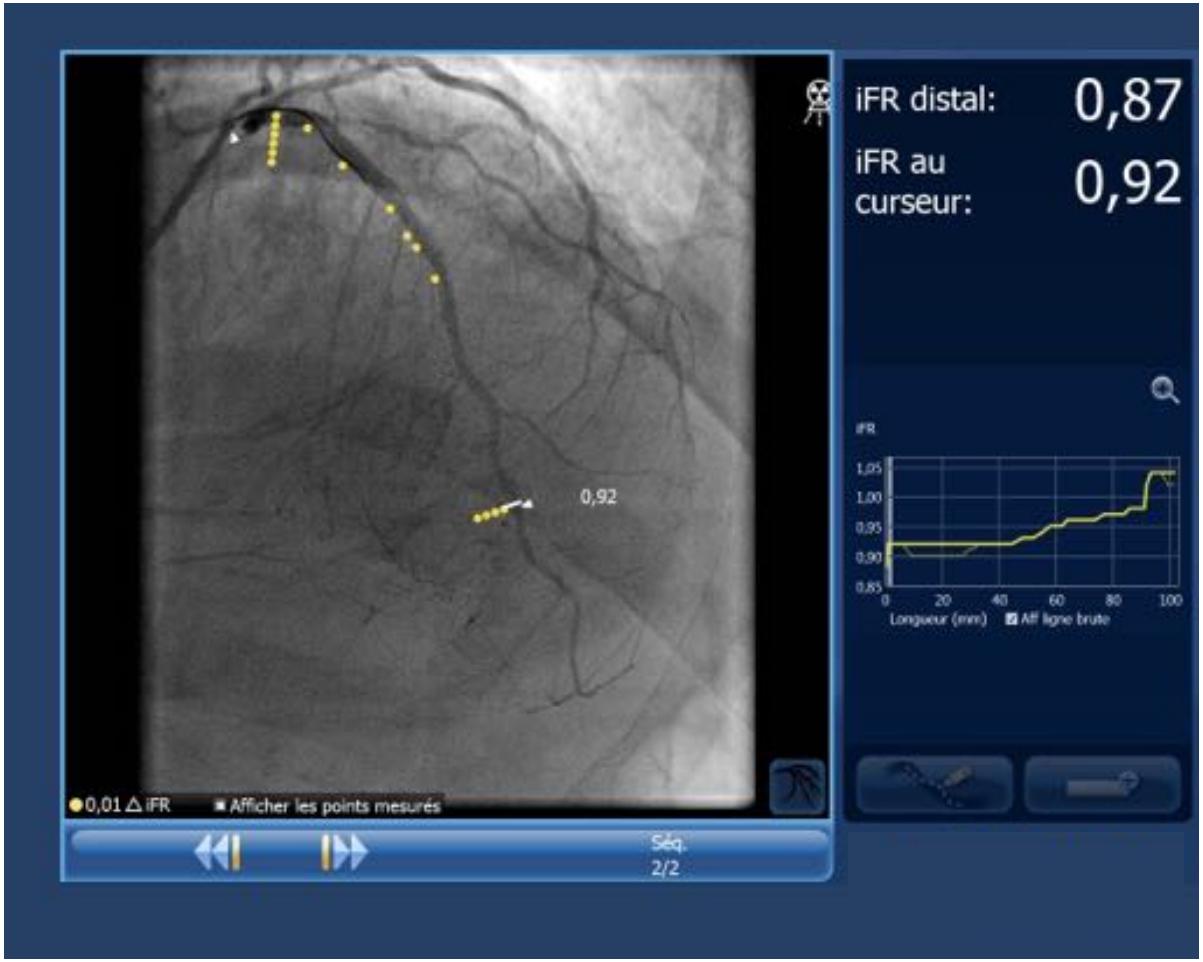

Excellent résultat hémodynamique avec iFR final au même point à 0,92.

Gain de 0,23 par la revasularisation

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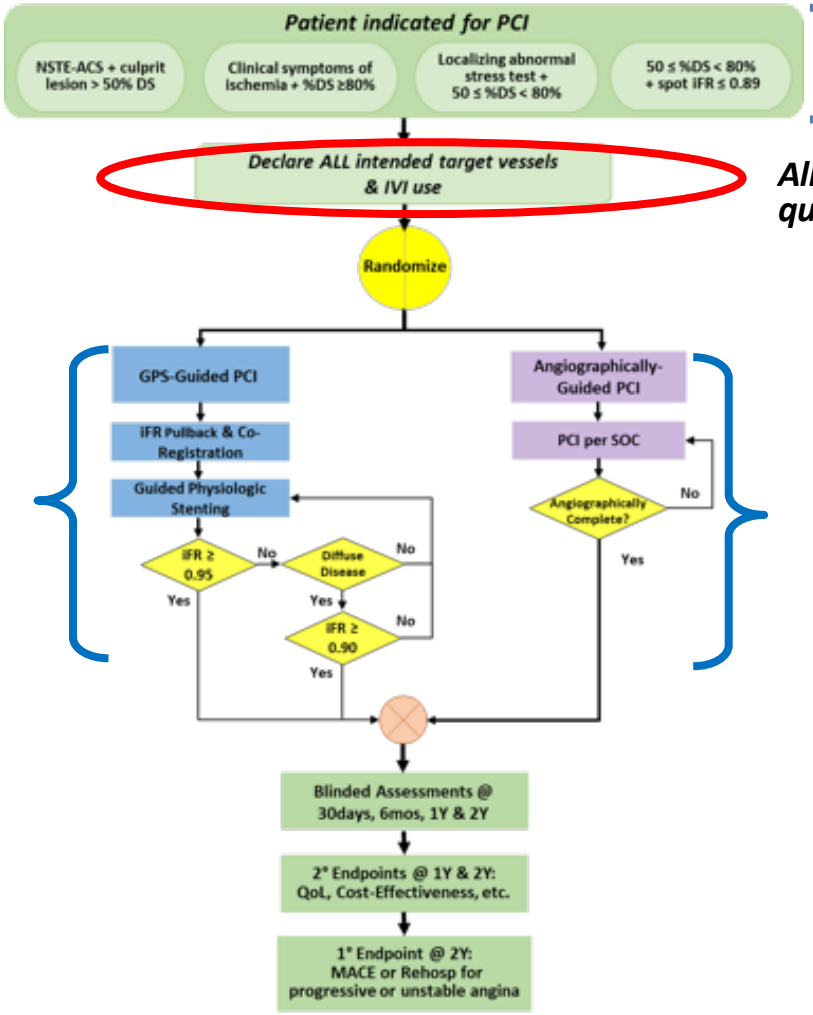
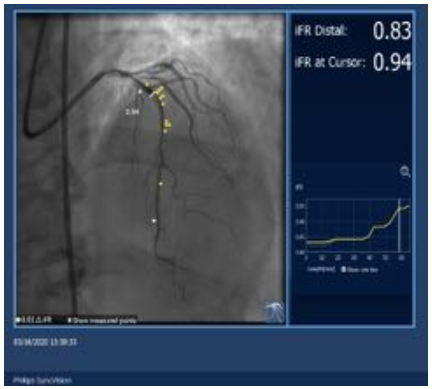
DEFINE GPS Flow



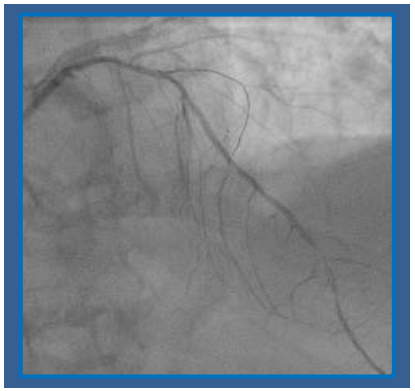
Aligned with Guideline Recommendations for PCI

All vessels to undergo PCI must be qualified prior to randomization

Physiology-Guided PCI



Standard of Care PCI



2019 ESC Guidelines on the diagnosis and management of chronic coronary syndromes

ESC
European Society of Cardiology

What is new in the 2019 Guidelines?

New recommendations (1)

ESC European Society of Cardiology

Basic testing, diagnostics, and risk assessment

Non-invasive functional imaging or coronary CTA as the initial test for diagnosing CAD.	Invasive angiography to diagnose CAD in patients with - a high clinical likelihood and severe symptoms refractory to medical therapy - typical angina at low level of exercise and clinical evaluation that indicates high event risk. Invasive functional assessment must be available and used to evaluate stenoses before revascularization, unless very high grade (>90% diameter stenosis).	Invasive coronary angiography with availability of invasive functional evaluation for confirmation of CAD diagnosis in patients with uncertain diagnosis on non-invasive testing.
Initial non-invasive diagnostic test based on the clinical likelihood of CAD, patient characteristics, local expertise and availability.		Coronary CTA as an alternative to invasive angiography if another non-invasive test is equivocal or non-diagnostic.
Functional imaging for myocardial ischaemia if coronary CTA has shown CAD of uncertain functional significance or is not diagnostic.		Coronary CTA when any conditions make good image quality unlikely.

Class I Class IIa Class IIb Class III

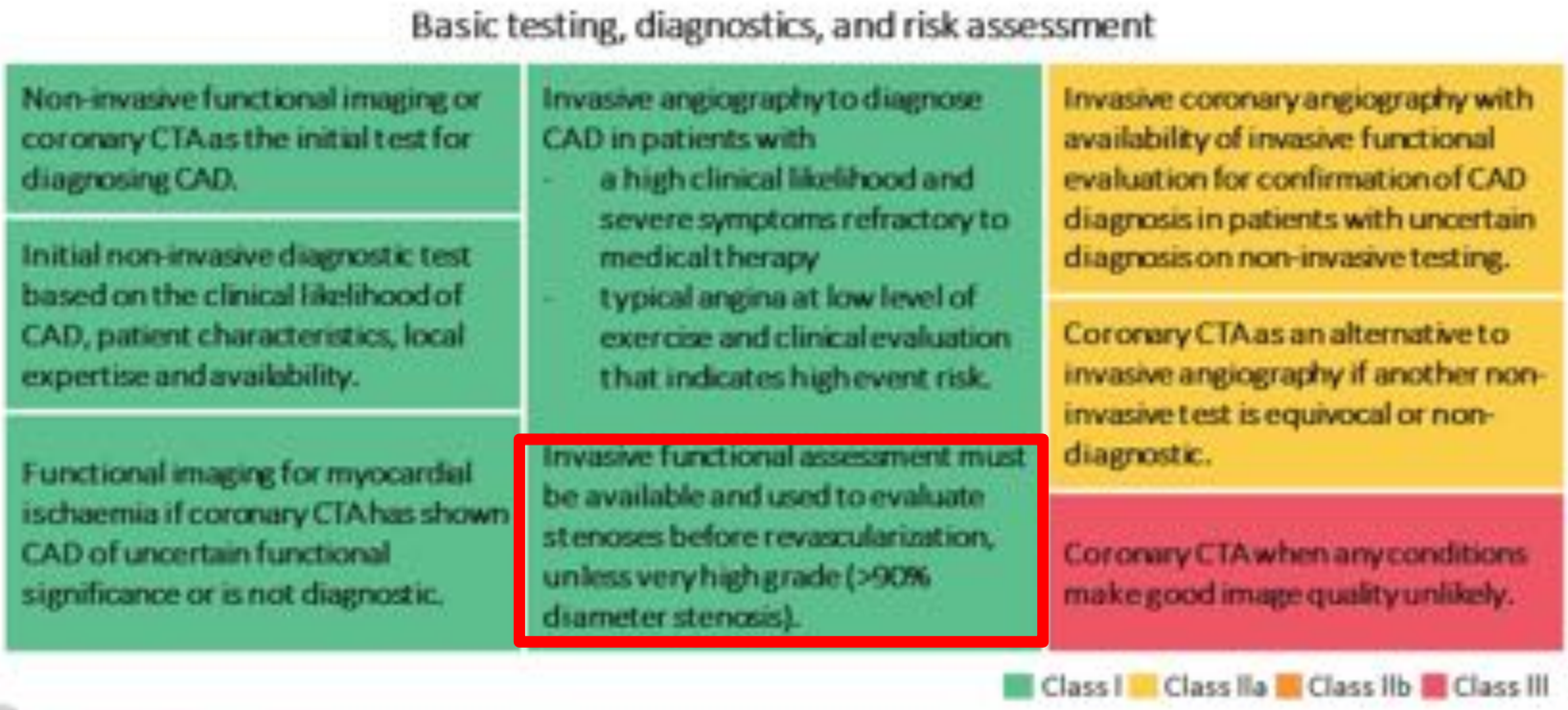
esc

ESC Guidelines on the diagnosis and management of chronic coronary syndromes (European Heart Journal 2019; 10.1093/eurheartj/ehz425)

What is new in the 2019 Guidelines?

New recommendations (1)

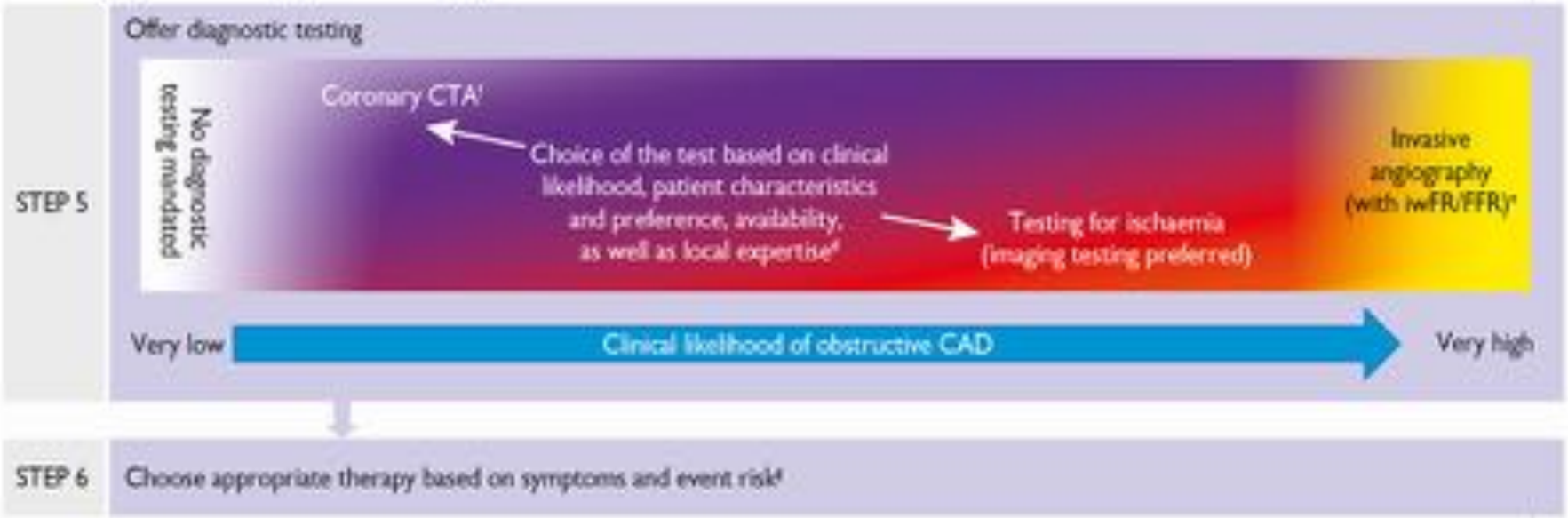
ESC European Society of Cardiology



Patients with angina and/or dyspnoea and suspected coronary artery disease

ESC European Society of Cardiology

Diagnostic approach (2)



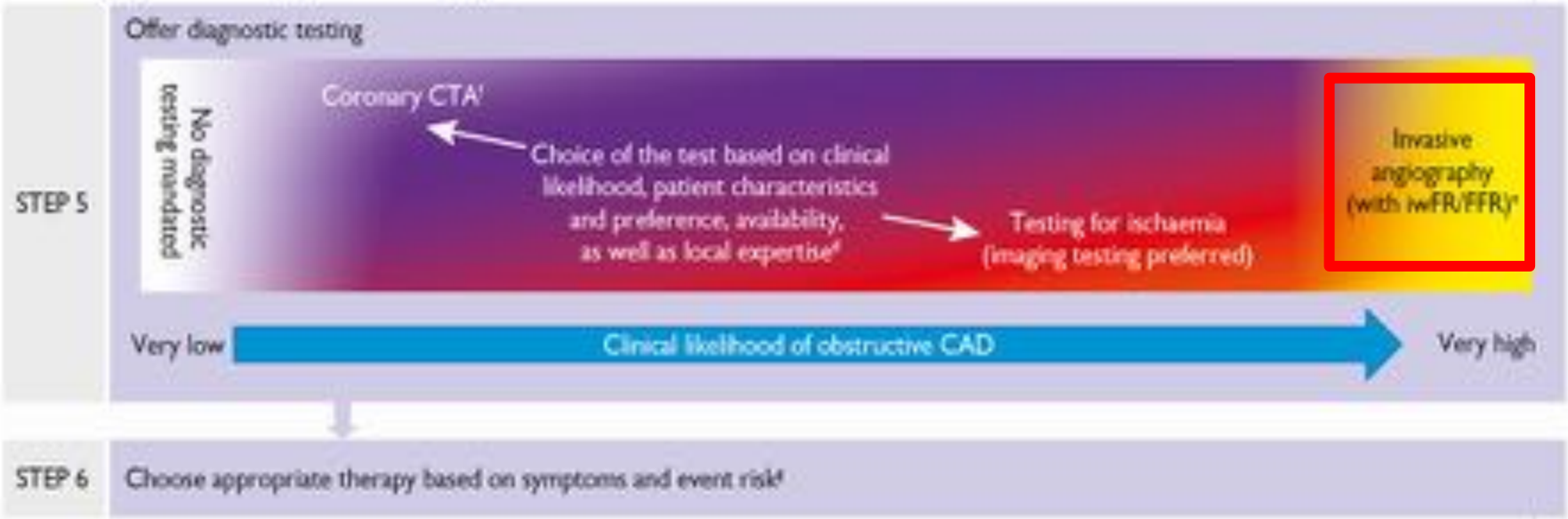
[1] Ability to exercise, individual test-related risks, and likelihood of obtaining diagnostic test result. [2] High clinical likelihood and symptoms inadequately responding to medical treatment, high event risk based on clinical evaluation (such as ST-segment depression, combined with symptoms at a low workload or systolic dysfunction indicating CAD), or uncertain diagnosis on non-invasive testing. [3] Functional imaging for myocardial ischaemia if coronary CTA has shown CAD of uncertain grade or is non-diagnostic. [4] Consider also angina without obstructive disease in the epicardial coronary arteries (see section 6 of full text).

esc

ESC Guidelines on the diagnosis and management of chronic coronary syndromes (European Heart Journal 2019; 10.1093/eurheartj/ehz425)

Patients with angina and/or dyspnoea and suspected coronary artery disease

Diagnostic approach (2)



[1] Ability to exercise, individual test-related risks, and likelihood of obtaining diagnostic test result. [2] High clinical likelihood and symptoms inadequately responding to medical treatment, high event risk based on clinical evaluation (such as ST-segment depression, combined with symptoms at a low workload or systolic dysfunction indicating CAD), or uncertain diagnosis on non-invasive testing. [3] Functional imaging for myocardial ischaemia if coronary CTA has shown CAD of uncertain grade or is non-diagnostic. [4] Consider also angina without obstructive disease in the epicardial coronary arteries (see section 6 of full text).

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