

GACI



# Apport de l'angioplastie Virtuelle et de la Co-registrati n iFR Pour optimiser la revascularisation coronaire

Eric Van Belle,

**Lille University Hospital  
Heart & Lung Institute**



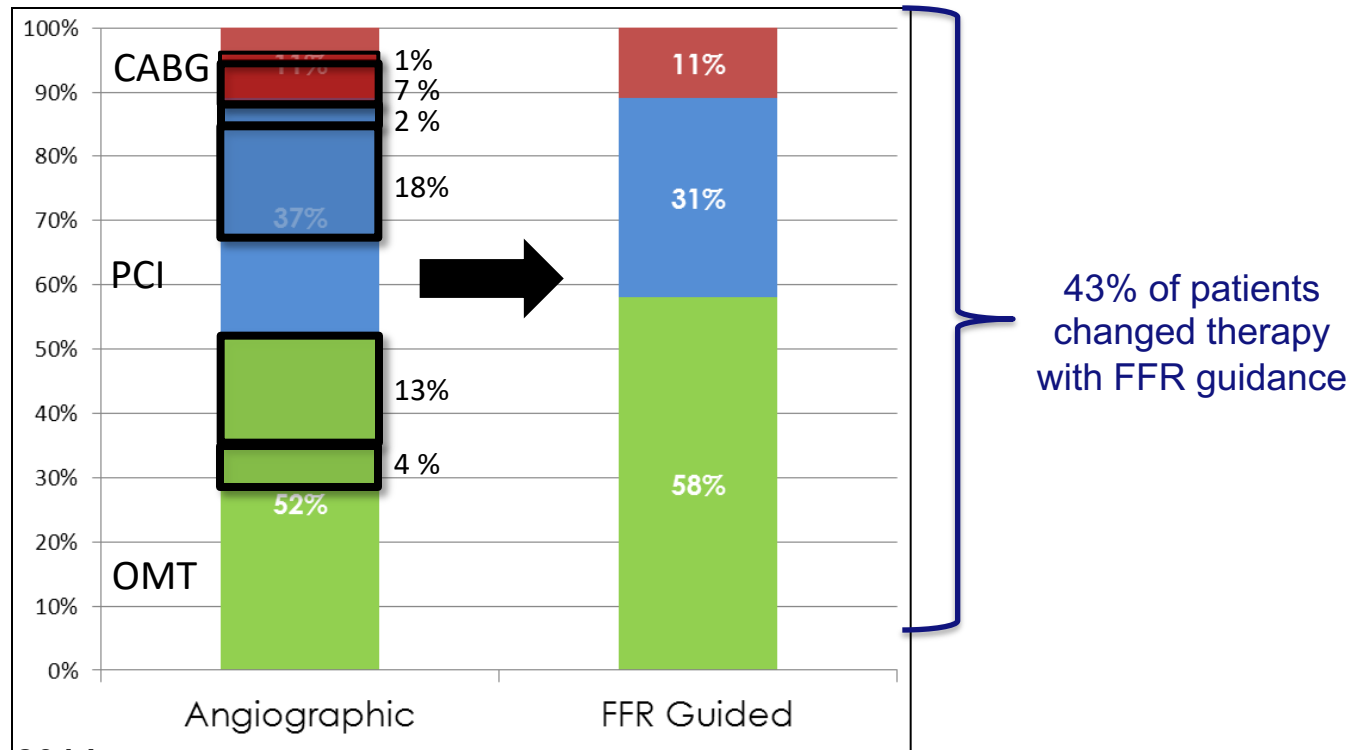
# Functional testing and intravascular imaging for lesion assessment

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

# 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;





**JACC**  
JOURNAL OF THE AMERICAN COLLEGE OF CARDIOLOGY



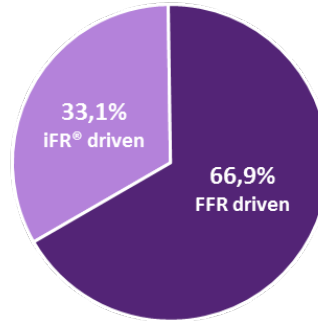
# Impact of Routine Invasive Physiology at Time of Angiography in Patients With Multivessel Coronary Artery Disease on Reclassification of Revascularization Strategy

## Results From the DEFINE REAL Study

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

# Reclassification according to the number of vessel investigated

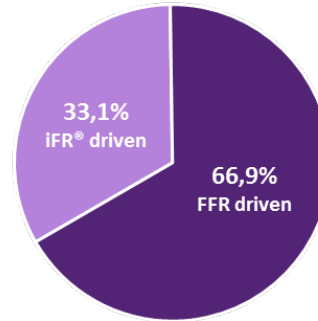
iFR<sup>®</sup> versus FFR driven physiology assesement in MVD patients



**iFR : 1.9 vessels**  
**FFR: 1.6 vessels**

# Reclassification according to the number of vessel investigated

iFR<sup>®</sup> versus FFR driven physiology assesement in MVD patients

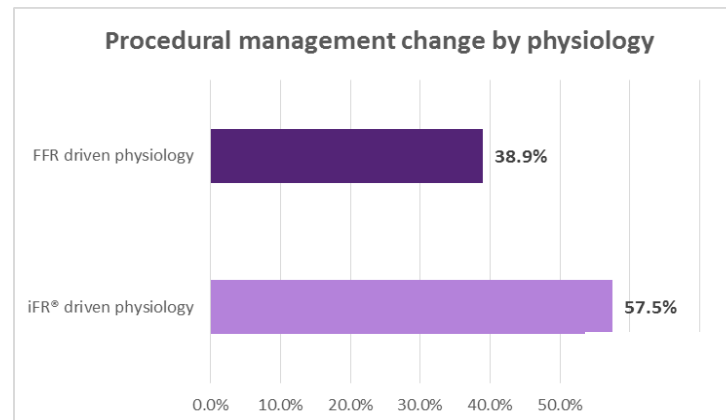


**iFR : 1.9 vessels**  
**FFR: 1.6 vessels**

P=0.0001

**FFR: 1.6 vessels**

**iFR : 1.9 vessels**



Van Belle et al.

Routine Invasive Physiology in MVD

# 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

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

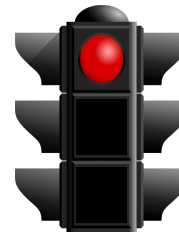
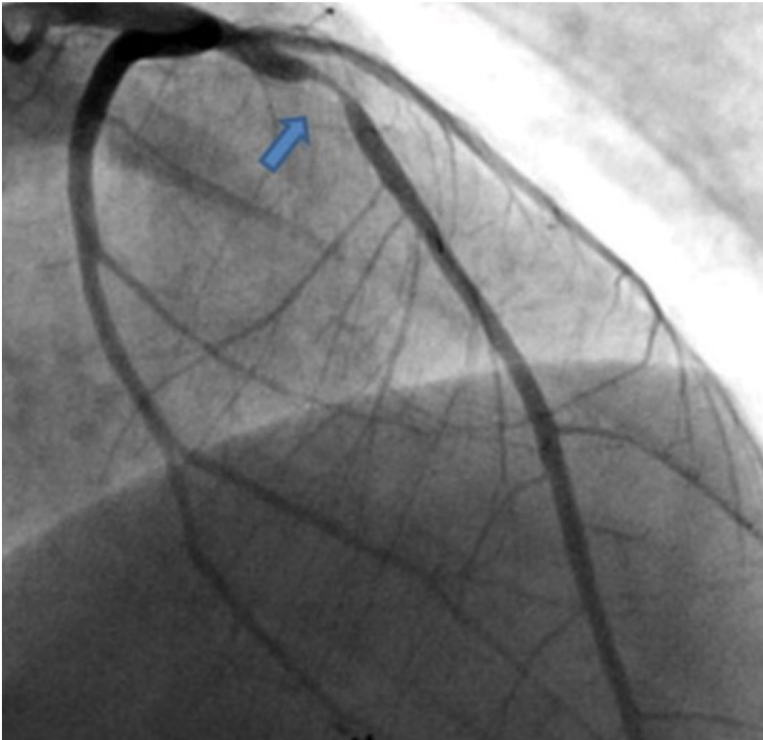
### Actual plan

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

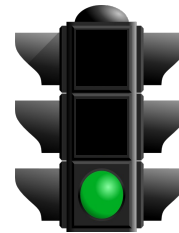


**Performing pressure wire  
measurements in patients with  
MVD is very rare**

## A simple case!

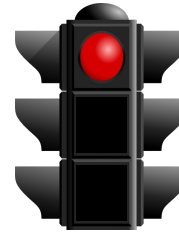
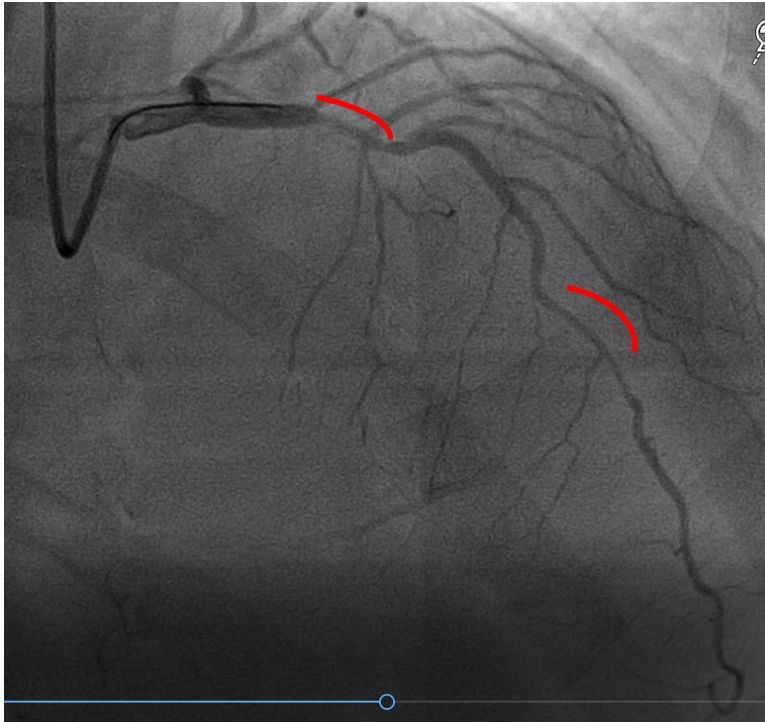


Traitement médical  
FFR > 0.81  
iFR > 0.89

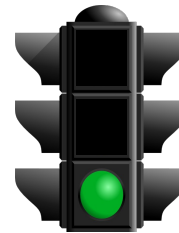


Angioplastie  
FFR ≤ 0.80  
iFR ≤ 0.89

## Amore complexe case!



Traitement médical  
FFR > 0.81  
iFR > 0.89



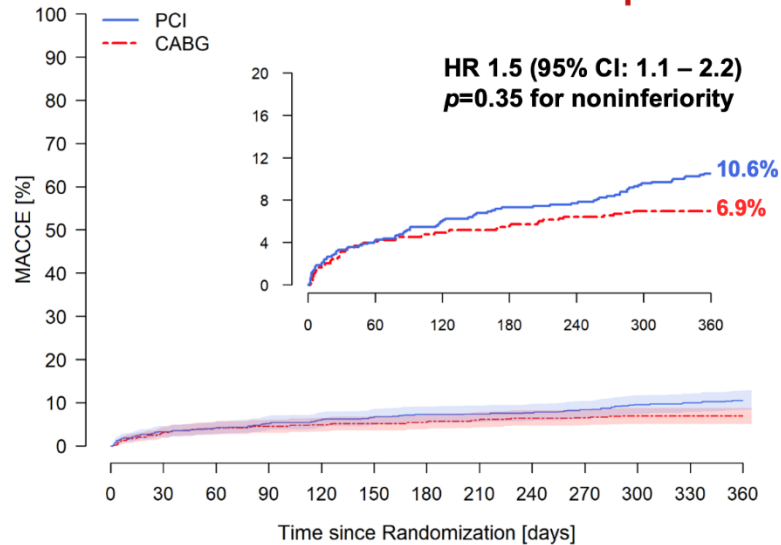
Angioplastie  
FFR ≤ 0.80  
iFR ≤ 0.89

## QCM 2

- Dans le cadre d'une angioplastie d'un vaisseau avec lésions diffuses/complexes, je vérifie la FFR à la fin de la procédure pour m'assurer qu'elle est  $> 0.80$ :
- A) Toujours
- B) Jamais, cela prend trop de temps
- C) Jamais, la valeur de FFR post-angioplastie n'est pas fiable

## Primary Endpoint

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



	No. at Risk												
PCI	757	728	721	713	707	702	697	696	693	687	678	674	670
CABG	743	709	701	698	695	693	691	686	683	682	679	679	679

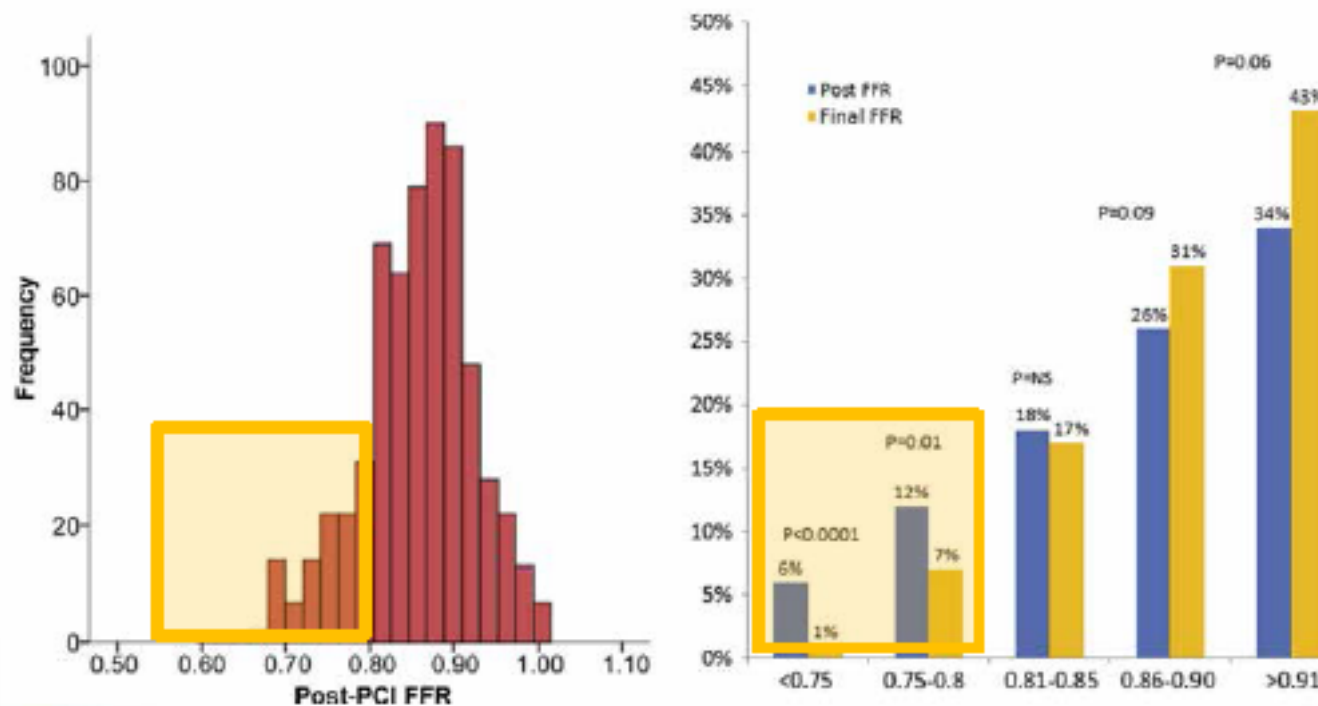
## Procedural Characteristics

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%

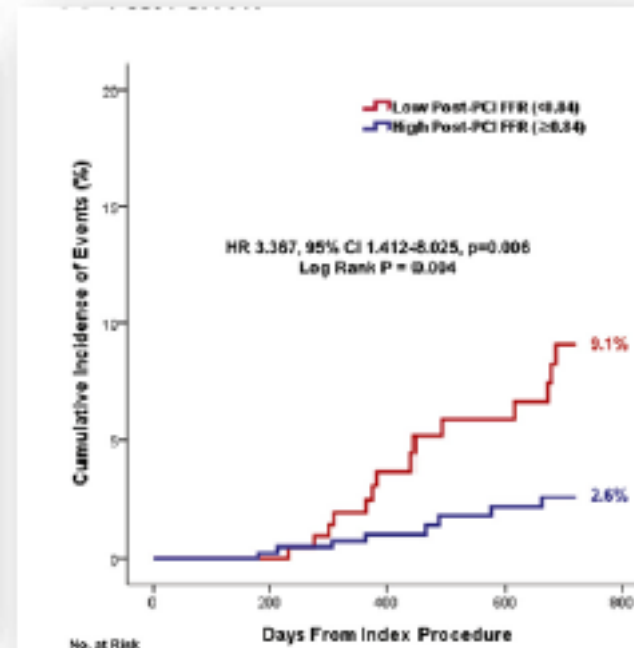
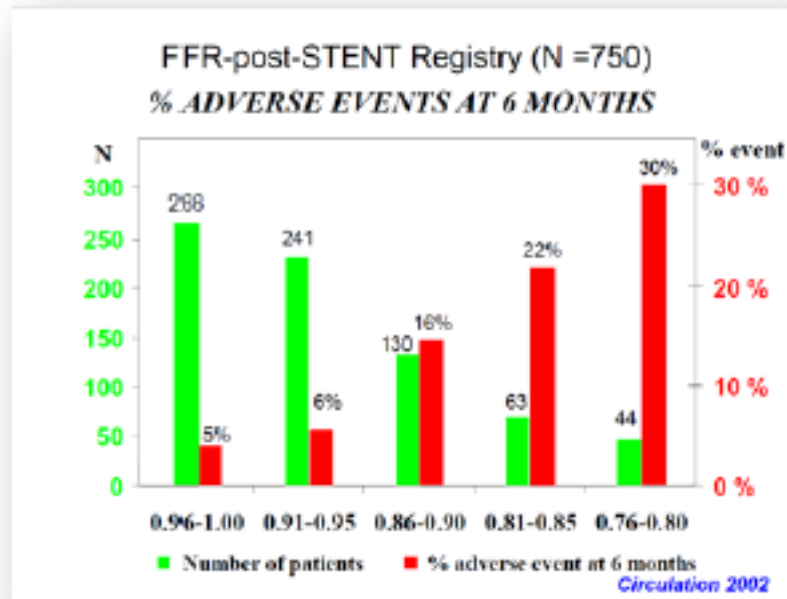


Post PCI ischemia based on FFR  $\leq 0.80$  occurs in 10-20% of cases



Lee JM, et al. *J Am Coll Cardiol Interv.* 2018;11:2099-109.  
 Agarwal SK, et al. *J Am Coll Cardiol* 2016;9:1022-31.

## Low post-PCI FFR is related to adverse events

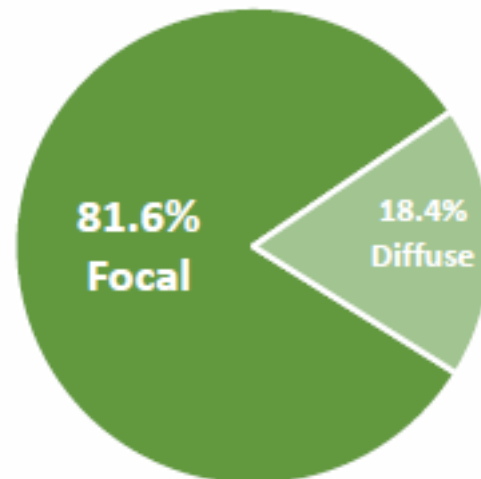
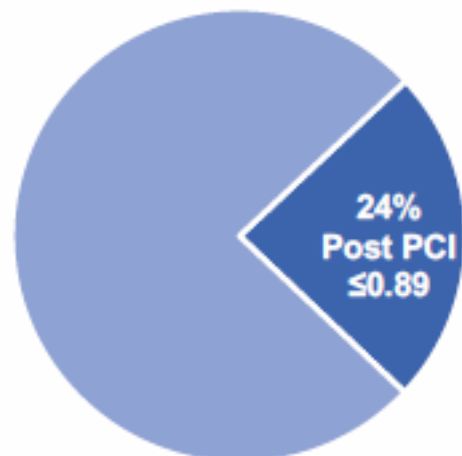


Pijls N, et al. *Circulation*. 2002;105:2950-54.  
Lee JM, et al. *J Am Coll Cardiol Interv*. 2018;11:2099-109.

# Primary Study Endpoint

480 Patients with  
Angiographically Successful PCI  
and qualified iFR pullbacks

24% Residual Ischemia  
(112 patients with Post PCI  
iFR $\leq$ 0.89)



■ Post iFR $\leq$ 0.89 ■ Post iFR $>$ 0.89

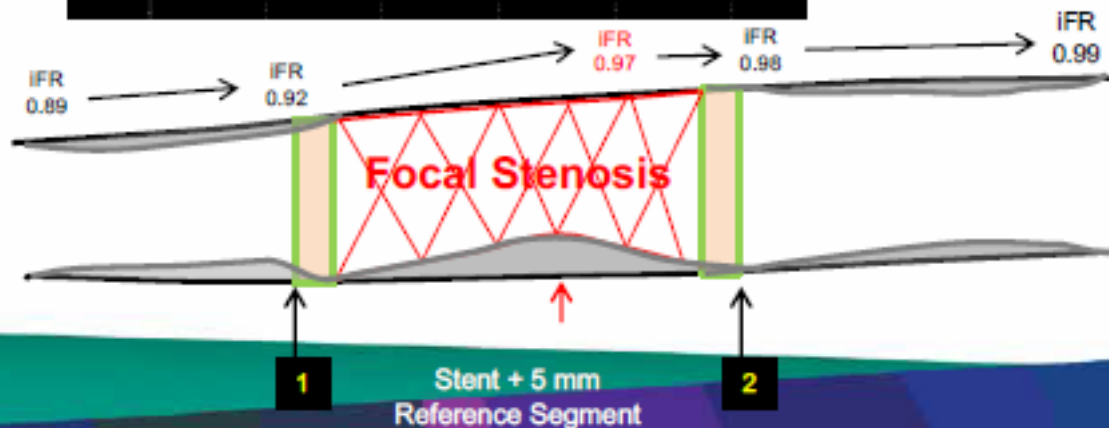
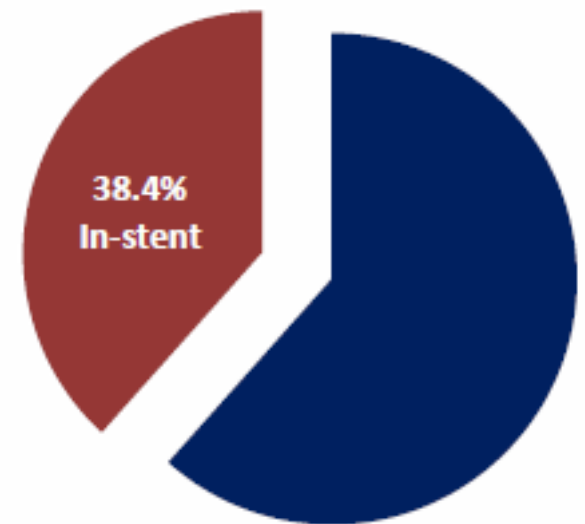
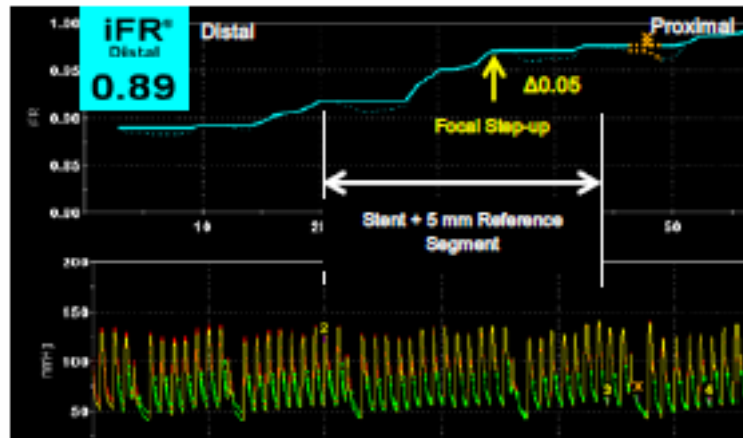
Focal defined as step-up of  $\geq$ 0.03 units in  $<$  15 mm segment  
Diffuse defined as  $>$  15 mm segment





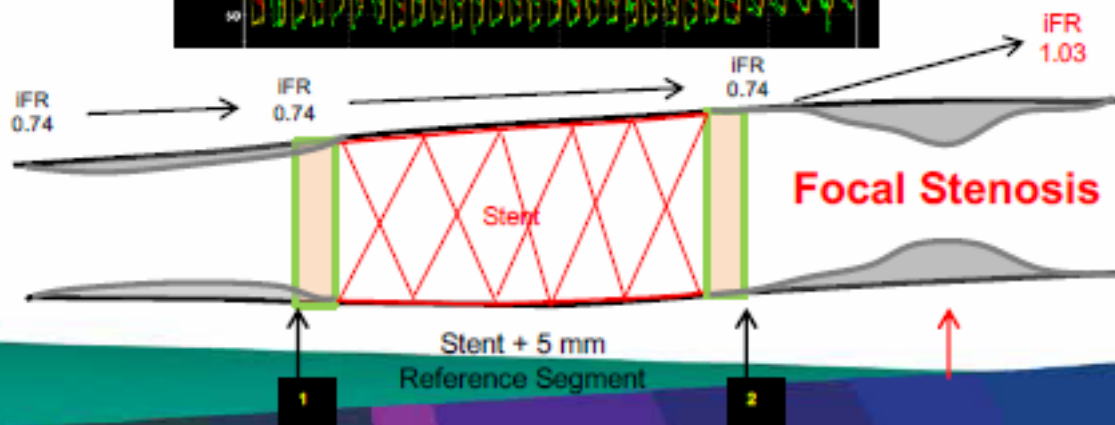
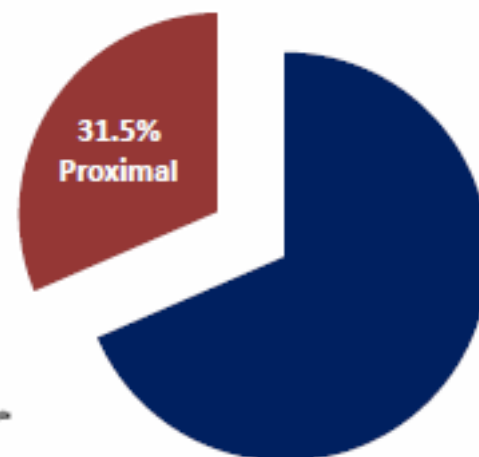
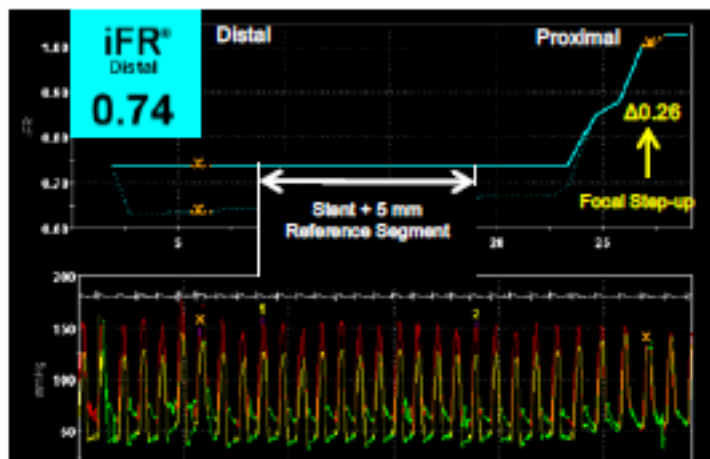
# Focal Residual Pressure Gradient in-stent

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



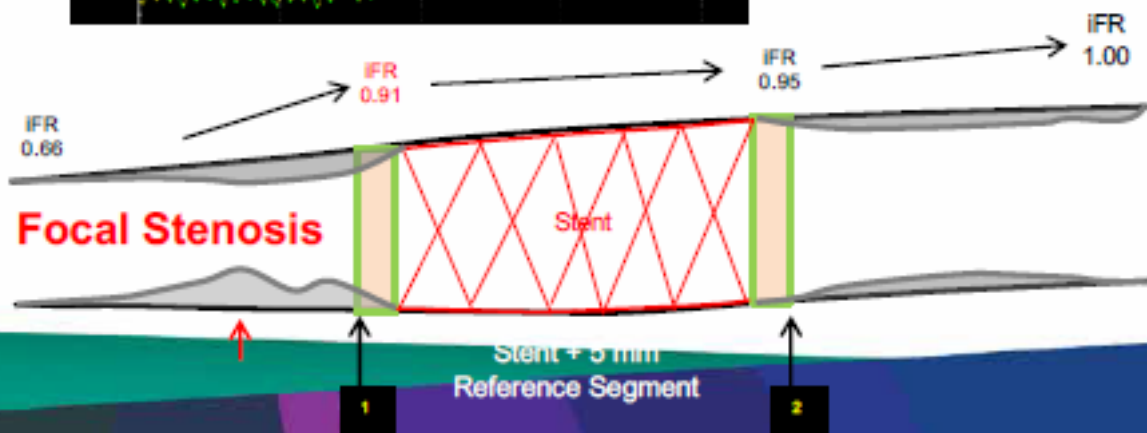
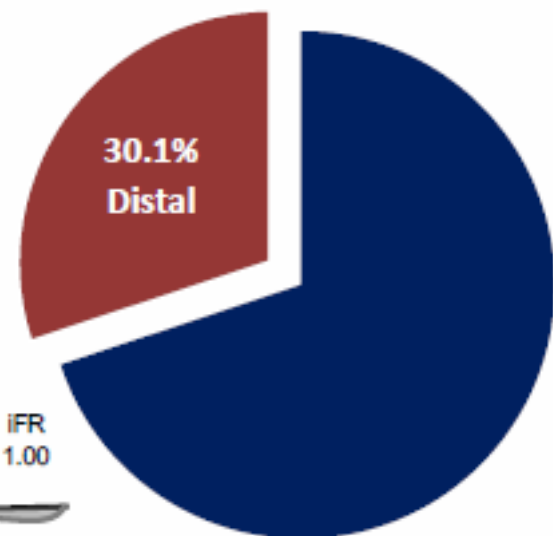
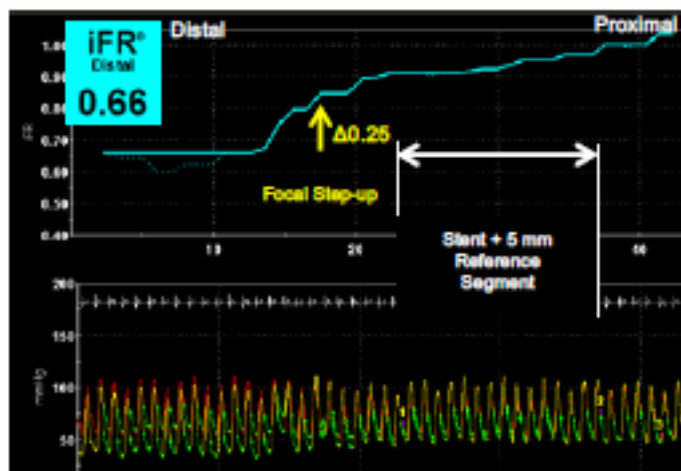
# Focal Residual Pressure Gradient Prox to stent

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



# Focal Residual Pressure Gradient Distal to stent

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



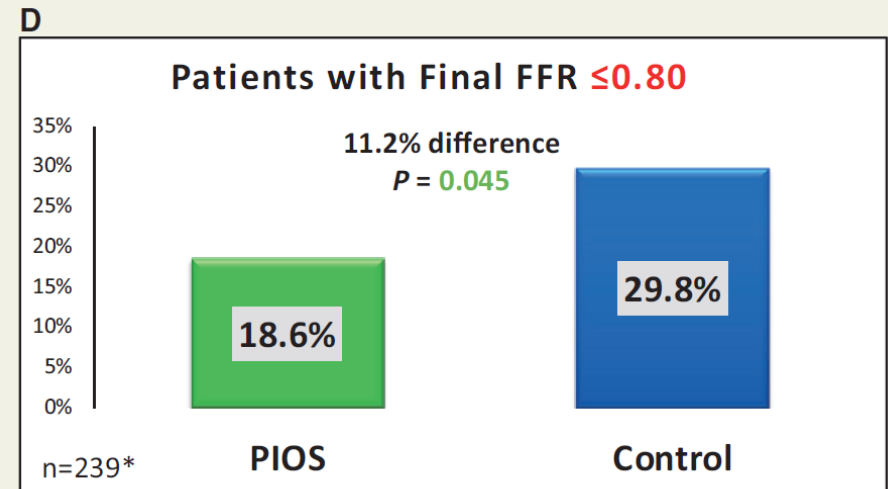
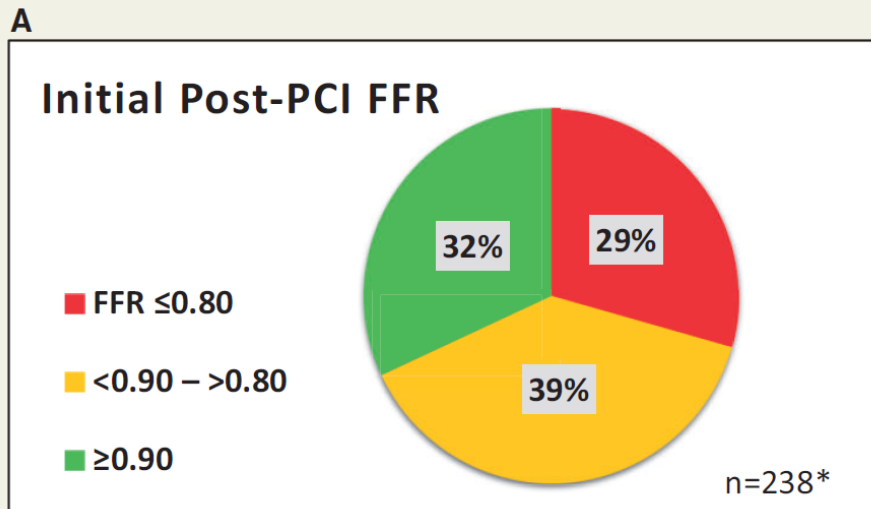
**In 10-20% of cases a vessel remains ischemic  
after an an appropriate PCI**

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

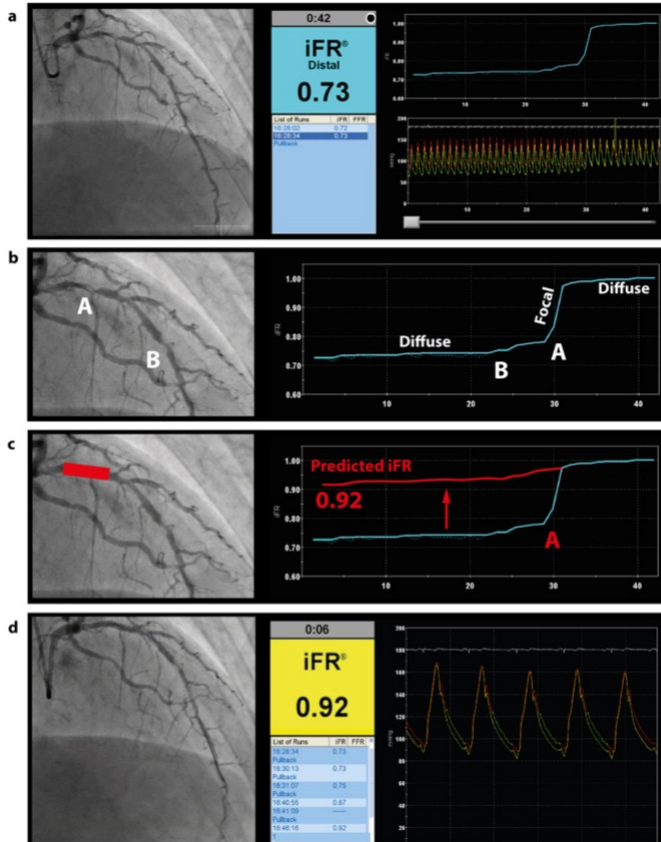
**In patients with multivessel PCI 30-50% of  
patients have « incomplete » coronary  
revascularization**

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

Damien Collison <sup>1,2\*</sup>, Matthaios Didangelos <sup>1</sup>,



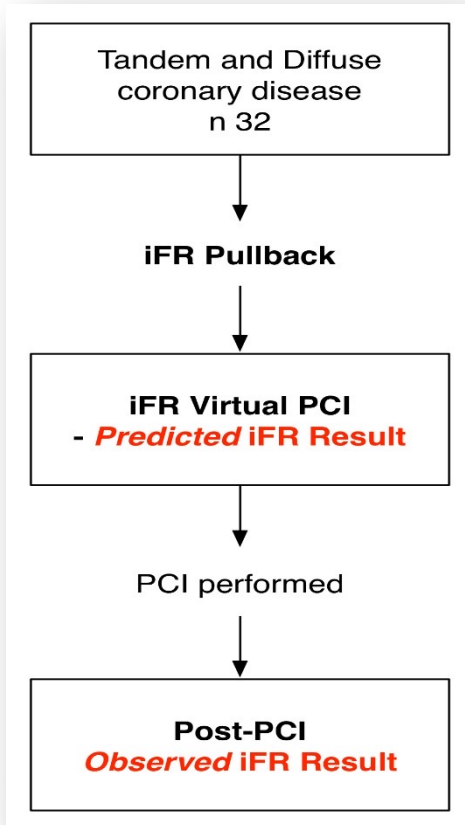
## iFR et lésions en série



- 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

# iFR PULLBACK STUDY

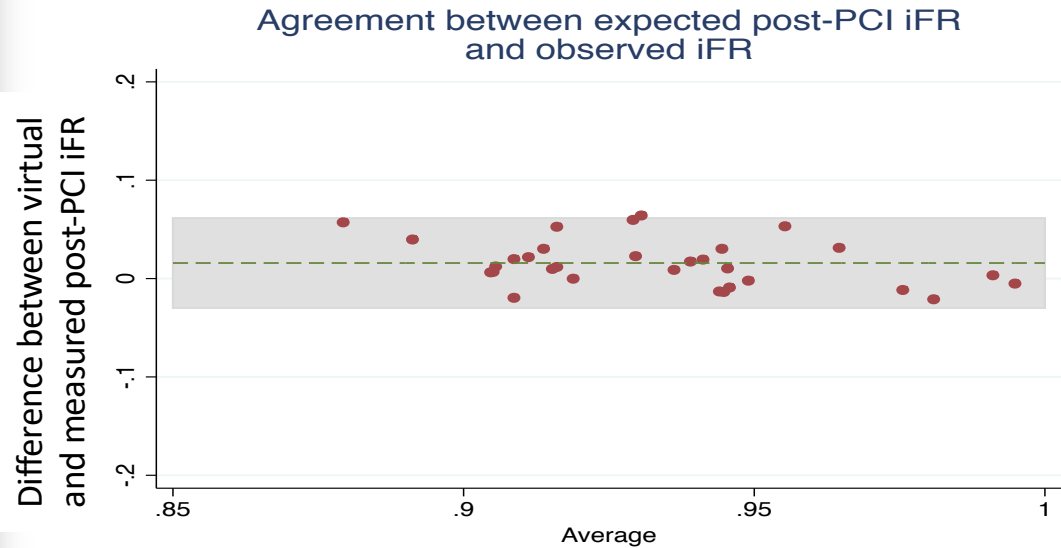


Pre-PCI iFR:  $0.78 \pm 0.03$

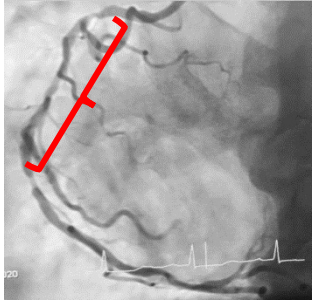
Predicted iFR:  $0.94 \pm 0.01$

Observed iFR:  $0.93 \pm 0.03$

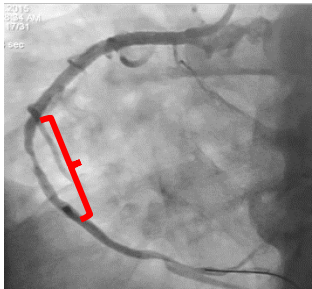
} p=0.48



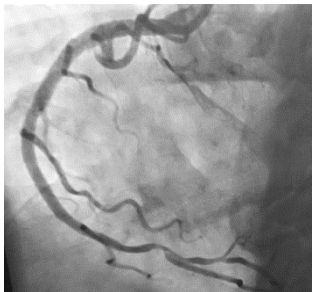
Nijjer SS, Davies J et al *JACC: Cardiovascular Interventions*. 2014;7:1386–1396



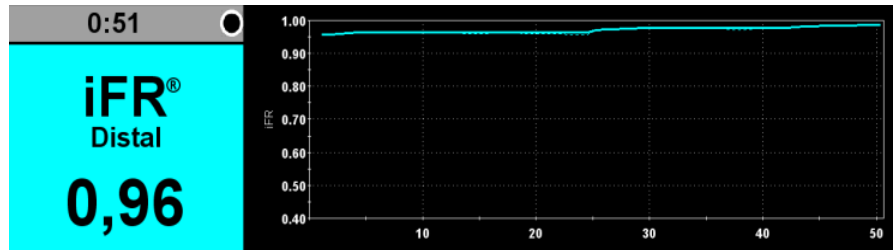
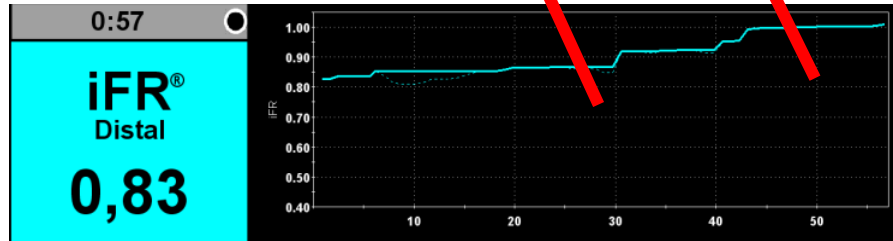
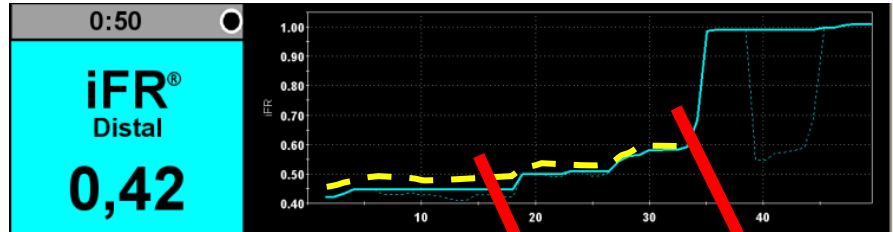
Profil de la perte de charge



Perte de charge résiduelle après 1<sup>er</sup> stenting

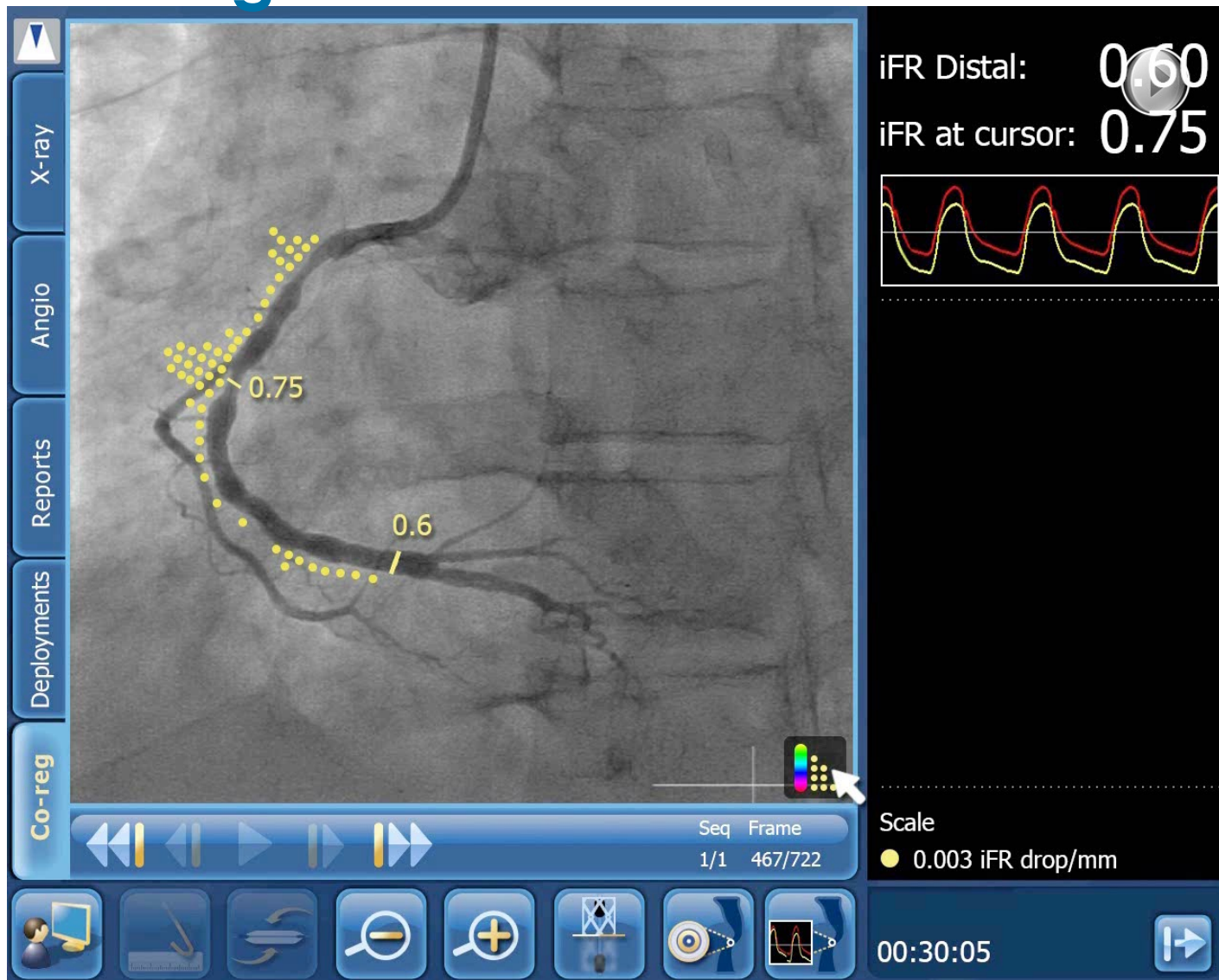


Profil hémodynamique normal





# iFR Co-registration et Virtual PCI



**Homme, 78 ans**

**Bon état général**

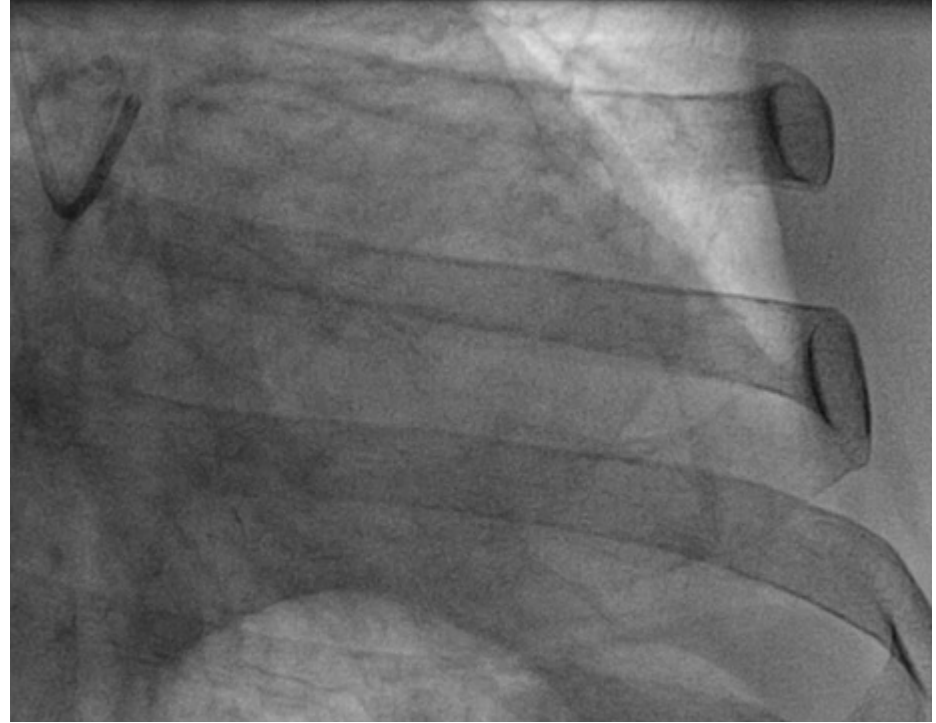
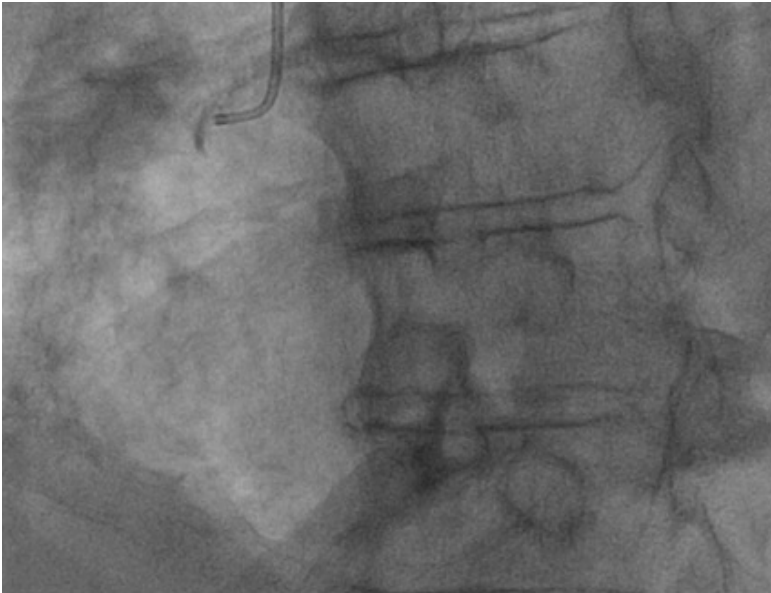
*ATCD IDM inférieur (10 ans) – CD occluse connue non revascularisée*

*Hospitalisé pour NSTEMI avec décompensation cardiaque.*

*ETT : FEVG conservée avec séquelle inférieure.*

*Anticoagulation efficace pour une fibrillation atriale.*

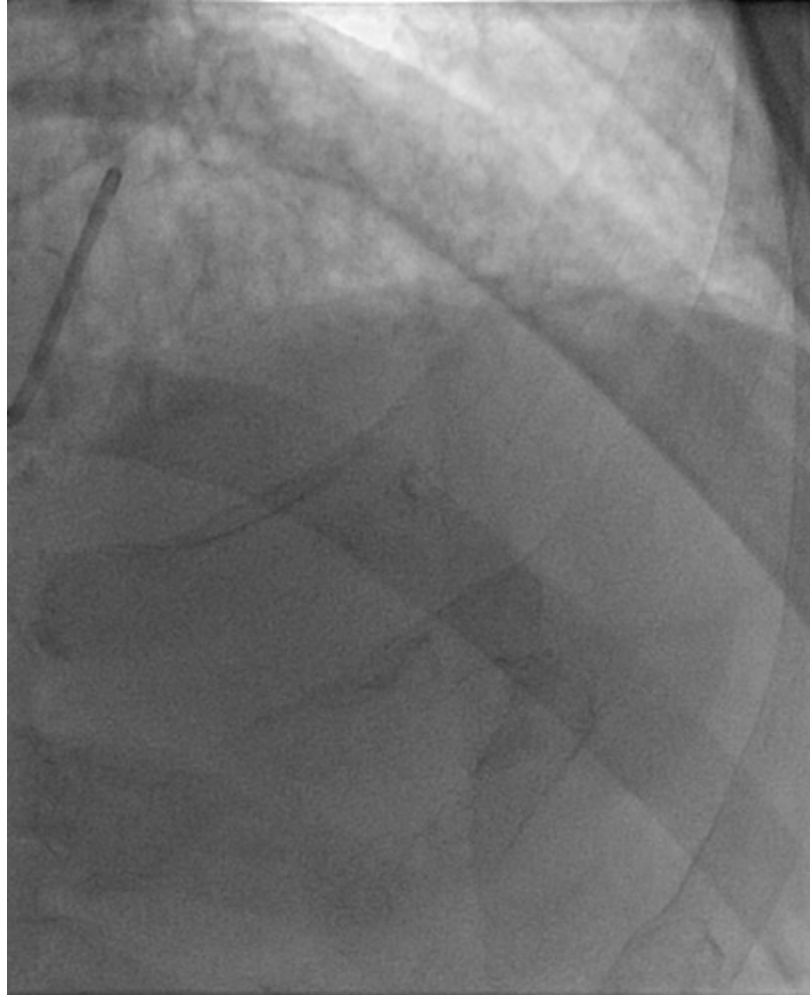
*Fonction rénale normale. Pas de diabète.*



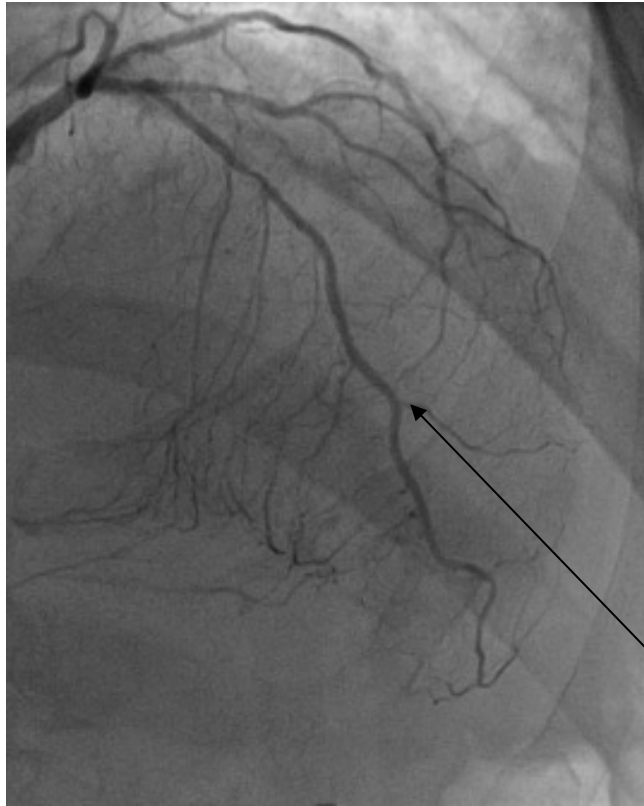
Pr Eric VAN BELLE MD, PhD

Institut Coeur et Poumon - CHU Lille, France

University of Lille - School Of Medicine Henri Warembourg



Pr Eric VAN BELLE MD, PhD  
Institut Coeur et Poumon - CHU Lille, France  
University of Lille - School Of Medicine Henri Warembourg



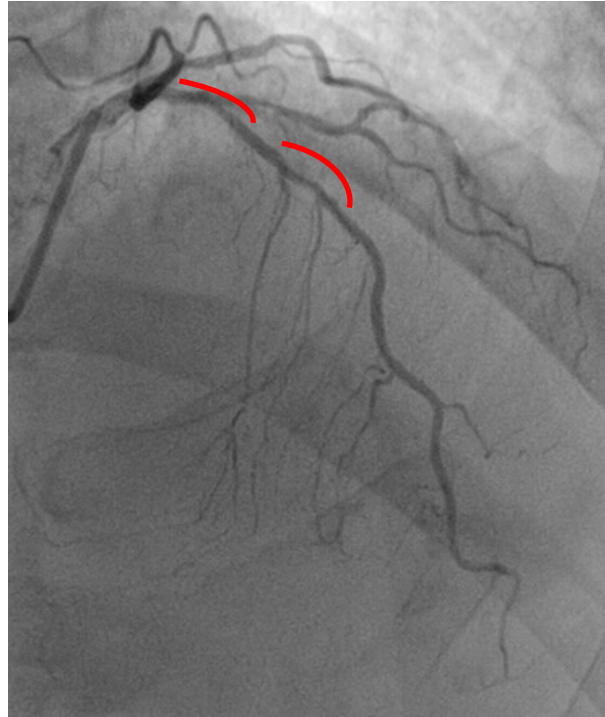
## Evaluation physiologique sur l'IVA

FFR à 0,74

iFR à 0,69

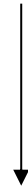
Vaisseau physiologiquement très  
ischémique

*Zone de mesure avec  
le guide de pression*

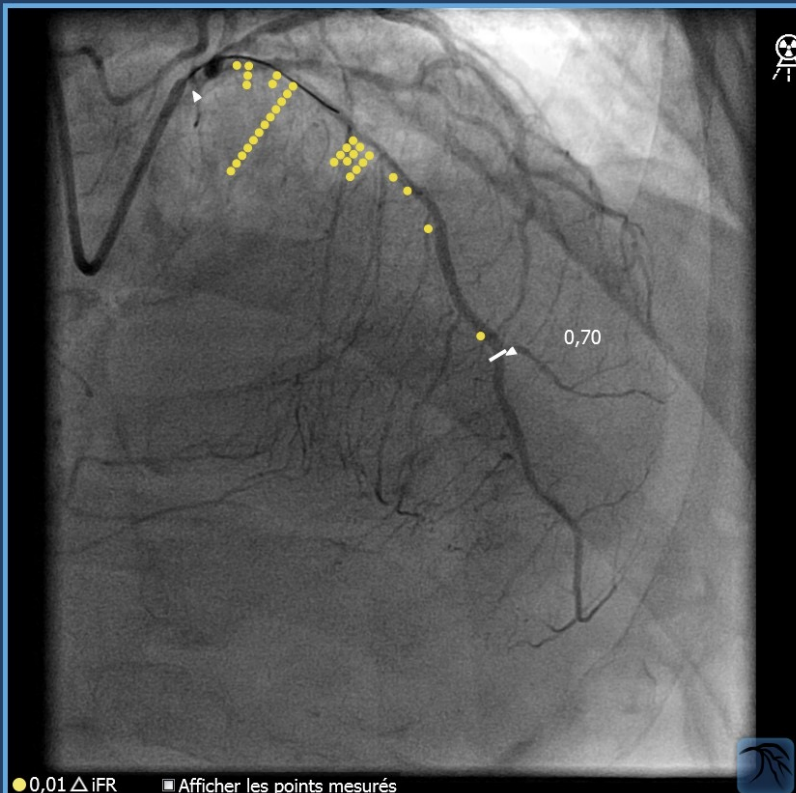


Angiographiquement :

Lésions relativement  
diffuses avec 2 zones  
distinctes



Quelle stratégie de  
revascularisation ?



iFR distal: 0,69  
 iFR au curseur: 0,70



● 0,01 △ iFR    ■ Afficher les points mesurés

◀▶ Séq. 1/2

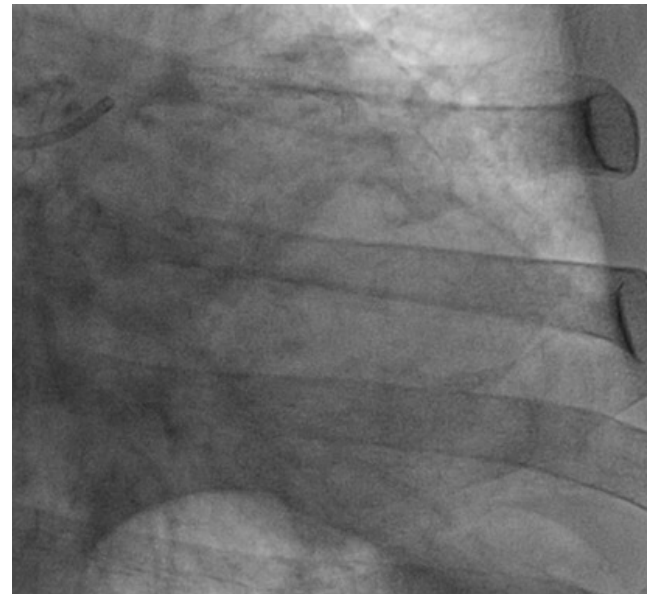
iFR pull back

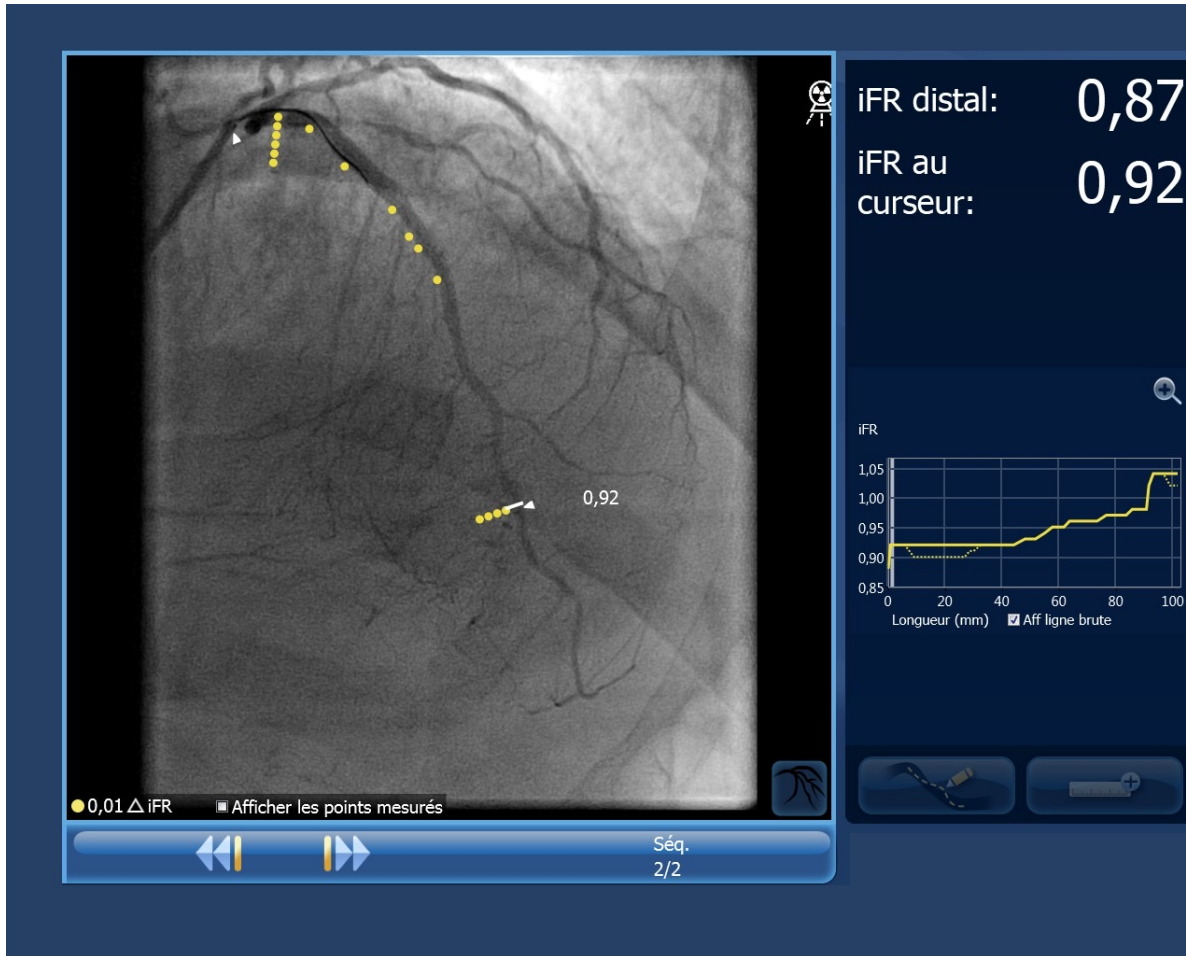
Perte de charge bien répartie entre les 2 lésions

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



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



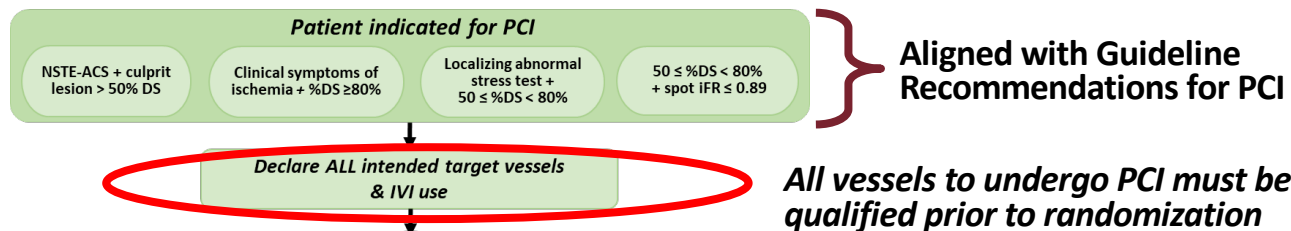


Excellent résultat  
hémodynamique avec iFR  
final au même point à 0,92.

Gain de 0,23 par la  
revascularisation

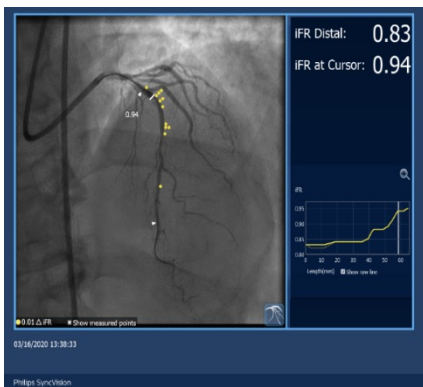


## DEFINE GPS Flow

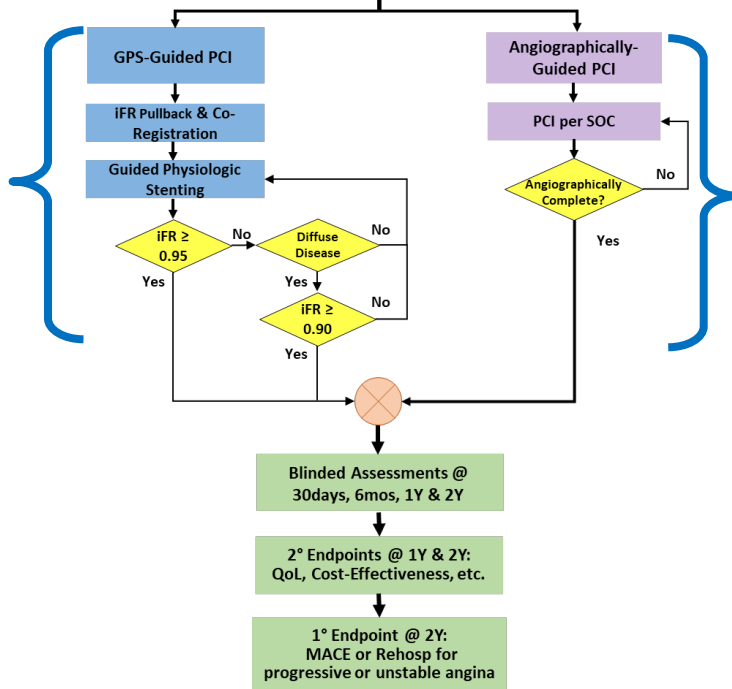
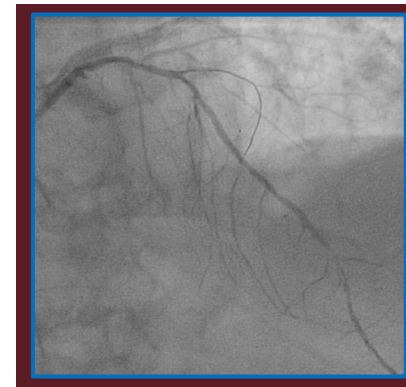


Randomize

### Physiology-Guided PCI



### Standard of Care PCI



# Summary

- ✓ Recent studies have shown that 20-25% vessel territories remain ischemic after an apparently appropriately conducted PCI:
  - ✓ Once the procedure is “finished” it is possible but difficult to correct (TARGET FFR)
  - ✓ Pre-procedural pullback-derived pressure coronary mapping“
  - ✓ Combined to
  - ✓ virtual PCI” and c  
would be key to improve the clinical outcome of our coronary patients, in particular those with MVD.
- ➔ It has also the potential to test different PCI scenarios and to predict the final “IFR/FFR” of these scenarios: Virtual PCI



# Summary 1

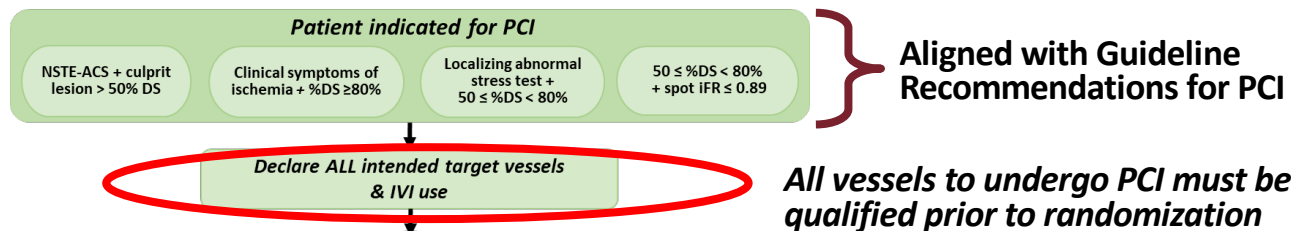
- ✓ Invasive pressure wire (FFR/iFR) is the “gold standard” for the detection of ischemic territory vessels.
- ✓ In patients with MVD, investigation of every vessel with lesion  $> 30\%$  is critical to propose the best treatment option.

# Summary 2

- ✓ Recent studies have 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.
- ➔ It has also the potential to test different PCI scenarios and to predict the final “FFR” of these scenarios: Virtual PCI

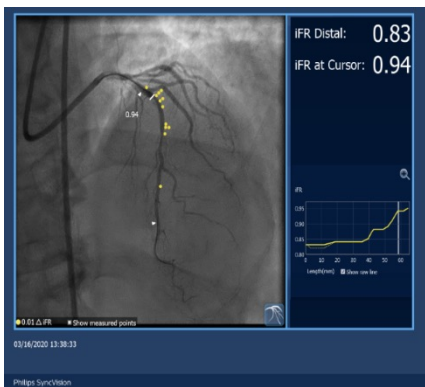


## DEFINE GPS Flow

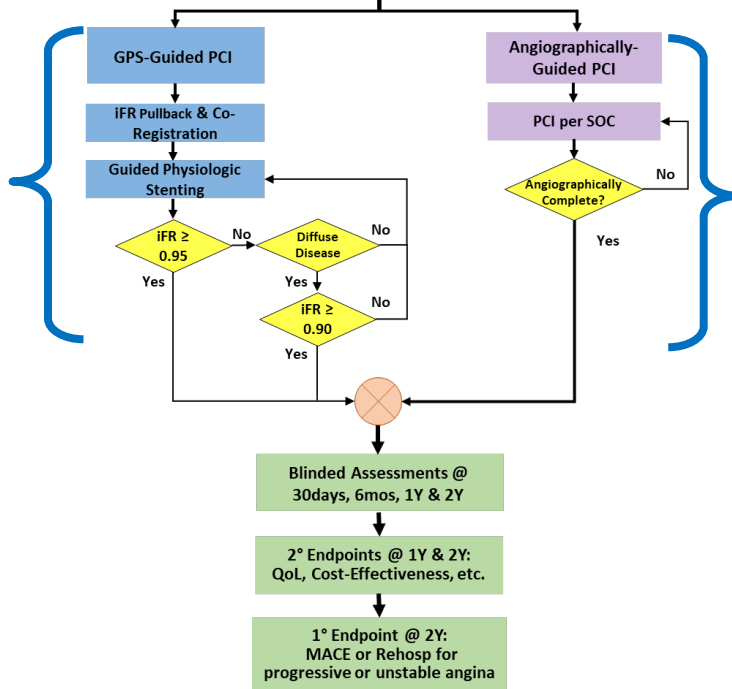


Randomize

### Physiology-Guided PCI



### Standard of Care PCI



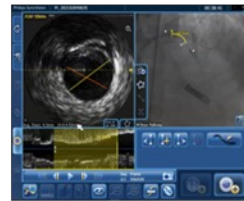
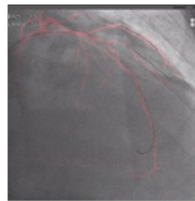
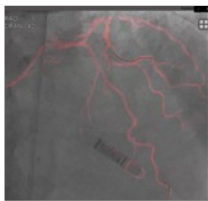
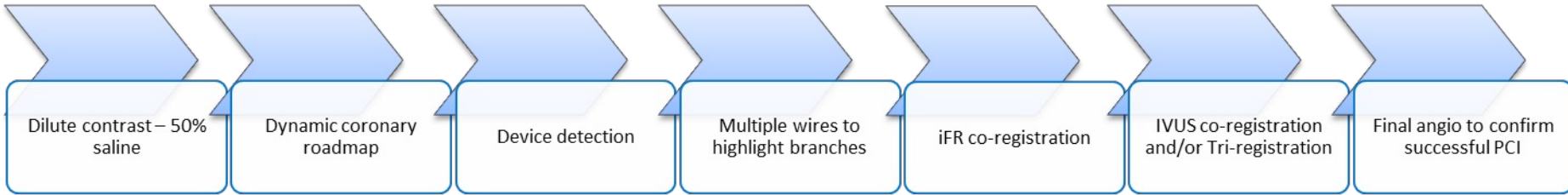


# Procédure Ultra low Contrast

## Steps to reduce contrast in PCI

*Dr. Billal Patel*

*- Head of Interventional Cardiology, Lancashire Cardiac Centre, Blackpool, UK*



Presented: 4<sup>th</sup> Asia Physiology Coronary Imaging (APACI) live webinar, PCI in Advanced CKD – When Less Contrast is More. 20<sup>th</sup> March 2021.

*The opinions and clinical experiences herein are specific to the featured physicians and featured patients and are for information purposes only. The results from their experiences may not be predictive for all patients. Individual results may vary depending on a variety of patient-specific attributes and related factors. Nothing in this presentation is intended to provide specific medical advice or to take the place of written law or regulations.*

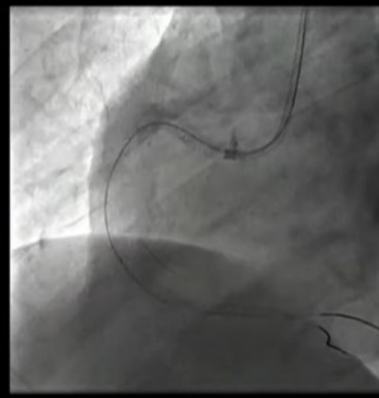




# Procédure Ultra low Contrast



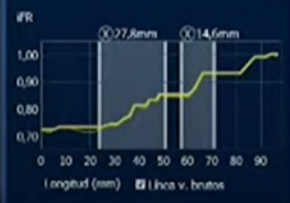
DAI 44°  
CRAN 1°



14,6mm  
 $\Delta 0,08$

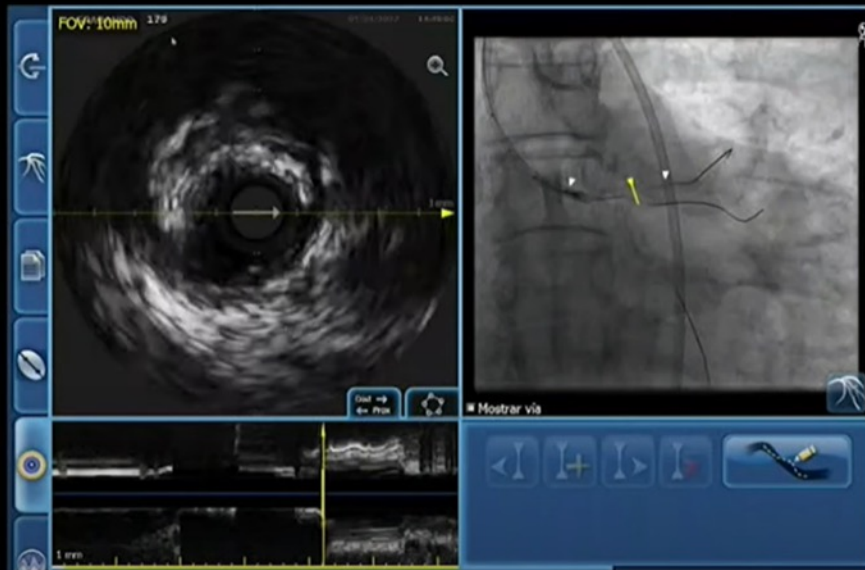
27,8mm  
 $\Delta 0,12$

iFR distal: **0,72**  
Estimación de iFR: **0,92**



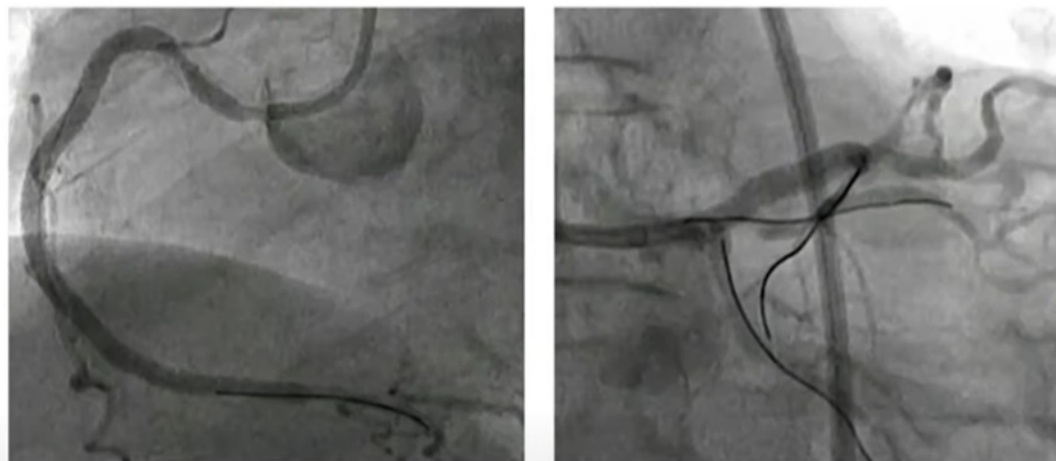


# Procédure Ultra low Contrast



## Procédure

### Ultra low Contrast



- Total amount of contrast: 25 ml (CV/GFR 0.83)
- Uneventful in-hospital evolution.
- Patient discharged 2 days later. No modification of serum Cr levels.

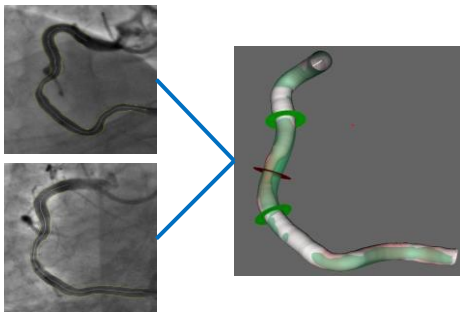
---

**Further virtualization to  
« estimate » the pressure  
drop**

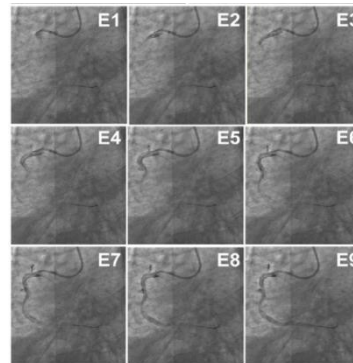
# Quantitative Flow Ratio (QFR)



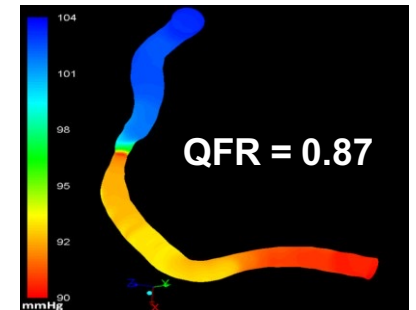
## 3D Reconstruction



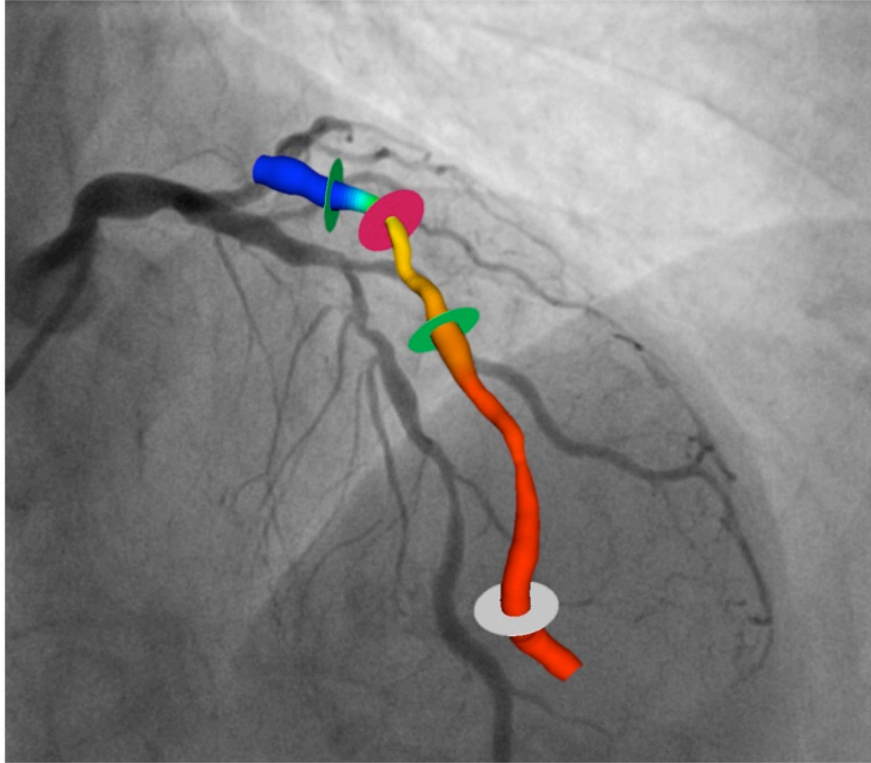
## Modified Frame Count



## QFR



**Without Inducing Hyperemia**

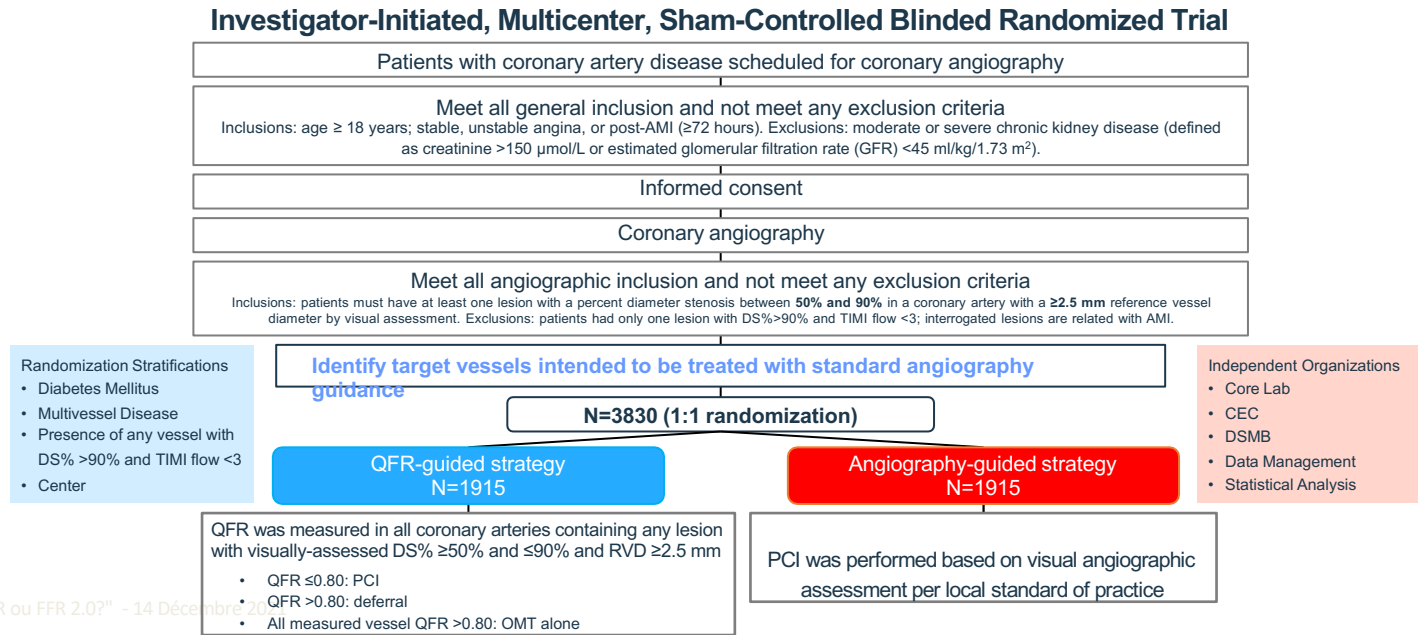


# Study Design



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

Bo Xu\*, Shengxian Tu\*, Lei Song\*, Zening Jin, Bo Yu, Guosheng Fu, Yujie Zhou, Jian'an Wang, Yundai Chen, Jun Pu, Lianglong 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 Stoner†; FAVOR III China study group‡



# 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 have 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 techniques

# 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

Thank you for your attention!

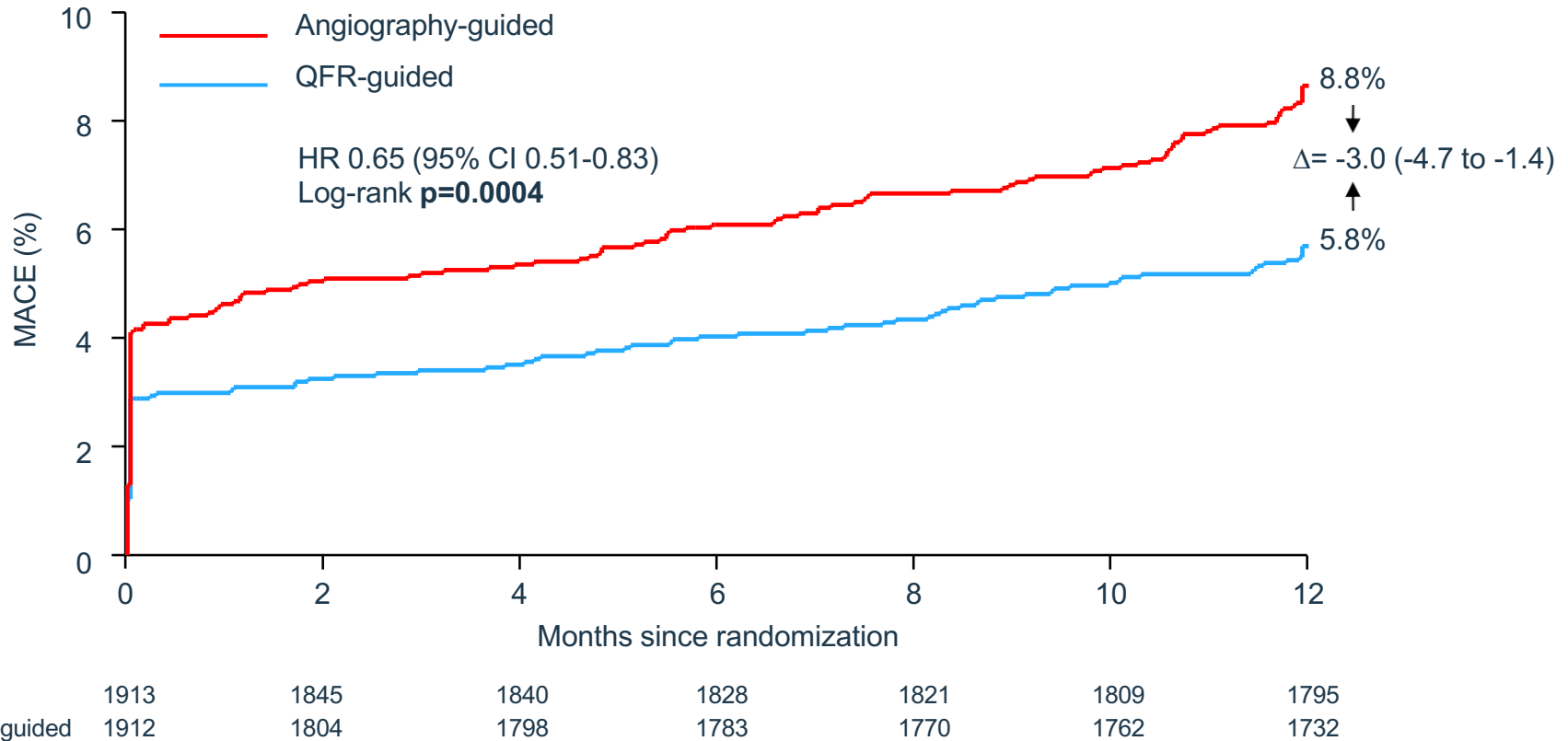


Pr Eric VANBELLE MD, PhD, FESC, FACC  
Institut Coeur et Poumon - CHU Lille, France  
University of Lille - School Of Medicine Henri Warembourg

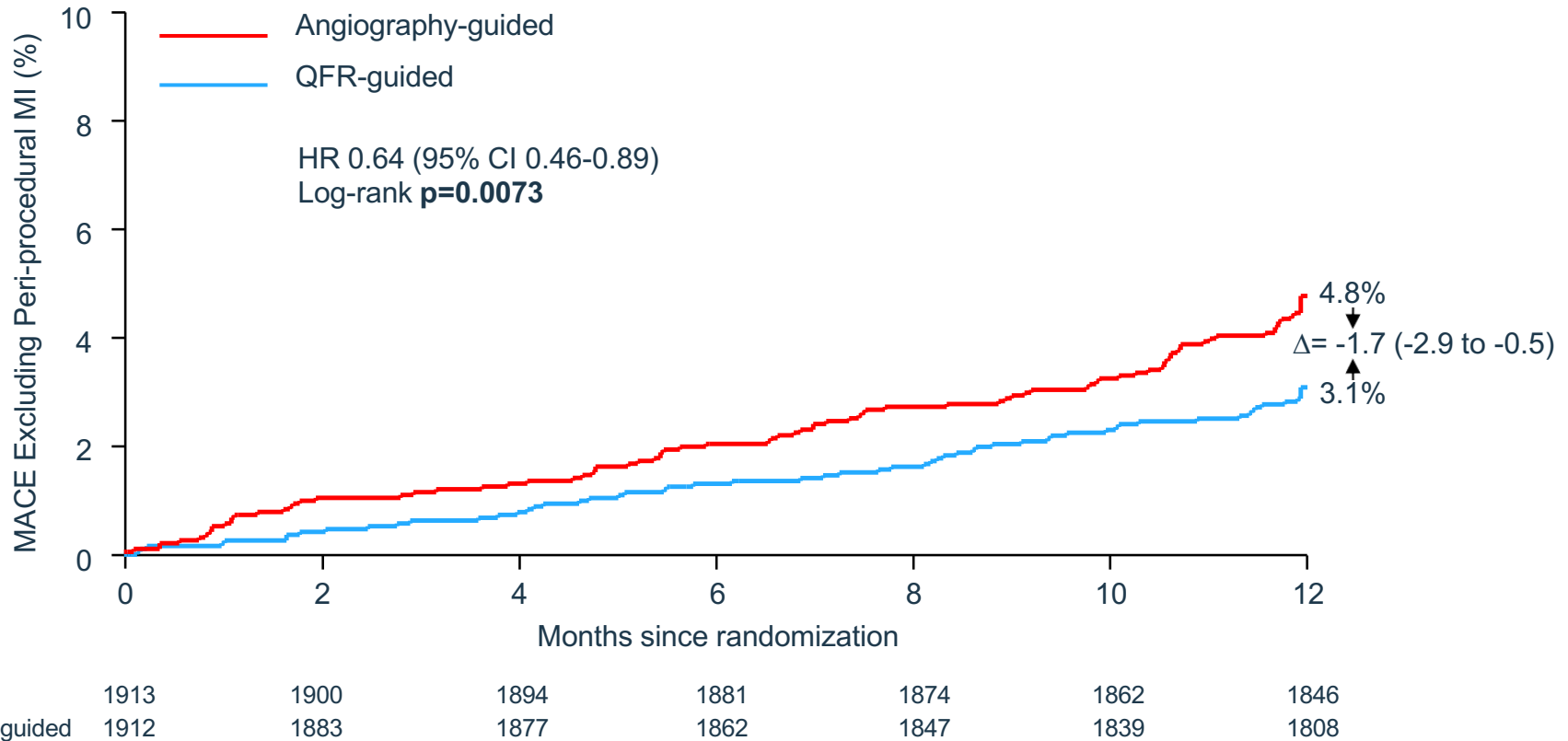




# Primary Endpoint (ITT)



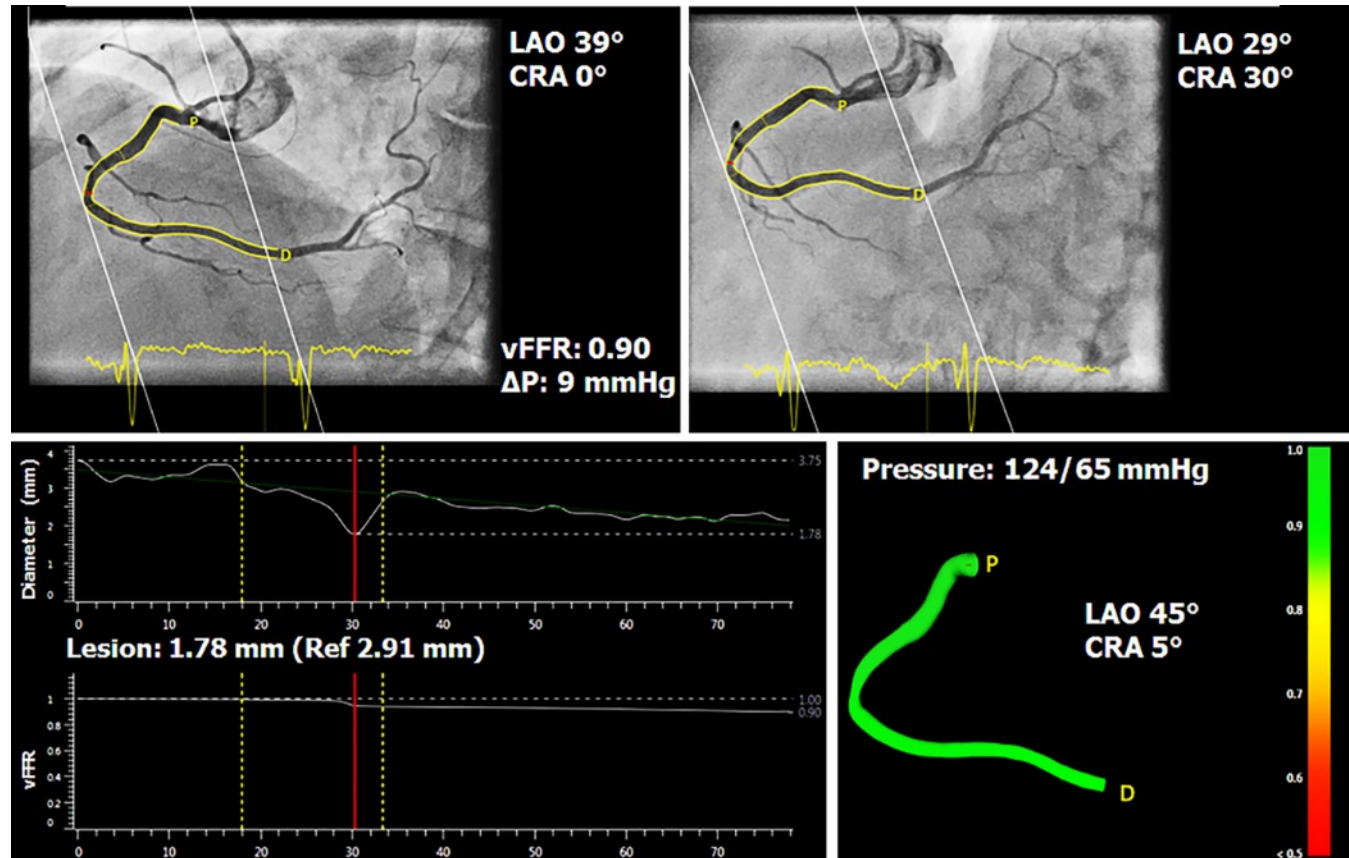
# Major Secondary Endpoint (ITT)



# Virtual FFR based on Angiography

## Required:

- 2 contrast filled angiograms
- Orthogonal views:  $\geq 30$  degrees
- Invasive aortic pressure



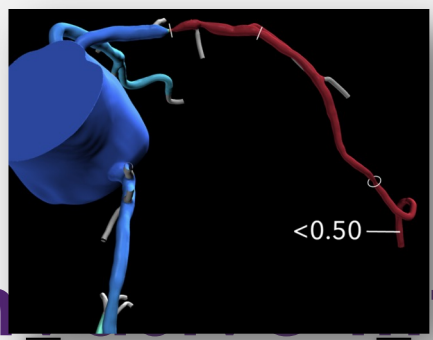
Pre-PCI

ICA



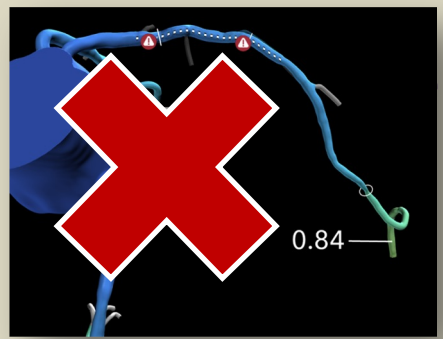
ICA-based plan  
38mm stent

FFR<sub>CT</sub> Planner

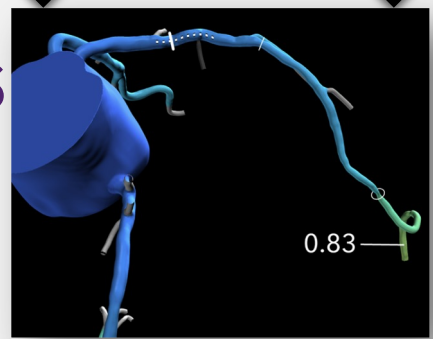


Baseline FFR<sub>CT</sub>

Post-PCI



ICA-based plan reproduced on FFR<sub>CT</sub> Planner  
38mm stent



FFR<sub>CT</sub> Plan  
15mm stent

on-in...terc  
clas  
"PC

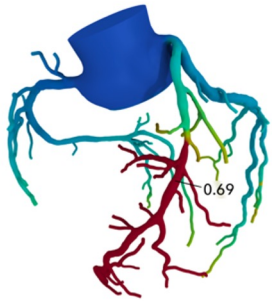
Reduced stent length using FFR<sub>CT</sub> Planner strategy yielded similar physiologic result as ICA-based plan



# FFR<sub>CT</sub> Planner Core Components

1

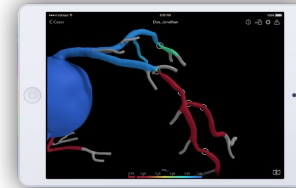
Starts with the HeartFlow Analysis



Interactive Mobile Platform

2

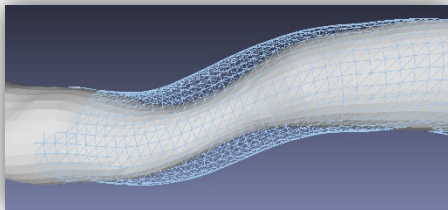
- iOS, interactive viewer



3

Ideal Geometry

- Contains a second anatomic model representing the “ideal” vessel



HeartFlow Planner



Real-time FFR<sub>CT</sub> calculation

4

- Modified vessel combined with updated physiology



\*Not yet commercially available, pending Regulatory Review

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

# What is new in the 2019 Guidelines?

## New recommendations (1)

### 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 <ul style="list-style-type: none"><li>- a high clinical likelihood and severe symptoms refractory to medical therapy</li><li>- typical angina at low level of exercise and clinical evaluation that indicates high event risk.</li></ul> 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

# What is new in the 2019 Guidelines?

## New recommendations (1)

### Basic testing, diagnostics, and risk assessment

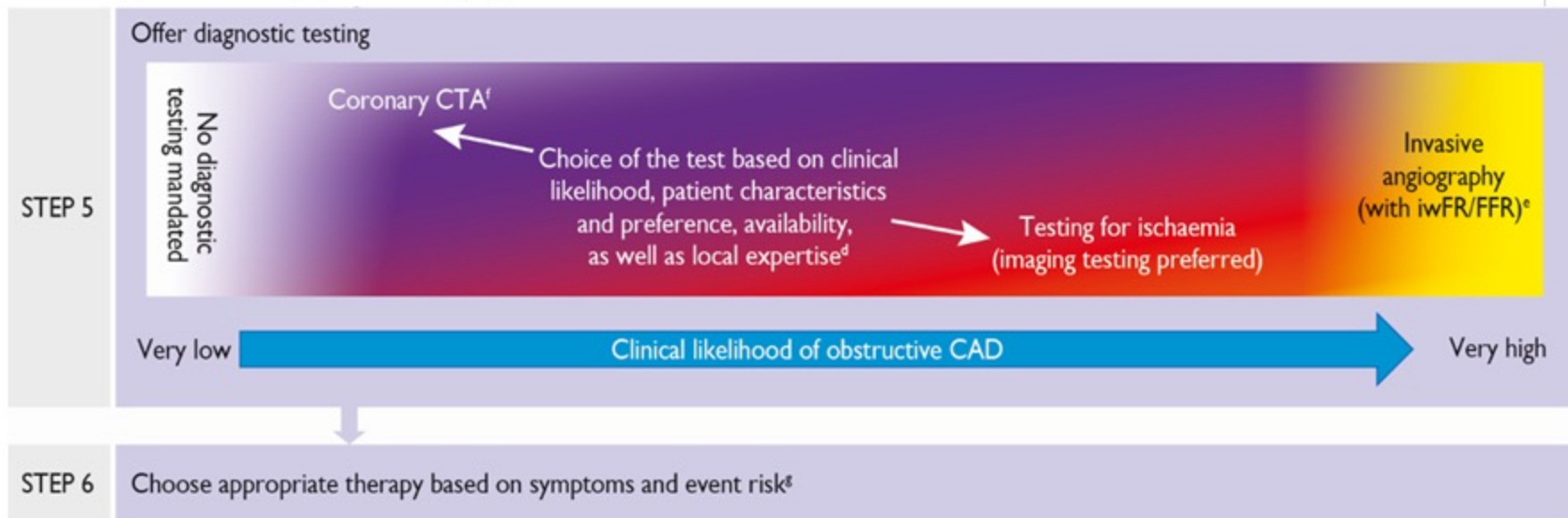
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Functional imaging for myocardial ischaemia if coronary CTA has shown CAD of uncertain functional significance or is not diagnostic.	<b>Invasive functional assessment must be available and used to evaluate stenoses before revascularization, unless very high grade (&gt;90% diameter stenosis).</b>	Coronary CTA when any conditions make good image quality unlikely.

■ Class I ■ Class IIa ■ Class IIb ■ Class III

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

## Diagnostic approach (2)

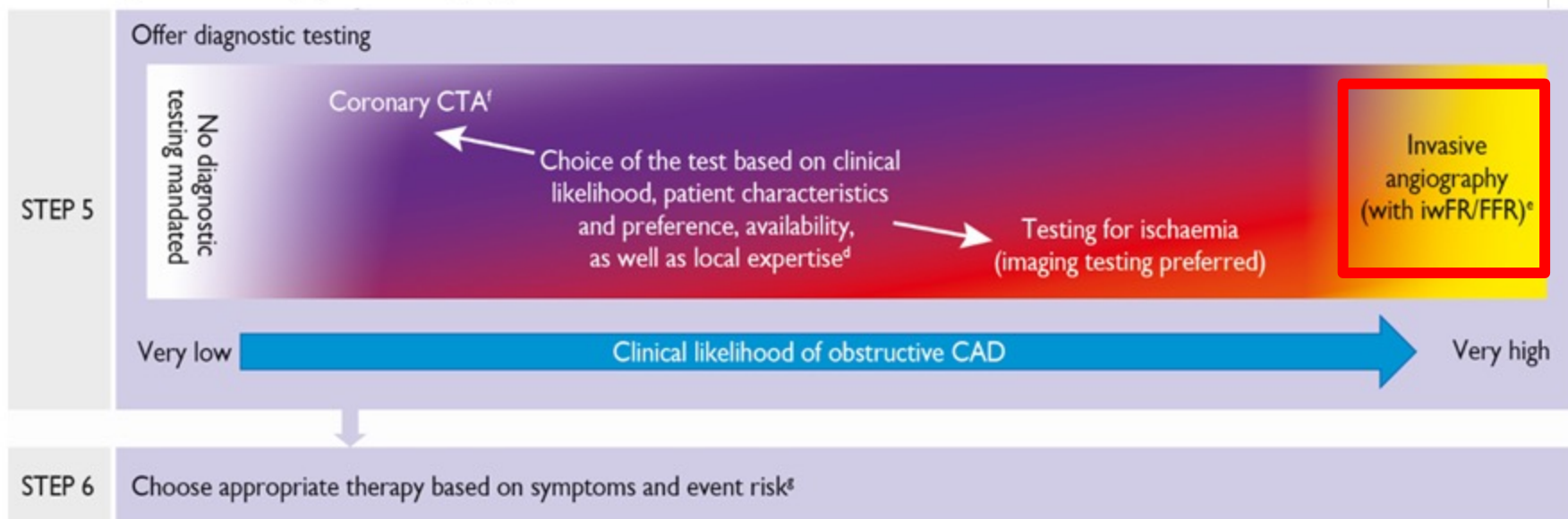


<sup>d</sup> Ability to exercise, individual test-related risks, and likelihood of obtaining diagnostic test result. <sup>e</sup> High clinical likelihood and symptoms inadequately responding to medical treatment, high event risk based on clinical evaluation (such as ST-segment depression, combined with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

© ESC

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## Diagnostic approach (2)



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