

# Coronary interventions and imaging

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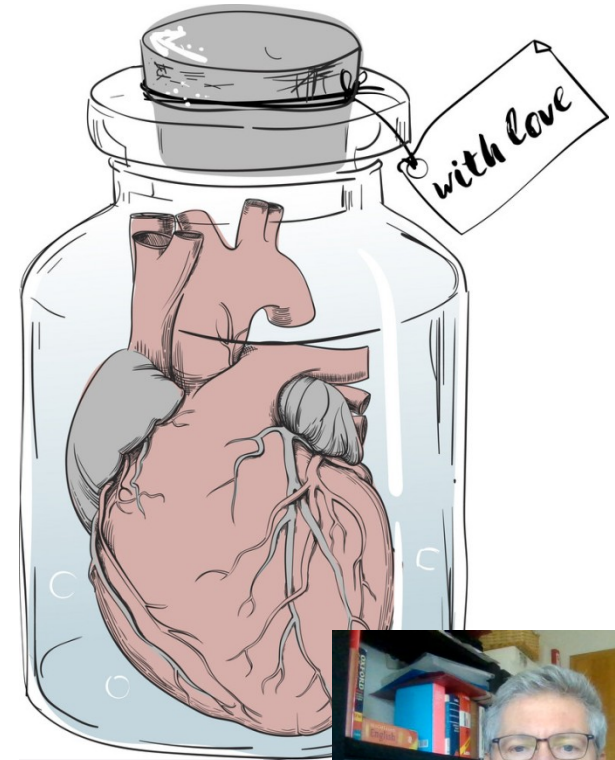
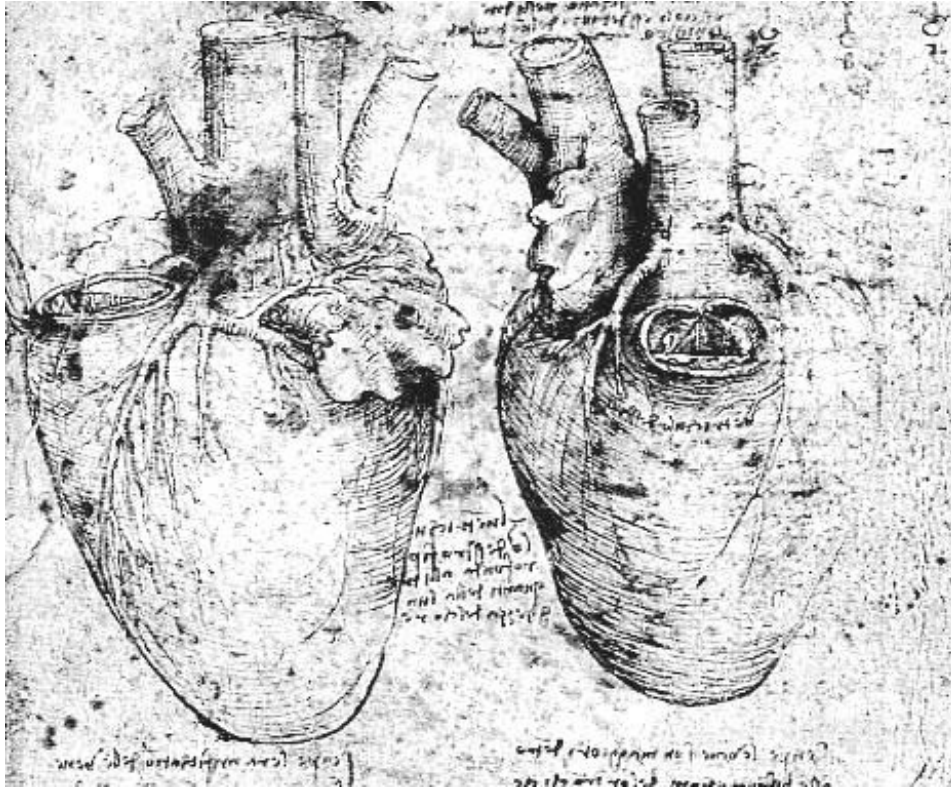
*University Hospital Brno*

*Czech Republic*

*v. 2020*



# Fascination by HEART... for a long time

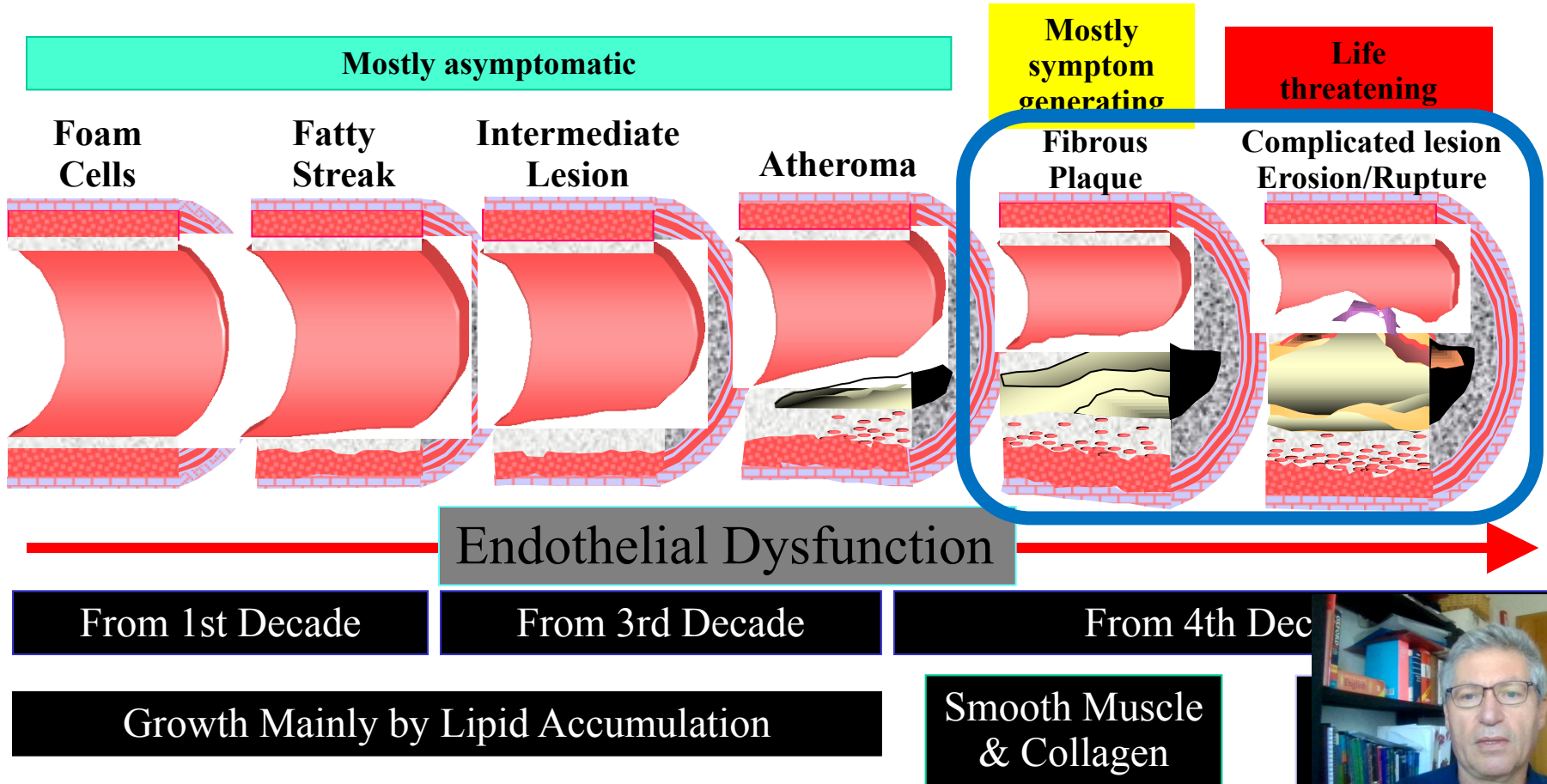


VectorStock®

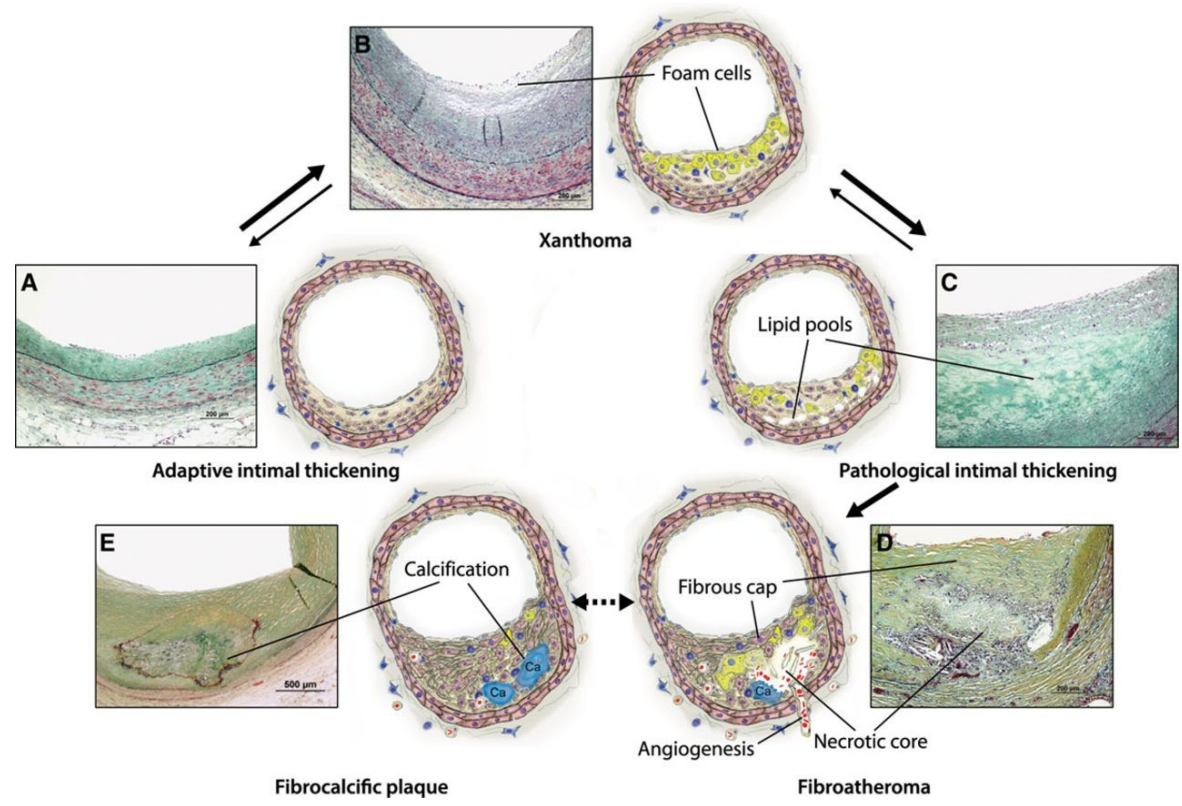


Image source: <https://leonardodavinci.stanford.edu/projects/anatomy/heart1.jpg>

# The Evolution of Atherosclerosis



# Mechanism of plaque formation



# Coronary artery disease (CAD)

- Myocardial ischemia mainly due to the atherosclerosis
- Definition is based on the angiography
  - Stenoses  $\geq 50\%$  (*i.e. the „old“ definition though still broadly accepted*)
    - respecting the limitations of angiography, more appropriate is to divide the lesions in two groups
      - 40-70% moderate or borderline lesions
      - $>70\%$  significant lesions (..mostly)
  - Total occlusions
    - Acute
    - Chronic ( $>3$  months)

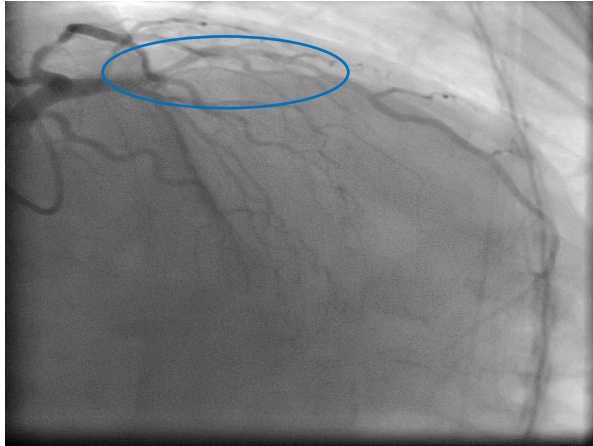


# Woman, 71yo

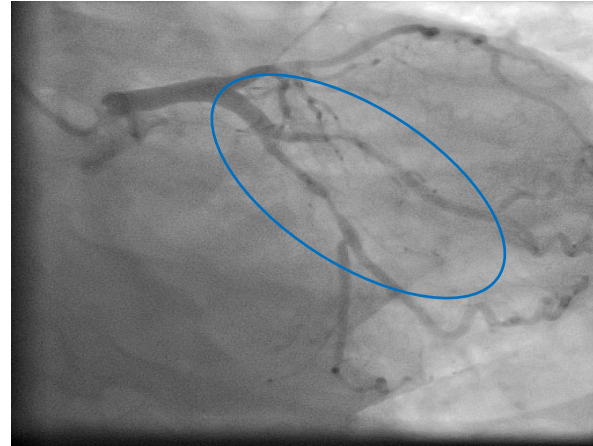
CAD for 3 months with progression in Unstable angina, NYHA II-III

Risk factors: Hypertension, Hyperlipidemia

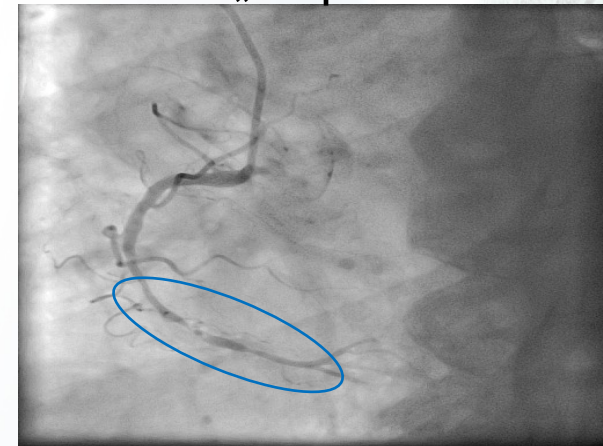
LAD



LCX - OM



RCA – „culprit“ lesion

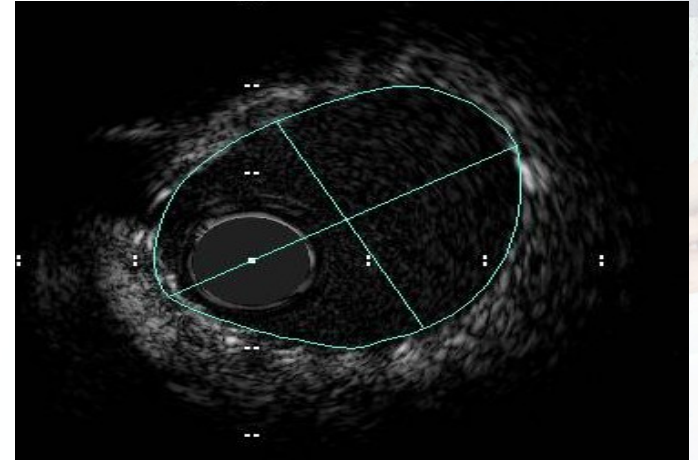
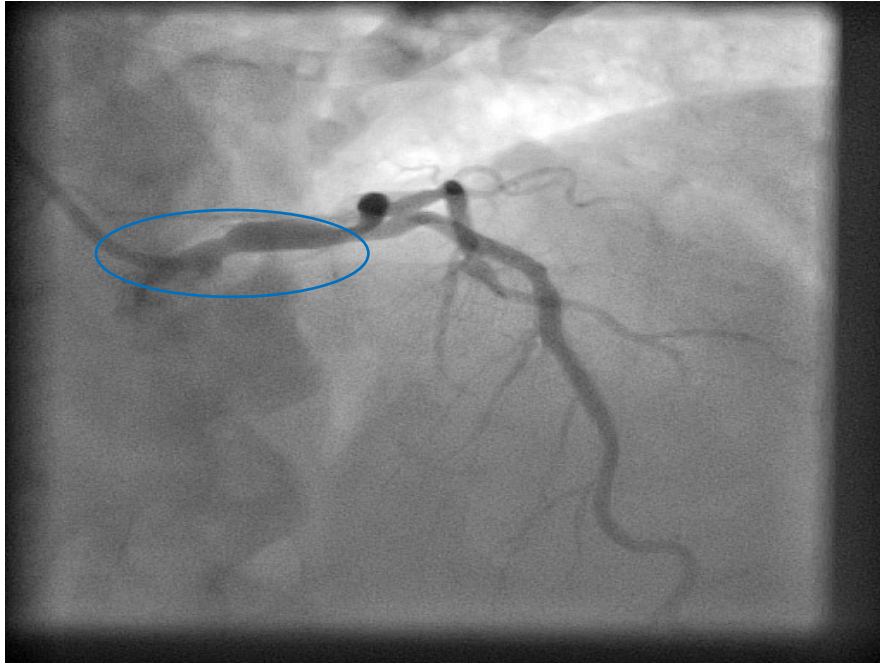


- 3VD, normal LVEF → HEARTteam → **FAME 3 trial** → patient was randomized in FFR (cut-off for rev



# Woman, 68yo

CAD w/o angina, dyspnea NYHA III, LVEF 67%, history of PCI + DES of LAD, LCx, RCA



Intravascular ultrasound - IVUS

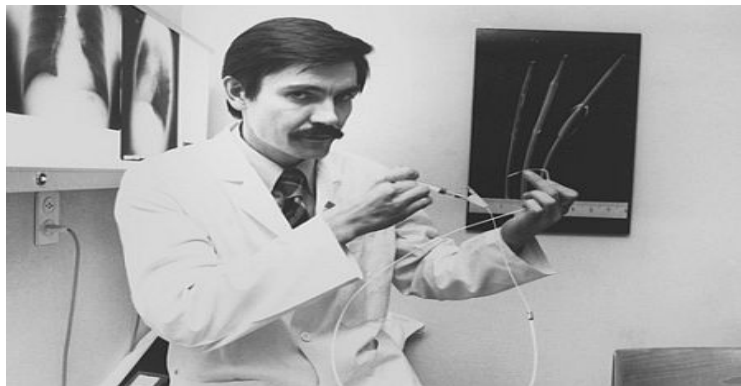
MLA - Minimal lumen area  
stem (LM) = 7,1 mm<sup>2</sup> = c  
(cut-off for revascularization of LM ≤6mm<sup>2</sup>)





# Sones - 1958

# Gruentzig - 1977





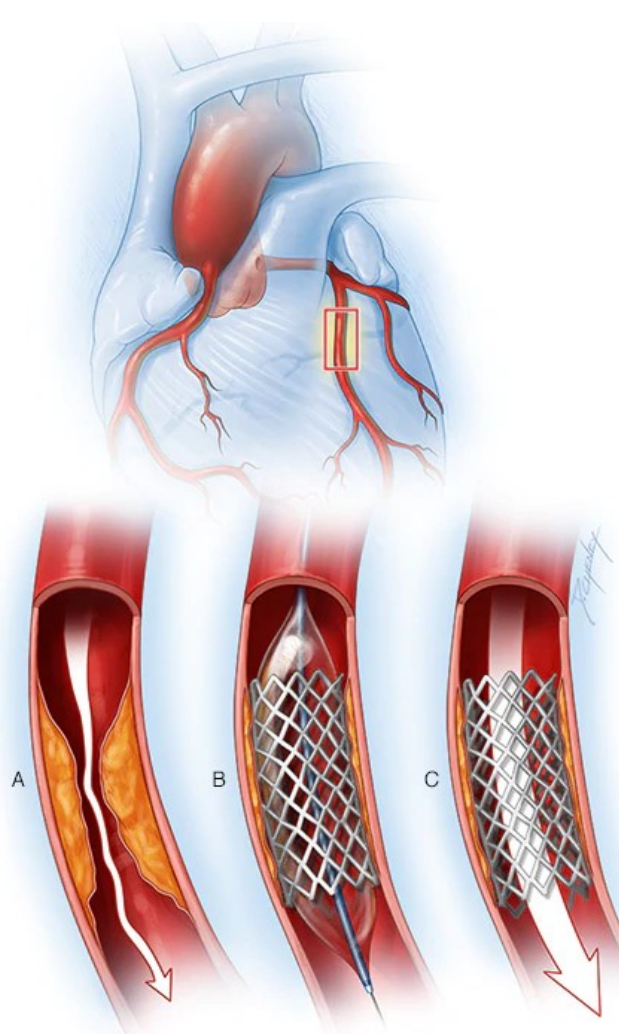
# History of PCI/PTCA

(PCI = percutaneous coronary intervention;  
PTCA = percutaneous transluminal coronary angioplasty)

- 1958 - selective coronary angiography
- **1977 - balloon angioplasty (POBA)**
- **1983 – mechanical reperfusion in acute myocardial infarction (AMI)**
- **1986 – intracoronary stenting**
- **1995 – stenting in AMI**
- **2001 – drug-eluting stents**



# Coronary stenting



# Coronary interventions

## Types of lesions and techniques

**1-3 diseased coronary arteries may be treated by PCI**

**Types of lesions:**

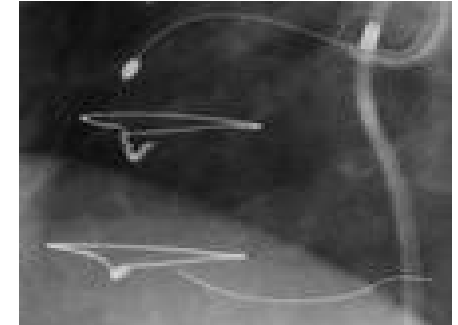
A, B1, B2, C (i.e. from simple, discrete to long, diffuse and/or chronic total occlusions)

**CAD forms:**

**Chronic Coronary Syndrome** - stable angina, silent ischemia

**Acute Coronary Syndrome (ACS)** - unstable angina (UA), acute myocardial infarction (AMI) with or without ST elevations = STEMI or NSTEMI

- **Stenting** (>90-95%)
- **Ballooning**
- **Atherectomy**
  - Rotational
  - Direct



- **Laser, ultrasound**



# Coronary interventions

## Pharmacotherapy

### Antiplatelet Tx

- **acetylosalicylic acid (ASA)** (chronic+acute..)
- **P2Y12 blockers** for oral administration
  - Ticlopidin
  - **Clopidogrel** (chronic..)
  - **Prasugrel** (acute..)
  - **Ticagrelor** (acute..)
- **P2Y12 blocker for i.v. administration**
  - Cangrelor (acute..)
- **Gp IIb/IIIa i.v. platelet blockers** (complications..)

### Anticoagulation

- **Heparin**
  - Unfractionated
  - Low-mollecular weight
- **Bivalirudin**



# PCI - Primary success rate and complications

- **Primary success in the cathlab = at the end of the procedure**
  - Stenoses > 90%
  - Acute occlusions > 85-90%
  - Chronic occlusions > 50% (up to 90% in dedicated centres)
- **Complications** (more often in acute patients)
  - Local 0.5 - 5% (radial vs. femoral a
  - Cardiac 0.5 - 2%



# PCI - Cardiac complications

**Acute** (relatively rare and mostly well manageable in the cathlab)

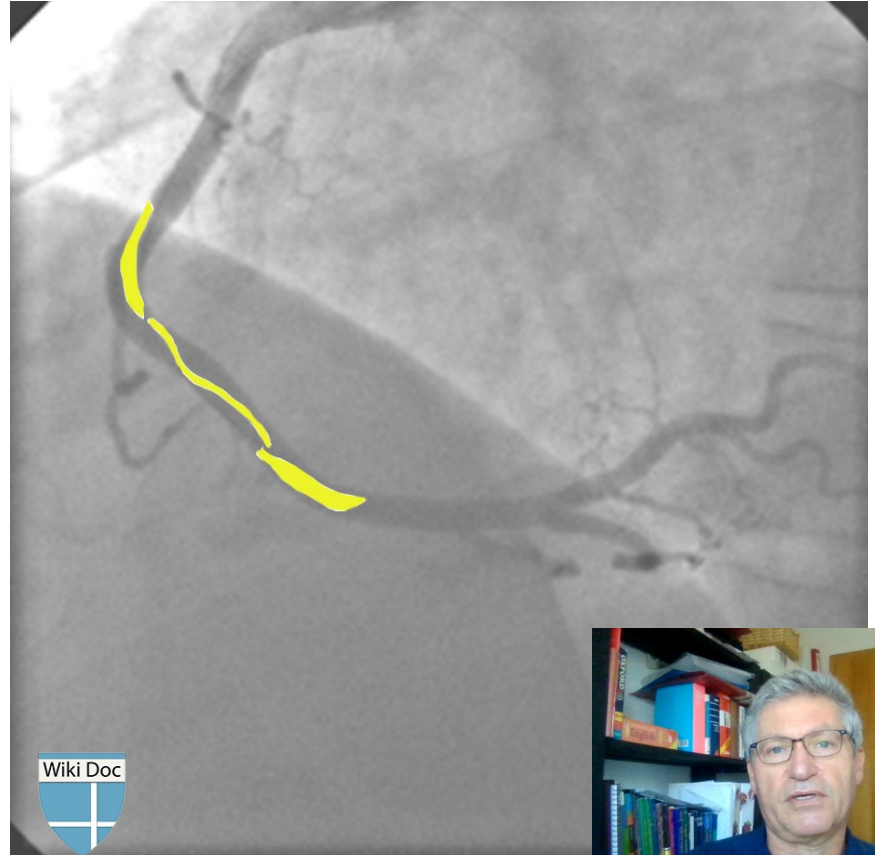
- Distal embolization
- Slow-flow, no-reflow phenomenon
- Thrombosis
- Coronary vessel closure
- Arterial wall dissection

**Late**

- **Restenosis**
  - clinically 10-50% after POBA, 5-30% after bare-metal stents, around 5% after DES)
  - anatomic rate is higher (based on the detection of  $\geq 50\%$  stenosis)

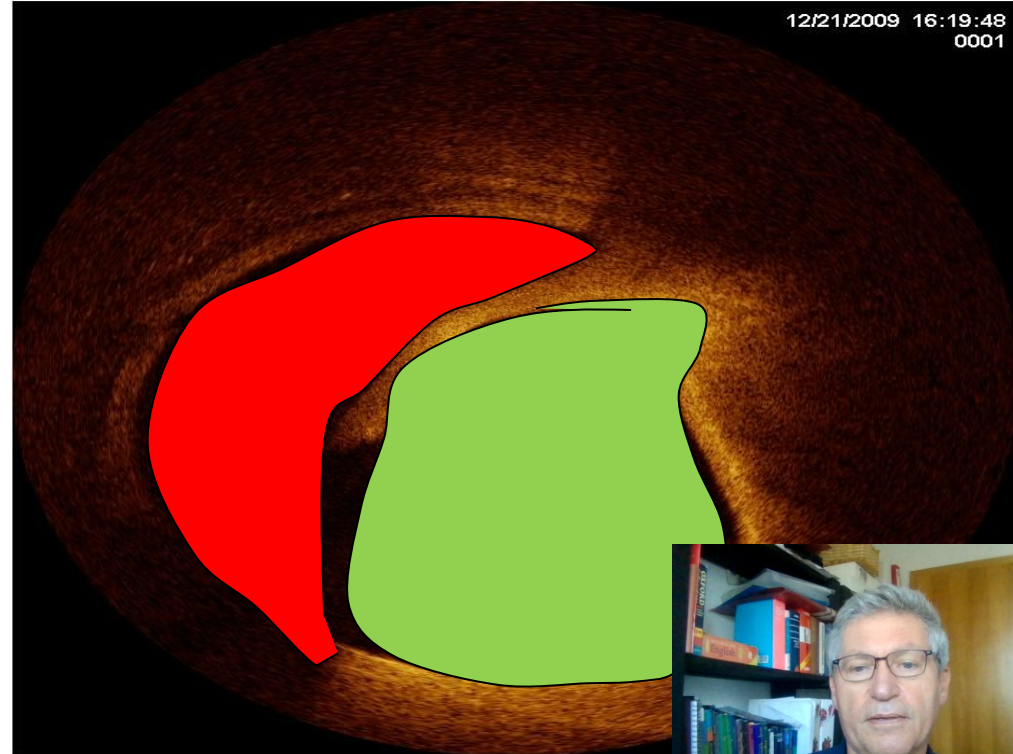
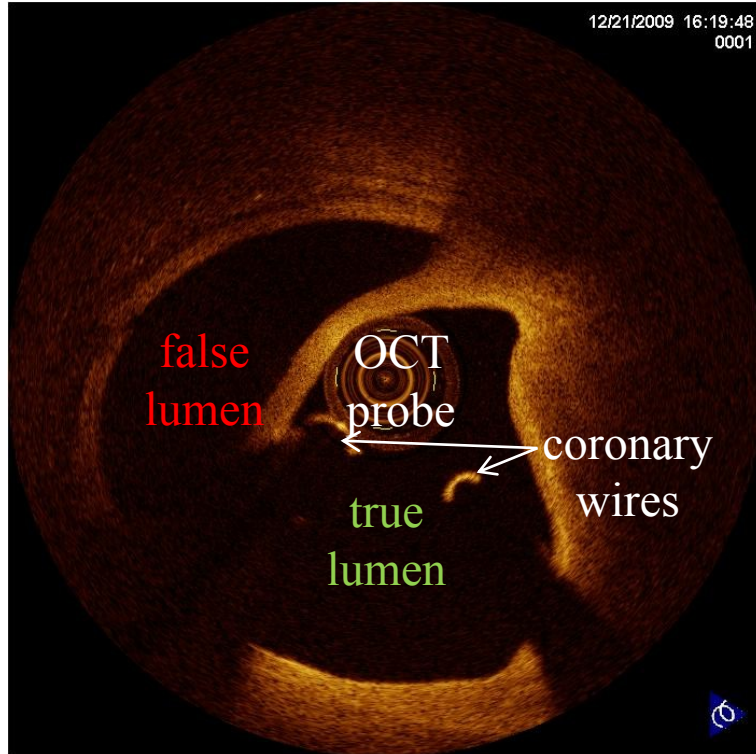


# Coronary dissection



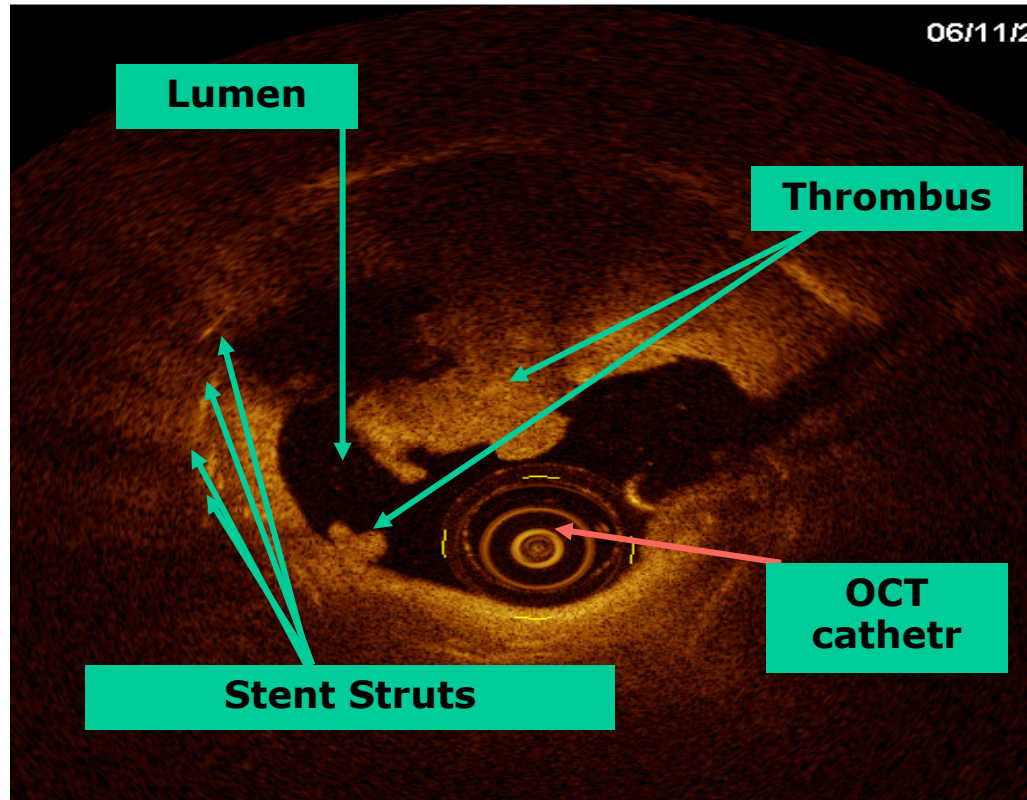
# Coronary dissection

## OCT – optical coherent tomography: cross-sectional view





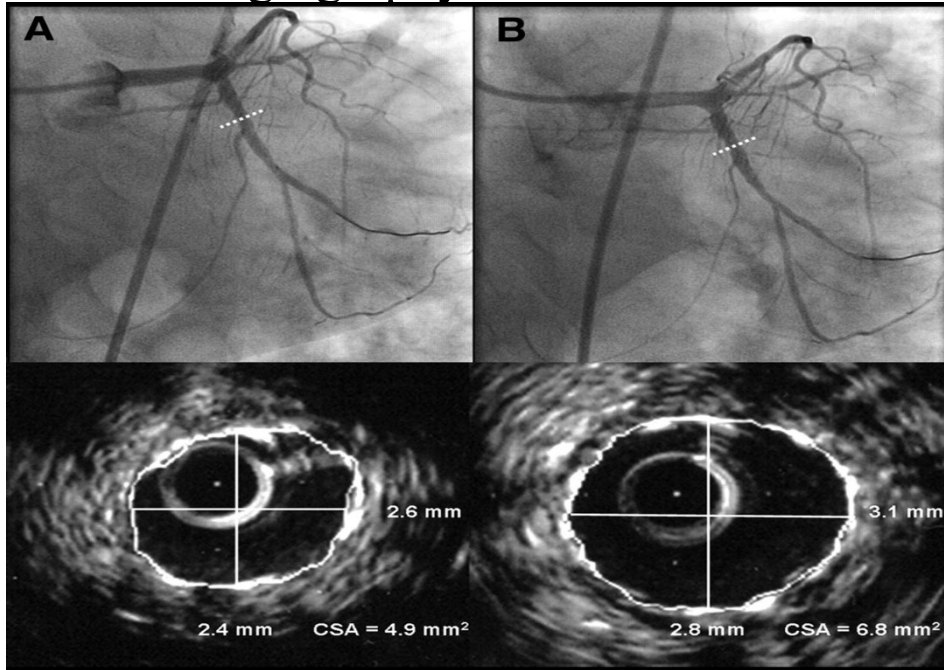
# Acute in-stent thrombosis on OCT



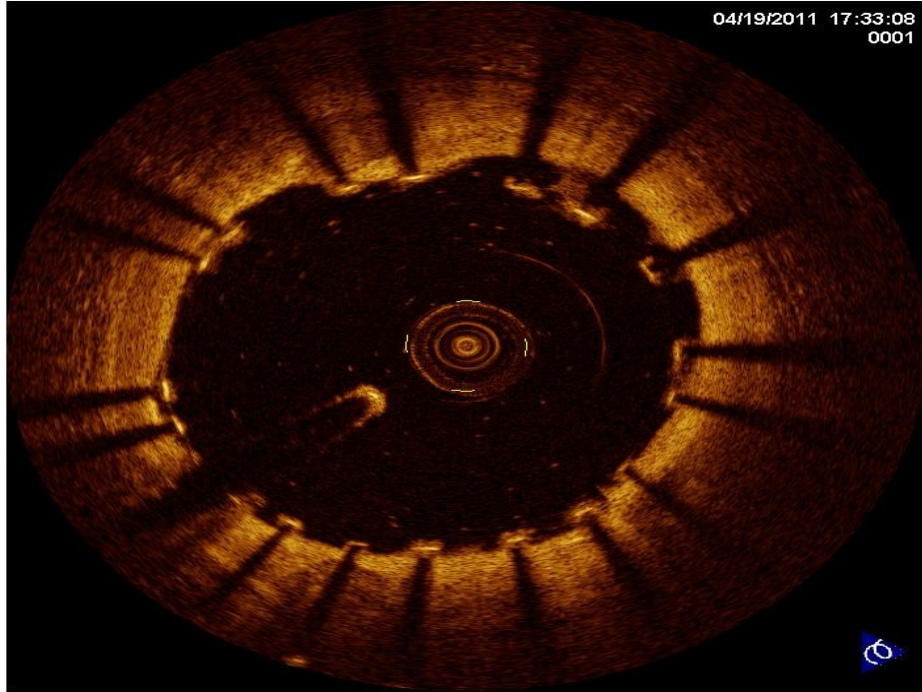
# Optimal result after stenting avoids restenosis

Angiography and IVUS

OCT



# Incomplete vs. complete stent apposition on OCT

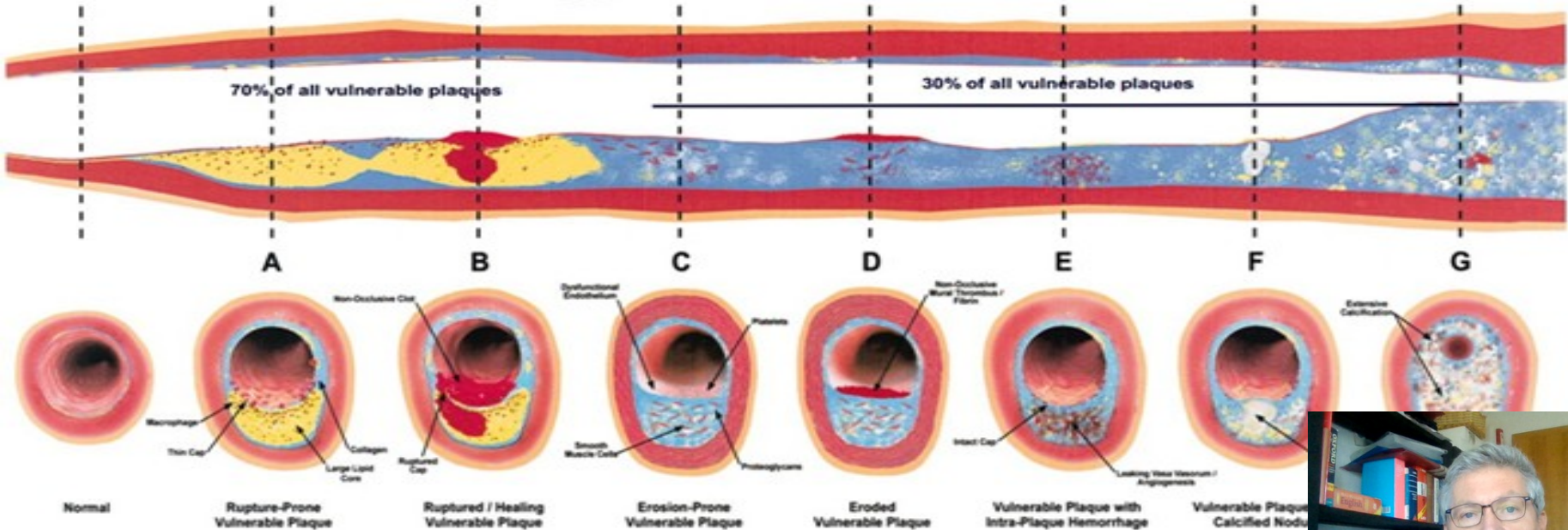


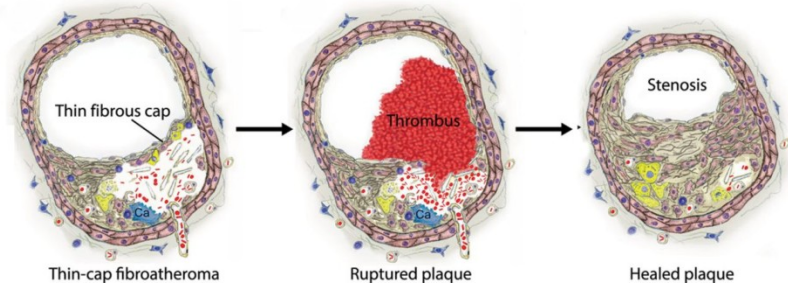
# ACS - Acute Coronary Syndrome



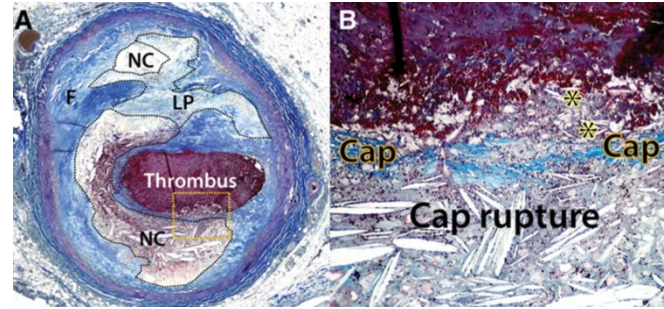
# Typy nestabilního plátu

## Different Types of Vulnerable Plaque

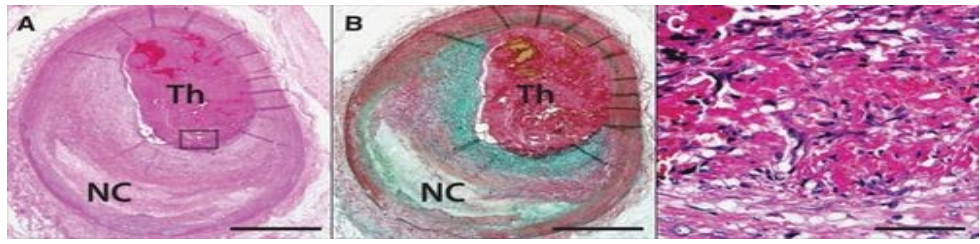




## Plaque rupture and healing



## Thrombosis caused by plaque rupture



## Plaque erosion

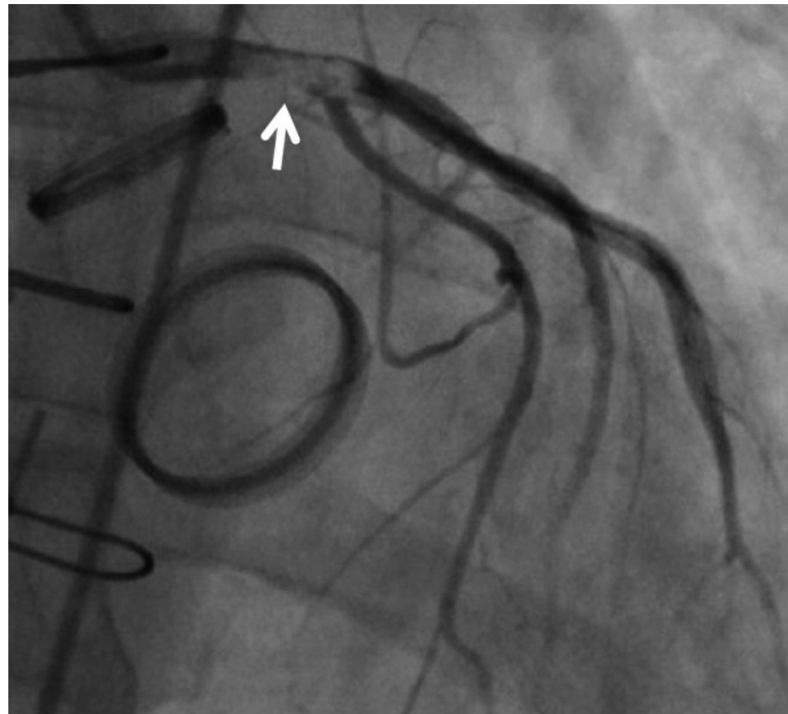


Jacob Fog Bentzon. Circulation Research. Mechanisms of Plaque Formation and Rupture, Volume: 114, Issue: 12, Pages: 1852-1866, DOI: (10.1161/CIRCRESAHA.114.302721)



# Coronary thrombus

Coronary angiography



IVUS




# UA and NSTEMI-ACS

## Unstable Angina and non-STEMI Acute Coronary Syndrome





# NSTE-ACS Risk stratification scores



## ACS Risk Model

At Admission (in-hospital/to 6 months)
At Discharge (to 6 months)

Age

HR

SBP

Creat.

CHF

US Units

Cardiac arrest at admission

ST-segment deviation

Elevated cardiac enzymes/markers

Probability of	Death	Death or MI
In-hospital	<input type="text" value="--"/>	<input type="text" value="--"/>
To 6 months	<input type="text" value="--"/>	<input type="text" value="--"/>

[Calculator](#) | 
 [Instructions](#) | 
 [GRACE Info](#) | 
 [References](#) | 
 [Disclaimer](#)

Carrier 7:13 PM 60%

**GRACE Risk Score**

Interpretation

Risk Score for NSTE-ACS  
 Probability of In Hospital Death

Risk Category (tertiles)	GRACE Risk Score	Probability of Death In-Hospital (%)
Low	1 – 108	<1
Intermediate	109 – 140	1 – 3
High	141 – 372	>3

Probability of Death Post Discharge to 6 Months

Risk Category (tertiles)	GRACE Risk Score	Probability of Death Post-discharge to 6 Months (%)
Low	1 – 88	<3
Intermediate	89 – 118	3 – 8
High	119 – 263	>8

Risk Score for STE-ACS  
 Probability of In Hospital Death

Risk Category (tertiles)	GRACE Risk Score	Pro
Low	1 – 88	<3
Intermediate	89 – 118	3 – 8
High	119 – 263	>8

Home
Calculation



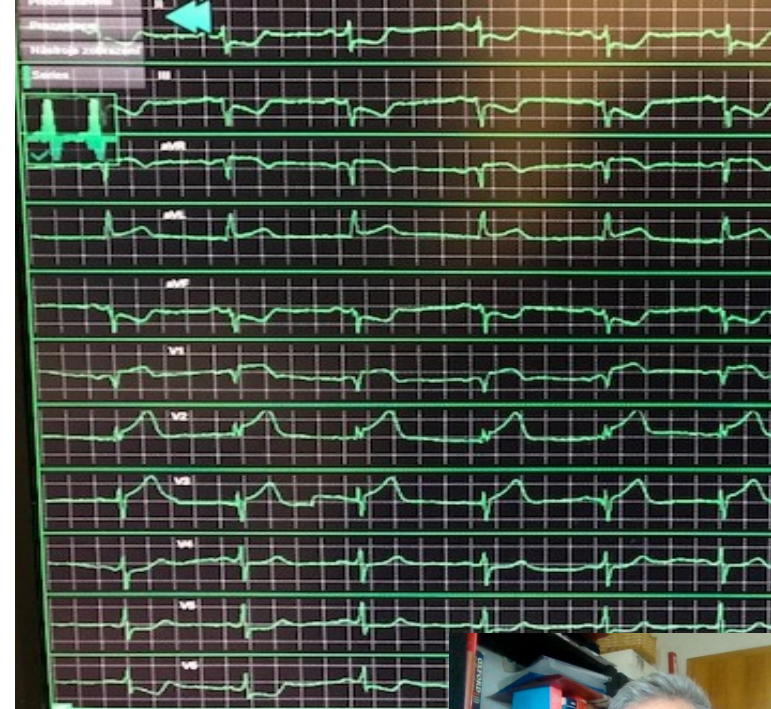
# STE-ACS = STEMI

## ST-Elevation Acute Myocardial Infarction



# F, 71 yo, AW STEMI

- STEMI as first presentation of CAD
  - Symptom onset: Time 0
  - EMS call: 63 mins
    - Lifenet telemedicine – AW STEMI
    - **UFH 5000 IU + ASA 250mg i.v.,**
    - **Fentanyl 2cc i.v.**
  - Transport to CCU: 47 mins
  - Cathlab+20mins! puncture +8mins; wire+17min
  - End of primary PCI in 70 mins from the CCU admission
  - Killip III ... progression in Killip IV in the cathlab = Cardiogenic shock
  - History: Hypertension on **ACEI + BB**



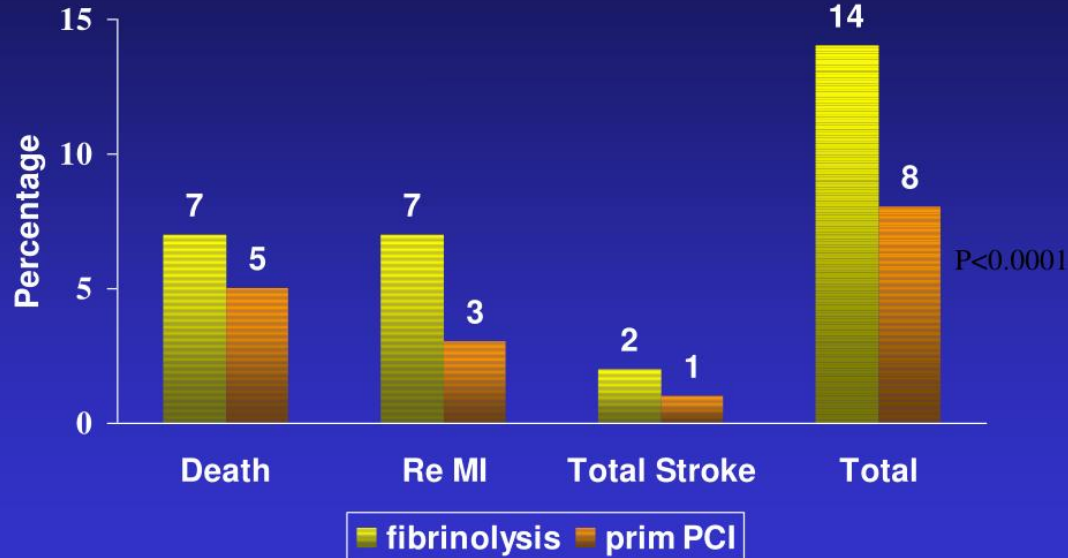
# F, 71 yo, AW STEMI

- **RADIAL** approach – 6F
- **MANUAL THROMBOASPIRATION**
- **DES**
- **HIGH-PRESSURE POSTDILATATION**
- **STENTING of LAD and LCx during the index procedure in patient with multi-vessel disease who was scheduled for staged non-culprit PCI of RCA in several weeks**
- **Adjunctive pharmacotherapy – Ticagrelor LD 180mg, GPI (abciximab bolus i.v.), furosemid, Noradrenalin**
- *Patient was discharged home after 5 days in good clinical status*
- Further Qs during the acute phase
  - Mechanical circulatory support? Timing? (IABP vs Impella vs ECMO?)
  - Imaging?



# Primary PCI vs. fibrinolysis

Primary PCI versus fibrinolysis for MI  
Meta analysis of 23 trials

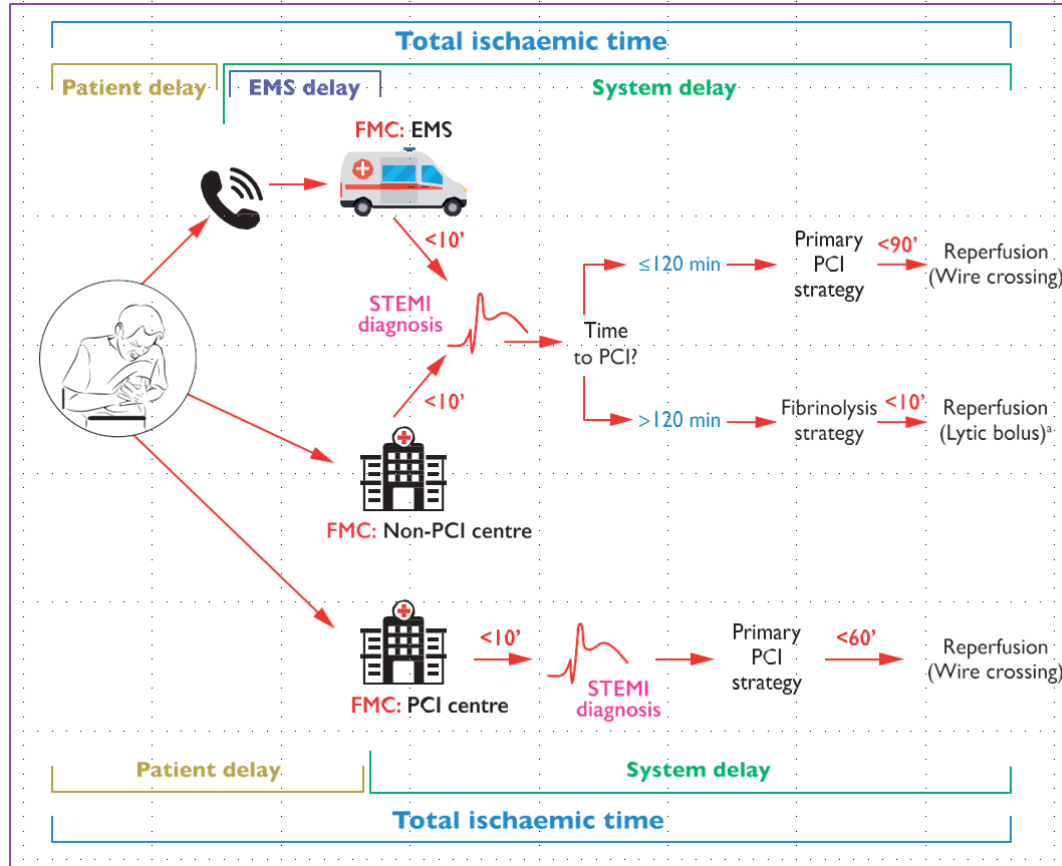


*Keeley EC. Lancet 2003;361:13-20*

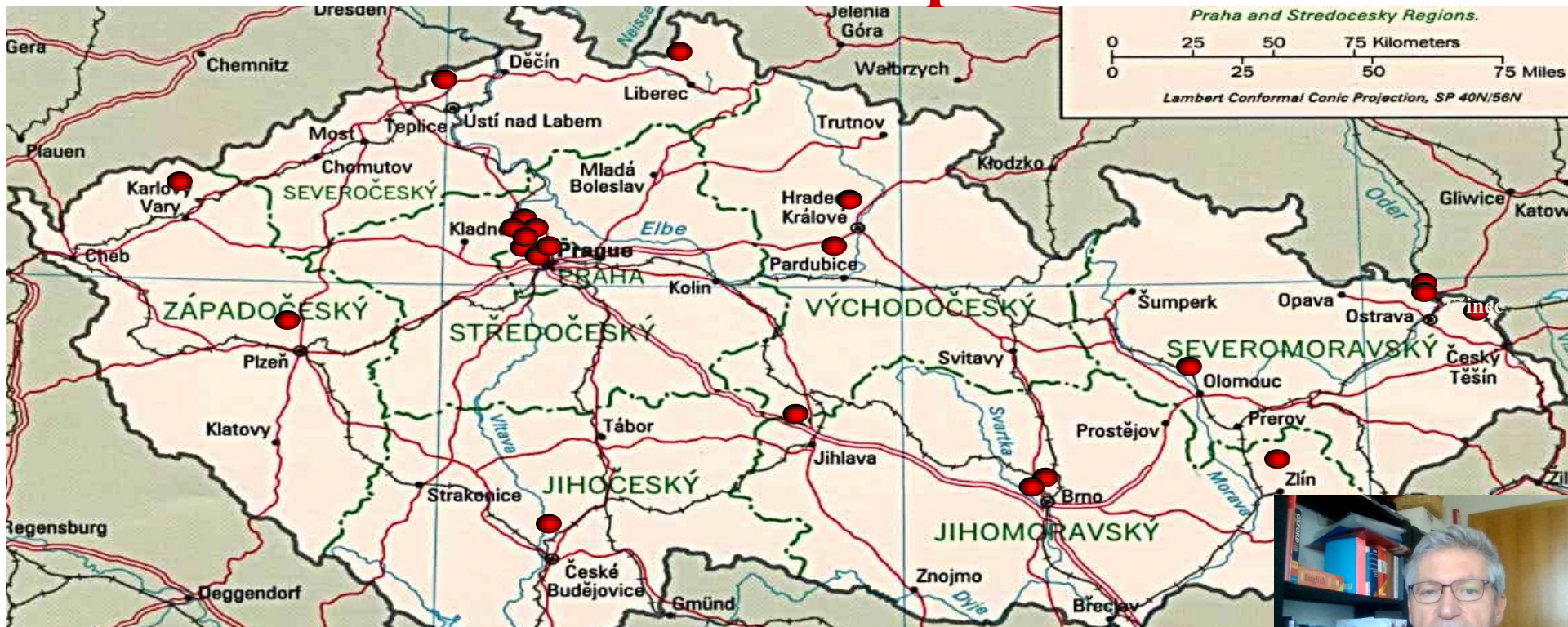


# ESC guidelines on STEMI

## Algorithm of reperfusion Tx and the time intervals



# Non-stop (24/7) PCI centres in the Czech Republic



22 centres per 10.6M population = 460.000 / cent



# Stent for Life INITIATIVE

To improve the delivery and patient access to the life saving indications of PCI thereby reduce the mortality and morbidity of patients suffering from acute coronary syndromes.



[www.stentforlife.com](http://www.stentforlife.com)





# Stent for Life Initiative Phase I

## Situation Mapping & Data Collection

### 2008 - 2009



# Stent for Life Initiative Phase II

## Learning the experience from the best practice countries

### 2009



**EuroIntervention**

**How to set up an effe network: lessons lear**

Jan Kralic<sup>1</sup>, MD, Petr Widimsky<sup>2</sup>, M MS, PhD, Steen Dalby Kristensen<sup>3</sup>, MD, PhD, FESC, Willem Janssen<sup>4</sup>, M Swenneker<sup>5</sup>, MD, Henri van de Stee, Ferdinand Bongaers<sup>6</sup>, MD, Christophe MSA, Jean Fajadet<sup>7</sup>, MD, PhD, FESC, F. D'Amico<sup>8</sup>, Department of Cardiology of University Hospital Carlo Poma<sup>9</sup>, J. Sanz-Rubio<sup>10</sup>, Hospital Cardiológico, Institute of Cardiology of Santiago del Estero, Institute Biomed Research, Spanish Institute of Research, State University of Rio de Janeiro, State University of Rio de Janeiro, Institute of Cardiology, Federal University of Rio de Janeiro, J.J. Department of Internal Medicine, Johns Hopkins University, Baltimore, MD

# Stent for Life Initiative Phase III

## Implementation in Countries

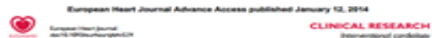
### 2009 - 2013



**EuroIntervention** 2012;8:35-42

### Implementation of primary angioplasty in Europe: Stent for Life initiative progress report

Steen Dalby Kristensen<sup>1</sup>, MD, DMSc, Jean Fajadet<sup>2</sup>, MD, Carlo Di Mario<sup>3</sup>, MD, Zoran Kraljic<sup>4</sup>, MD, Kristina Grundberg Laveit<sup>5</sup>, MPhD, Dan DeLano<sup>6</sup>, MD, Mianca Gilman<sup>7</sup>, MD, PhD, Giulio Gualtieri<sup>8</sup>, MD, Omer Goktekin<sup>9</sup>, MD, Julia Jurgova<sup>10</sup>, MD, PhD, FESC, FACC, Julia Kanczkova<sup>11</sup>, MD, Miodrag Ostojic<sup>12</sup>, MD, PhD, FESC, FACC, FISCAL, Halder Pereira<sup>13</sup>, MD, FESC, FACC, FISCAL, Maged Sabany<sup>14</sup>, MD, PhD, Muhammad Subhji<sup>15</sup>, MD, FACC, FESC, Christian Vissers<sup>16</sup>, MD, PhD, William Wijns<sup>17</sup>, MD, PhD, Petr Widimsky<sup>18</sup>, MD, DSc, FESC



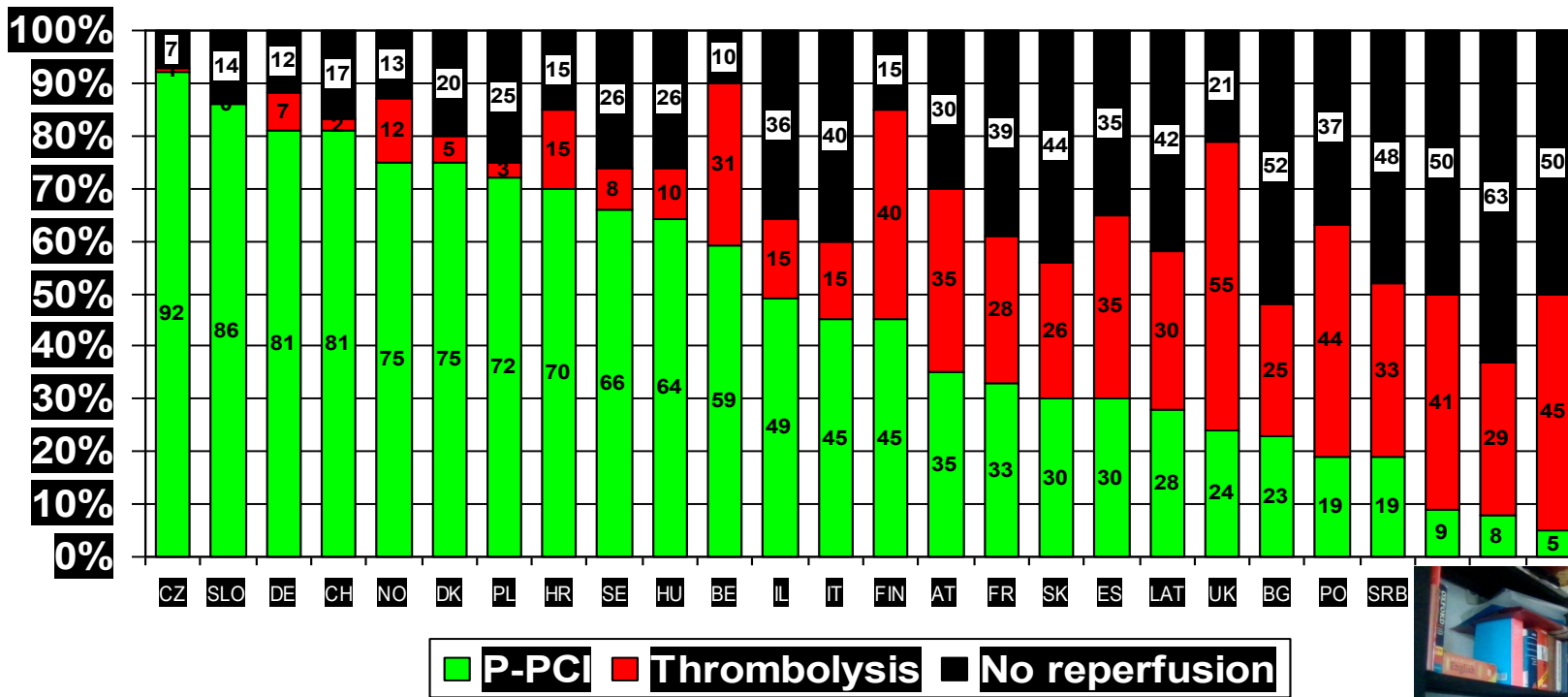
### Reperfusion therapy for ST elevation acute myocardial infarction 2010/2011: current status in 37 ESC countries

Steen D. Kristensen<sup>1</sup>, Petr Kala<sup>2</sup>, Carlo Di Mario<sup>3</sup>, Kristina Grundberg Laveit<sup>4</sup>, Dan DeLano<sup>5</sup>, Giulio Gualtieri<sup>6</sup>, Stefan Janssen<sup>7</sup>, Taro Kiril K. Karandjiev<sup>8</sup>, Bela Merkely<sup>9</sup>, Dan Marco Kraljic<sup>10</sup>, Maged Sabany<sup>11</sup>, Hans H. Van der Wal<sup>12</sup>, Ibrahim Terzic<sup>13</sup>, S. Ulf Steenstrand<sup>14</sup>, Martin Soustouls<sup>15</sup>, Marco Tullone<sup>16</sup>, Zoran V. Franz Woldinger<sup>17</sup>, Adam Witkowski<sup>18</sup>, and Uwe Zeymer<sup>19</sup> on behalf of Association for Percutaneous Cardiovascular Interventions





# Reperfusion Therapies and Mortality Differ among Countries



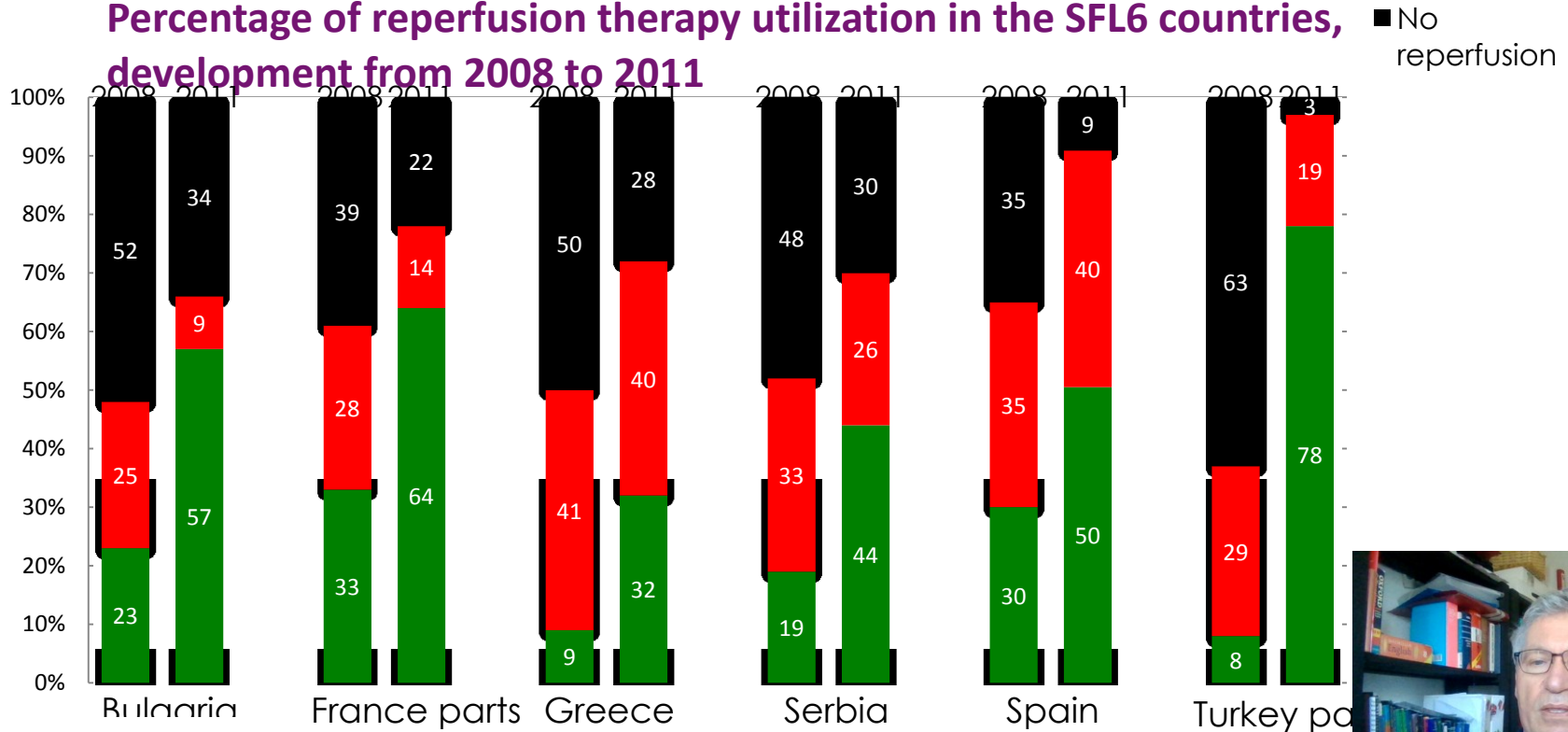
Widimsky P...Kala P. et al. Eur. Heart.J. 2010. doi

Stent for Life is a joint initiative between the European Association of Percutaneous Cardiovascular Interventions (EAPCI), a registered branch of the European Society of Cardiology



# SFL Impact on Access to PPCI – what can be achieved within several years..

Percentage of reperfusion therapy utilization in the SFL6 countries, development from 2008 to 2011





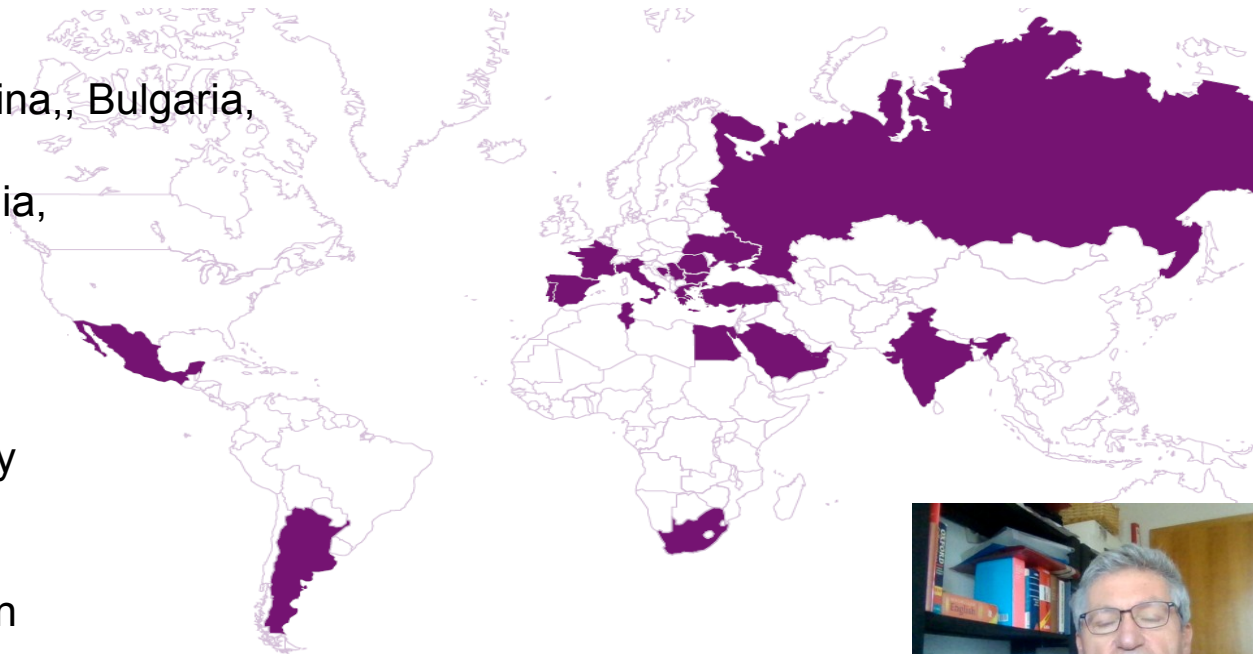
# 21 countries from 5 continents were actively participating in SFL Initiative

## SFL Member Countries

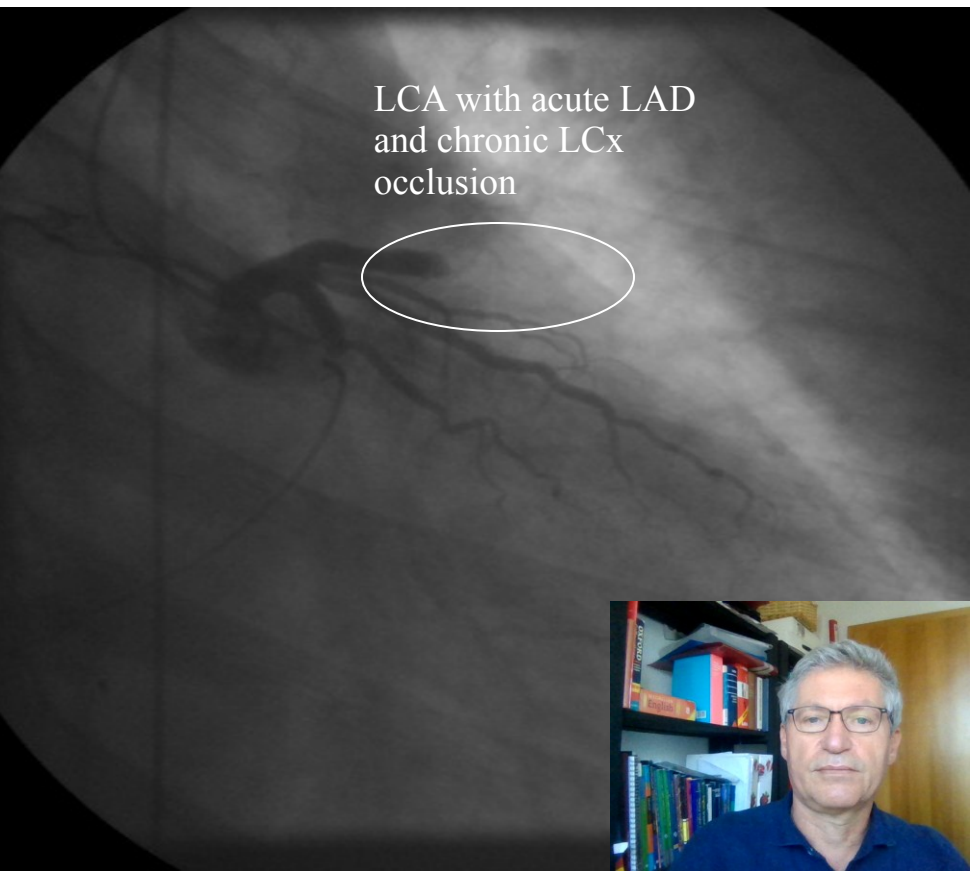
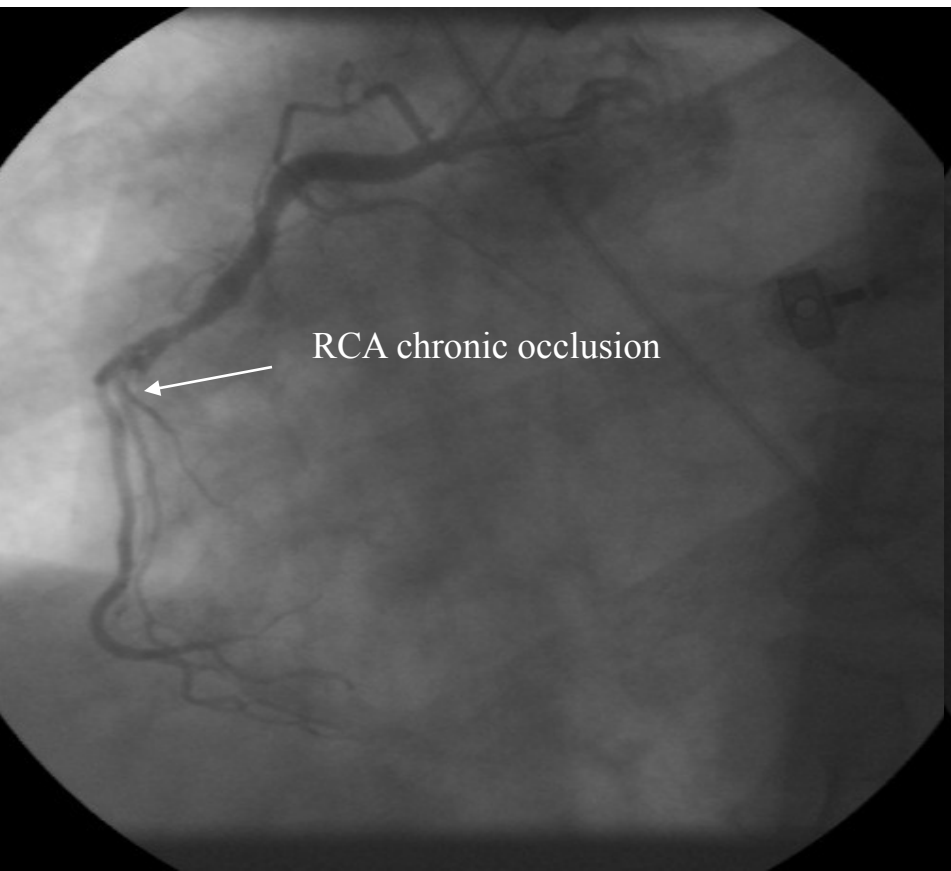
Belarus, Bosnia and Herzegovina,, Bulgaria, Cyprus, Egypt, France, Greece, Italy, Portugal, Romania, Russia, Serbia, Spain, Tunisia, Turkey, Ukraine

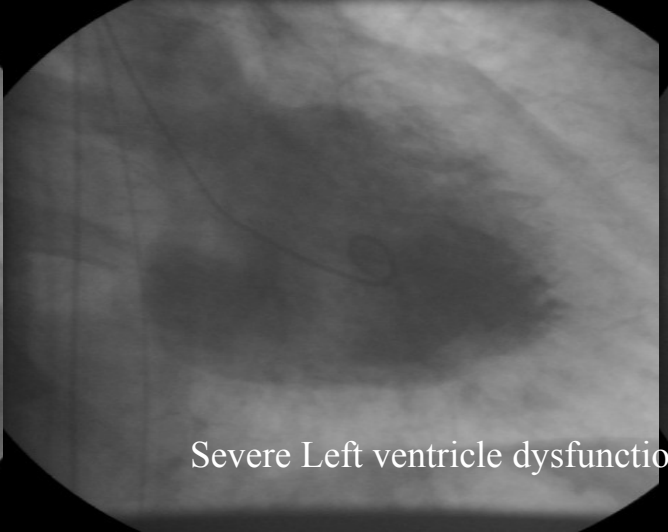
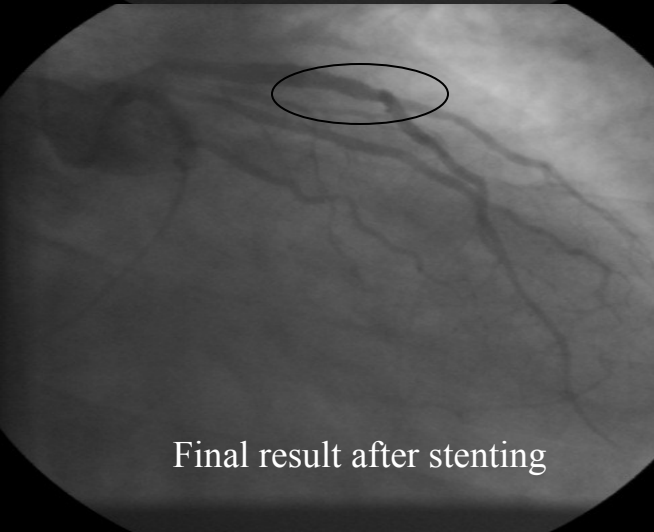
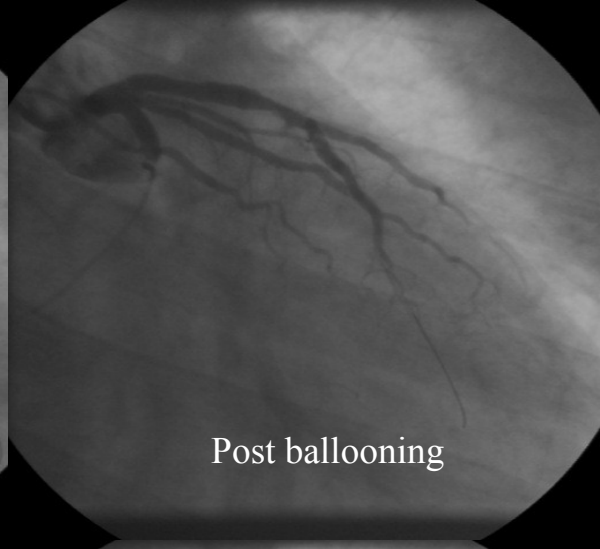
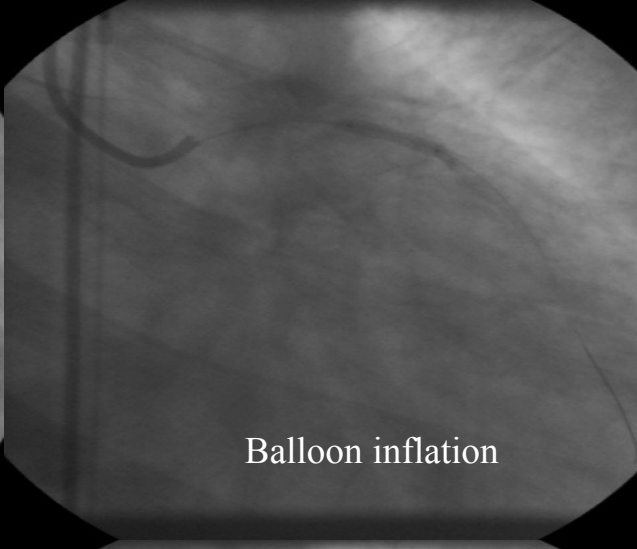
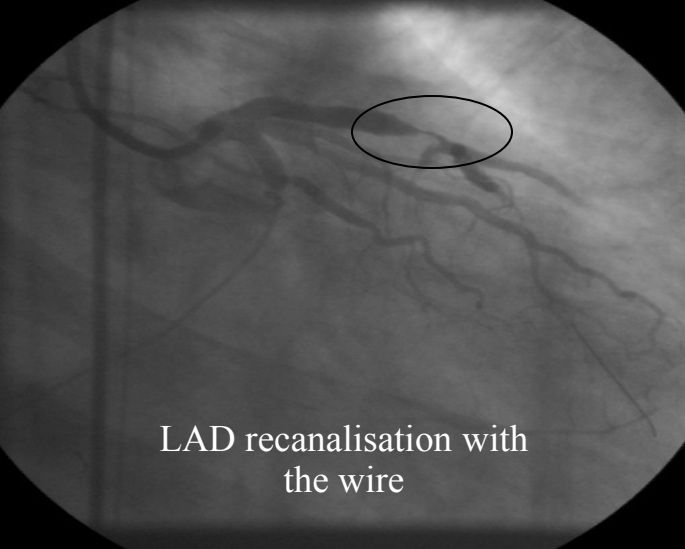
## SFL Affiliate Organizations

Argentine Society of Cardiology  
Saudi Heart Association  
SOCIME (Mexico)  
South African Heart Association  
STEMI INDIA



# Male, 51 yo in Cardiogenic Shock due to the anterior wall STEMI with chronic occlusion of RCA





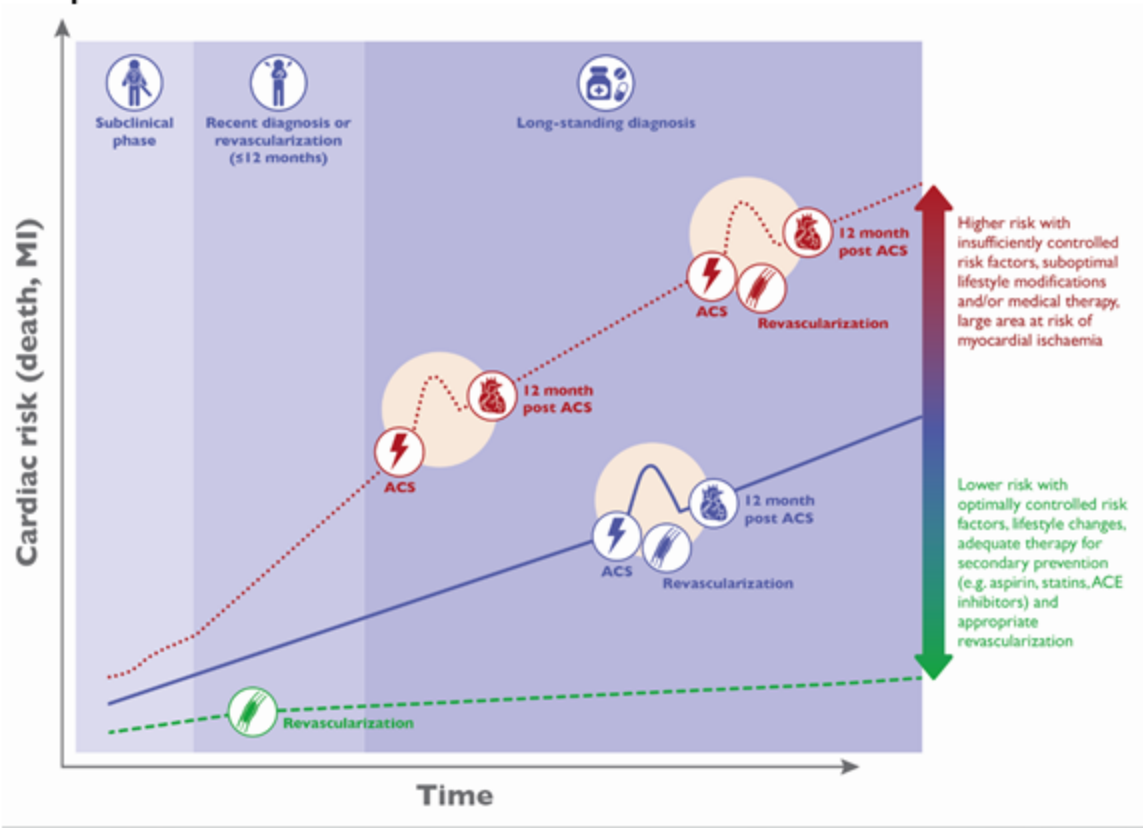
# Chronic CAD

*newly known as CCS = Chronic Coronary  
Syndrome*



# Natural history of chronic coronary syndromes

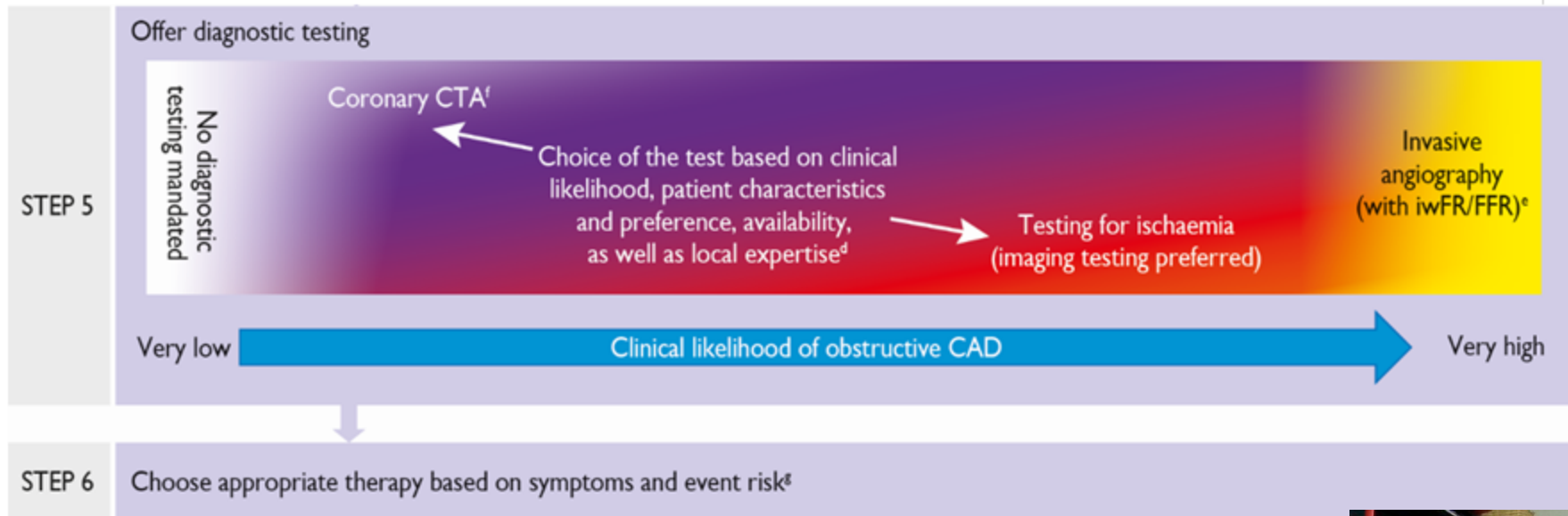
A dynamic process





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

## Diagnostic approach (2)

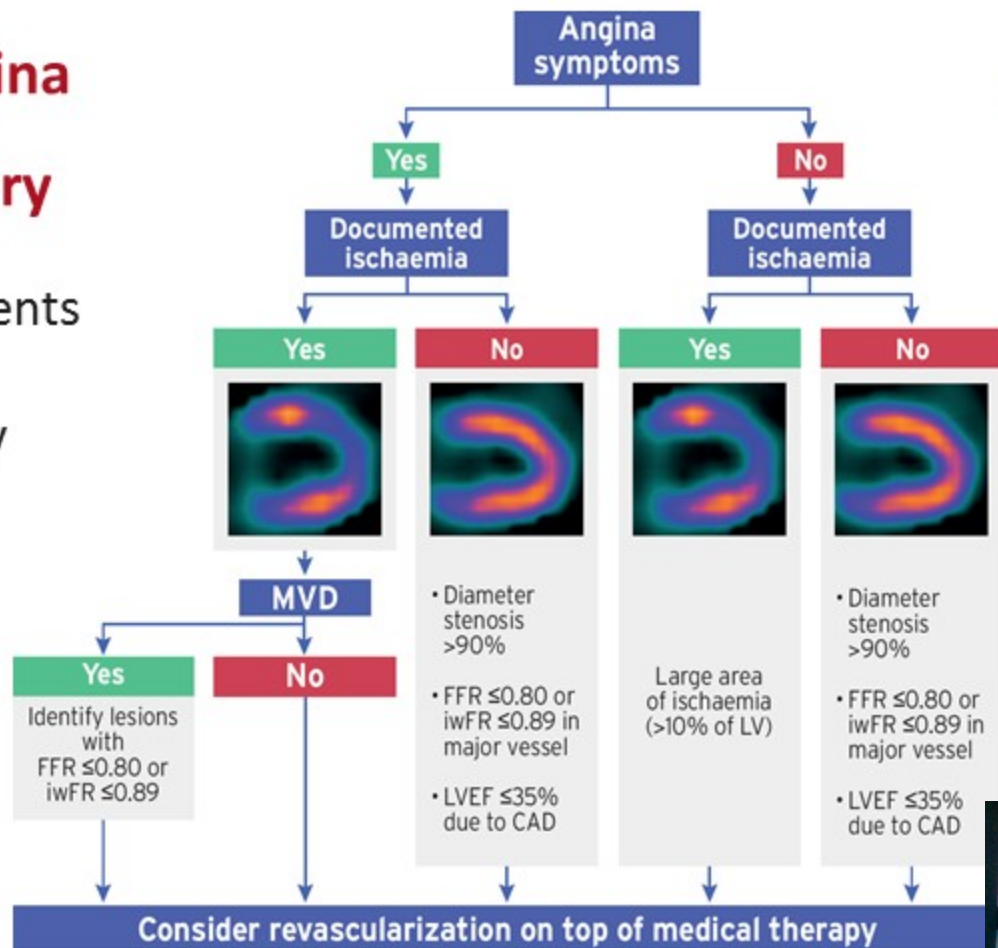


<sup>d</sup> Ability to exercise, individual test-related risks, and likelihood of obtaining diagnostic test result. <sup>e</sup> High clinical likelihood and symptoms inadequate response to medical treatment, high event risk based on clinical evaluation (such as ST-segment depression, combined with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



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

Decision tree for patients undergoing invasive coronary angiography



CAD = coronary artery disease;  
FFR = fractional flow reserve;  
iwFR = instantaneous wave-free ratio;  
LV = left ventricle;  
LVEF = left ventricular ejection fraction;  
MVD = multivessel disease.



# ESC Guidelines on Revascularization PCI vs CABG

## Indications for revascularization in patients with stable angina or silent ischaemia

Extent of CAD (anatomical and/or functional)		Class <sup>a</sup>	Level <sup>b</sup>
<b>For prognosis</b>	Left main disease with stenosis >50% <sup>c 68-71</sup>	I	A
	Proximal LAD stenosis >50% <sup>c 62,68,70,72</sup>	I	A
	Two- or three-vessel disease with stenosis >50% with impaired LV function (LVEF ≤35%) <sup>c 61,62,68,70,73-83</sup>	I	A
	Large area of ischaemia detected by functional testing (>10% LV) or abnormal invasive FFR <sup>d 24,59,84-90</sup>	I	B
	Single remaining patent coronary artery with stenosis >50% <sup>c</sup>	I	C
<b>For symptoms</b>	Haemodynamically significant coronary stenosis <sup>c</sup> in the presence of limiting angina or angina equivalent, with insufficient response to optimized medical therapy. <sup>e 2463,91-97</sup>	I	A

CAD = coronary artery disease; FFR = fractional flow reserve; iwFR = instantaneous wave-free ratio; LAD = left anterior descending coronary artery; LV = left ventricular; LVEF = left ventricular ejection fraction.

<sup>a</sup>Class of recommendation.

<sup>b</sup>Level of evidence.

<sup>c</sup>With documented ischaemia or a haemodynamically relevant lesion defined by FFR ≤0.80 or iwFR ≤0.89 (see section 3.2.1.1), or >90% stenosis in a major coronary vessel.

<sup>d</sup>Based on FFR <0.75 indicating a prognostically relevant lesion (see section 3.2.1.1).

<sup>e</sup>In consideration of patient compliance and wishes in relation to the intensity of anti-anginal therapy.

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## Recommendation for the type of revascularization in patients with stable coronary artery disease with suitable coronary anatomy for both procedures and low predicted surgical mortality<sup>d</sup>

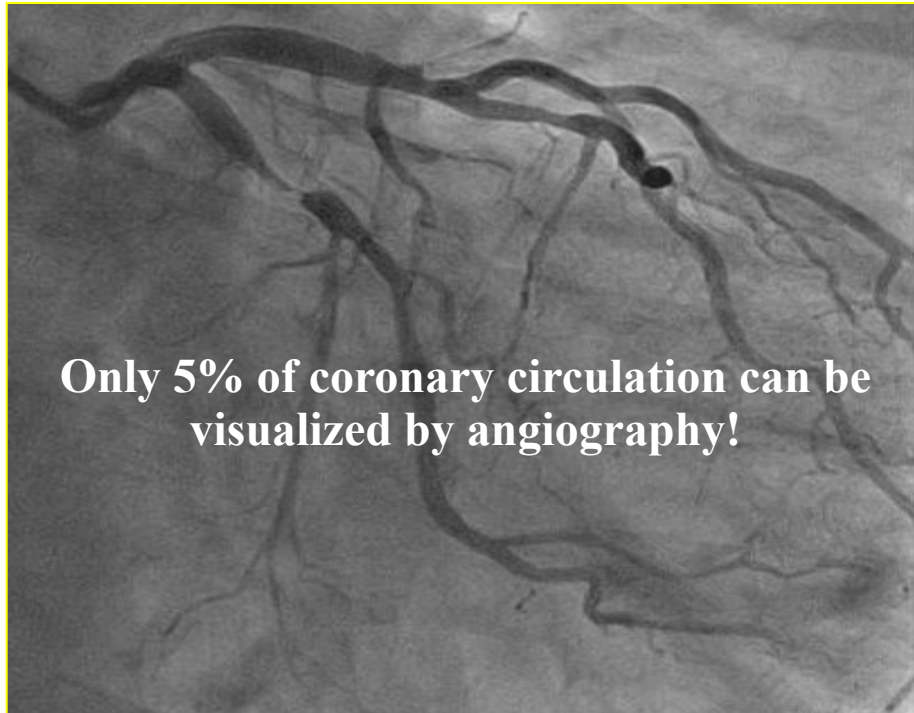
Recommendations according to extent of CAD	CABG		PCI	
	Class <sup>a</sup>	Level <sup>b</sup>	Class <sup>a</sup>	Level <sup>b</sup>
<b>One-vessel CAD</b>				
Without proximal LAD stenosis.	IIb	C	I	C
With proximal LAD stenosis. <sup>68,101,139-144</sup>	I	A	I	A
<b>Two-vessel CAD</b>				
Without proximal LAD stenosis.	IIb	C	I	C
With proximal LAD stenosis. <sup>68,70,73</sup>	I	B	I	C
<b>Left main CAD</b>				
Left main disease with low SYNTAX score (0 - 22). <sup>69,121,122,124,145-148</sup>	I	A	I	A
Left main disease with intermediate SYNTAX score (23 - 32). <sup>69,121,122,124,145-148</sup>	I	A	IIa	A
Left main disease with high SYNTAX score (≥33). <sup>c 69,121,122,124,146-148</sup>	I	A	III	B
<b>Three-vessel CAD without diabetes mellitus</b>				
Three-vessel disease with low SYNTAX score (0 - 22). <sup>102,105,121,123,124,135,149</sup>	I	A	I	A
Three-vessel disease with intermediate or high SYNTAX score (>22). <sup>c 102,105,121,123,124,135,150</sup>	I	A	I	A
<b>Three-vessel CAD with diabetes mellitus</b>				
Three-vessel disease with low SYNTAX score 0-22. <sup>102,105,121,123,124,135,150-157</sup>	I	A	I	A
Three-vessel disease with intermediate or high SYNTAX score (>22). <sup>c 102,105,121,123,124,135,150</sup>	I	A	I	A



# From morphology to coronary physiology



# Two-Compartment Model of the Coronary Circulation



Courtesy t

# Coronary morphology - summary

- Coronary angiography = luminography – the gold standard in ACS patients though suffering several limitations.
- IVUS and virtual histology provide better knowledge of the artery and plaque distribution/composition.
- OCT provides the highest resolution at present and becomes an important imaging technique complementary to IVUS.

**but...there is a BUT**



# Anatomic vs. Functional CAD

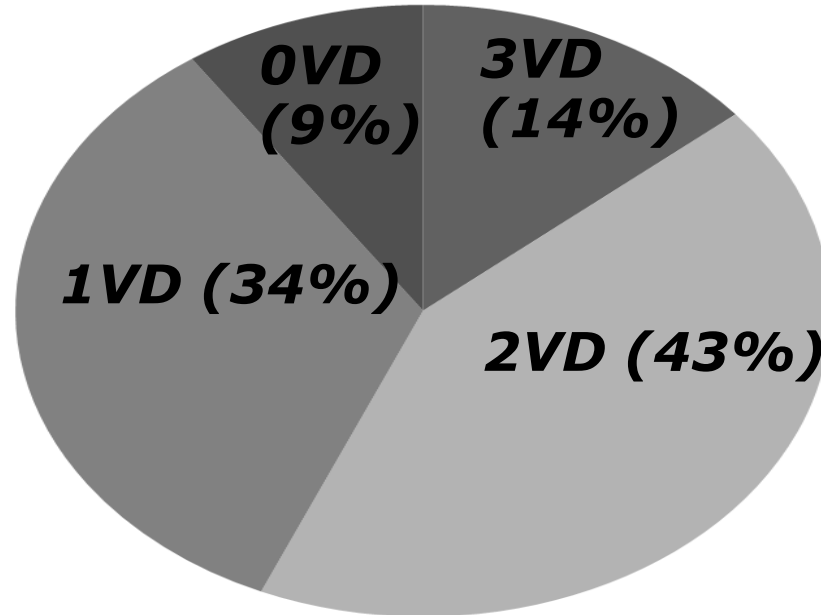
Patients with angiographically 3VD (N=115), proportions per number of diseased vessels after assessment by FFR

***Angiographic  
3 Vessel  
Disease***



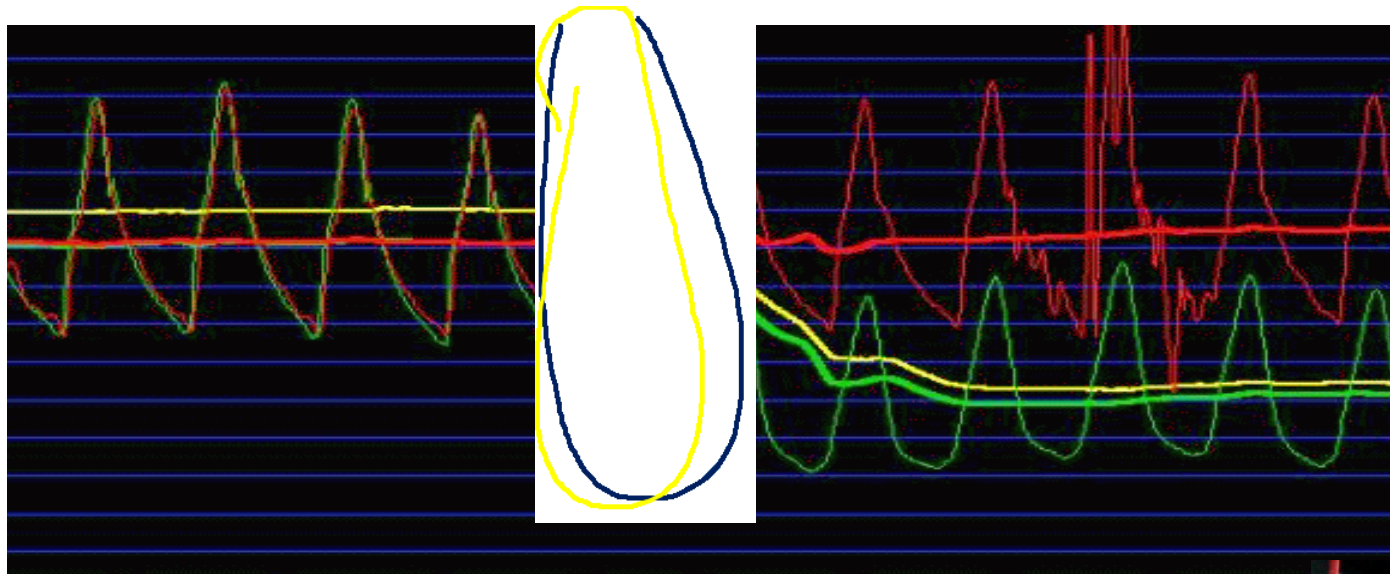
# Anatomic vs. Functional CAD

Patients with angiographically 3VD (N=115), proportions per number of diseased vessels after assessment by FFR





# Fractional flow reserve - FFRmyo



**1993 – Dr. Nico Pijls, Catharina Hospital, Eindhoven**  
**Dr. Bernard De Bruyne, Cardiovascular Center, A**



# Woman, 71yo

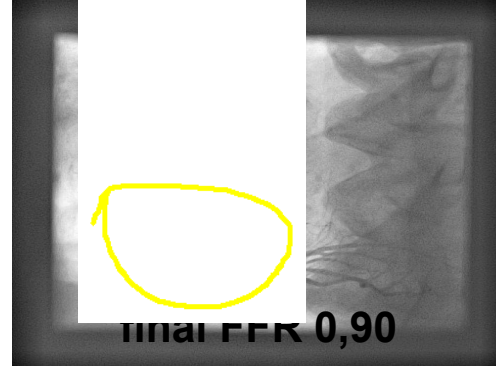
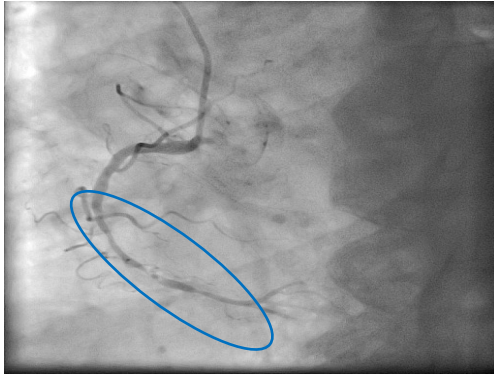
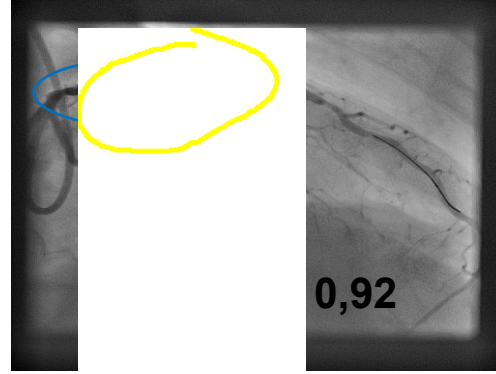
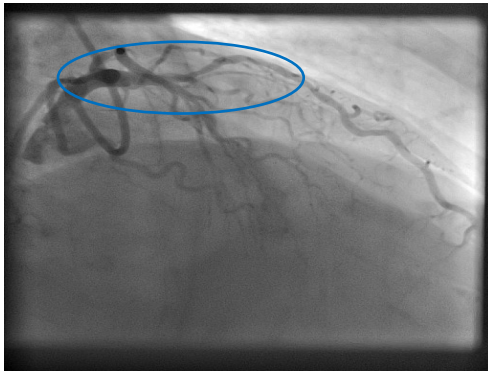
Coronary CT angiography (CTA) showing a 71-year-old woman with a 3-vessel disease (3VD) and normal left ventricular ejection fraction (LVEF). The patient was randomized in the FAME 3 trial.



- 3VD, normal LVEF → HEARTteam → **FAME 3 trial** → patient was randomized in FFR (cut-off for revascularization)



# Woman, 71yo, FINAL RESULT after STENTING of LAD and RCA



# Enjoy your healthy, full-sized aortic pump 😊

