CORONARY PHYSIOLOGY IN THE CATHLAB:

THEORY AND PRACTICAL SET-UP OF FFR

Educational Training Program ESC
European Heart House
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catharina ziekenhuis

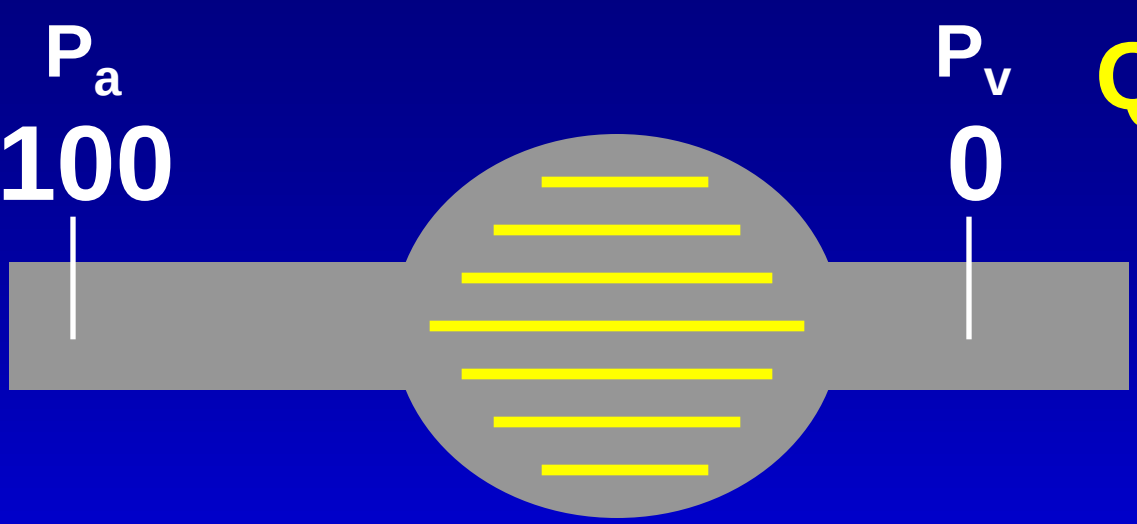
FRACTIONAL FLOW RESERVE:

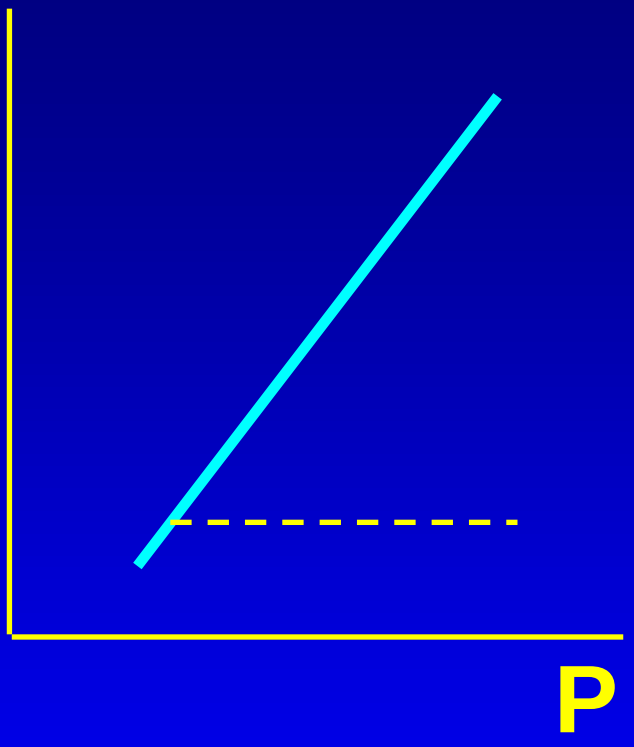
The index FFR (***Fractional Flow Reserve***)
is based upon the two following principles:

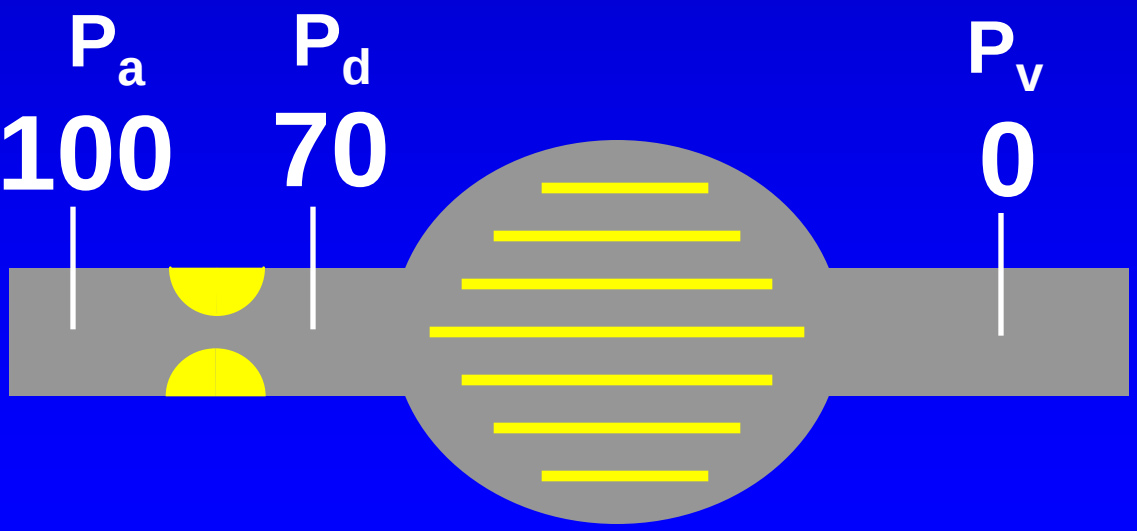
- *It is not resting flow, but **maximum achievable flow** which determines the functional capacity (exercise tolerance) of a patient*

- *At maximum vasodilation (corresponding with maximum hyperemia or with maximum exercise), blood flow to the myocardium is proportional to **myocardial perfusion pressure***
  *(**~hyperemic distal coronary pressure**)*

During Maximal Vasodilatation







$$FFR_{myo} = \frac{P_d}{P_a}$$

$$= 0.70$$

$$\text{FFR}_{myo} = \frac{P_d}{P_a}$$

P_a = mean aortic pressure at maximum hyperemia

P_d = mean distal coronary pressure at maximum hyperemia

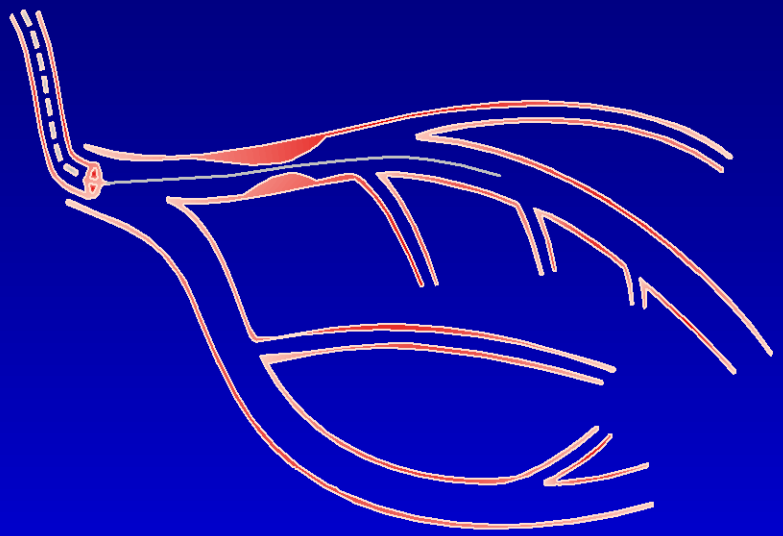
FFR = 0.6 means:

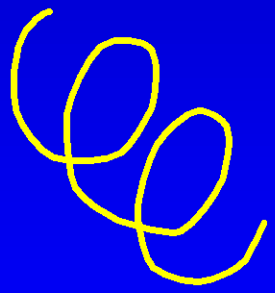
"Due to this particular stenosis, maximum achievable blood flow to the myocardium supplied by this artery, is only 60 % of what it would be if this coronary artery were completely normal"

If, after PCI, FFR increases to 0.9, this means:

"Maximum achievable flow (and therefore maximum oxygen supply) has increased by 50% and is 90 % now of the value achievable if the artery were completely normal"

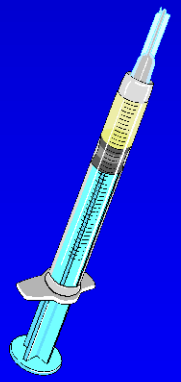
Application in catherization laboratory





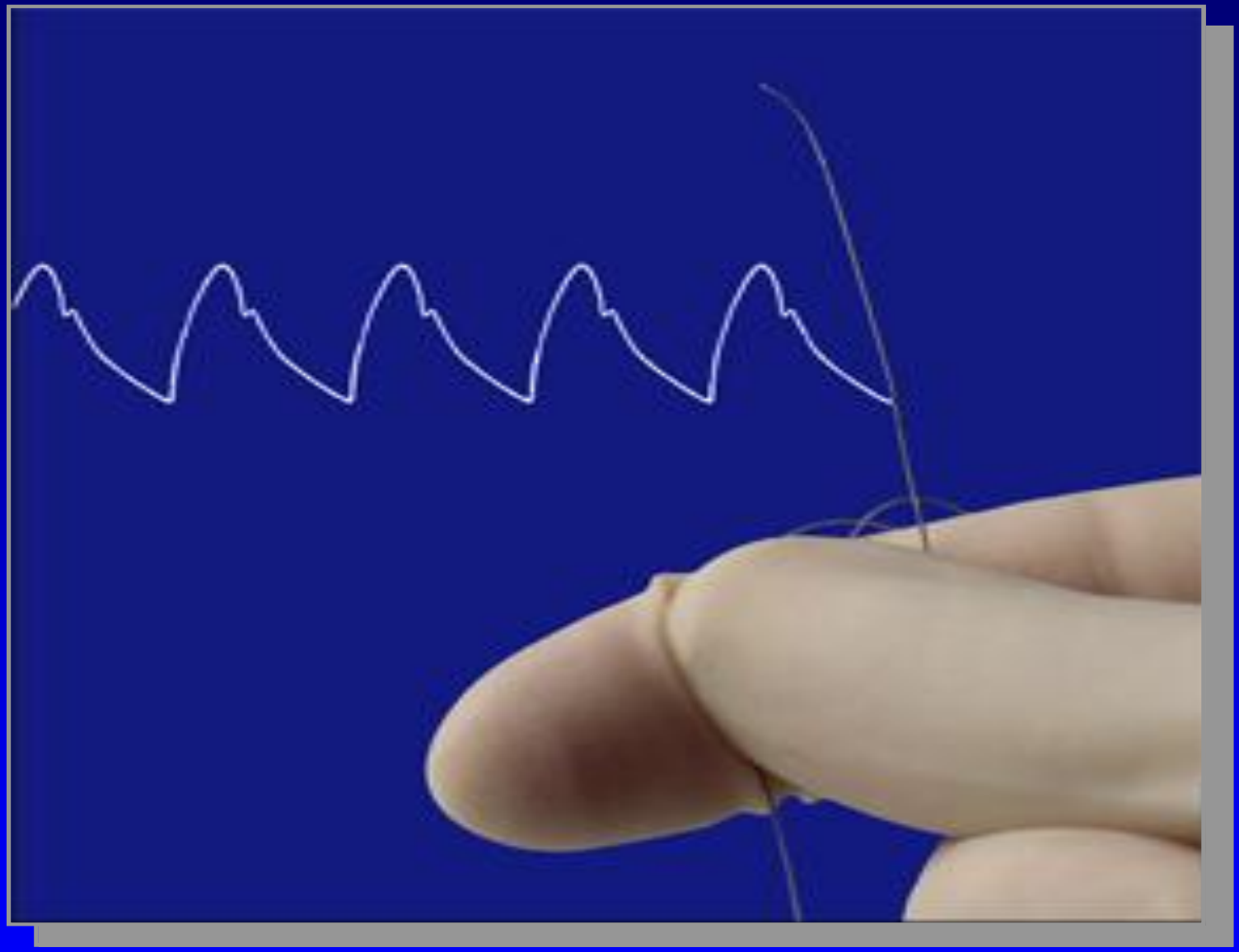
pressure wire

+



hyperemic stimulus

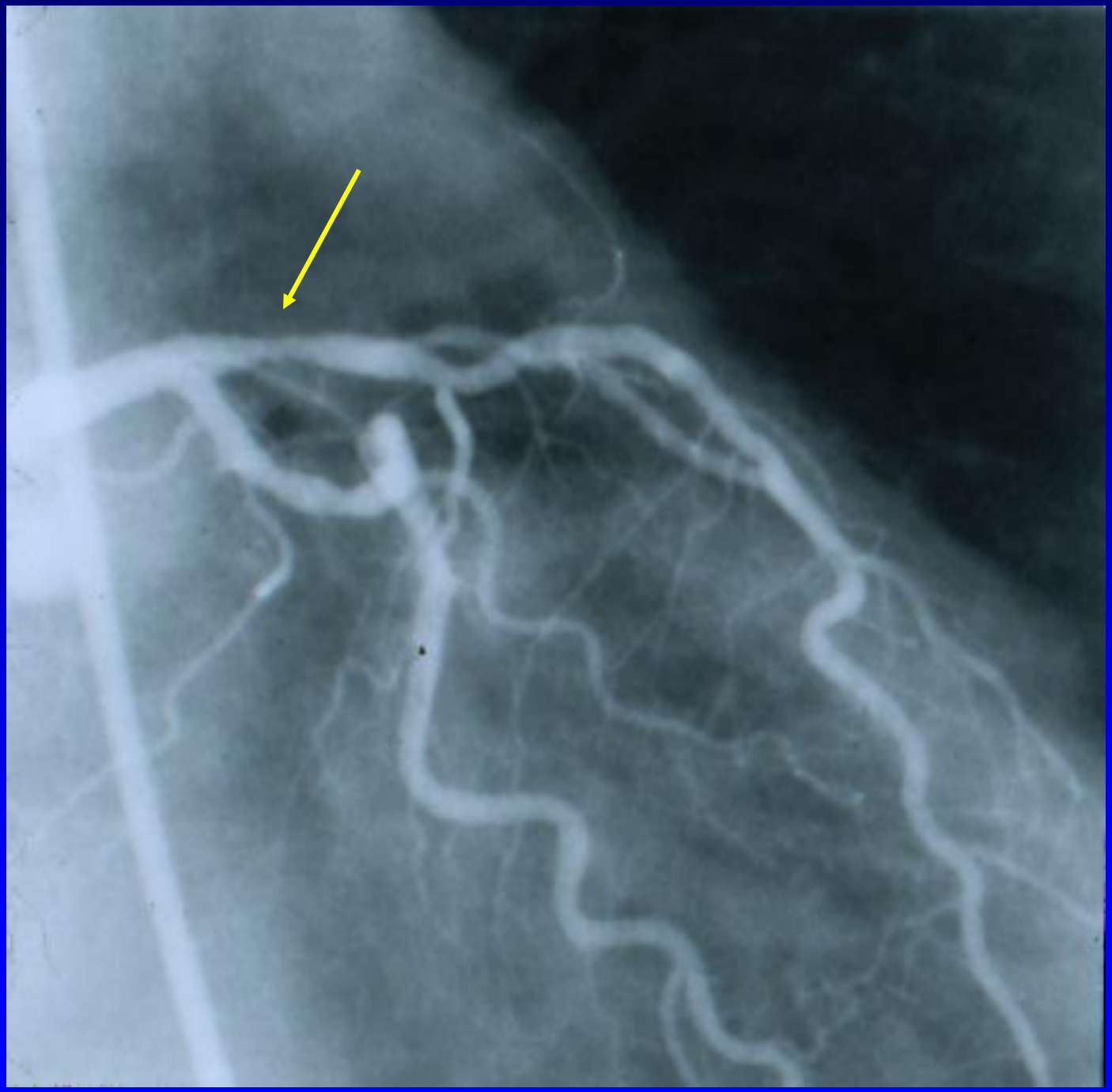
= **FFRmyo**



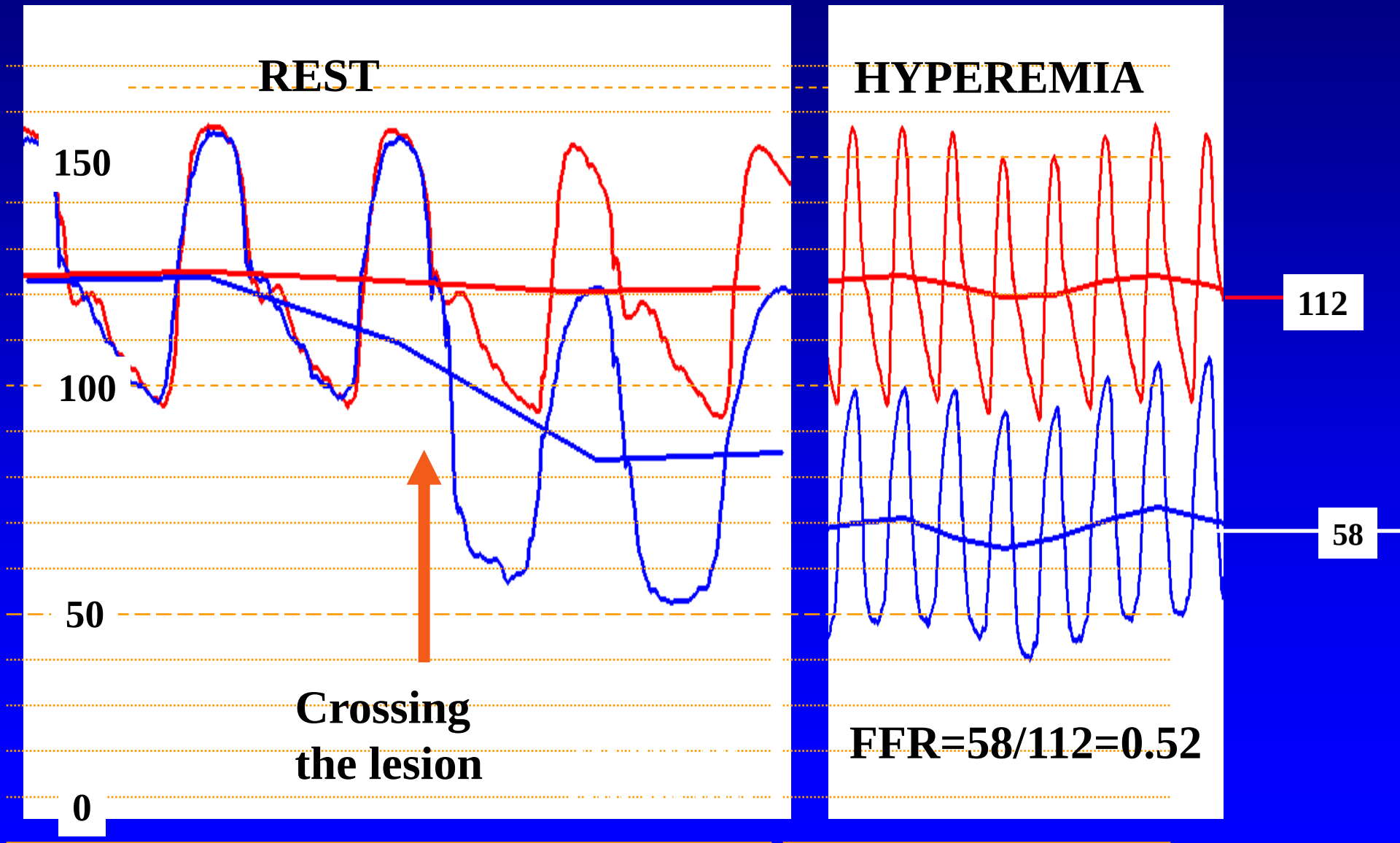
0.014 sensor-tipped PTCA guidewire
(electronic or fiberoptic)

***CLINICAL PRACTICE*:**

Mr van Z.
77 years,
stable ang 2-3
posit ET



Fractional Flow Reserve in Clinical Practice



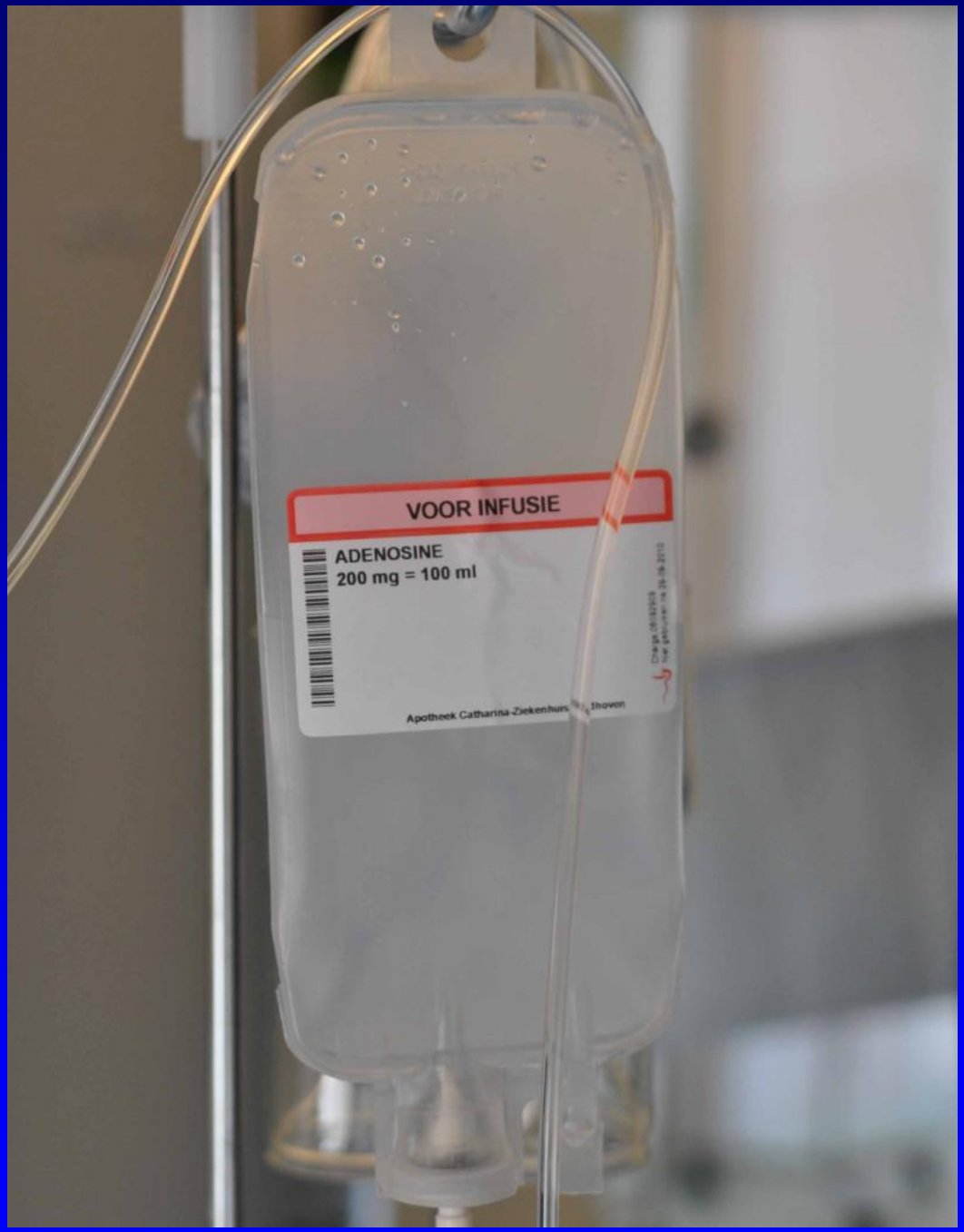
A Few Words About Hyperemia:

(next speaker, Dr De Bruyne)

- intravenous infusion of adenosine or ATP
- intracoronary injection of adenosine
- single intravenous bolus of regadenoson

If used according to the guidelines, full and reliable hyperemia is obtained in close to 100% of patients.

(key papers: De Bruyne, Circulation 2003;107:1877-1883
McGeoch, CCI 2008;71:198-204
FAME studies, VERIFY study
Fearon & Johnson, LBT PCR 2015



Adenosine for
i.v. infusion

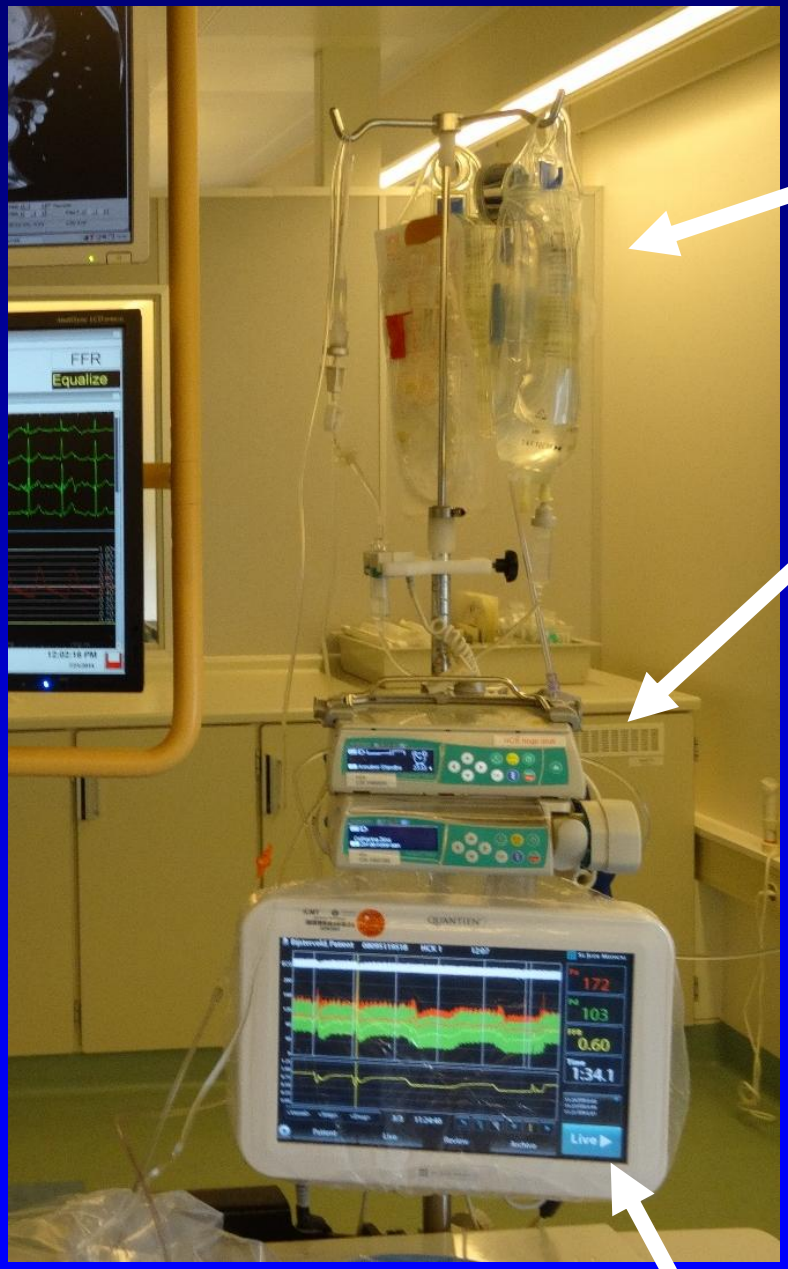
(standard bag
200 mg = 100 ml)

price: Euro 2,=
per bag

prepared by
hospital pharmacy

manifacturing
protocol available
at carias@cze.nl

Infusion rate simply adjusted according to body weight (….kg ⟶ ……ml/min)



adenosine

Infusion pump

Quantien

- *no preparation in the lab*
- *no difficult calculations*
- *always the same dilution*
- *no risk of dosage error*
- *no loss of time*

MAXIMUM HYPEREMIA IS IMPORTANT !

NOTE:

- sometimes, periodic fluctuations are present during i.v. adenosine induced steady state hyperemia
- this is related to the speed of metabolization of adenosine (patient-dependent) and the breathing pattern
- *always take the lowest value of FFR*

(key papers: De Bruyne, Circulation 2003;107:1877-1883
McGeoch, CCI 2008;71:198-204
FAME studies, VERIFY study
Fearon & Johnson, LBT PCR 2015

Is it necessary to use hyperemia ?

- For practical reasons, it is advocated presently by some investigators to skip hyperemia *(iFR, Pd/Pa $_{resting}$)* with cut-off of 0.90 or to use a hybrid approach, but in exchange diagnostic accuracy decreases to 80%

- semi-hyperemic stimulus: single shot of contrast Pd/Pa $_{contrast}$ (called ***cFFR***)

→ some pilot studies: cut-off point around 0.85 with accuracy of 90% compared to FFR cut-off point of 0.80

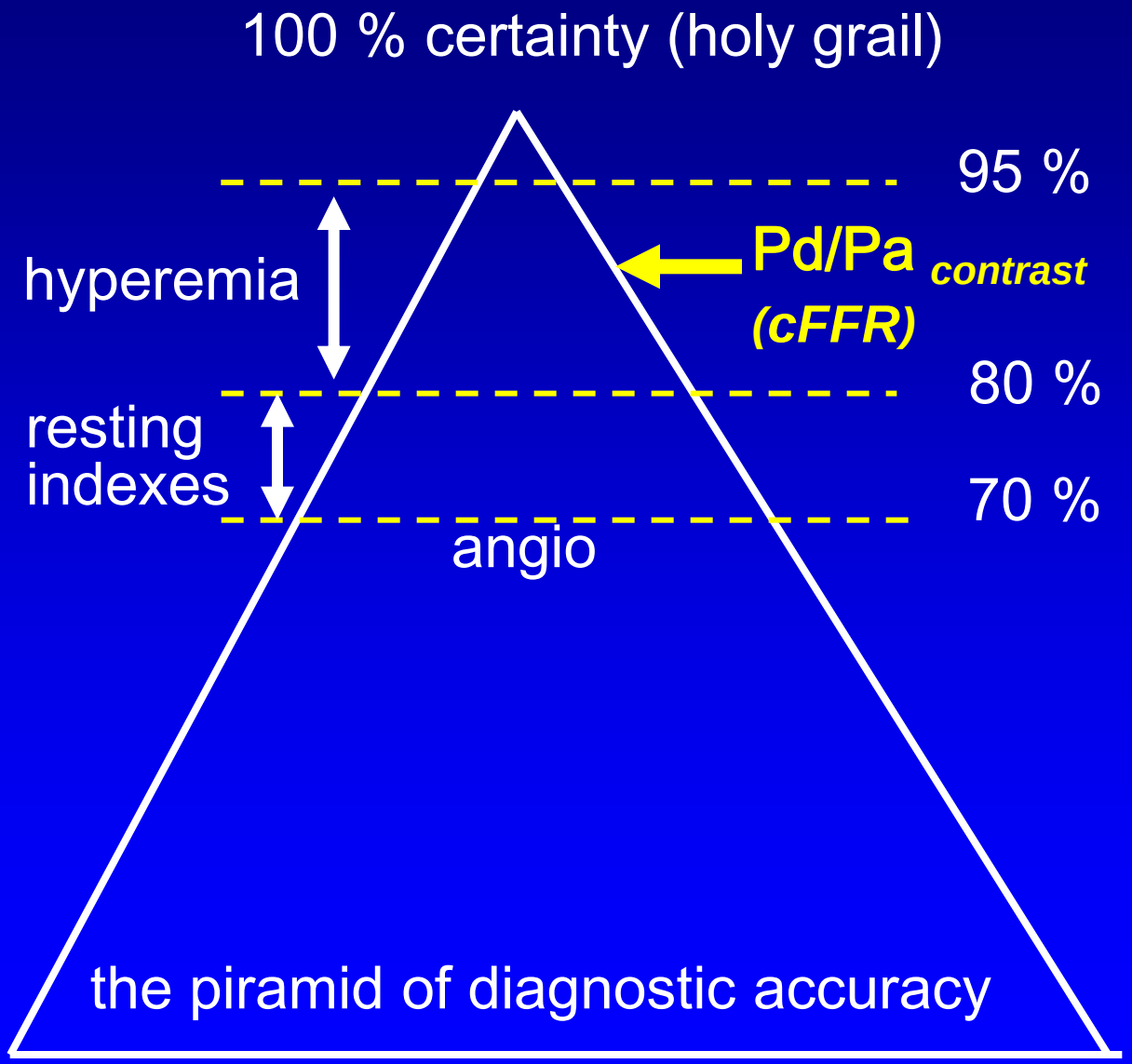
(Dr Ribichini, N. Johnson, Friday afternoon; LBT at PCR 2015)

Correct Classification of Ischemic Stenosis

FFR

resting Pd/Pa,
iFR, bSVr

angiography



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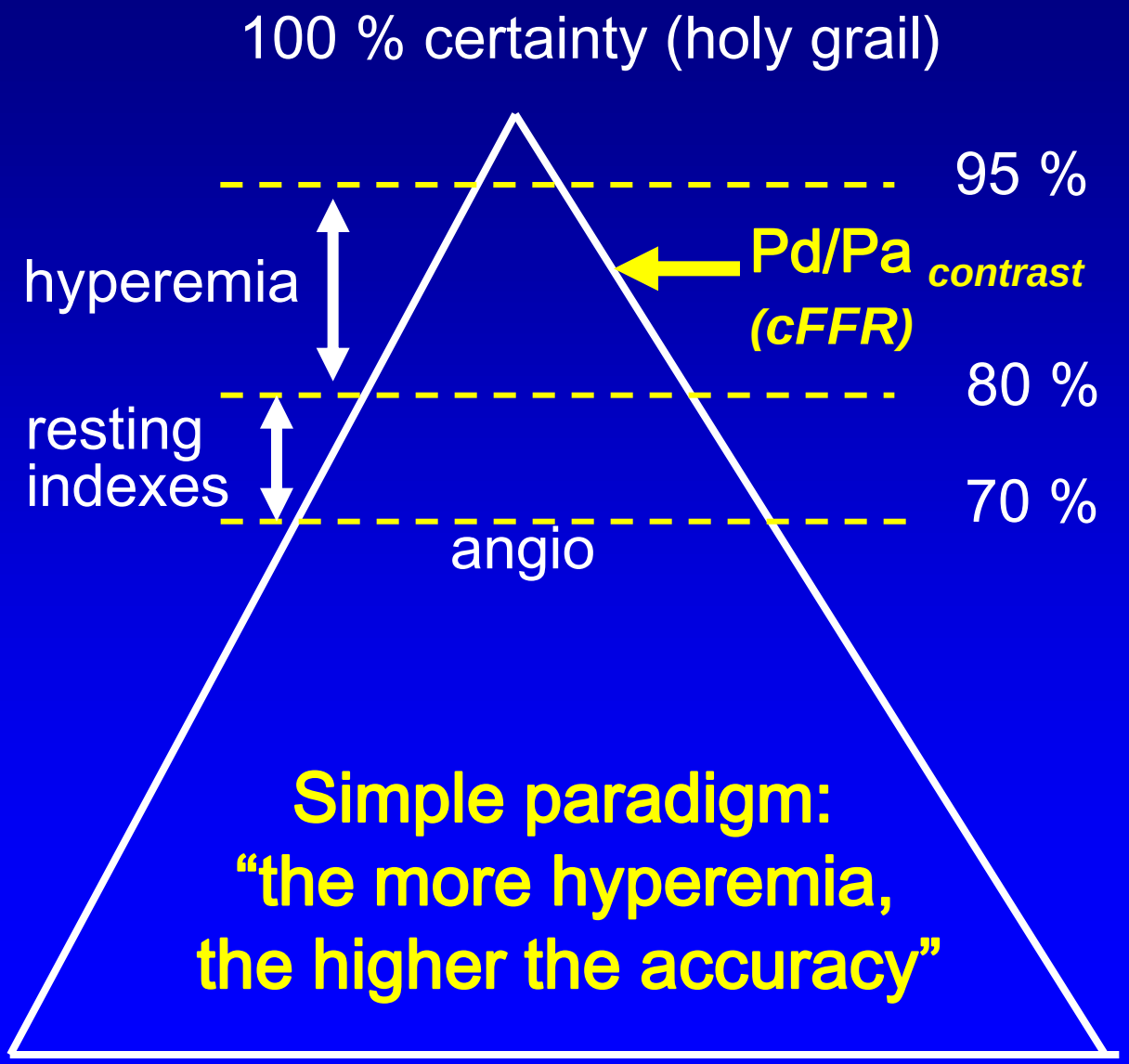


Before going to clinical practice, Let's have a closer look to FFR

Prerequisites for a reliable index for decision making

- sound scientific basis and experimental validation
- accurate
- reproducible
- easy to perform
- predict outcome

Prerequisites for a reliable index for decision making

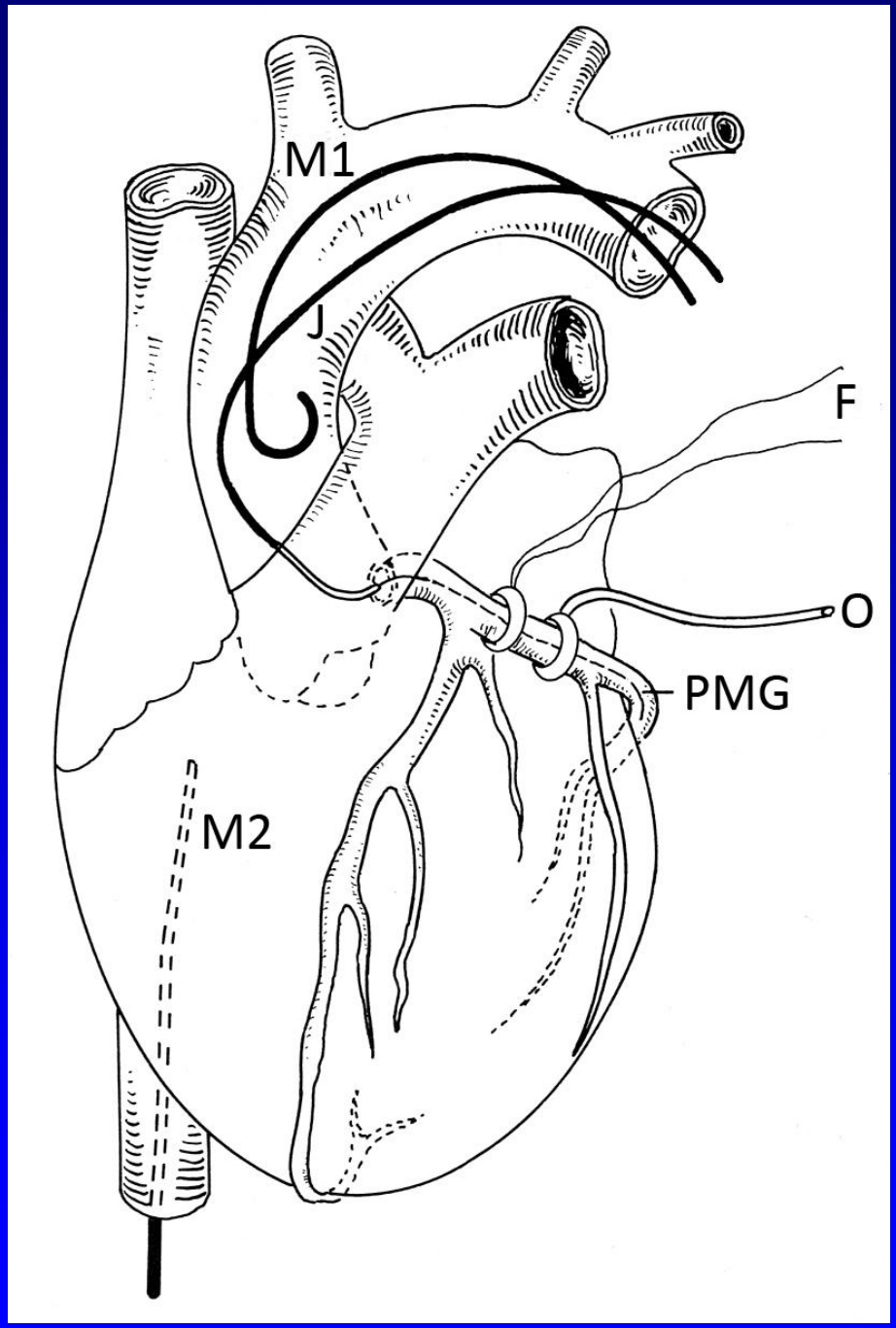
- sound scientific basis and experimental validation

All basic features of FFR have been thoroughly validated experimentally over more than 10 years

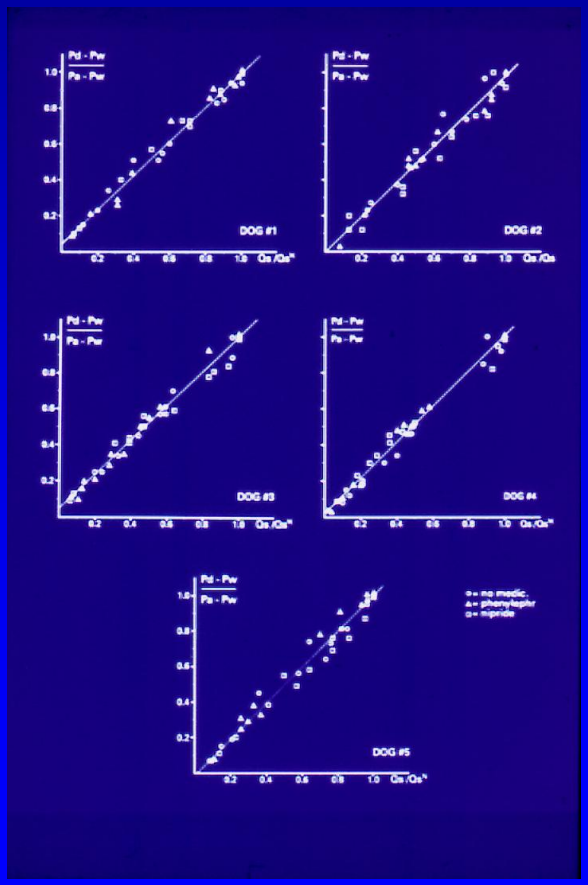
1993-2006: 5 original papers in Circulation on animal studies in dogs and swine

1994-2012: 64 original papers in NEJM, Circulation, JACC and EHJ in humans

> 2000 publications in PubMed



FFR:
experimental validation
in chronic dog studies



Prerequisites for a reliable index for decision making

- sound scientific basis and experimental validation
- ***accurate, i.e. uniform normal value and clear cut-off with narrow gray zone***
- reproducible
- easy to perform
- predict outcome

} tomorrow

Fractional Flow Reserve in Normal Coronary Arteries

33 truely normal coronary arteries in patients\ without coronary artery disease:

FFR = 0.98 +/- 0.02 (range 0.93 – 1.00)

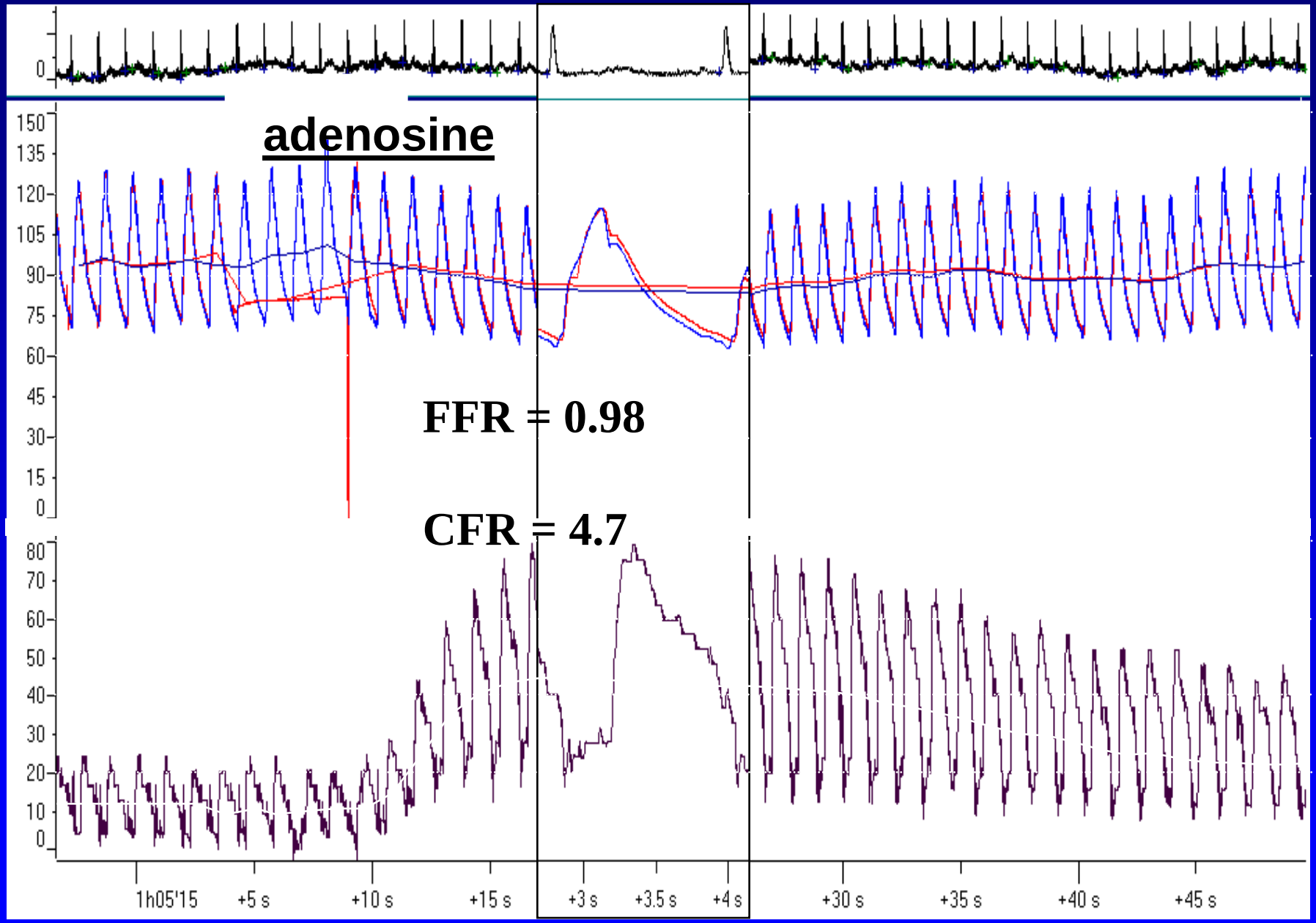
Pijls, Circulation 1995;92: 183-193

86 apparently normal contralateral arteries In patients with coronary disease:

FFR = 0.87 +/- 0.09 (range 0.64 – 0.97)

De Bruyne, Circulation 2001; 104:2401-2406

Normal Coronary Artery



Threshold value of FFR to detect significant stenosis in humans

How can you validate a new index if no Standard exists ???

→ prospective multitesting Bayesian approach

Pijls et al, N Engl J Med 1996; 334:1703-1708

How to search for the threshold of a new index ?

Mostly seen (as also for all other physiologic indices:

*Analysis of **ROC curve** in a particular population and "cherry-picking" the best value*

*Such studies are often called "prospective" but **in fact** are based upon a retrospective analysis of data (that is inherent to ROC analysis)*

In another population, another ROC and another "best cut-off point" and "accuracy" will be found !!!

Author	Meeting or Citation	Date	N	iFR cutoff*
Davies	TCT	2011 November	157	none**
Sen	JACC 59:1392	2011 December		0.83
Park	EuroPCR	2012 May	238	0.89
Petraco	EuroIntervention	2012 August	339	0.89
Jeremias	TCT	2012 October	1548	0.90
Indolfi	TCT	2012 October	71	0.93
Johnson	JACC 61:1428	2013 February	1129	0.89
Sen	JACC 61:1409	2013 April	51	0.86

→ ***Value of iFR best corresponding to FFR of 0.80 varies from 0.83 -0.93***

How to search for a threshold that can be truly used as gold standard ?

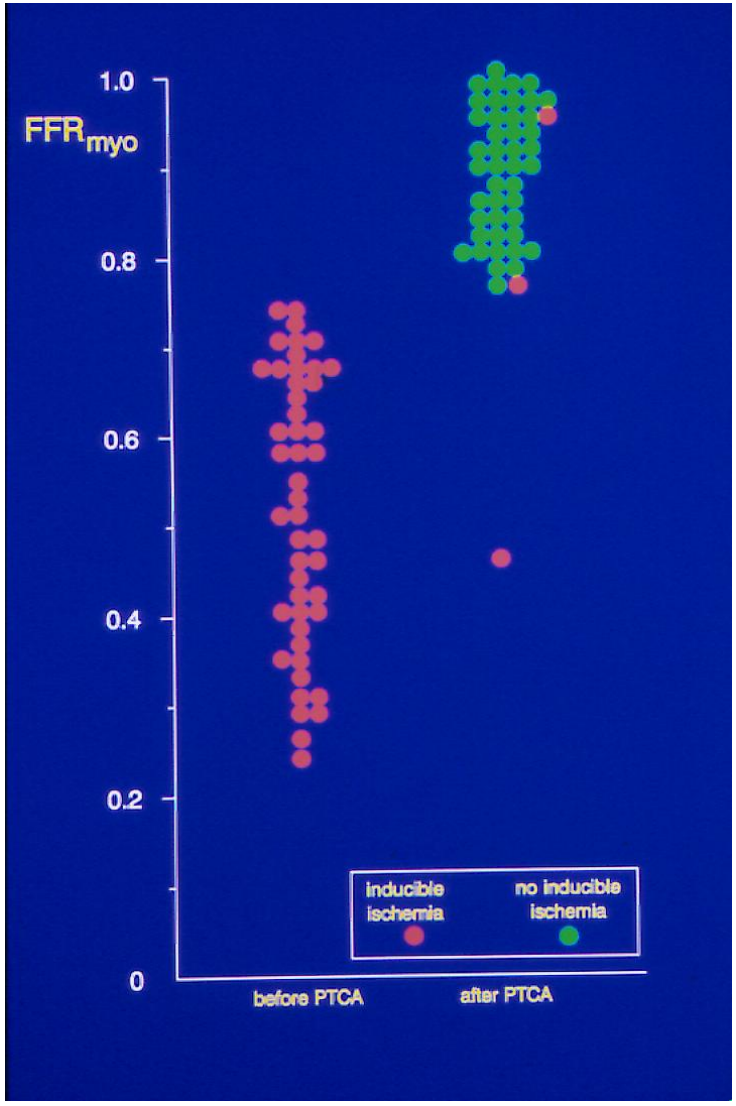
The right way to go is a 2-step approach:

1. Exploration of range where a true threshold is expected:
   in a population in whom you can definitely conclude if there is disease or not

2. Truly prospective validation *of that particular threshold* in an arbitrary population, using a combined gold standard
   (prospective multitesting Bayesian approach; NEJM 1996; 334:1703-08)

→ **Fractional Flow reserve**

Validation of FFR in humans (step 1)



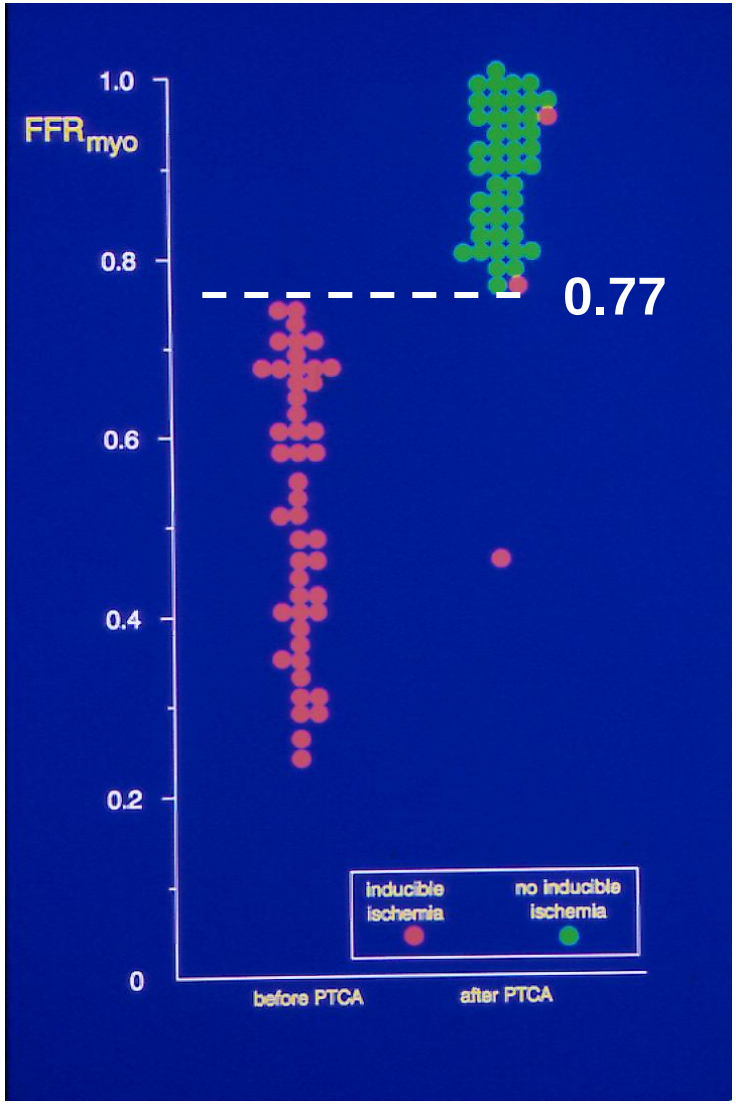
Proper validation of any index needs ***2 steps:***

1. ***Searching for the threshold value in a selected population (sens, specif, NPV, PPV, ROC analysis***)

2. Prospective validation in a population with unknown characteristics

Pijls et al, Circulation 1995
De Bruyne, Circulation 1996

Validation of FFR in humans (step 1)



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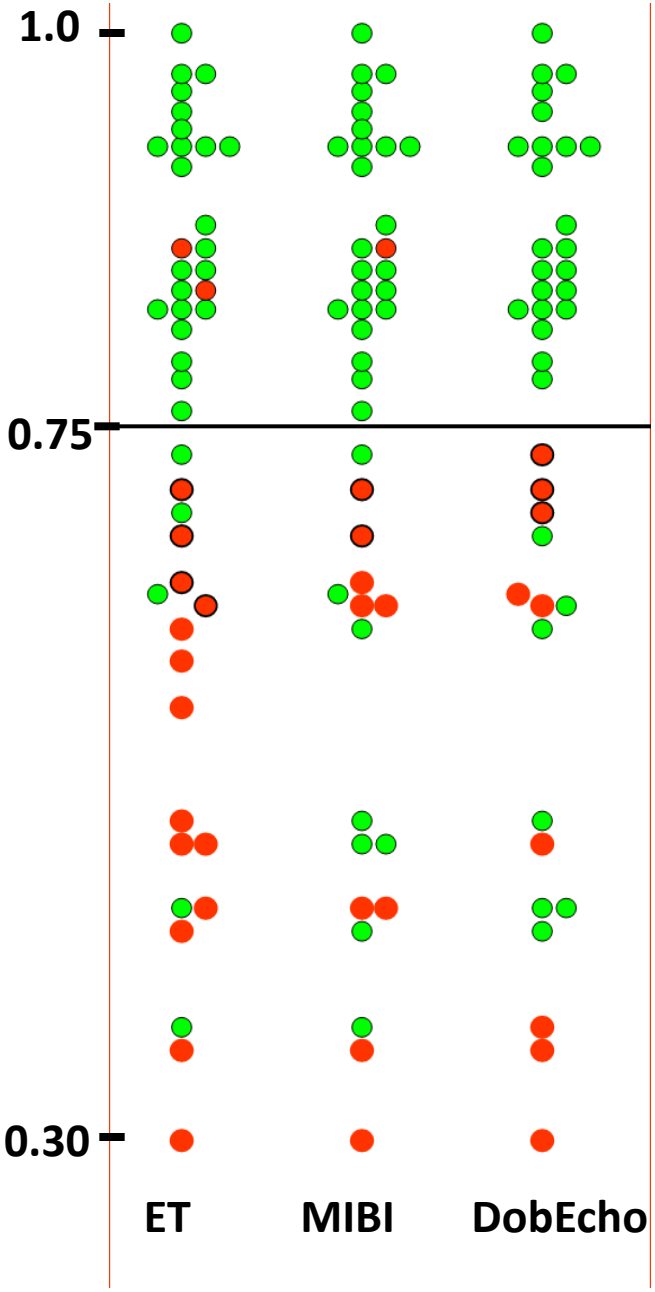


Testing of FFR versus True Gold Standard

Creating a gold standard by ***Prospective Multitesting Sequential Bayesian Approach:***

- Exerc testing = electrical index of ischemia
- MIBISpect = perfusion index of ischemia
- Dobutrex Echo = contractile index of ischemia
- *reversal from positive before to negative after intervention, proves true positivity before and true negativity after test*

Diagnostic accuracy of FFR =

$$\left[(1-0.75) \times (1-0.8) \times (1-0.8)\right]^{-1} = 99\ \%$$

3 unclassifiable patients (no intervention)

→ worst case scenario for FFR → **93 %**

Pijls et al, NEJM 1996

Threshold value of FFR to detect significant stenosis in humans

FFR is the ***only*** functional index which has ever been validated versus a **true gold standard**.
(Prospective multi-testing Bayesian methodology)

ALL studies ever performed in a wide variety of clinical & angiographic conditions, found threshold between 0.75 and 0.80

Diagnostic accuracy ≥ 93%

Pijls et al, N Engl J Med 1996; 334:1703-1708
Oldroyd et al, Circulation 2010

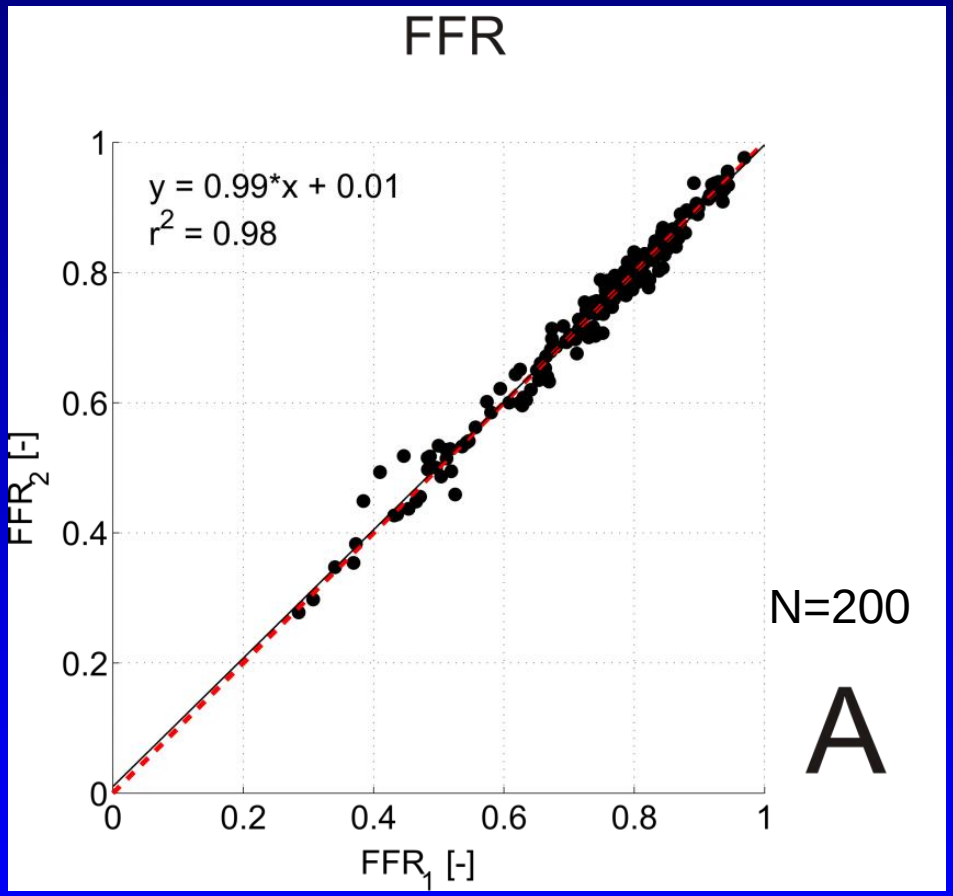
Let's have a closer look to FFR

Prerequisites for a reliable index for decision making

- sound scientific basis and experimental validation
- accurate
- ***reproducible***
- easy to perform
- predict outcome

} tomorrow

Reproducibility of FFR



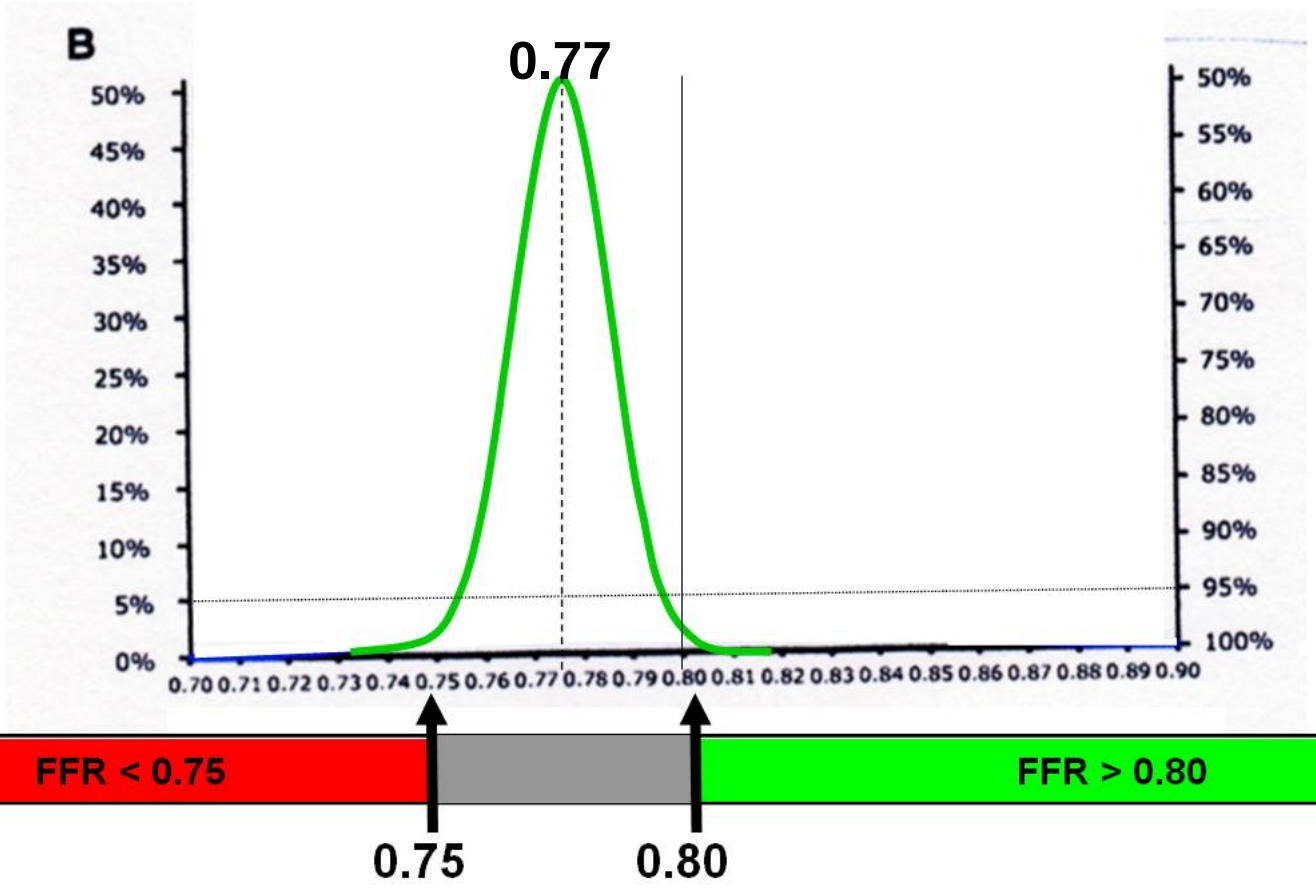
VERIFY study, Berry et al, JACC 2013 (published februari 2013)

(all-comers during one month in 5 large centers)

There is not any other index in physiology so reproducible as FFR

Probability that treatment decision will change if the respective index measurement is repeated

Classification certainty of single measurement



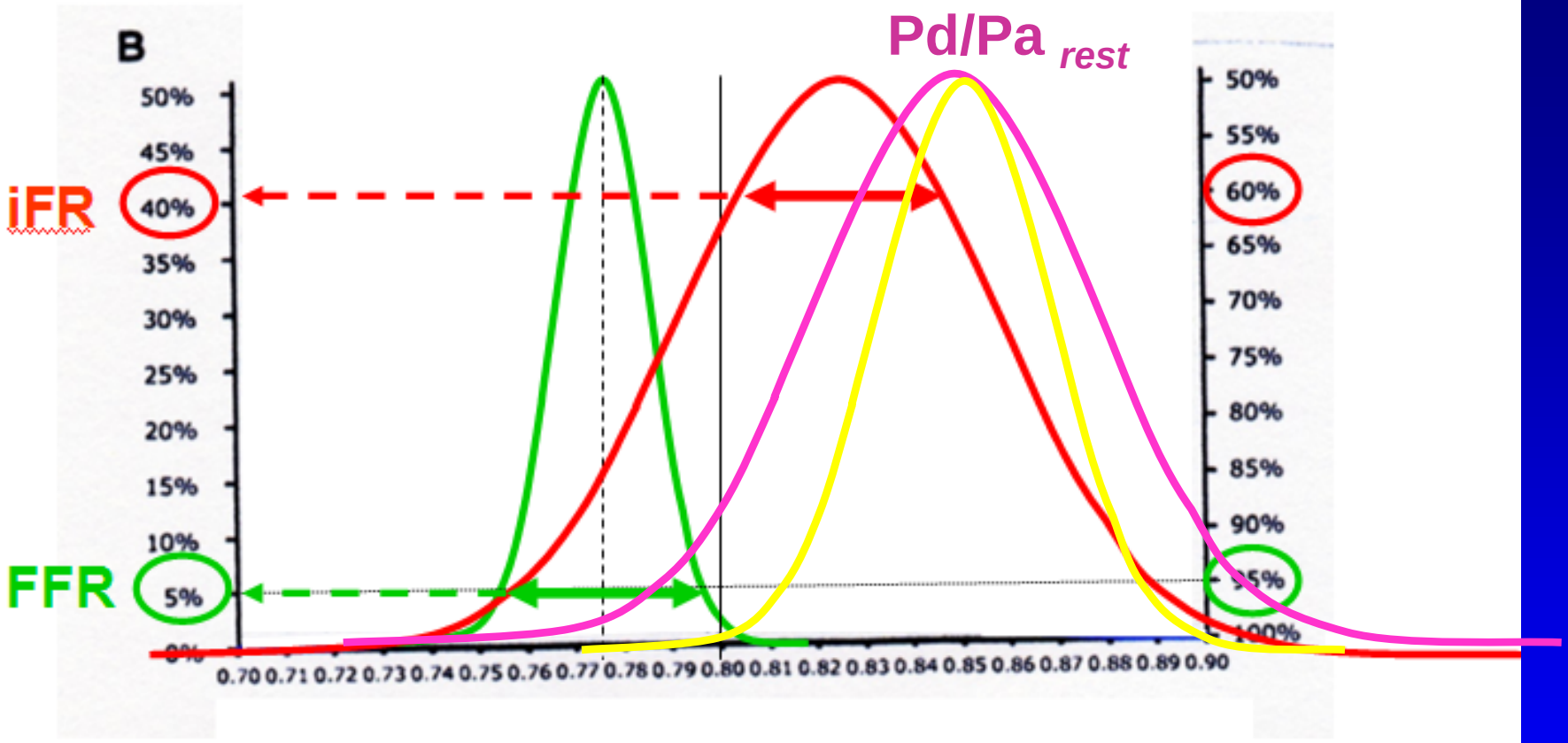
FFR, VERIFY study

2.4 % of patients go from green to gray or v.v. and 2.4 % from red to gray
Almost nobody ever crosses from red to green or v.v.

Adapted from Petrarco et al, Eurointervention 2013

Probability that treatment decision will change if the respective index measurement is repeated

Classification certainty of single measurement



FFR, VERIFY study

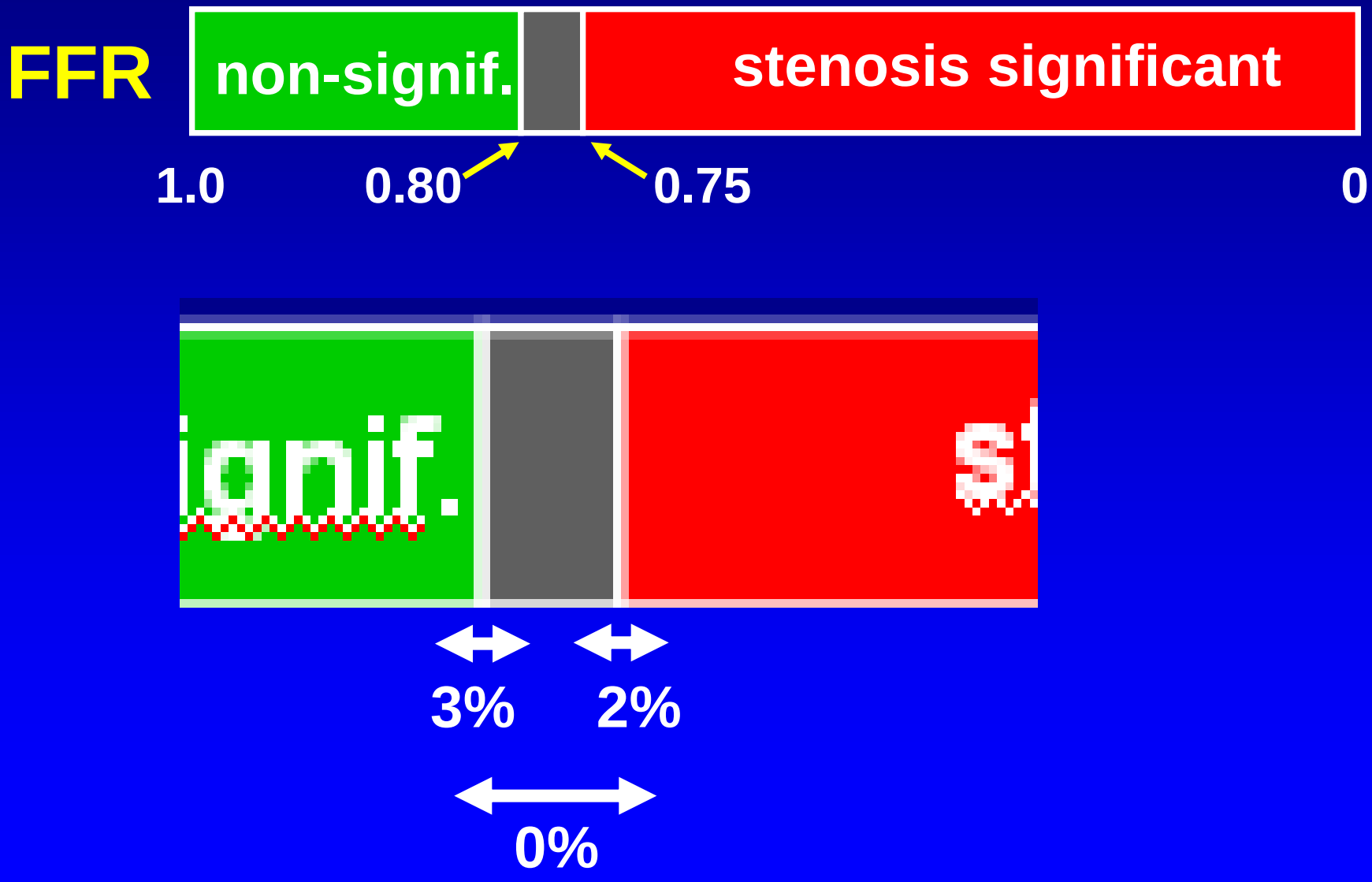
iFR, ADVISE study

Pd/Pa *rest* VERIFY study

contrast

Adapted from Petrarco et al, Eurointervention 2013

At <u>1200</u> consecutive in-duplo measurements of FFR, there was <u>NOT ANY cross-over</u> across the gray zone



Let's have a closer look to FFR

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PRACTICAL PERFORMANCE OF FFR - MEASUREMENT

Mr R, born 22-01-1968 (46-year-old

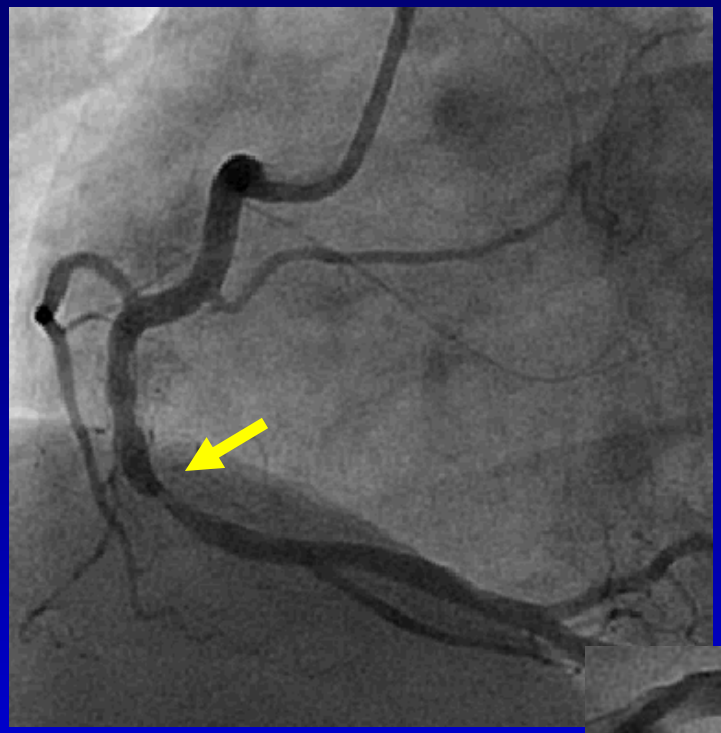
- admission on jan 25th, 2014 with acute lateral wall MI
- PPCI of occluded diagonal branch

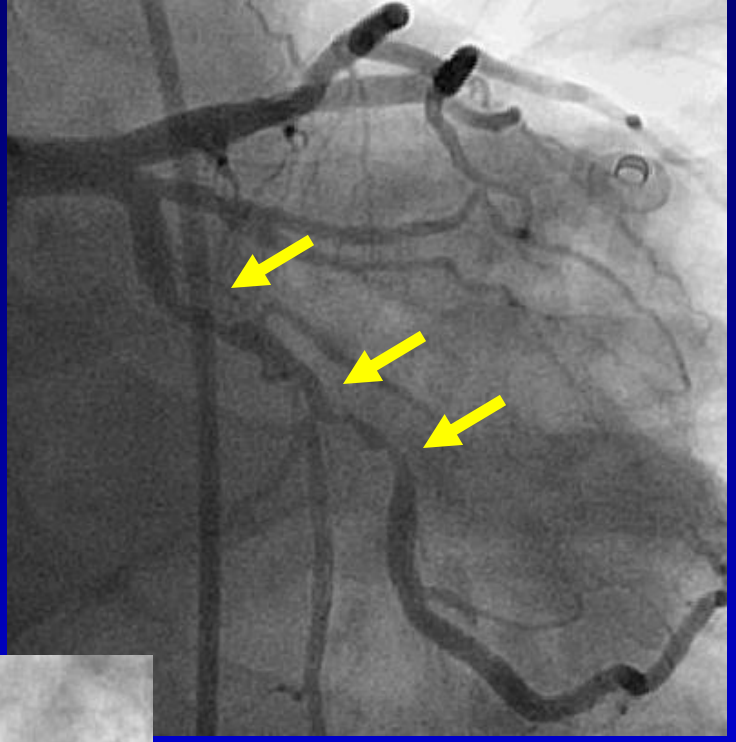
- Concomittant 3-vessel disease:
  - LAD : 50%
  - LCX : long tandem lesion 50-70% + 70-90%
  - RCA : 50-70%

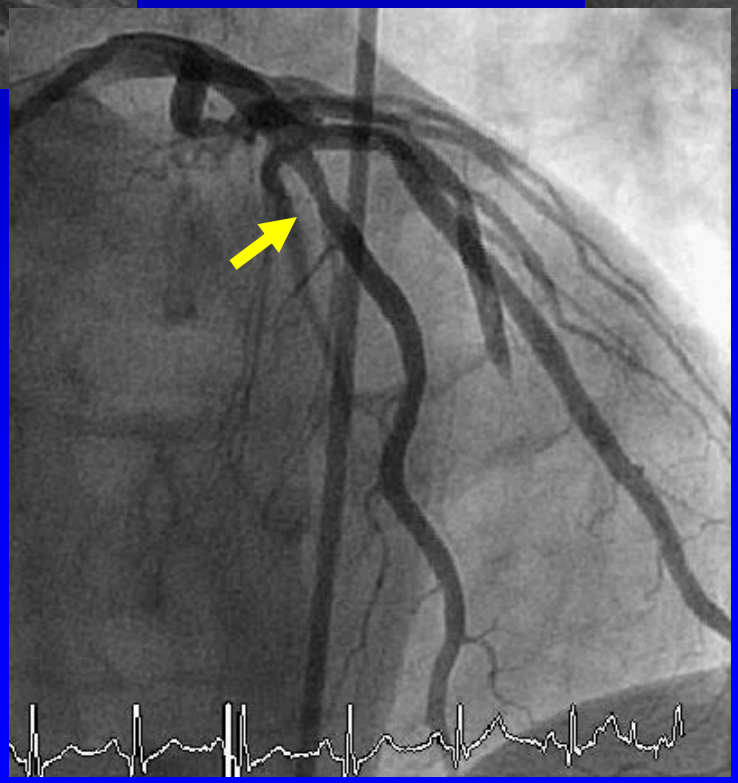
- Syntax score: 22

- Heartteam: CABG or FFR-guided MVD PCI

⟶ ***choice for FFR guided PCI, as pilot for FAME-3***







70% RCA
50% LAD
90% long LCX

Nitroglycerine

Note !

As in any intracoronary manipulation, before entering the coronary circulation, administer *200-300 µg NTG i.c.*

200 – 300 µg NTG i.c.

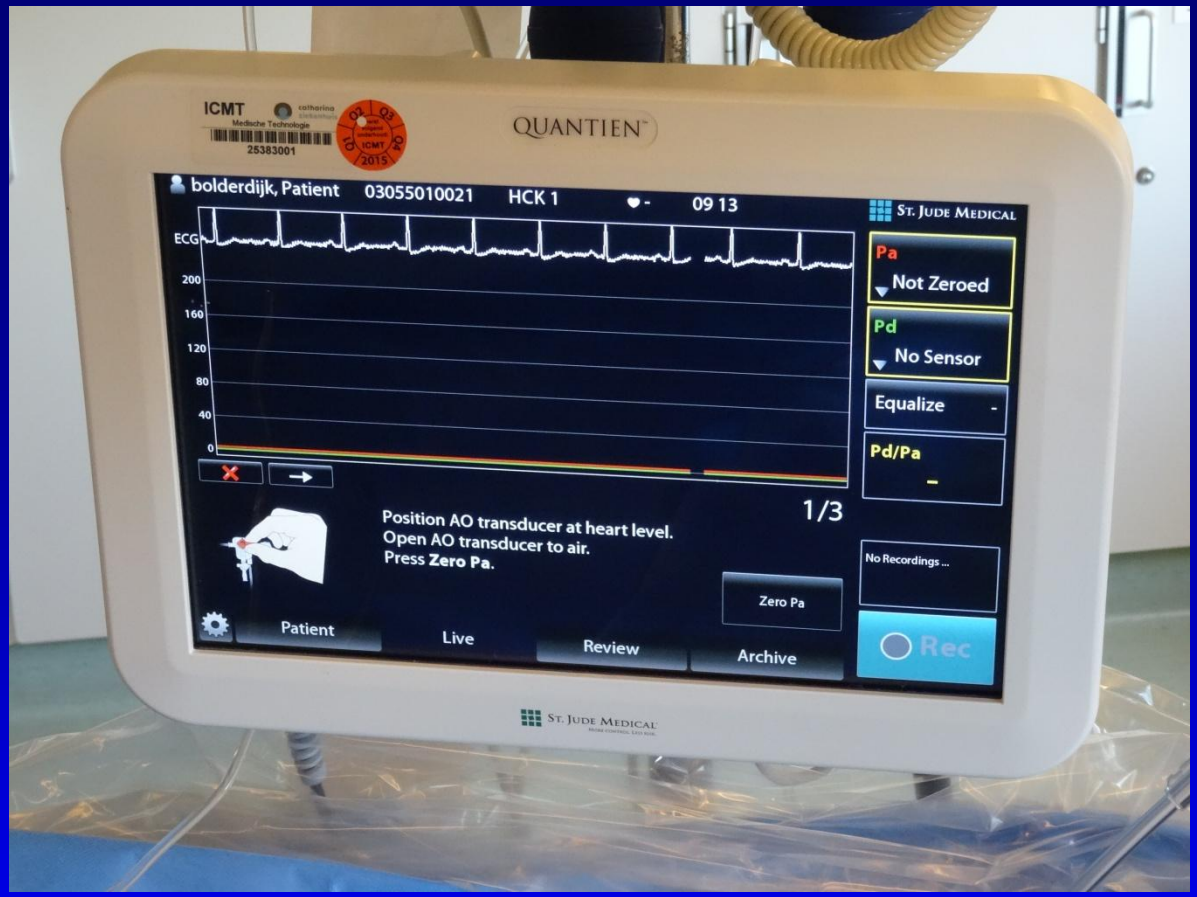
Ready to measure:

- Pressure Wire
- Interface

St Jude Medical, Philips/Volcano, Opsens, Acist

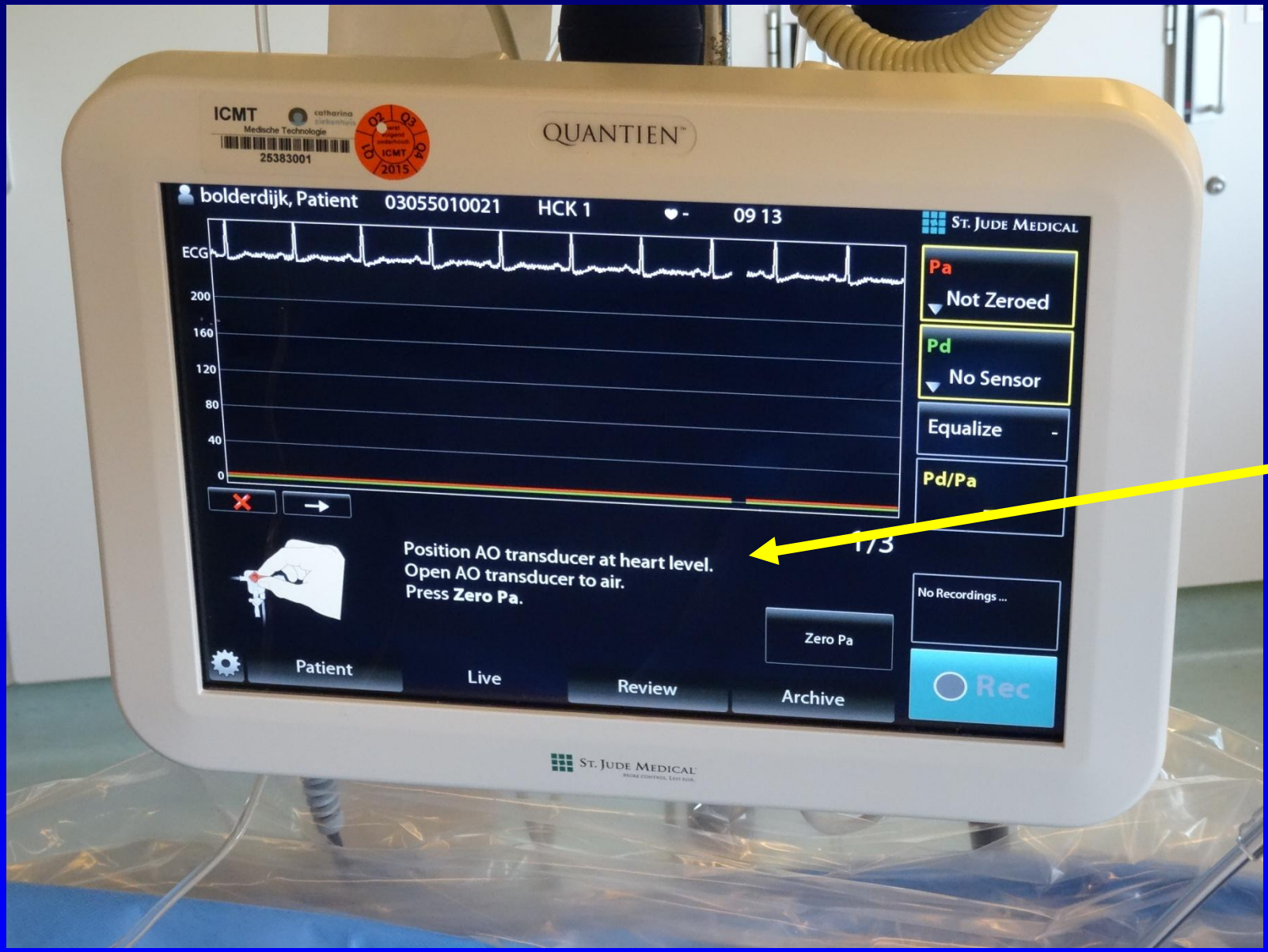
Saturday morning session

users friendly, “quiet” interface



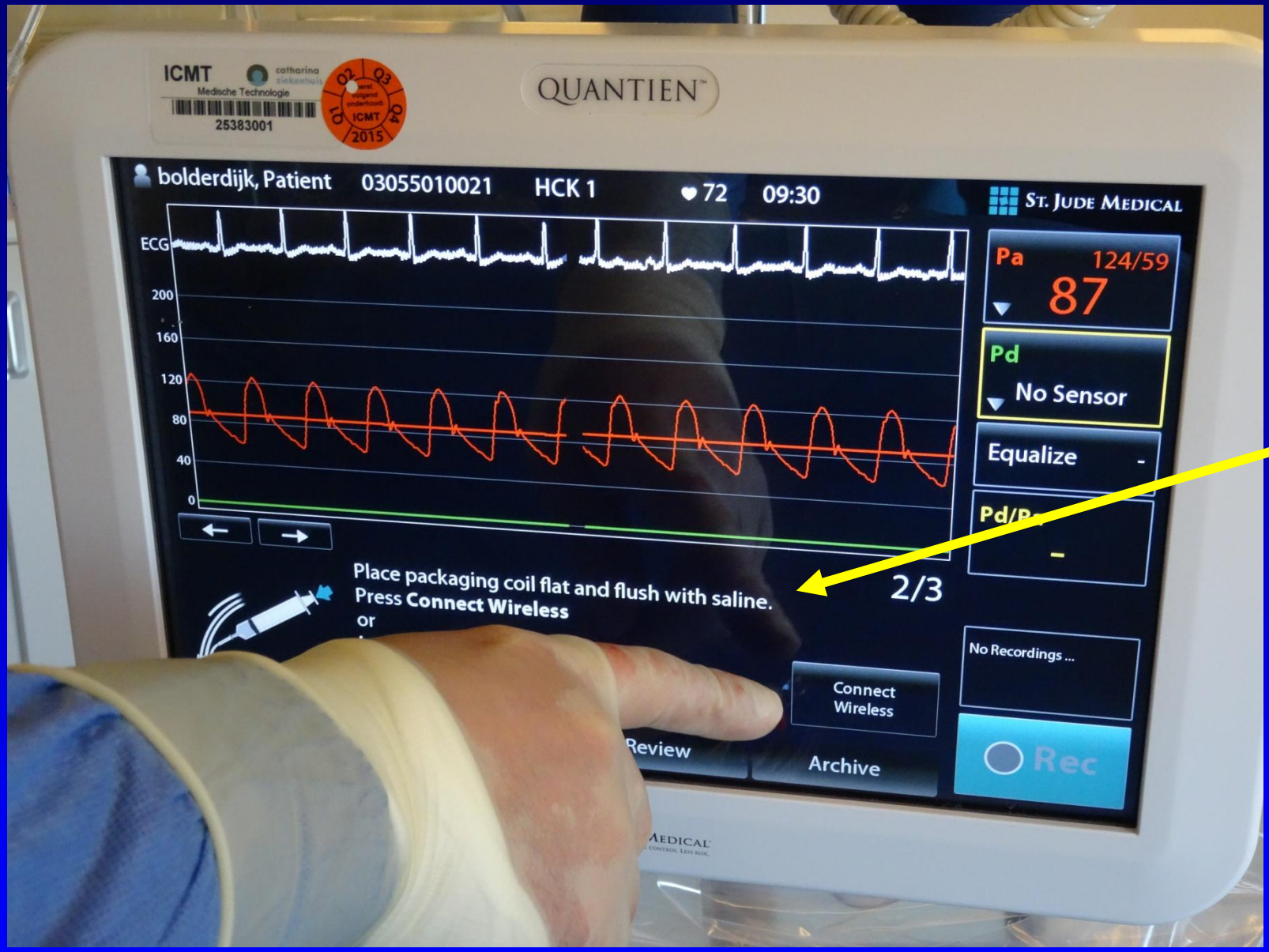
Ready to go!

⟶ Completely interactive preparation of signals and pressure wire, guided by interface takes < 30 seconds



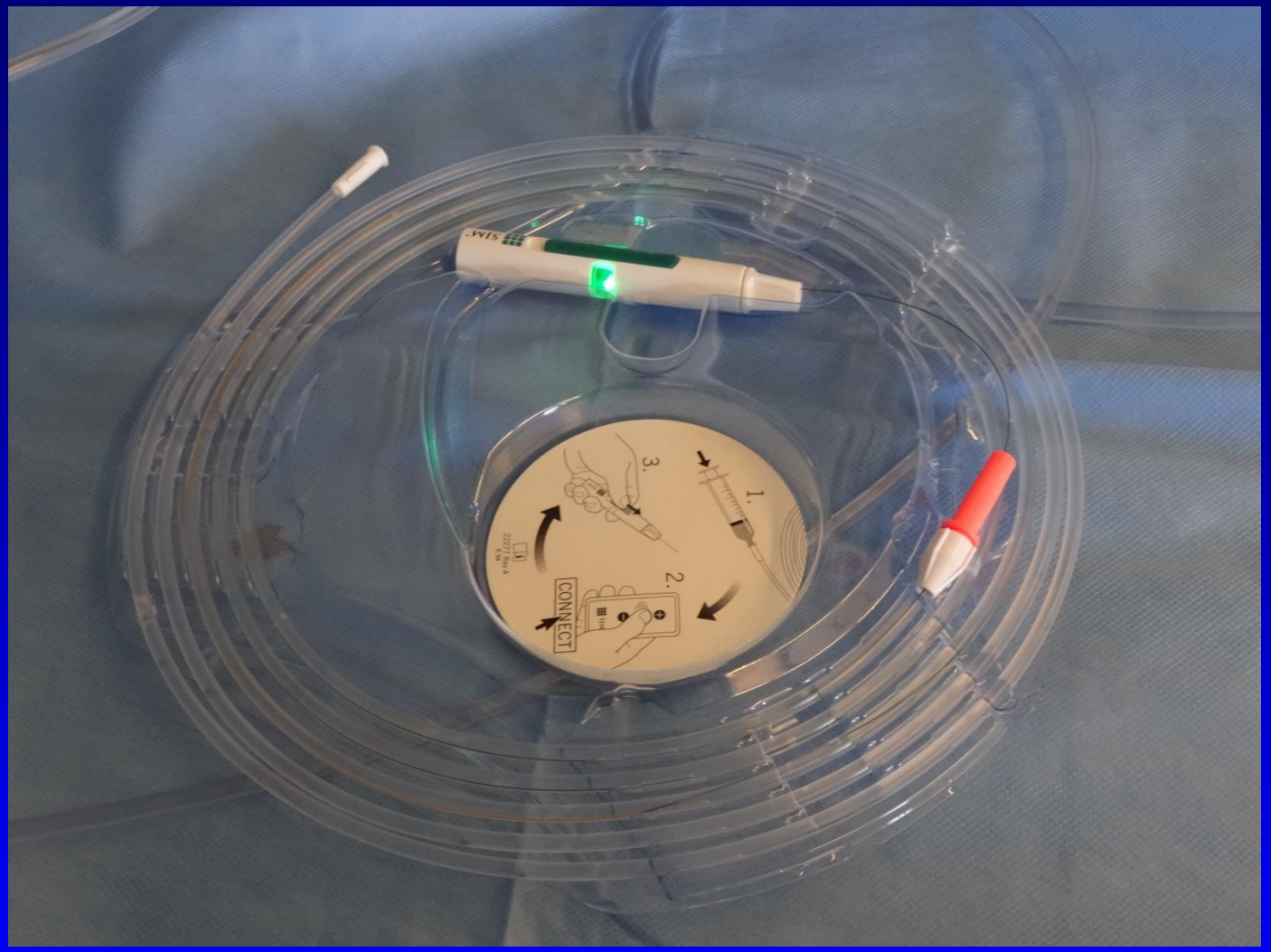
zeroing and displaying Pa on interface

zeroing and displaying Pa on interface


ICMT
Medische Technologie
25383001
QUANTIEN
bolderdijk, Patient
03055010021
HCK 1
72
09:30
ST. JUDE MEDICAL
ECG
200
160
120
80
40
0
Pa
124/59
87
Pd
No Sensor
Equalize
Place packaging coil flat and flush with saline.
Press Connect Wireless
or
2/3
No Recordings ...
Connect Wireless
Review
Archive
Rec

Unpacking of the Pressure Wire

Flushing the Pressure Wire

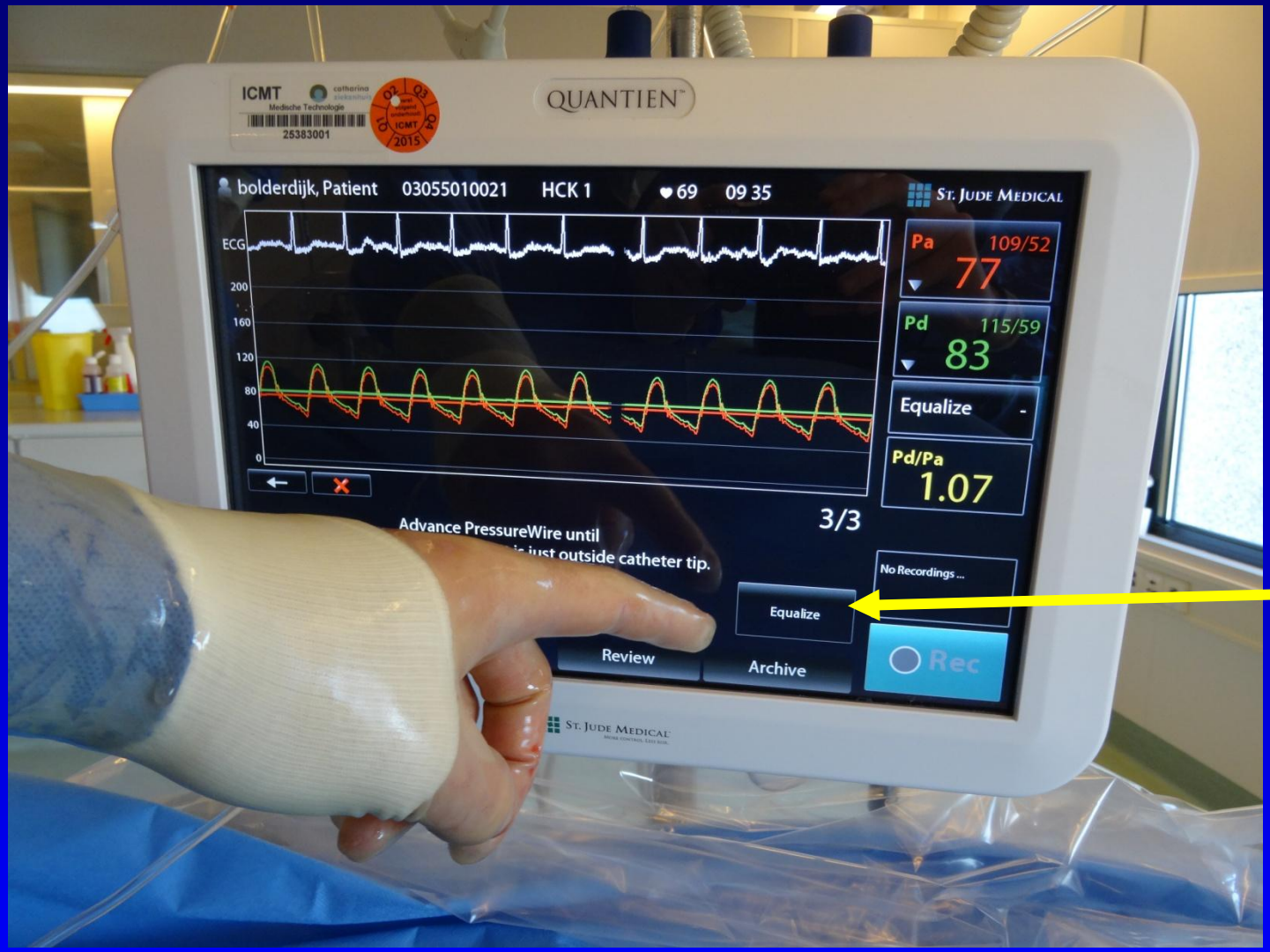


Green light indicates that pressure wire is ready

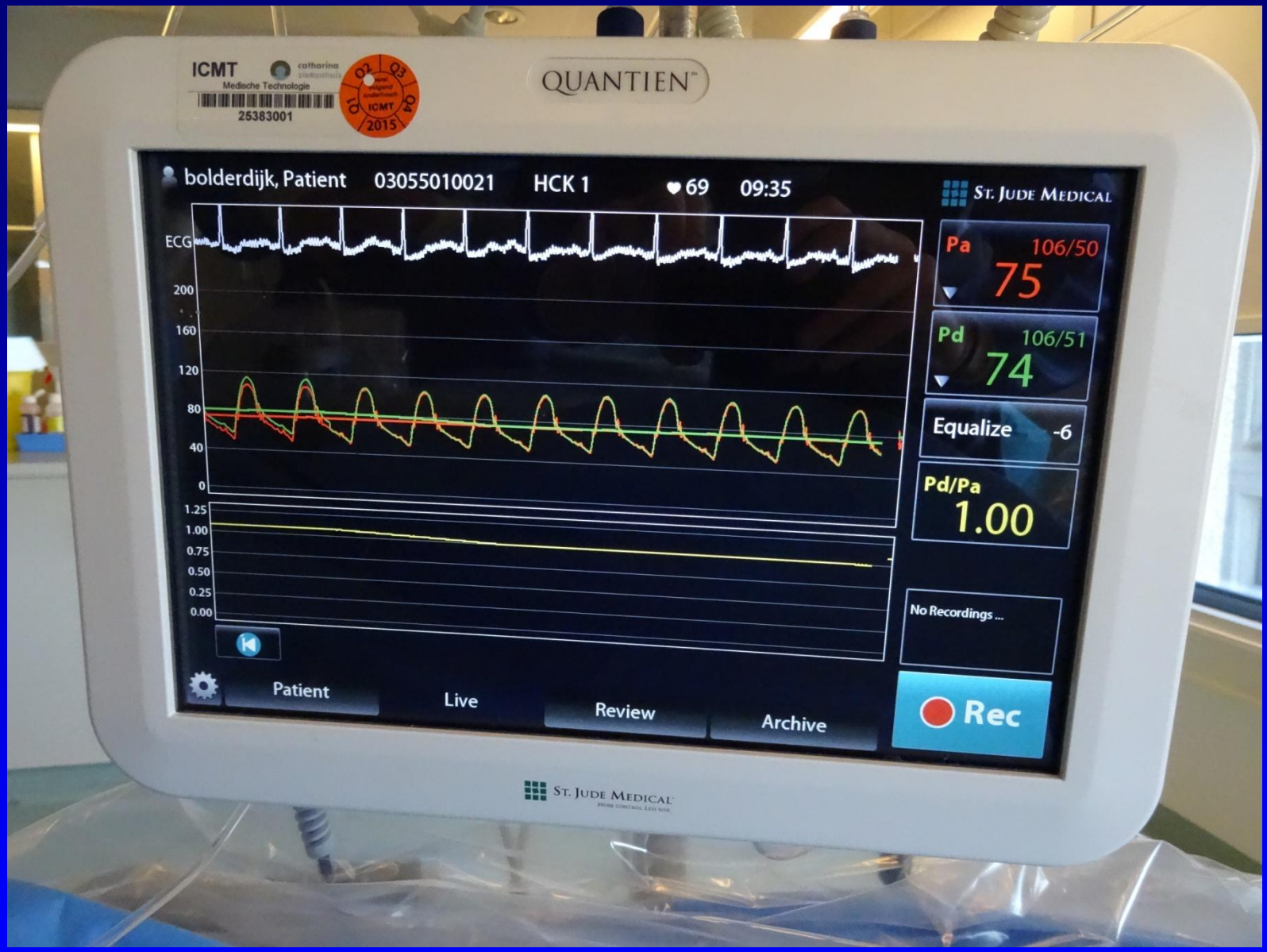
Pressure Wire introduced into Y-connector

Shaping of the tip of the PW

Introducing the PW into the Guiding Catheter



start with verification of equal signals when sensor is located at tip of the guiding catheter and equalize



Signals have been equalized

ICMT
25383001
QUANTIEN
bolderdijk, Patient
03055010021
HCK 1
71
09:36
ST. JUDE MEDICAL
ECG
200
160
120
80
40
0
1.25
1.00
0.75
0.50
0.25
0.00
Pa
110/52
78
Pd
110/54
78
Equalize
-5
Pd/Pa
1.00
No Recordings ...
Rec

record

NOTE:

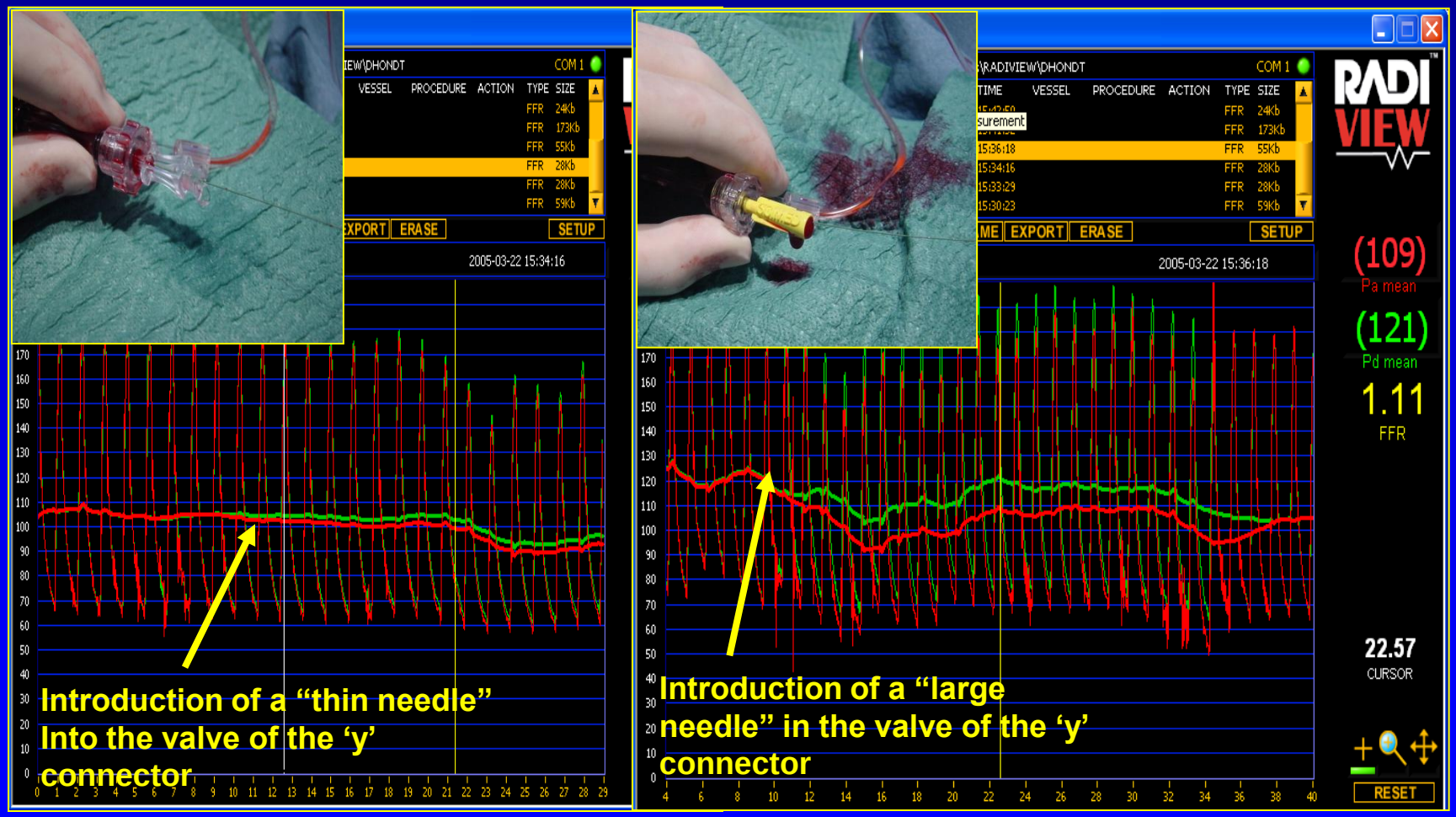
introducer needle in or out !?!

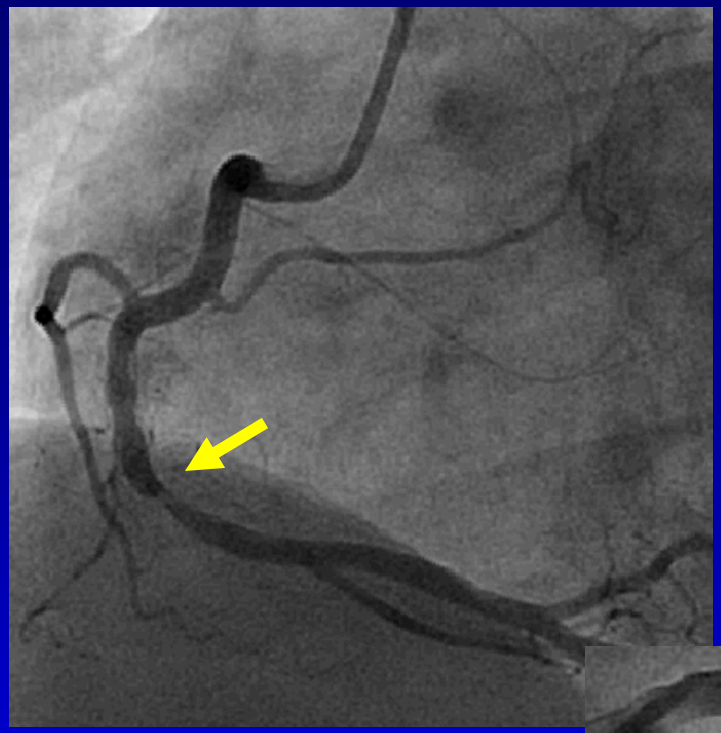
→ ***doesn't matter as long as you realize what you are doing***

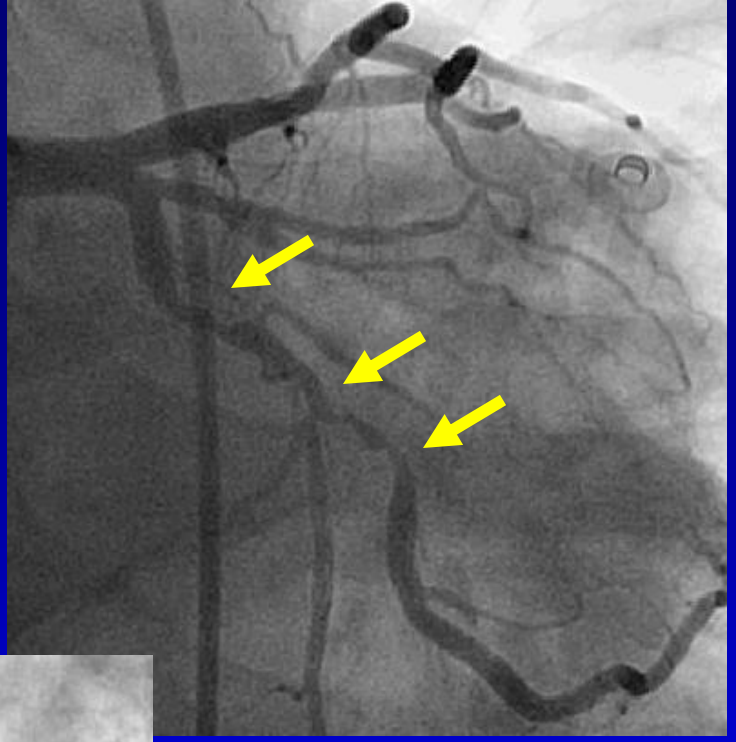
1. ***Know your needle***

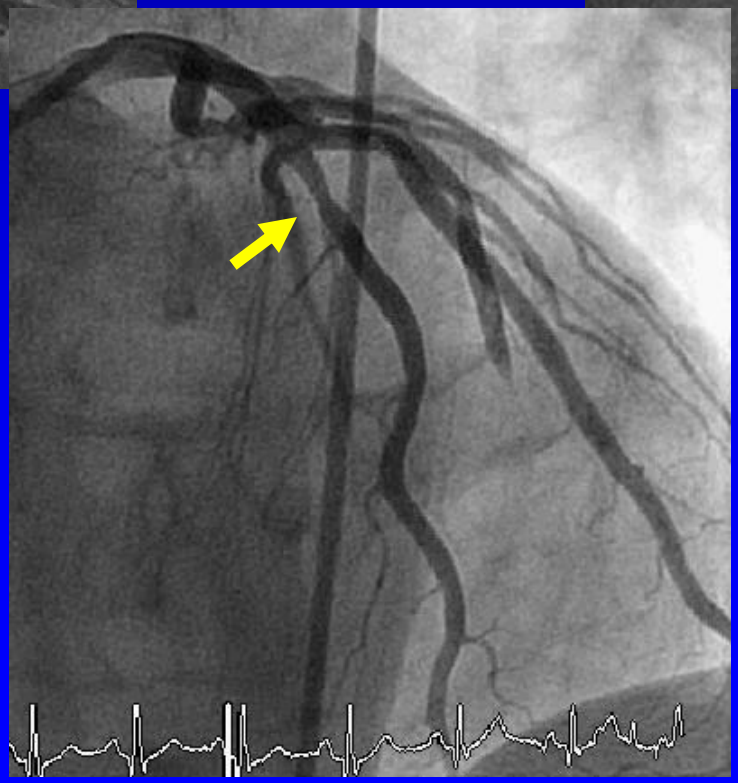
2. ***Realize that some apparent "drift" at the end is not drift per se but can be caused by the presence of the introducer when doing the initial measurement and absence of the (removed) introducer at the end***

Introducer effect *(mistake in live case in PCR 2010)*

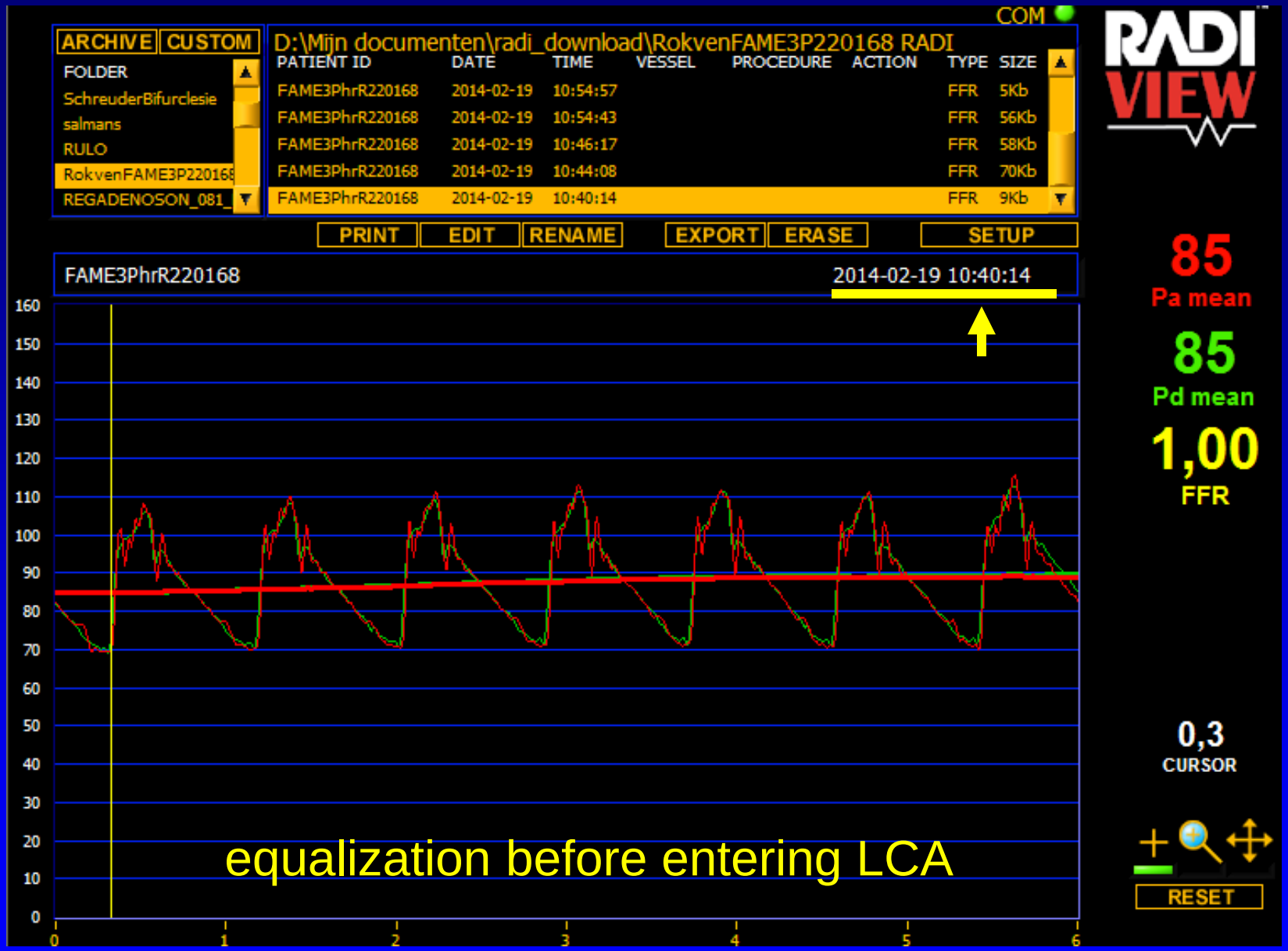








70% RCA
50% LAD
90% long LCX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RokvenFAME3P220168
REGADENOSON_081_
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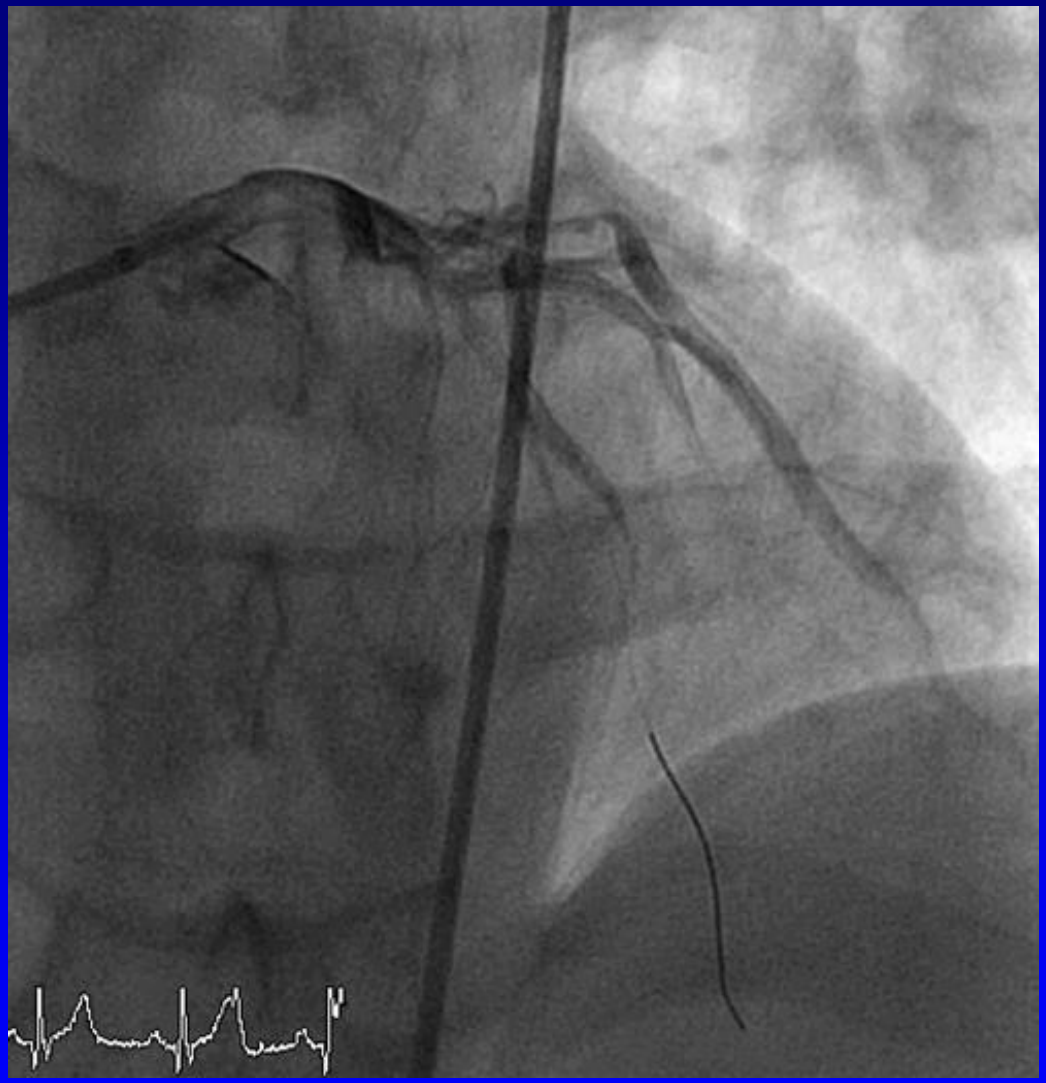
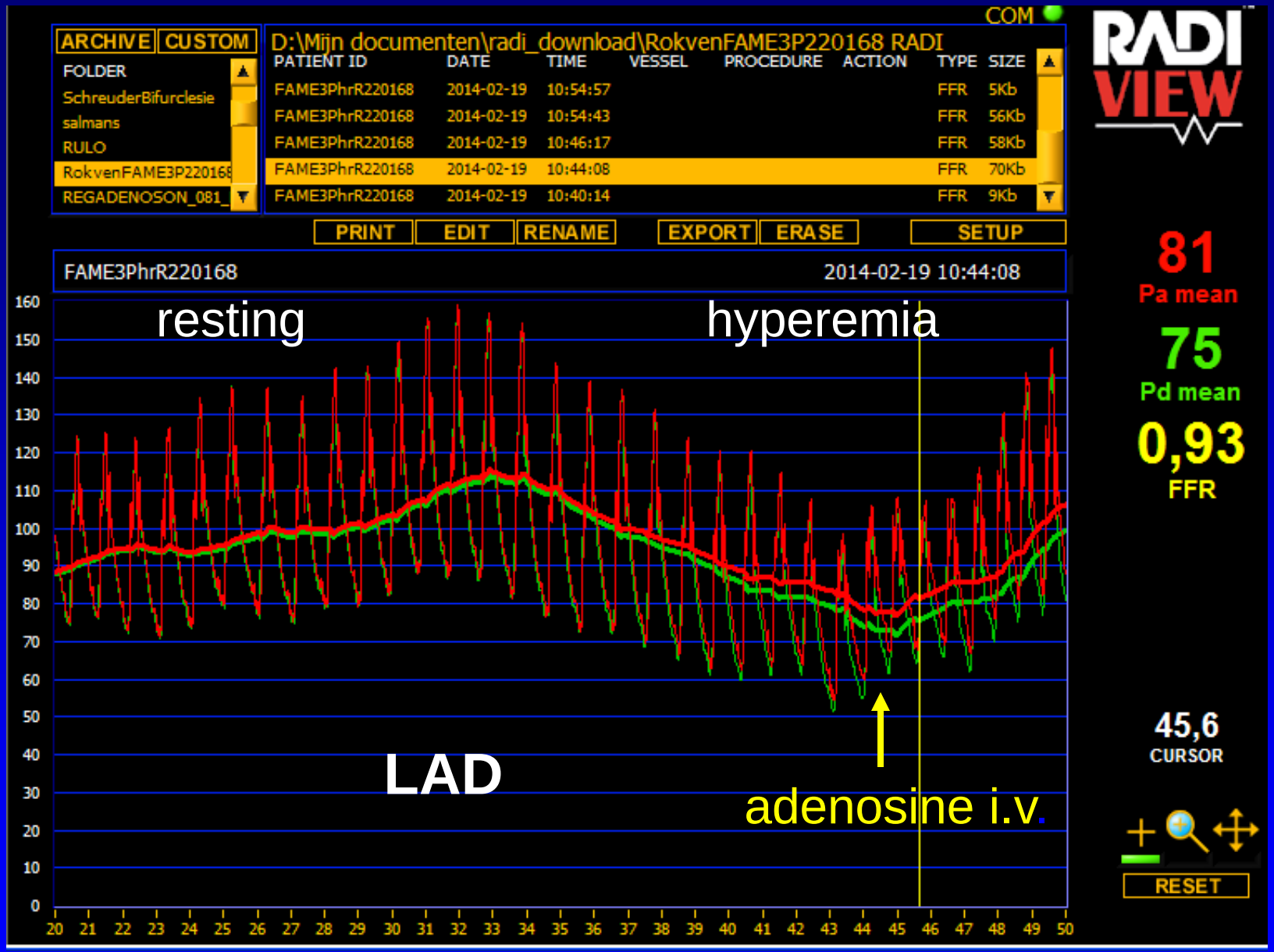
PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
FAME3PhrR220168 2014-02-19 10:54:57 FFR 5Kb
FAME3PhrR220168 2014-02-19 10:54:43 FFR 56Kb
FAME3PhrR220168 2014-02-19 10:46:17 FFR 58Kb
FAME3PhrR220168 2014-02-19 10:44:08 FFR 70Kb
FAME3PhrR220168 2014-02-19 10:40:14 FFR 9Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
FAME3PhrR220168
2014-02-19 10:40:14
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
equalization before entering LCA
RADI VIEW
85
Pa mean
85
Pd mean
1,00
FFR
0,3
CURSOR
RESET



PressureWire in LAD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salmans
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REGADENOSON_081_
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PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
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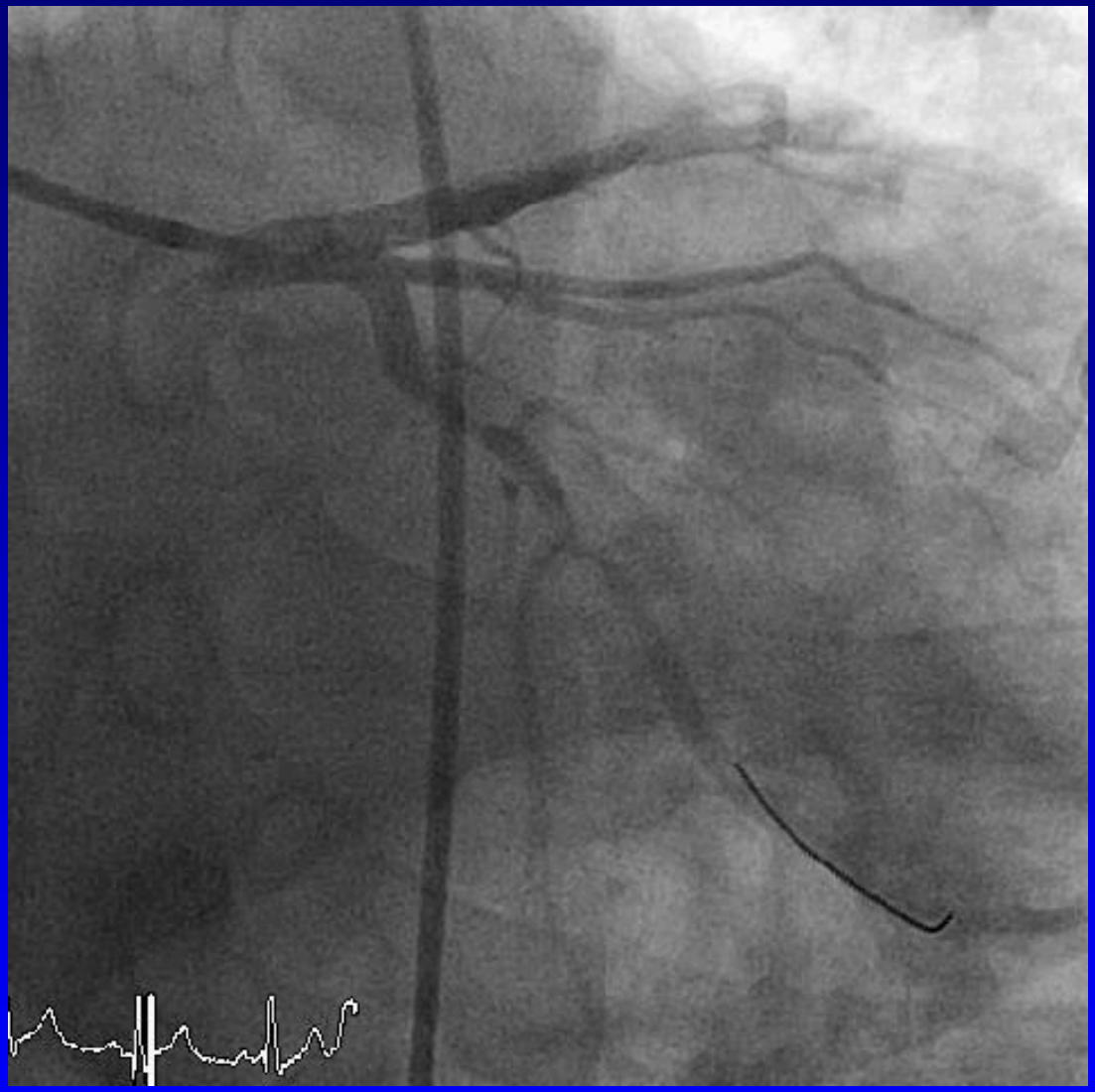
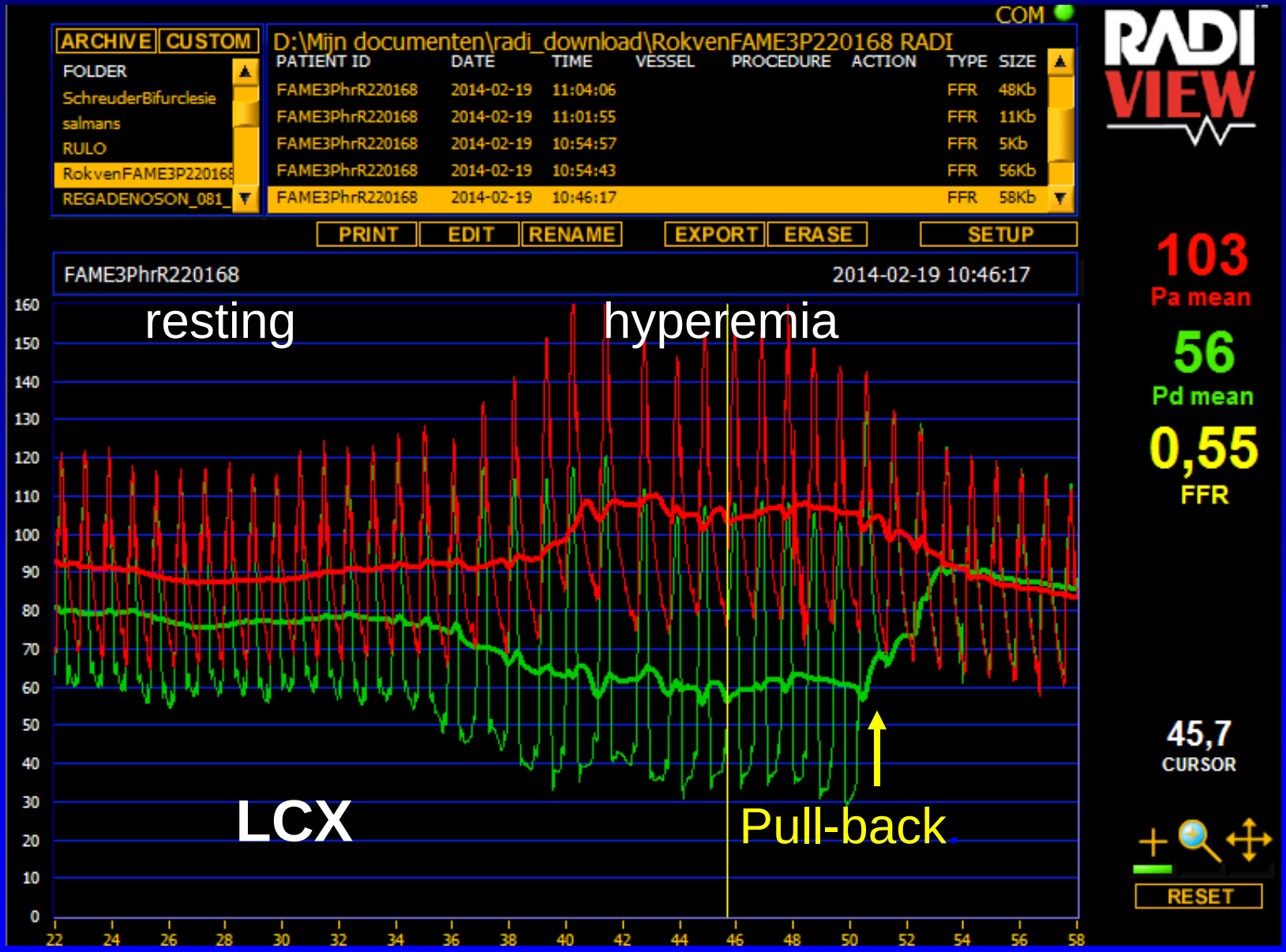
FAME3PhrR220168 2014-02-19 10:54:43 FFR 56Kb
FAME3PhrR220168 2014-02-19 10:46:17 FFR 58Kb
FAME3PhrR220168 2014-02-19 10:44:08 FFR 70Kb
FAME3PhrR220168 2014-02-19 10:40:14 FFR 9Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 10:44:08
resting
hyperemia
LAD
adenosine i.v.
81
Pa mean
75
Pd mean
0,93
FFR
45,6
CURSOR
RESET
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50



PressureWire in LCX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REGADENOSON_081_
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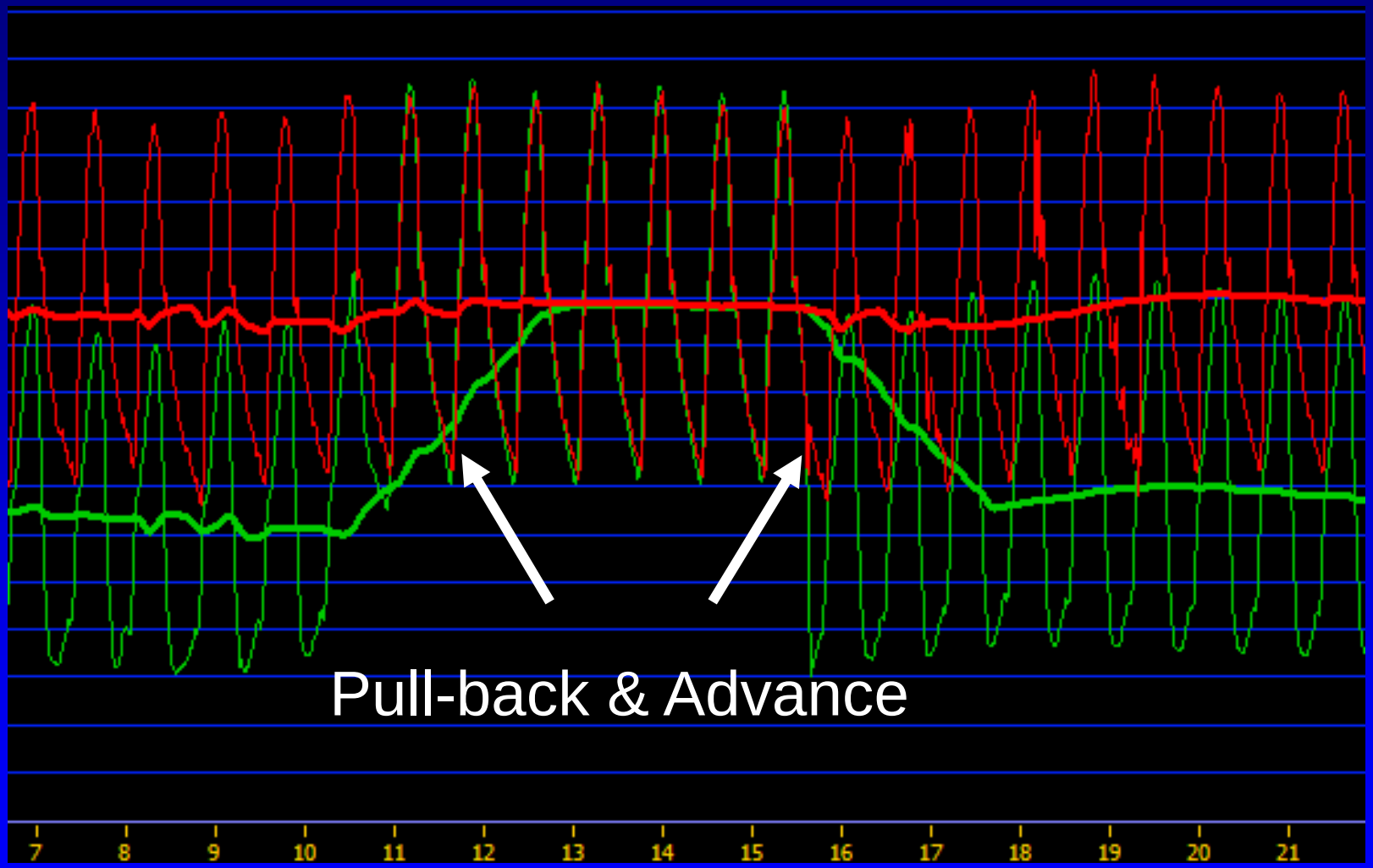
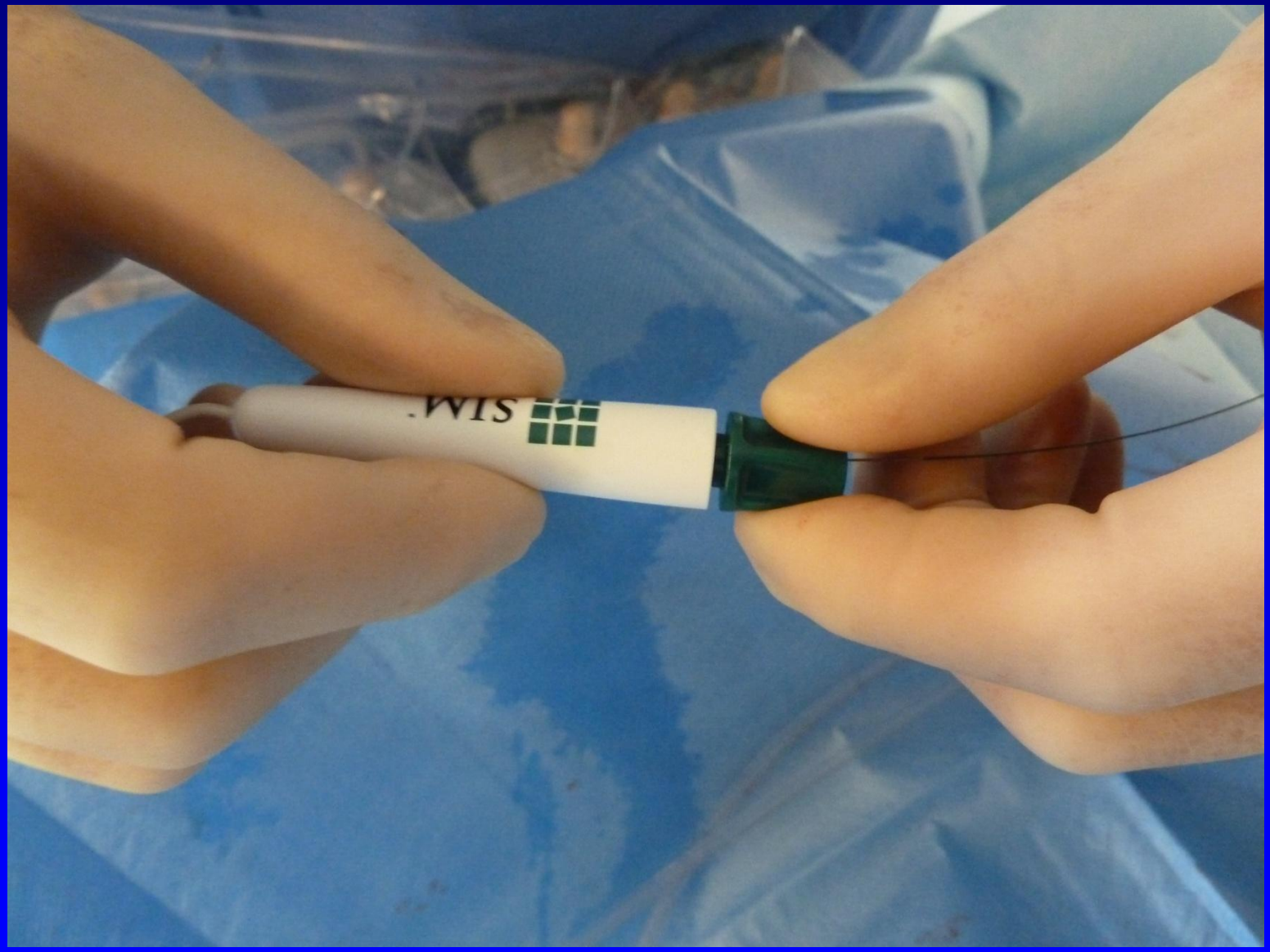
PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
FAME3PhrR220168 2014-02-19 10:54:57 FFR 5Kb
FAME3PhrR220168 2014-02-19 10:54:43 FFR 56Kb
FAME3PhrR220168 2014-02-19 10:46:17 FFR 58Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 10:46:17
resting
hyperemia
LCX
Pull-back
103
Pa mean
56
Pd mean
0,55
FFR
45,7
CURSOR
RESET

Because sensor is 3 cm from tip, easily pull-back and push-up for exact spatial information.

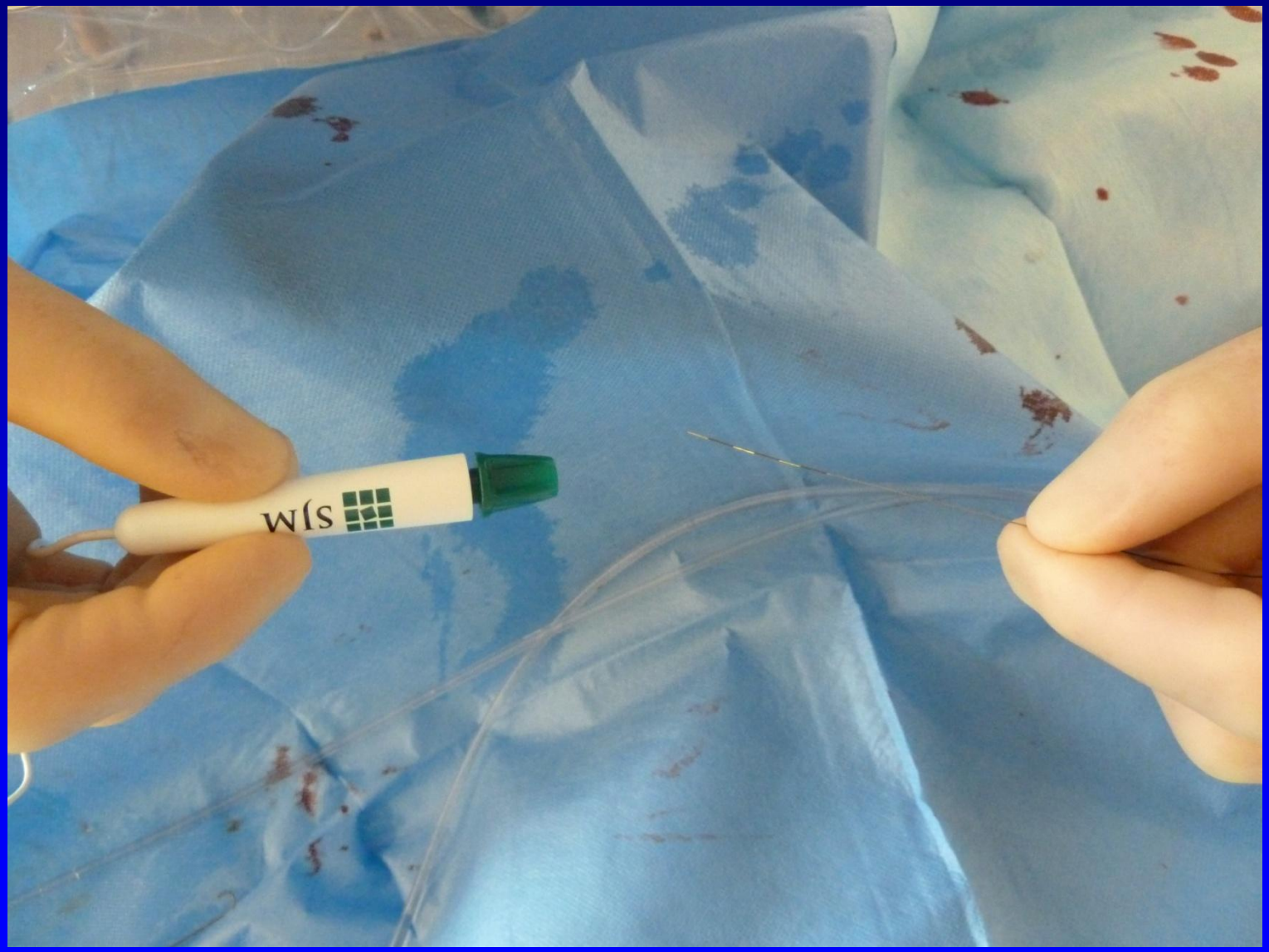


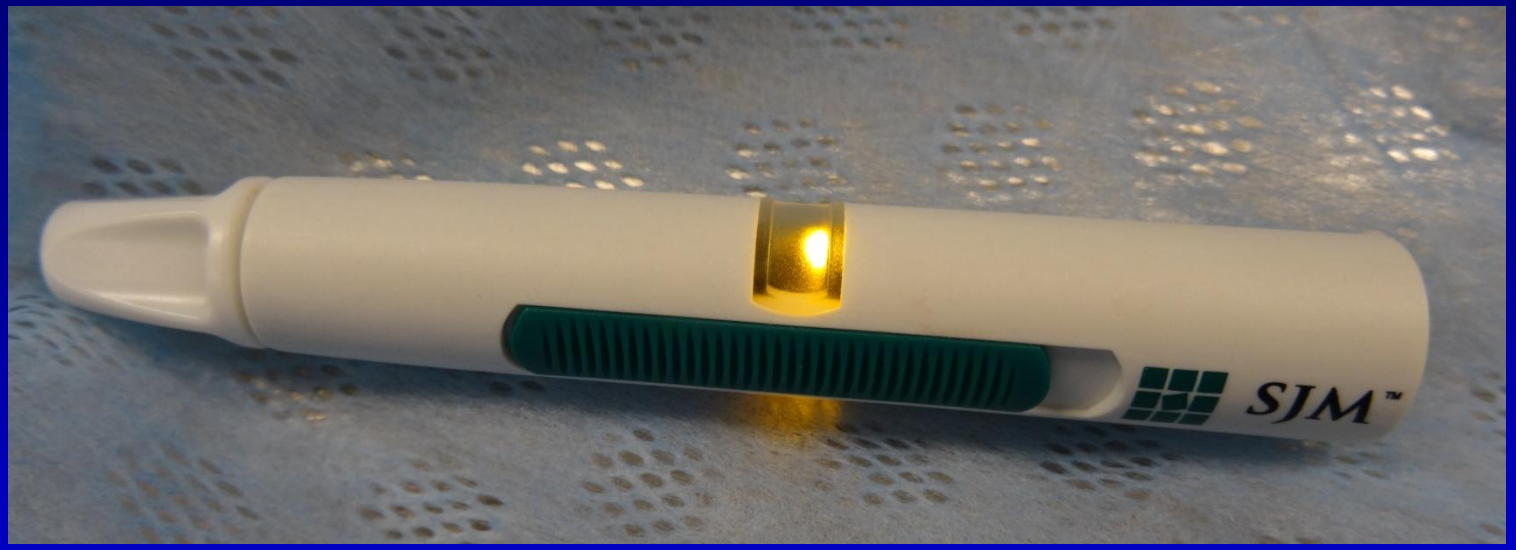
Pull-back recording for detailed spatial information about distribution of lesions along the complete artery

If you need to treat, disconnect pressure wire

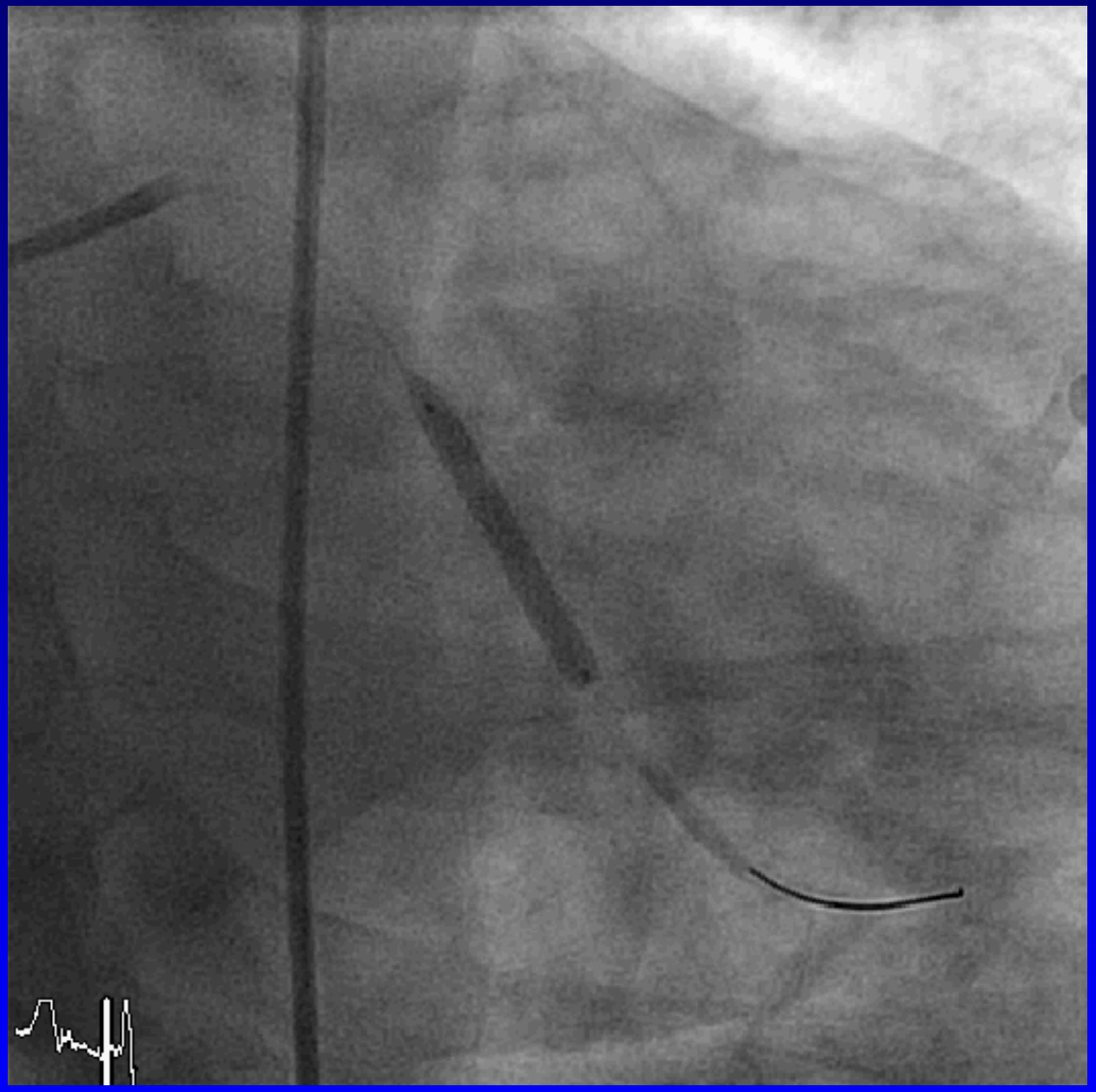


disconnecting the pressure wire…….

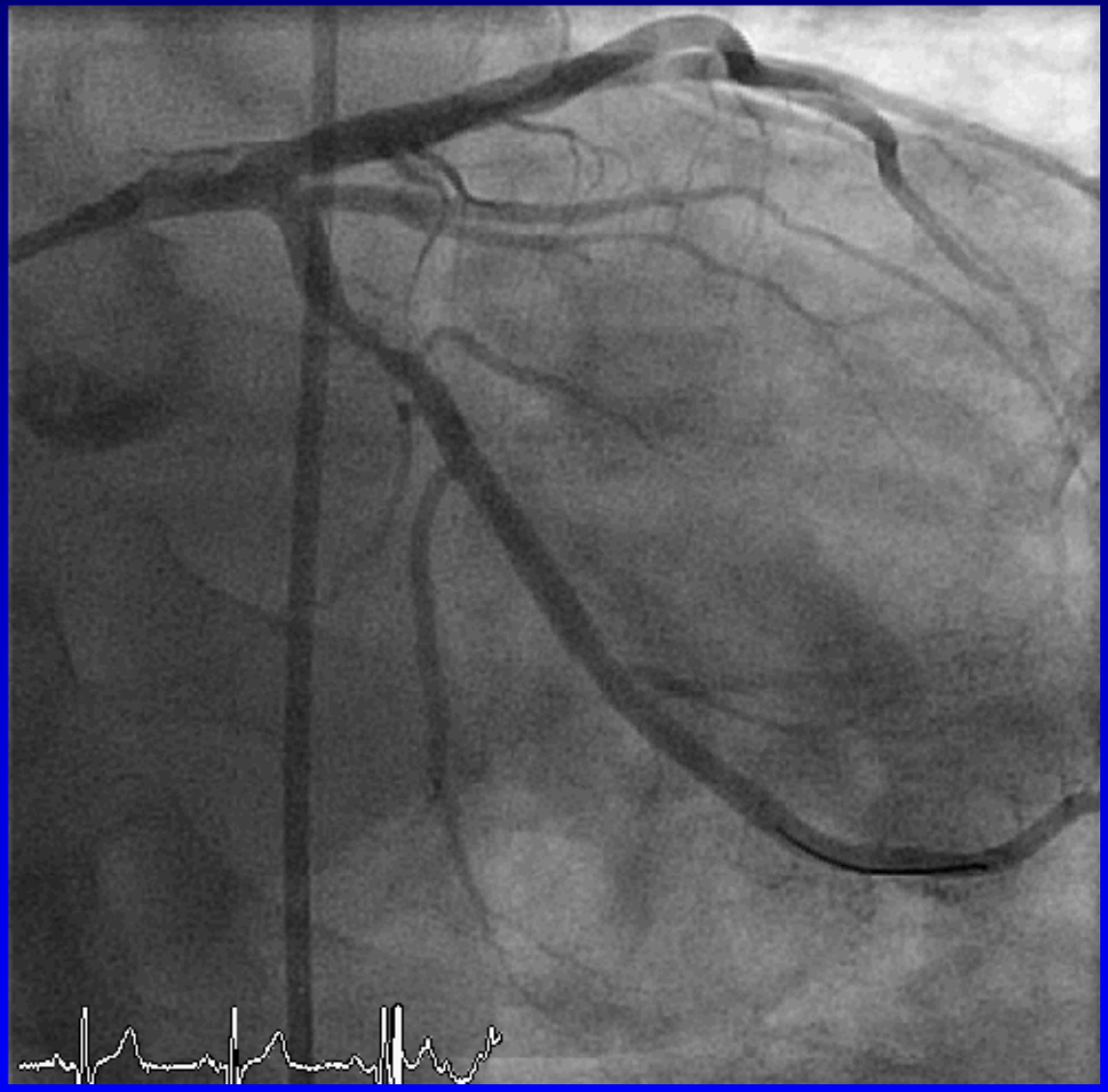




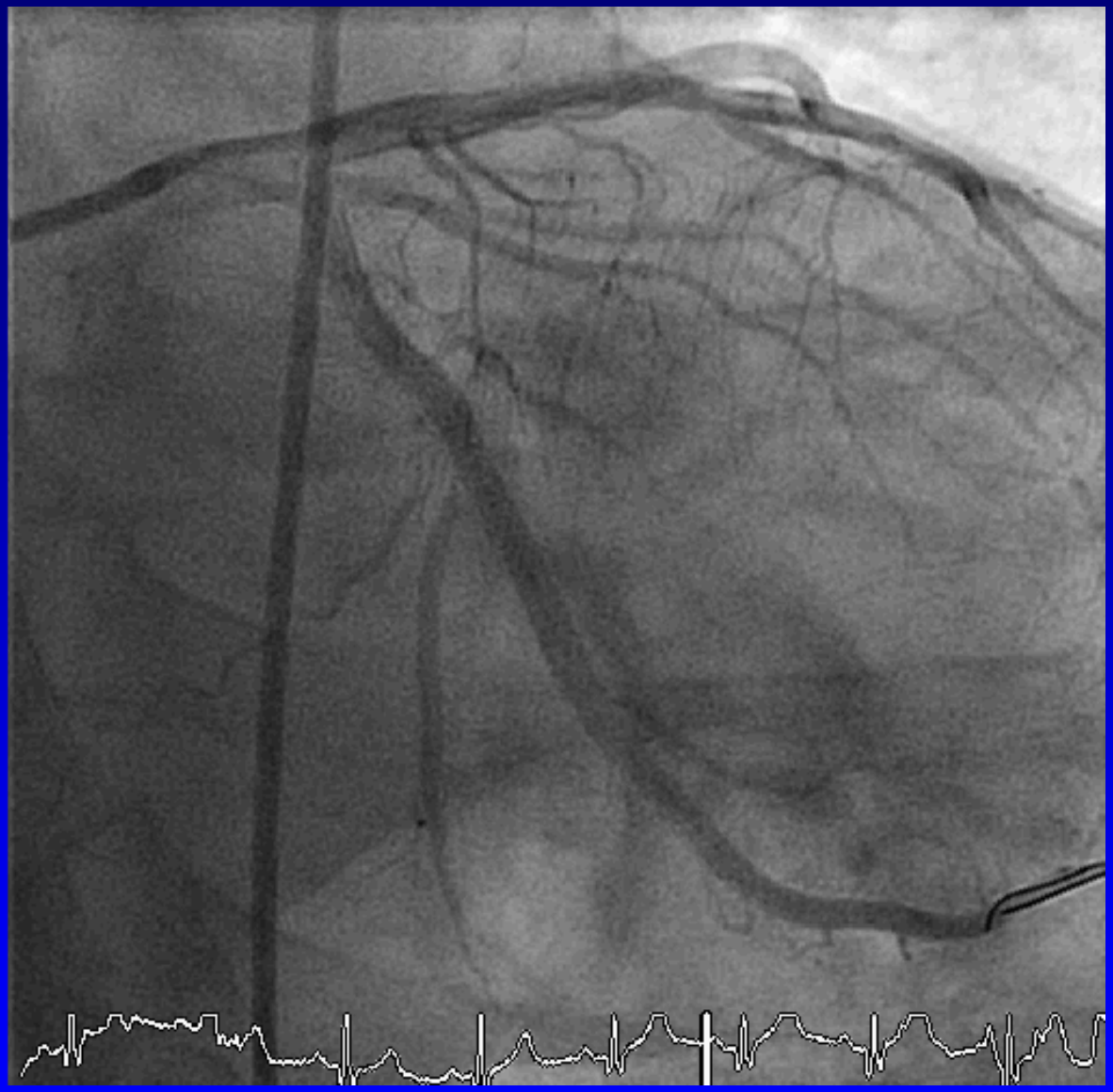
Wire disconnected→ indicator orange



first stent in LCX (3.0x22)

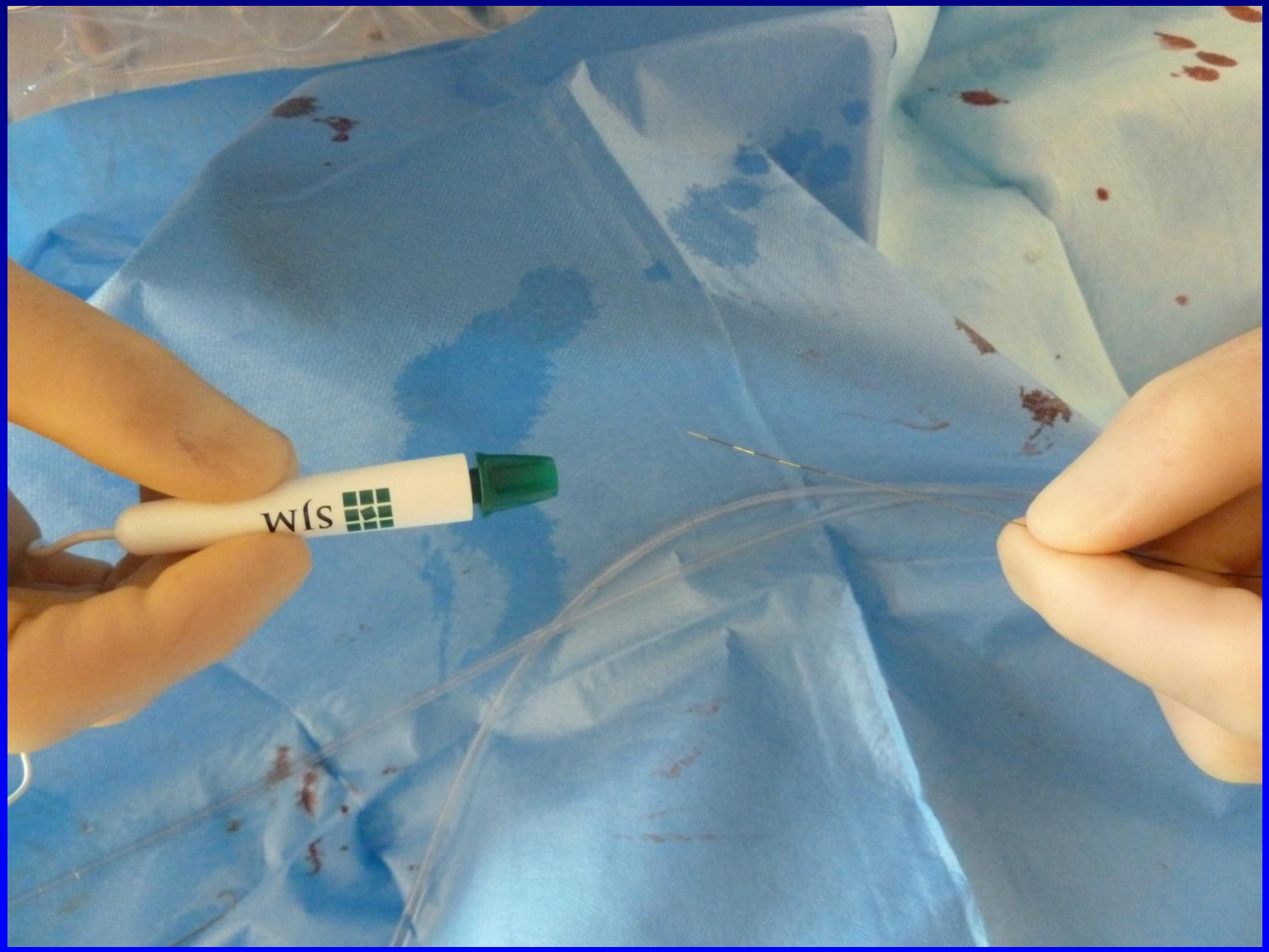


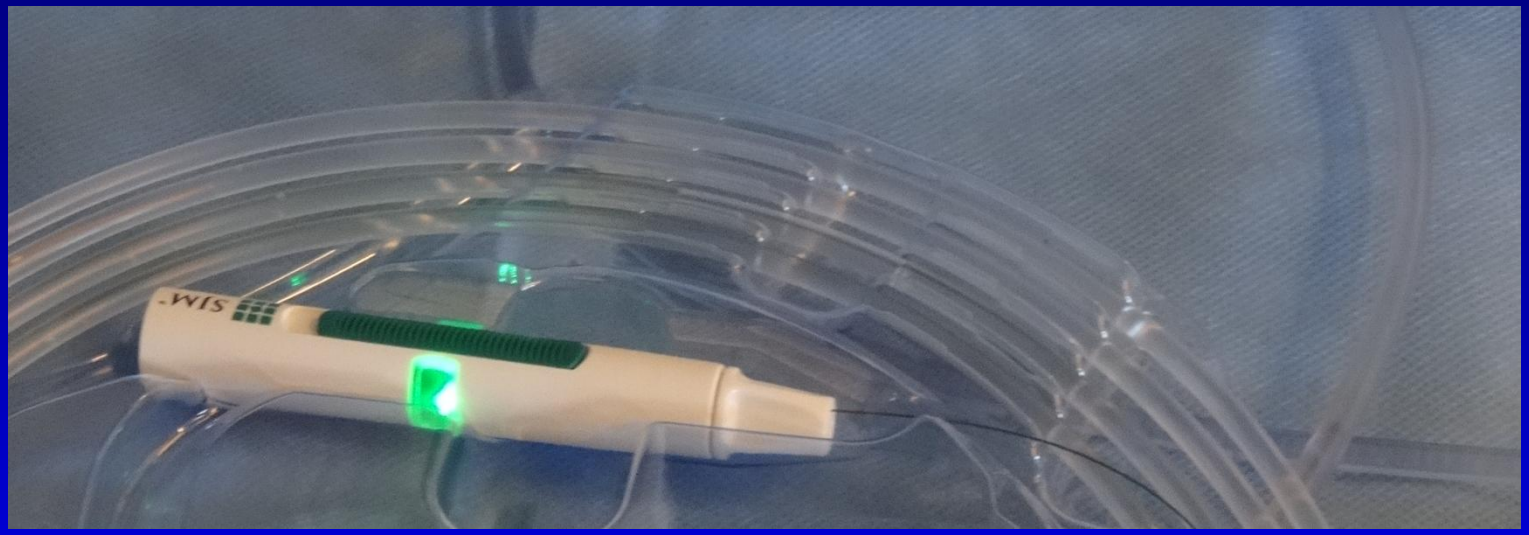
LCX after first stent



LCX after second stent

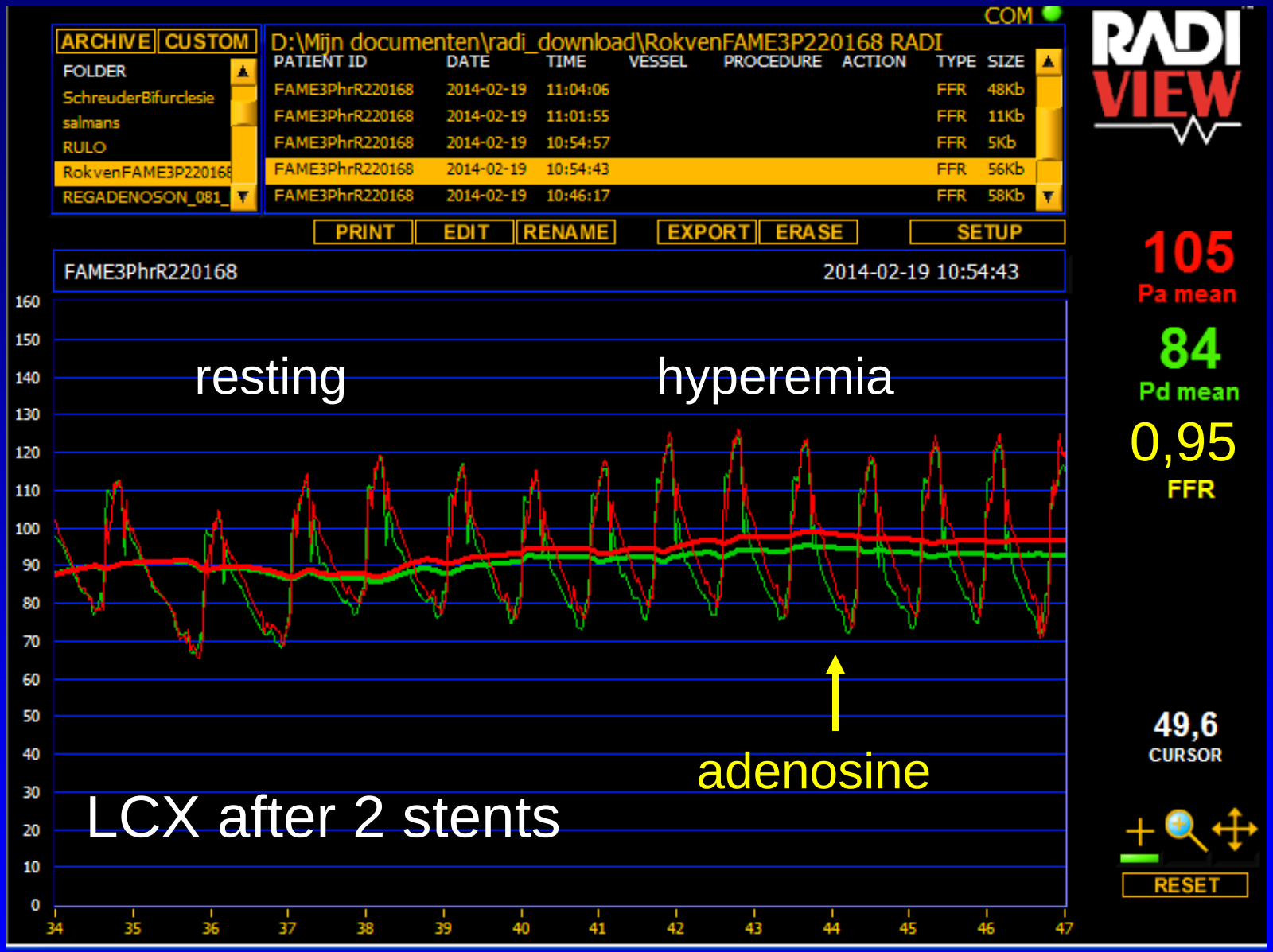
For post-stent FFR → simply connect the pressure wire



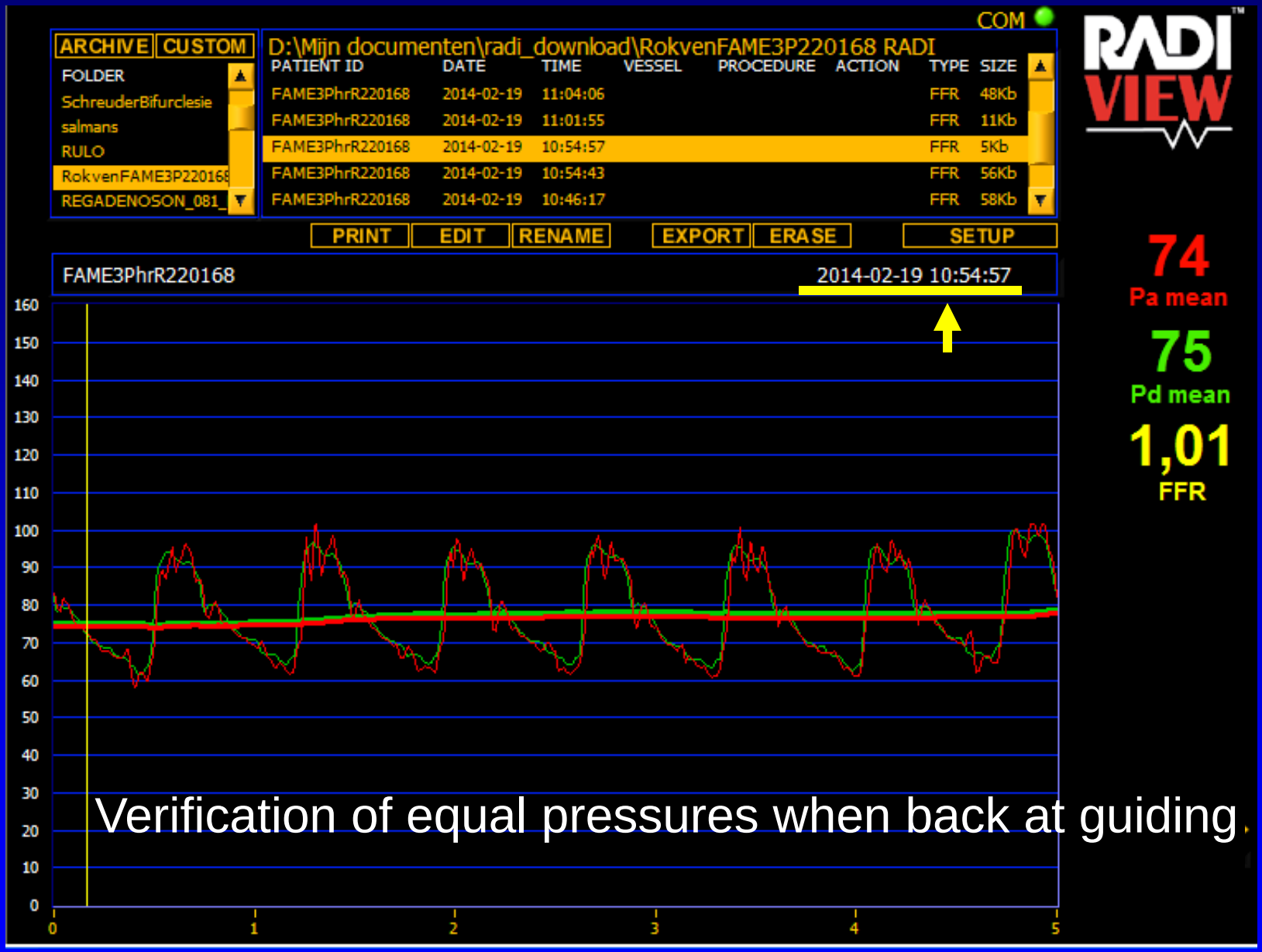


Re-connected → indicator light green

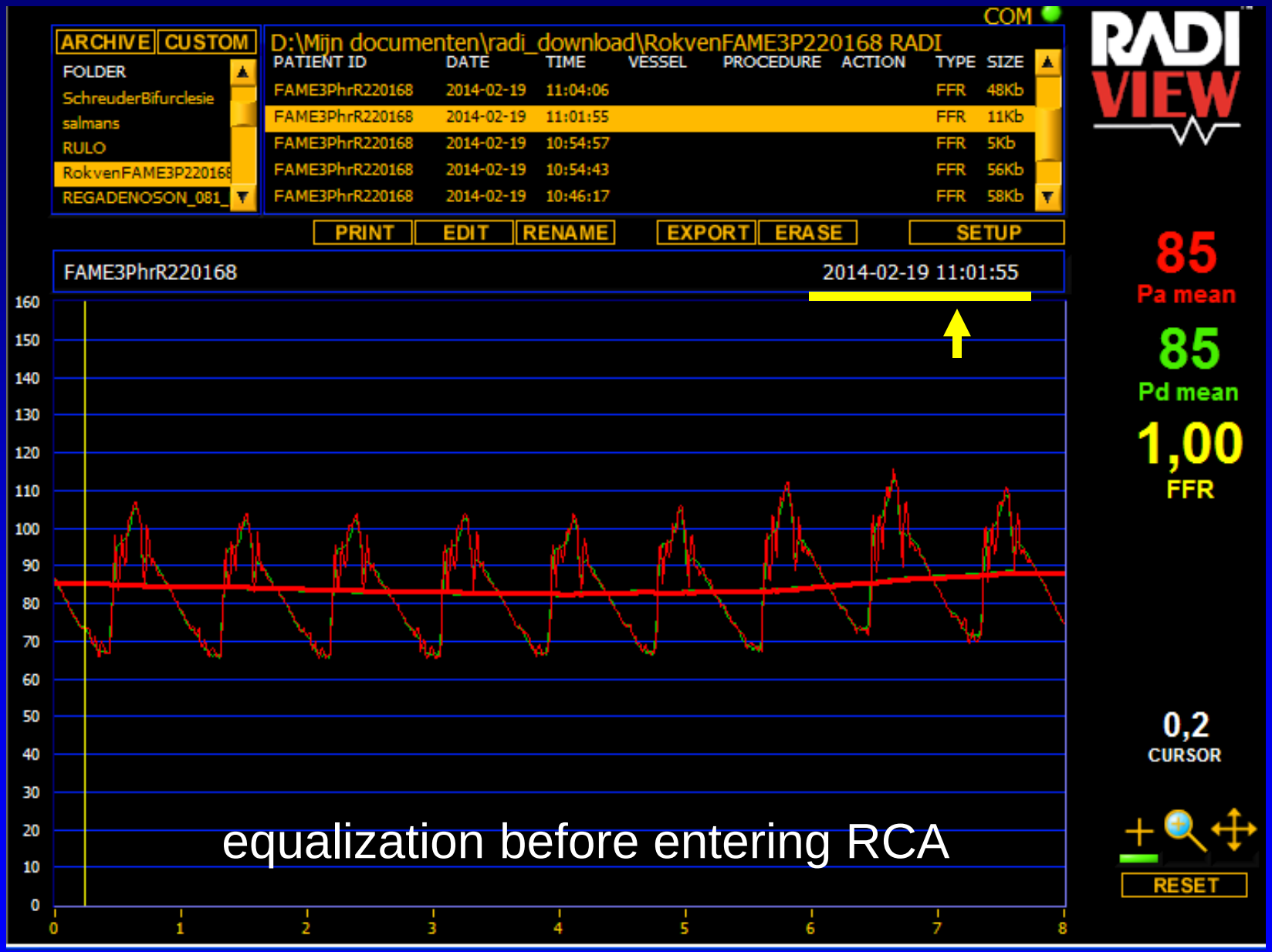
Note: after reconnecting it can take 15-20 Seconds for signal to stabilize



Post-stent FFR measurement to evaluate result



Verification of equal pressures when back at guiding.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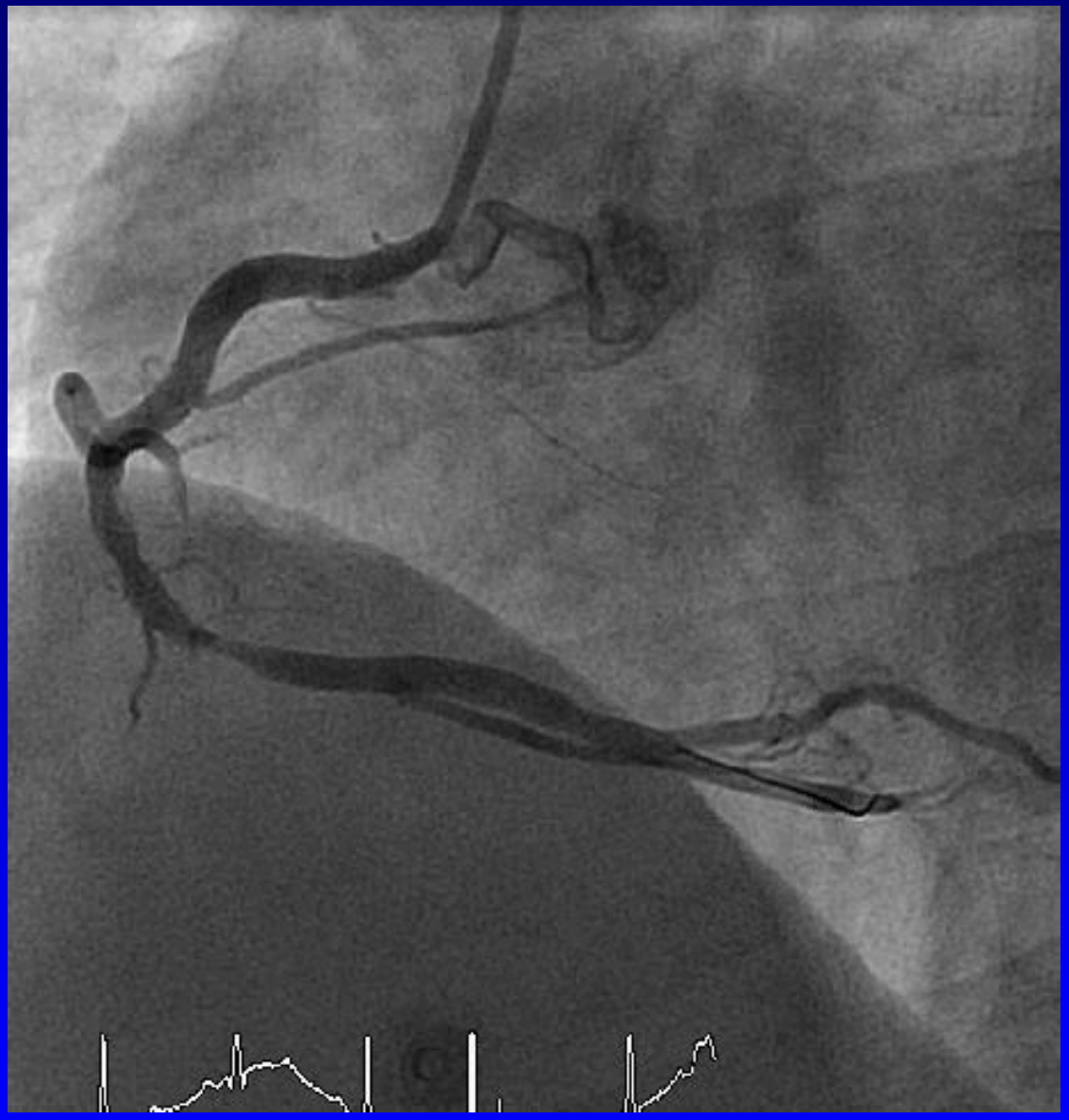
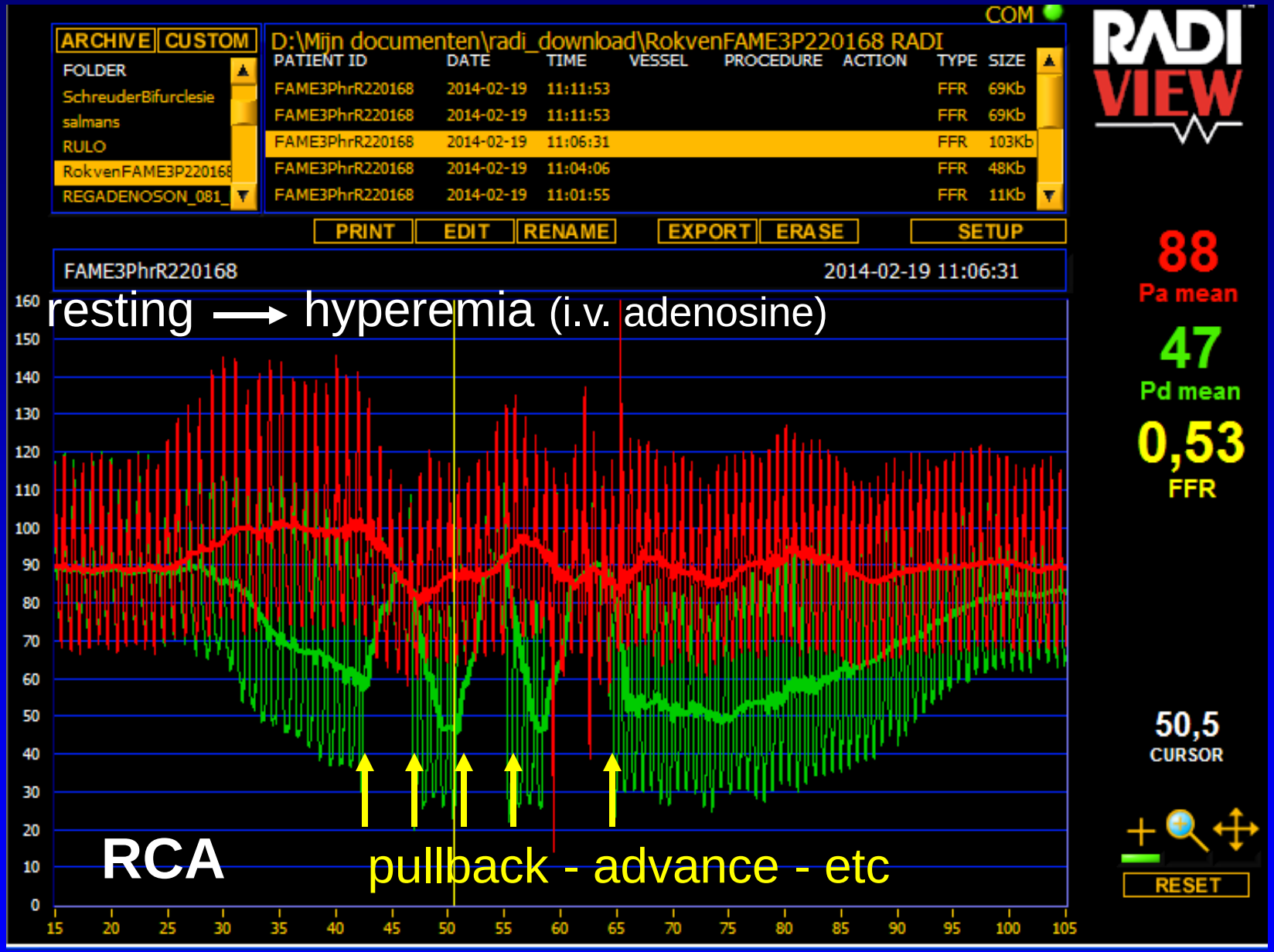
PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
FAME3PhrR220168 2014-02-19 10:54:57 FFR 5Kb
FAME3PhrR220168 2014-02-19 10:54:43 FFR 56Kb
FAME3PhrR220168 2014-02-19 10:46:17 FFR 58Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
FAME3PhrR220168
2014-02-19 11:01:55
RADI VIEW
85
Pa mean
85
Pd mean
1,00
FFR
0,2
CURSOR
RESET
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
1
2
3
4
5
6
7
8
equalization before entering RCA



PressureWire in RCA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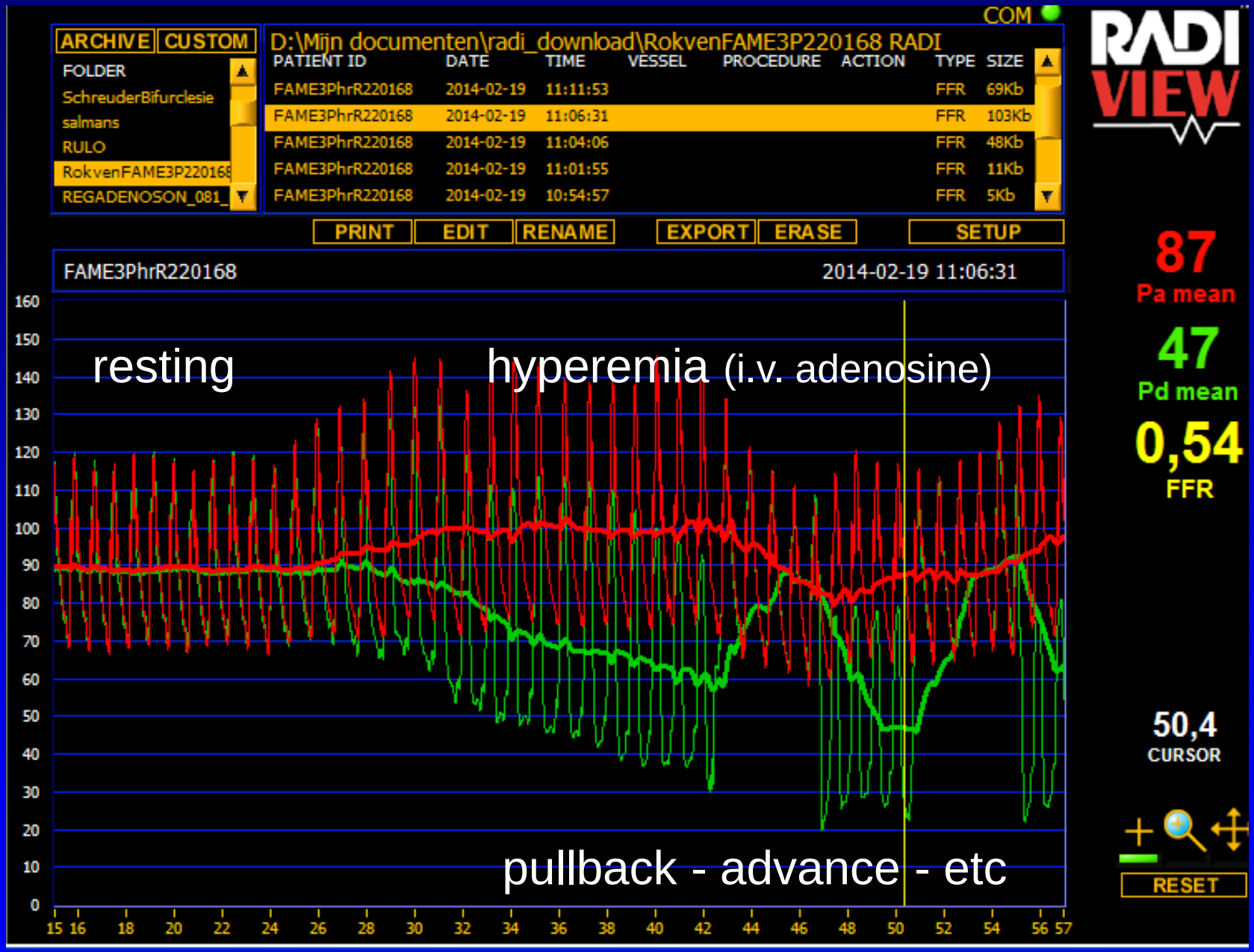
PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
FAME3PhrR220168 2014-02-19 11:11:53 FFR 69Kb
FAME3PhrR220168 2014-02-19 11:11:53 FFR 69Kb
FAME3PhrR220168 2014-02-19 11:06:31 FFR 103Kb
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 11:06:31
88
Pa mean
47
Pd mean
0,53
FFR
50,5
CURSOR
RESET
resting ⟶ hyperemia (i.v. adenosine)
RCA
pullback - advance - etc
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100 105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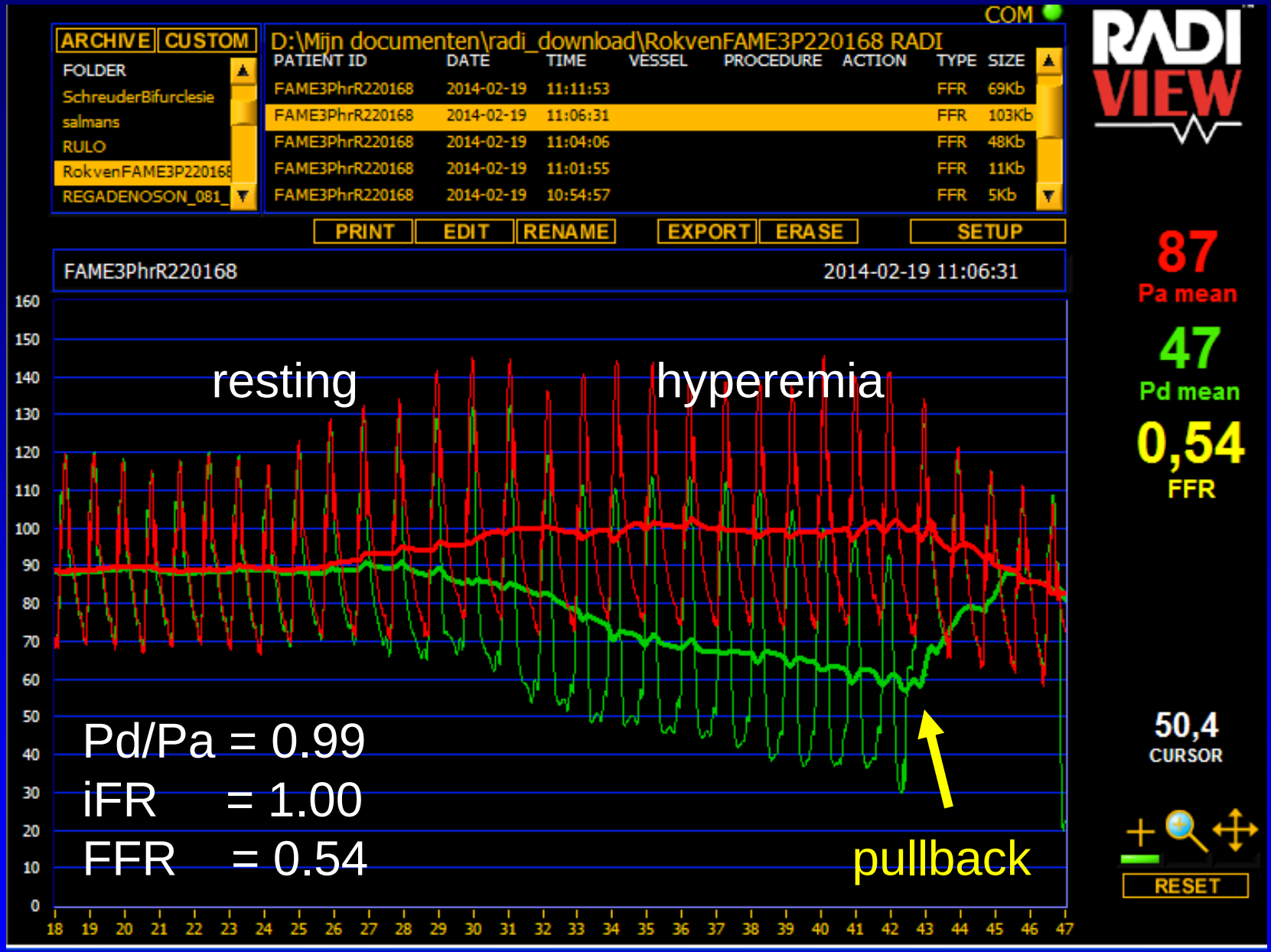
PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
FAME3PhrR220168 2014-02-19 11:11:53 FFR 69Kb
FAME3PhrR220168 2014-02-19 11:06:31 FFR 103Kb
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
FAME3PhrR220168 2014-02-19 10:54:57 FFR 5Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 11:06:31
resting
hyperemia (i.v. adenosine)
pullback - advance - etc
87
Pa mean
47
Pd mean
0,54
FFR
50,4
CURSOR
RESET
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
15 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54 56 57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PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
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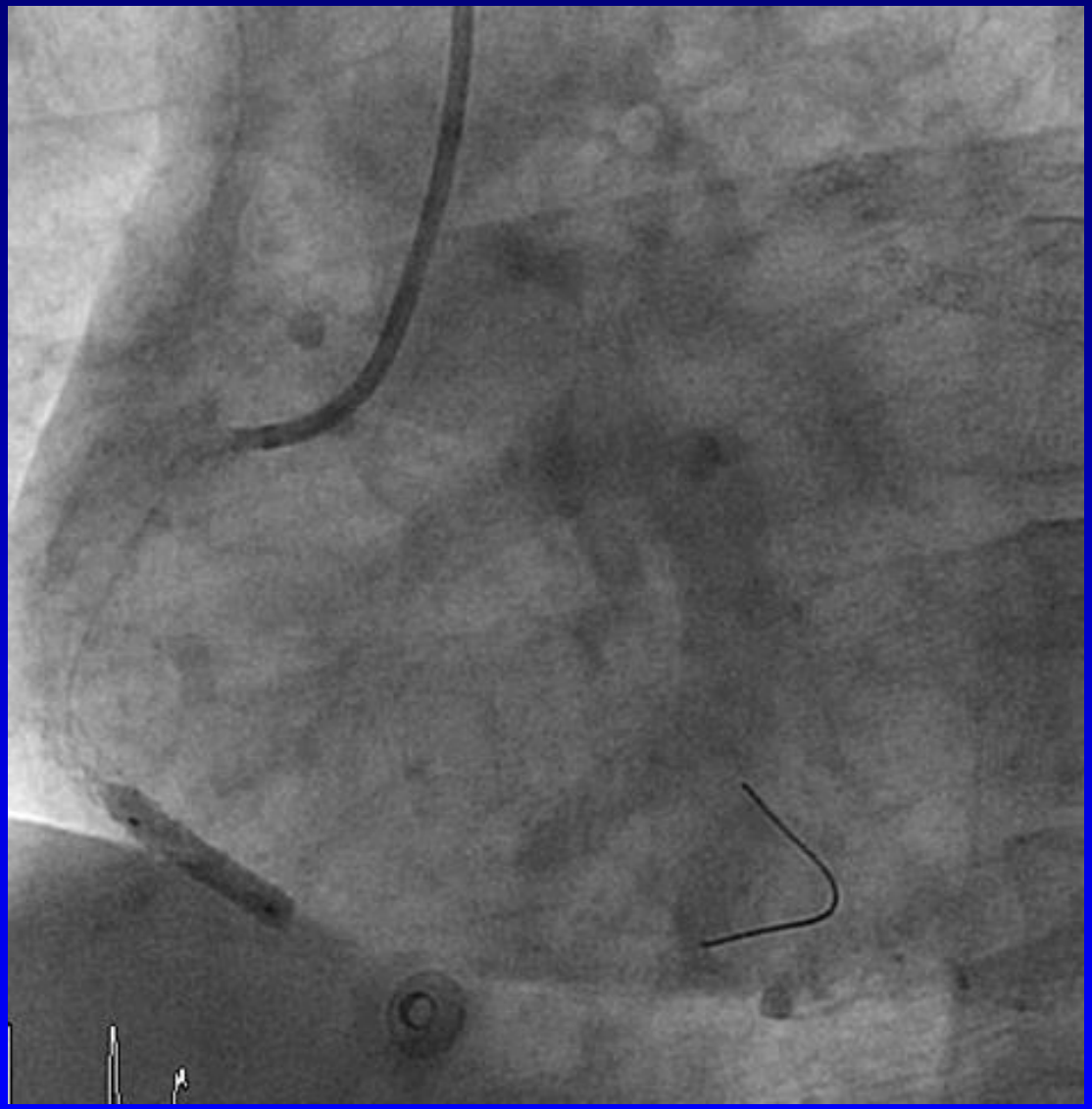
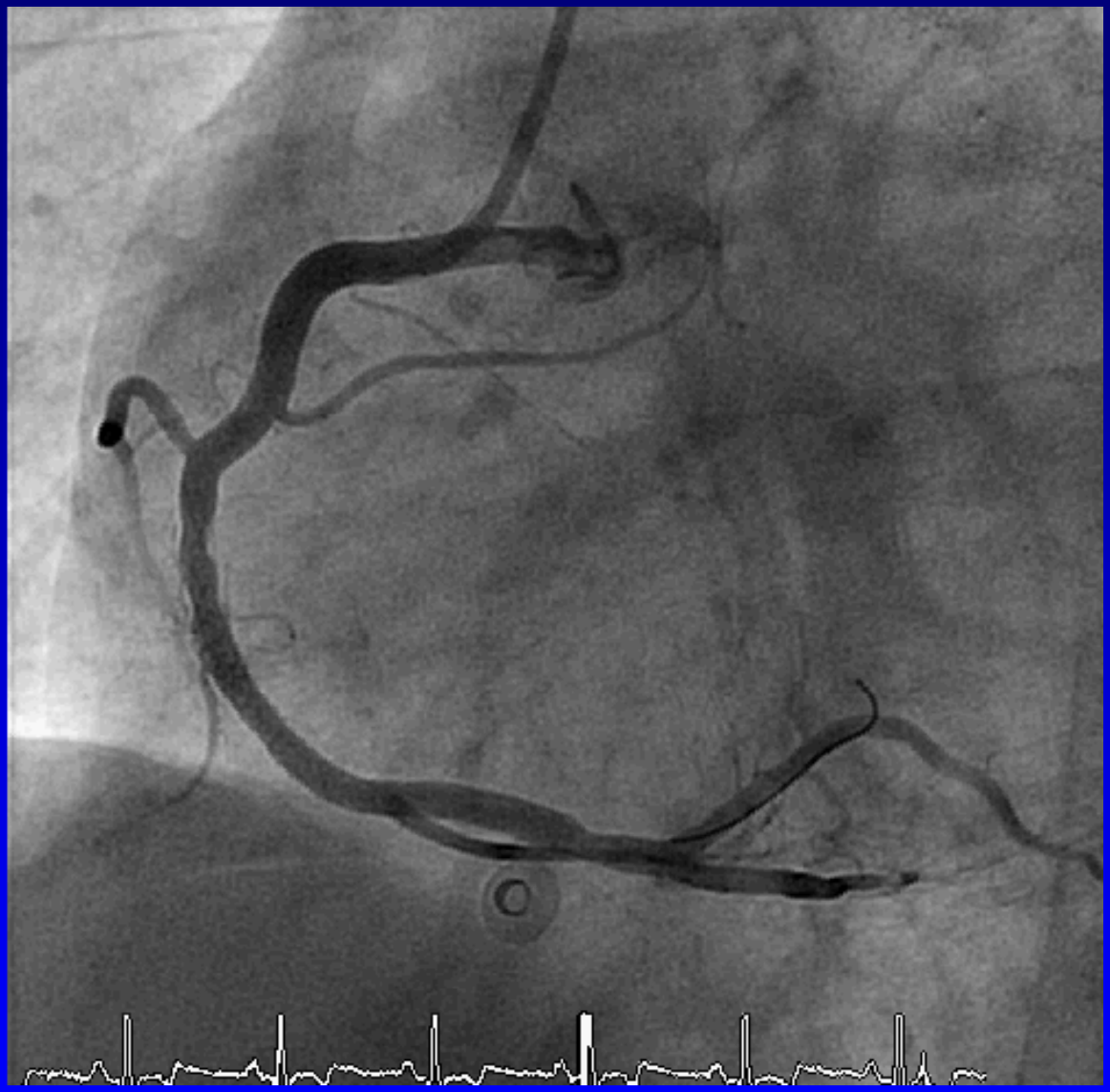
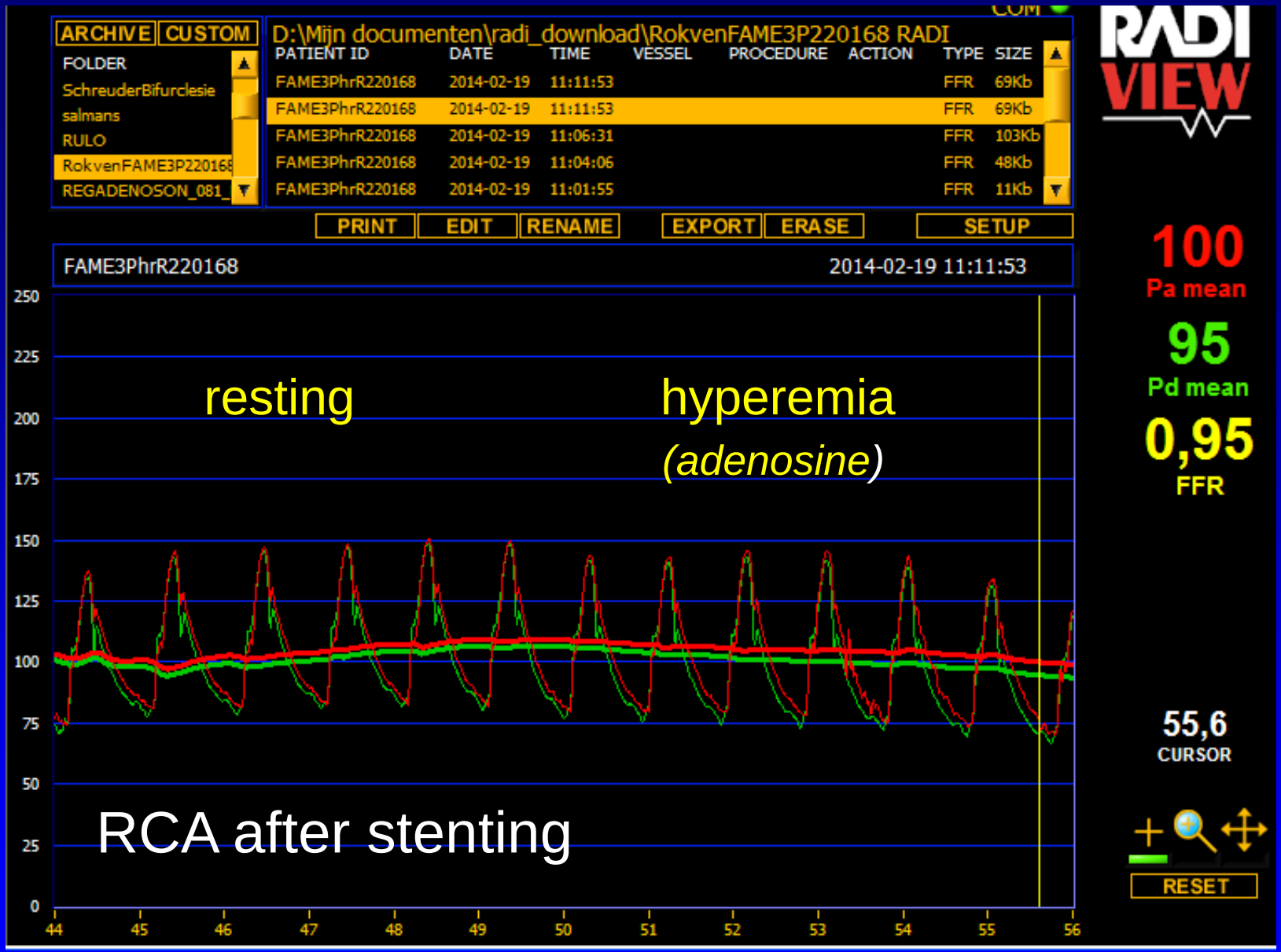
FAME3PhrR220168 2014-02-19 11:06:31 FFR 103Kb
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
FAME3PhrR220168 2014-02-19 10:54:57 FFR 5Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 11:06:31
87
Pa mean
47
Pd mean
0,54
FFR
resting
hyperemia
Pd/Pa = 0.99
iFR = 1.00
FFR = 0.54
pullback
50,4
CURSOR
RESET
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47



Stent in RCA (3,5x 18)



RCA after stenting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PATIENT ID DATE TIME VESSEL PROCEDURE ACTION TYPE SIZE
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FAME3PhrR220168 2014-02-19 11:11:53 FFR 69Kb
FAME3PhrR220168 2014-02-19 11:06:31 FFR 103Kb
FAME3PhrR220168 2014-02-19 11:04:06 FFR 48Kb
FAME3PhrR220168 2014-02-19 11:01:55 FFR 11Kb
PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
FAME3PhrR220168
2014-02-19 11:11:53
resting
hyperemia
(adenosine)
RCA after stenting
100
Pa mean
95
Pd mean
0,95
FFR
55,6
CURSOR
RESET
250
225
200
175
150
125
100
75
50
25
0
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45
46
47
48
49
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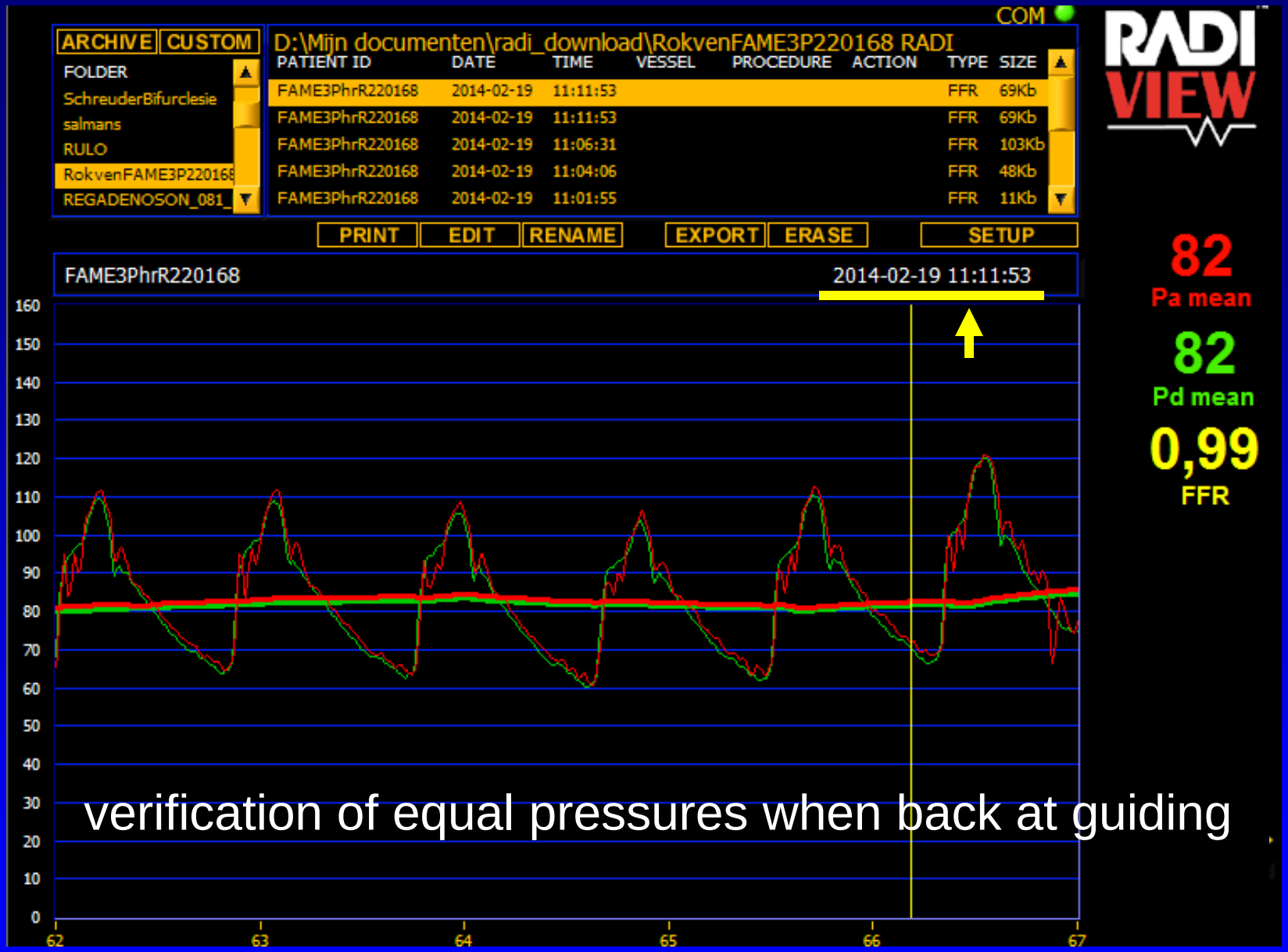
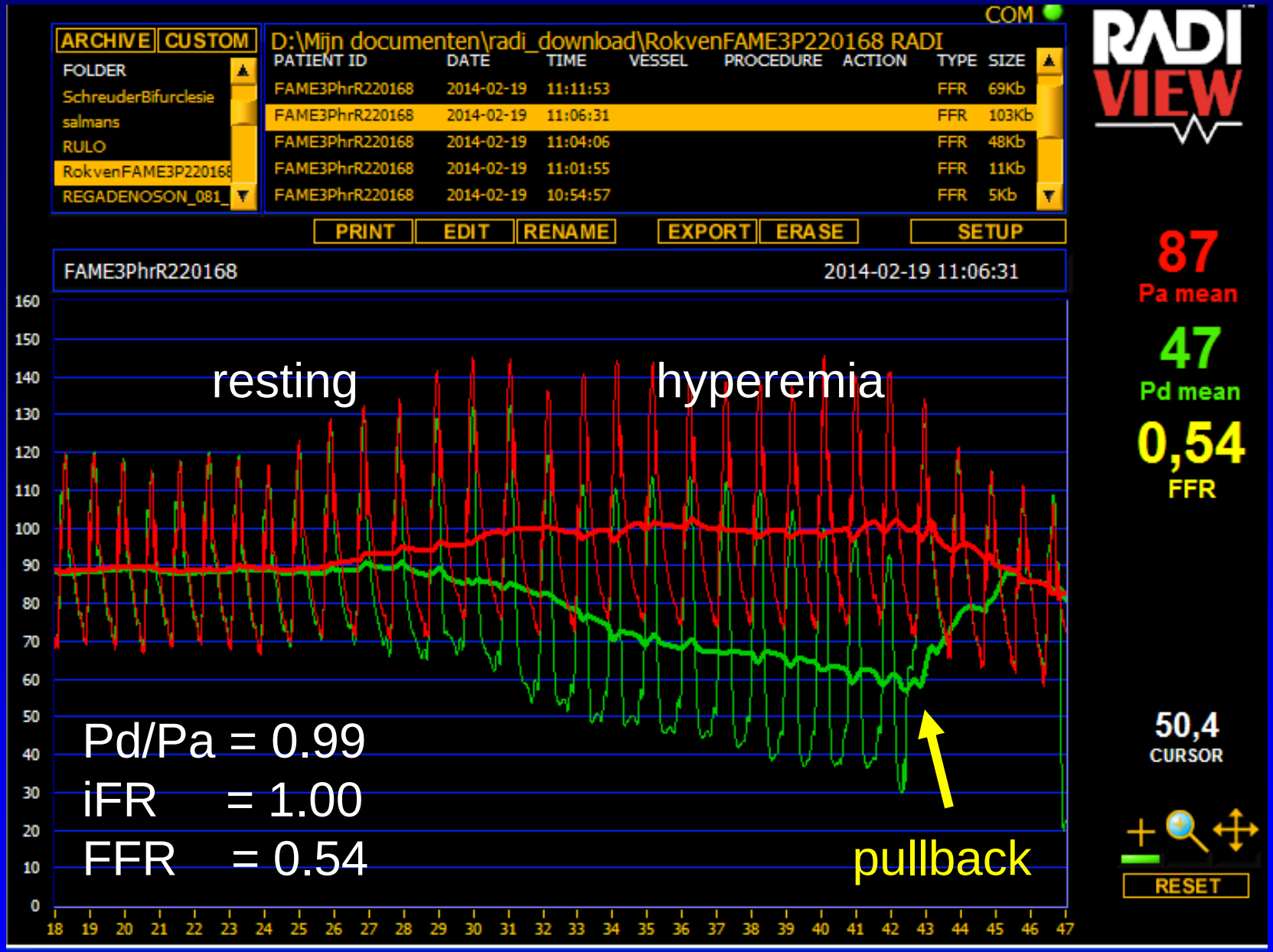
51
52
53
54
55
56



verification of equal pressures when back at guiding

Total time for all measurements in 3 arteries (with central i.v. adenosine) and 3 stents in 2 arteries: 31 minutes



It is often mandatory to use some kind of hyperemia to unmask the true severity of a coronary stenosis !!

In general:

- small perfusion territory, distal stenosis, older patient, moderate long lesion, small artery, microvascular disease:

  → *often moderate gradient at rest with little increase at hyperemia*

- large perfusion territory, proximal stenosis, young patient, short severe lesion, large artery, intact microvasculature:

  → *often minimal gradient at rest with large increase at hyperemia*

Let's have a closer look to FFR

Prerequisites for a reliable index for decision making

- sound scientific basis and experimental validation
- accurate
- reproducible
- easy to perform
- ***predict outcome → tomorrow***

Recent developments:

- wireless connections (*Aeris Wire, SJM*)
- complete integration of FFR measurement in the regular environment of the cathlab *(General Electric)*
- new hyperemic stimuli (single peripheral injection of Regadenoson) → *next speaker*
- non-hyperemic or semi-hyperemic indices and even non-invasive FFR by CT *(friday afternoon session)*
- development of fiberoptic wires and a monorail hypotube *(Opsens, BostonSc, Acist; saturday morning)*

In many complex angiographic conditions, FFR can be assessed as regular:

- **ostial lesions**
- **MVD**
- **left main lesions**
- **tandem lesions**
- **diffuse disease**

} *tomorrow morning*

the hyperemic pull-back recording is necessary to guide where exactly the stent(s) should be Placed and to evaluate the result

FFR and microvascular disease

In microvascular disease, FFR may be higher than it would be without microvascular disease

(Because FFR compares maximum myocardial flow in the presence of the stenosis with maximum flow as it would be without that stenosis, but still not normal because of the microvascular disease)

But it still indicates exactly to what degree maximum blood flow can be improved by stenting an epicardial coronary stenosis !

GUIDELINES ESC SEPTEMBER 2010

FFR UPGRADED TO LEVEL I A INDICATION

10 – Procedural aspects of PCI

Table 28: Specific PCI devices and pharmacotherapy		
	Class	**Level**
FFR-guided PCI is recommended for detection of ischemia-related lesion(s) when objective evidence of vessel-related ischamia is not available	**I**	**A**
DES* are recommended for reduction of restenosis/reocclusion, if no contraindication to extended DAPT	**I**	**A**
Distal embolic protection is recommended during PCI of SVG disease to avoid distal embolisation of debris and prevent MI	**I**	**B**
Rotablation is recommended for preparation of heavily calcified or severely fibrotic lesions that cannot be crossed by a balloon or adequately dilated before planned stenting	**I**	**C**

ESC-EACTS Guidlines for Myocardial Revascularisation, August 30, 2010

Finally, a few practical tips…..

OPTIMUM FFR TECHNIQUE: catheters

Guiding or diagnostic catheter ? 6F or smaller ?

- FFR has been measured by 5F diagnostic catheters

- but: - *more difficult steering/wire manipulation* (because diagnostic catheter lacks inner coating)
  - *damping of aortic pressure signal* due to smaller lumen

→ ***I advice to use guiding catheter***
(changing catheter is less cumbersome than long manipulation with wire or suboptimum signal

OPTIMUM FFR TECHNIQUE: manipulation of PW

How to prepare and manipulate the pressure wire

- short curve of 45-60 degree

- use the pressure wire with a torquer (cf Sion wire), i.e. *true steering*

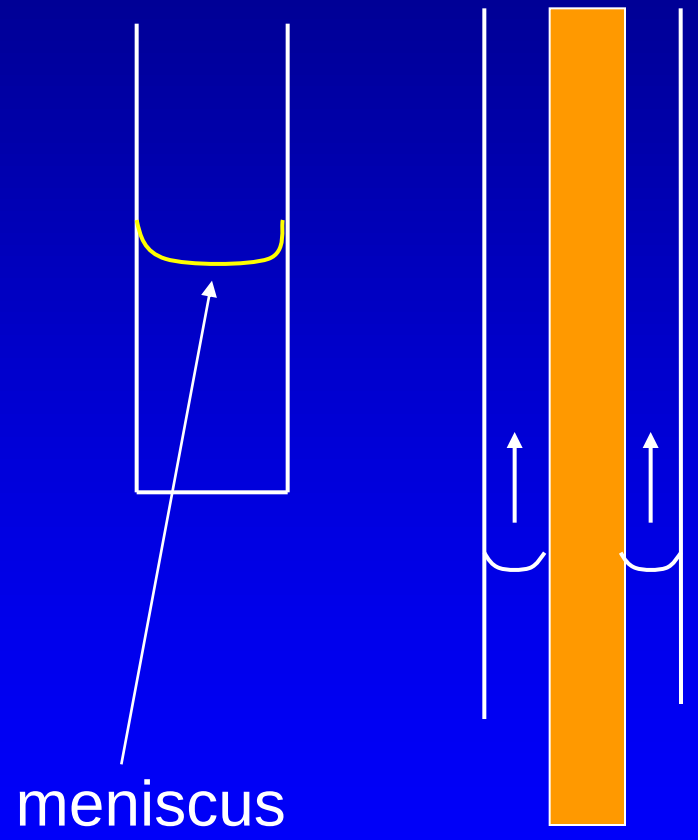
OPTIMUM FFR TECHNIQUE: decrease of drift

How to decrease (apparent) drift

- after equalization (sensor at the tip of the guiding catheter), *wait for 20-30 seconds for stabilization* (small airbubbles in sensor cavity are flushed away)

- realize that more often as you believe, there is no drift but an inaccuracy with the guiding catheter signal (*dynamic pressure; capillary forces; you forgot about the introducer*)

Capillary forces in guiding catheter



sometimes capillary forces result in misregistration of pressure by the guiding up to 10 mm Hg

in procedures without pressure wire, this remains unnoticed

vigorous manual flushing of the guiding with 5-10 cc of saline, might restore true aortic pressure

Starting – up FFR measurements in your Lab:

- study the principles and understand the concept
- be prepared to rely upon your brains, rather than on the angio: what you measure is more reliable than what you see
- involve your nurses/technicians/residents and convince your fellow staff members
- do not just an occasional patient with a mild stenosis once in a week, but use the PW consistently in 10 or 20 consecutive cases (also in tight stenosis) during 1 or 2 weeks and try out several hyperemic stimuli

HOW TO START A FFR PROGRAM IN YOUR CATH-LAB

cooperation of your nurses is of paramount importance !

- preparing the equipment, cables, pressure wire
- taking care of hyperemic stimulus
  (keep it simple)
- anticipate to the procedure, remind you to measure
- willingness to spend some extra time, if needed

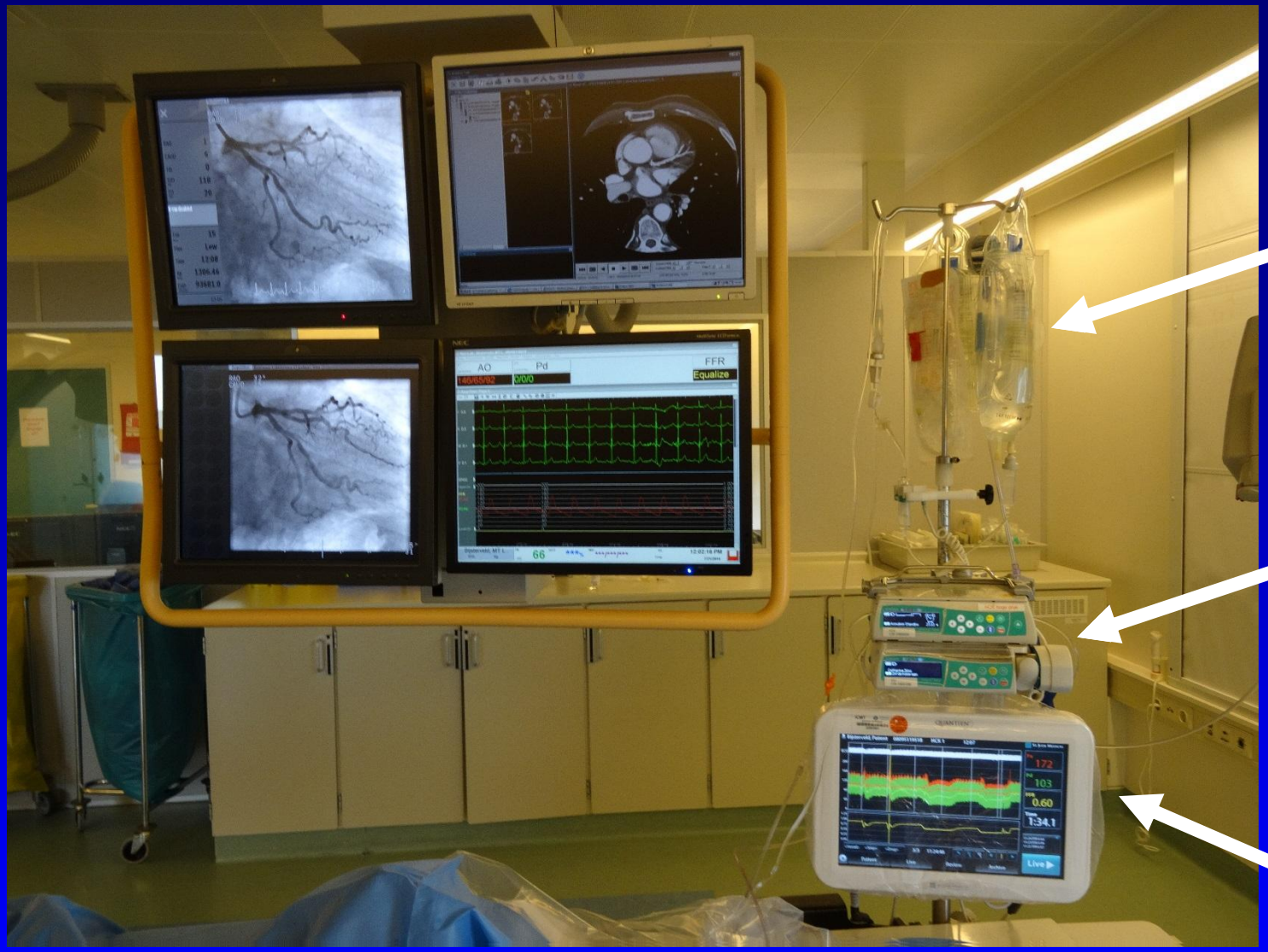
therefore, train your nurses and make them understand the principles, practice, and great advantages of FFR

Similar for fellows and colleagues !

....and last but not least:

EASY to use **means** ***READY to use*** **:**

→ Design the configuration in your cath.lab in an optimum way to enable instantaneous use of the PressureWire if the case demands it



Practical logistics in the cath lab: *Keep it simple*

Catharina Hospital, Eindhoven, NL

1600 FFR cases per year

“It is a pleasure to measure pressure”

EINDE