Imaging & Physiology Summit

PITFALLS IN FFR, iFR, CFR, IMR MEASUREMENTS

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Potential conflicts of interest

Speaker's name: NICO H J PIJLS

☒ **I have the following** potential conflicts of interest to report:

- ☒ Research contracts : St Jude Medical
- ☒ Consulting: St Jude Medical, Boston Scientific,Opsens
- ☐ Employment in industry
- ☒ Stockholder of a healthcare company: Philips, GE, ASML, Heartflow
- ☐ Owner of a healthcare company
- ☐ Other(s):

☐ **I do not have any potential conflict of interest**

RECOGNIZING PITFALLS DURING CORONARY PRESSURE MEASUREMENTS

Part 1: "technical pitfalls", related to practicalities during the procedure

→ avoidable by practical tips & tricks and skills *related to introducer, drift, guiding catheter, wire manipulations, practicalities of hyperemia*

Part 2: "physiologic" pitfalls & interpretation errors (avoidable by knowledge of physiology)

First a few practical tips to optimize your technique:

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

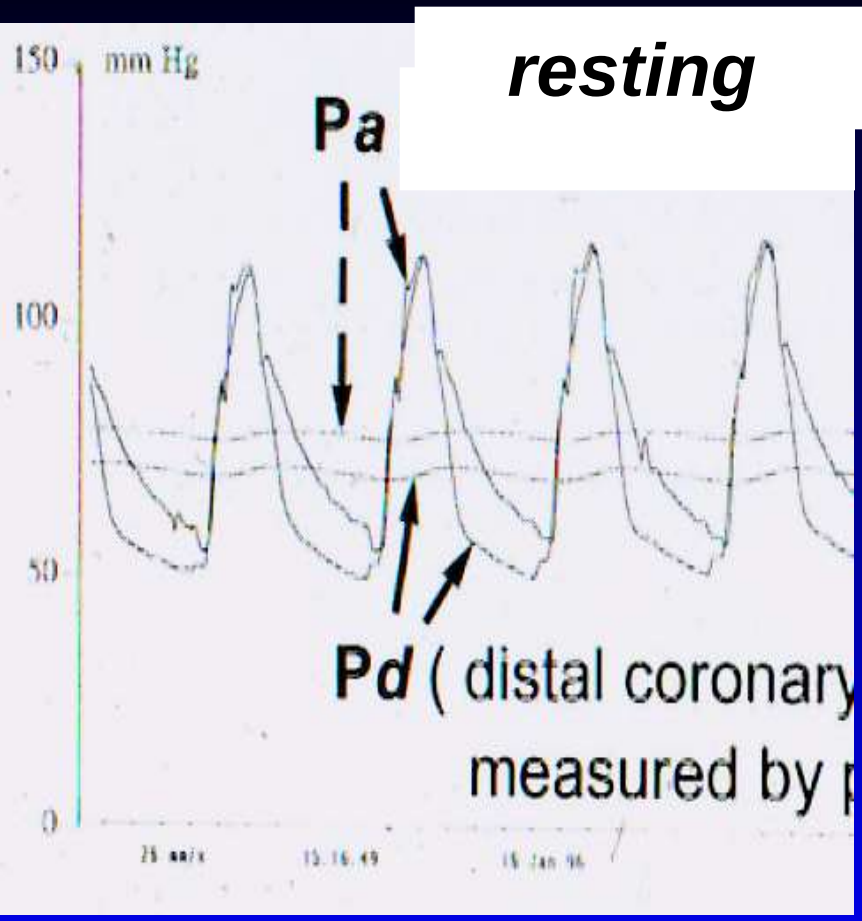
How to prepare and manipulate the pressure wire

- short curve of 45-60 degree

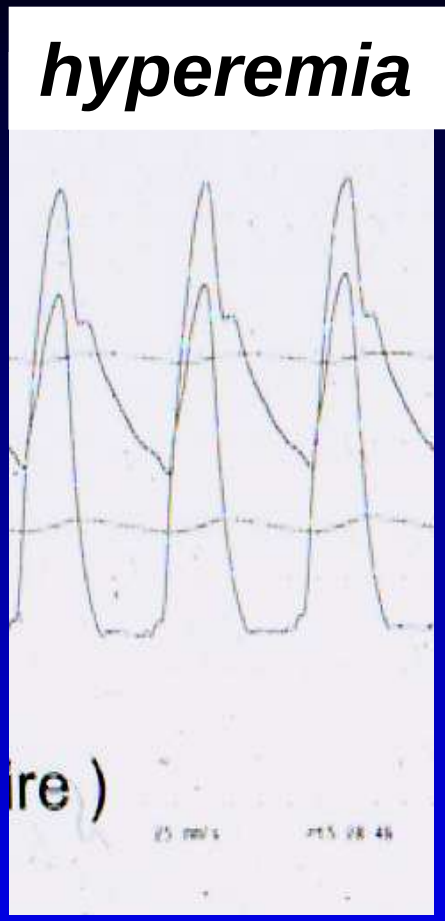
- use the pressure wire with a torquer (cf Sion wire), i.e. true steering

Most common pitfalls :

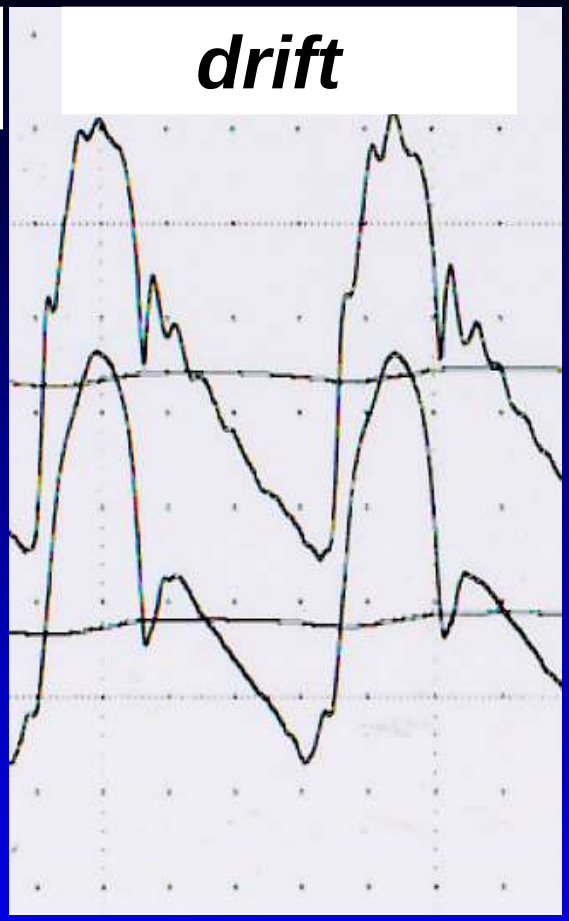
- ***drift of the signal***
- **introducer**
- **pitfalls associated with guiding catheter**
- **insufficient hyperemia**



resting



hyperemia



drift

Normal resting signal :

- Almost no systolic gradient
- small or moderate diastolic gradient

Hyperemia:

- also systolic gradient
- much larger diastolic gradient

drift:

- parellel signals
- diastolic notch remains visible

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 air-bubbles in sensor cavity are flushed away)

- if there is some *apparent drift* at the end of PCI, did you measure with the introducer before and without it afterwards ? (difference 3-10 mmHg)

Drift in the different pressure wires:

Electronic wires:

- *St Jude Medical: < 7 mmHg / hour*
- *Philips/Volcano: < 30 mmHg / hour*

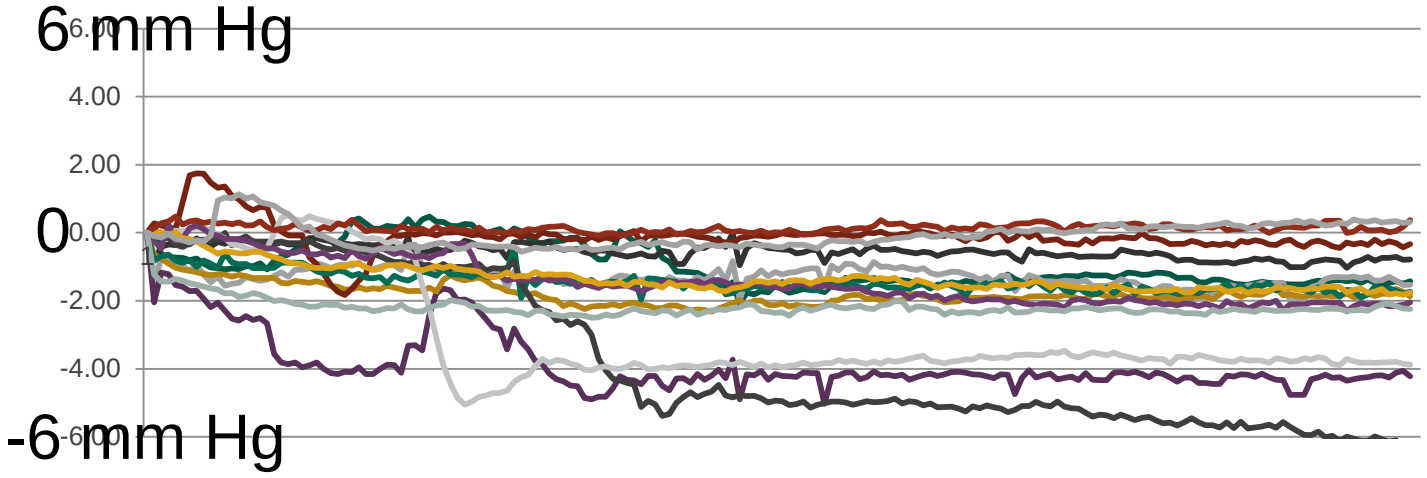
New fiberoptic wires:

- *Opsens (Optowire): ~ 0 mmHg*
- *Acist (Navvus): ~ 3 mmHg /h*
- *Boston Sc (Comet) : ?*

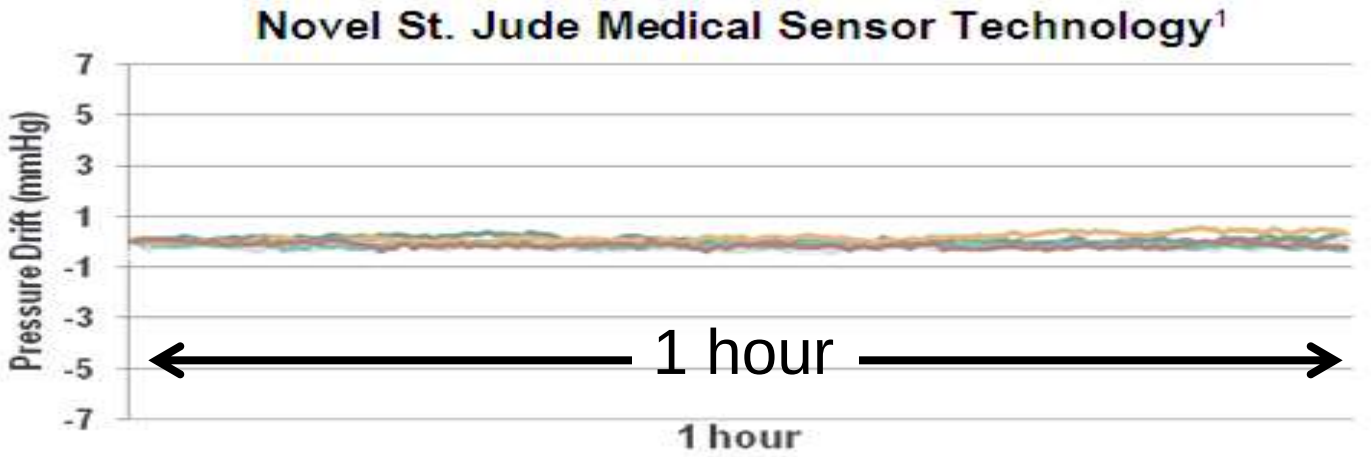
Resolution of resting vs hyperemic measurements

- *The intrinsic error in FFR measurement with electronic guidewires (St Jude Medical, Volcano) is 0.01-0.02*
- *the total hyperemic pressure gradient within a coronary artery, is generally 2-3 x higher than the resting gradient.*
- *Therefore, the accuracy of resting measurements like iFR (signal-to-noise ratio) is more affected by drift*
- *Consequently, the relative error of iFR or Pd/Pa at rest, is 2-3 x higher than with hyperemia / FFR*
- *in a similar way, the resolution of the pull-back recording is 2-3 x lower with iFR compared to FFR*

Present SJM Aeris wire:



Next generation aeris wire (*PressureWireX*)

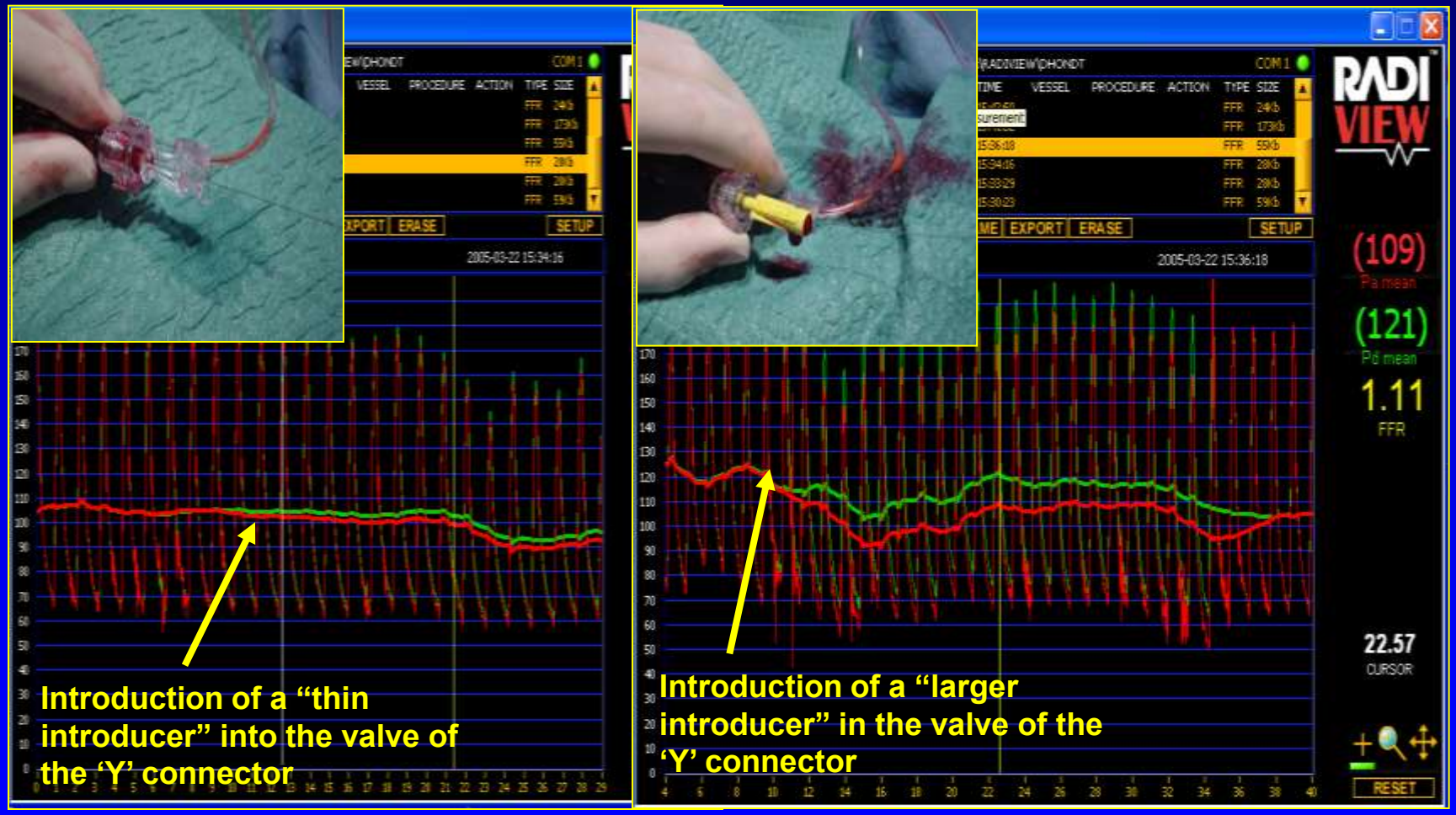


Most common technical pitfalls :

- **drift of the signal**
- ***introducery needle***
- **pitfalls associated with guiding catheter**
- **insufficient hyperemia**

Introducer effect *(mistake in live case in PCR 2014!)*

Specifically important when pre-PCI assessment was with introducer and post-PCI assessment without it



Most common technical pitfalls :

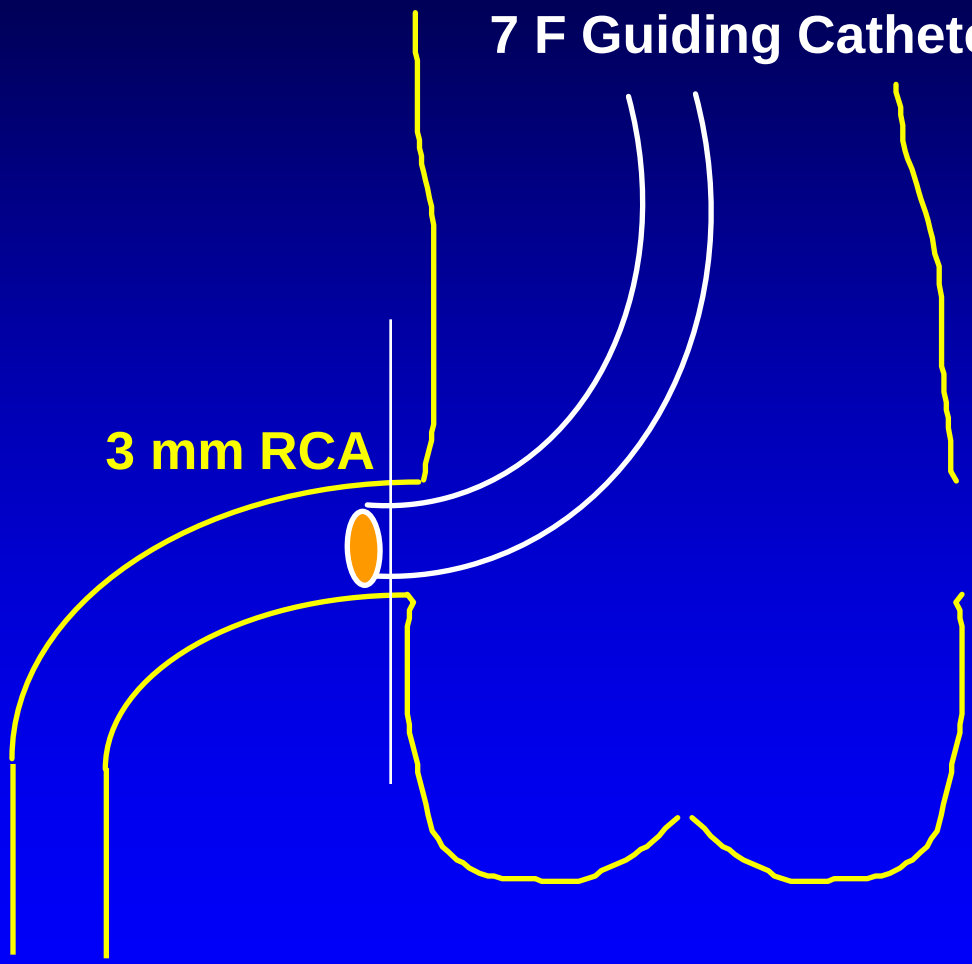
- **drift of the signal**
- **introducery needle**
- ***pitfalls associated with guiding catheter***
  (especially important in assessment of ostial lesions)
- **insufficient hyperemia**

pitfalls associated with guiding catheter

- ***avoid wedging***
  (deep engagement during measurement)

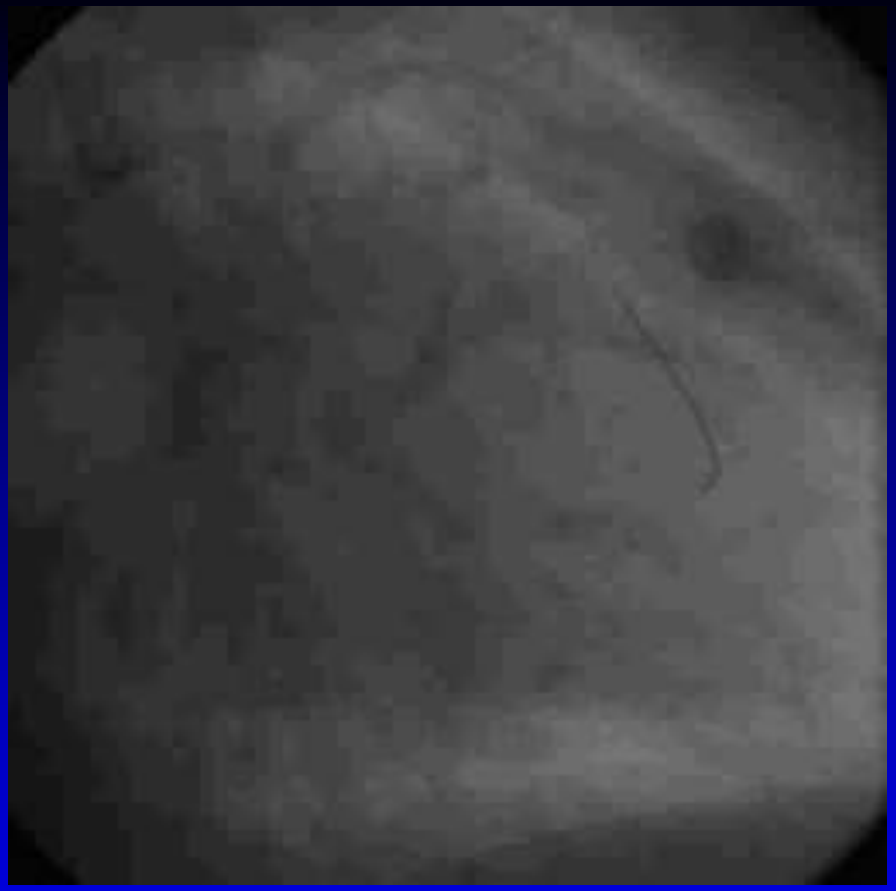
- ***special caveat with sideholes***

2. Wedging of the Guiding Catheter



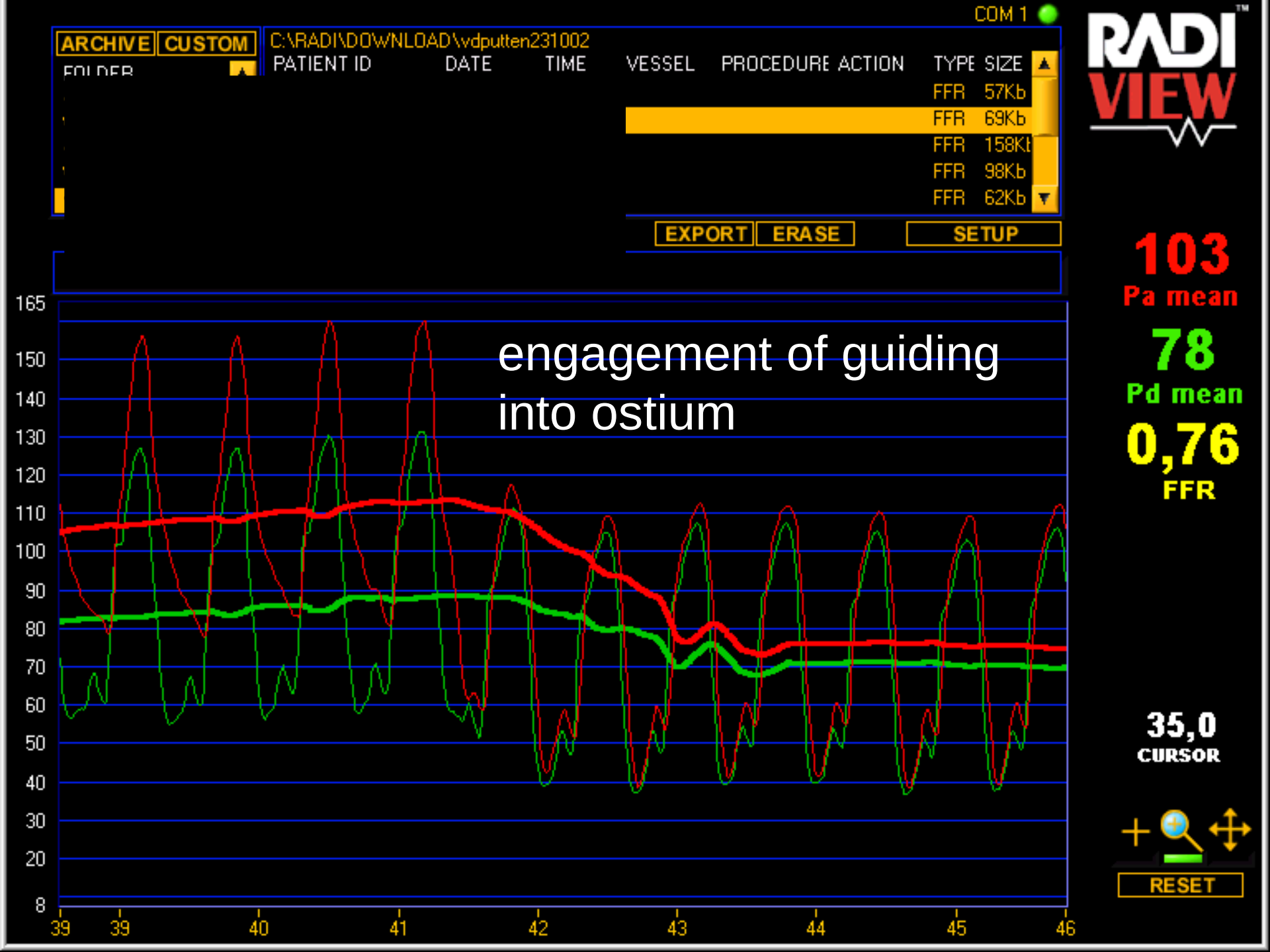
50% Area Stenosis

Recent study by Belgian Group



Influence of guiding catheter on FFR in case of narrow ostium

→ *use i.v. adenosine and dislodge guiding during measurement*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SETUP
RADI VIEW
103
Pa mean
78
Pd mean
0,76
FFR
35,0
CURSOR
RESET
engagement of guiding into ostium
165
150
140
130
120
110
100
90
80
70
60
50
40
30
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8
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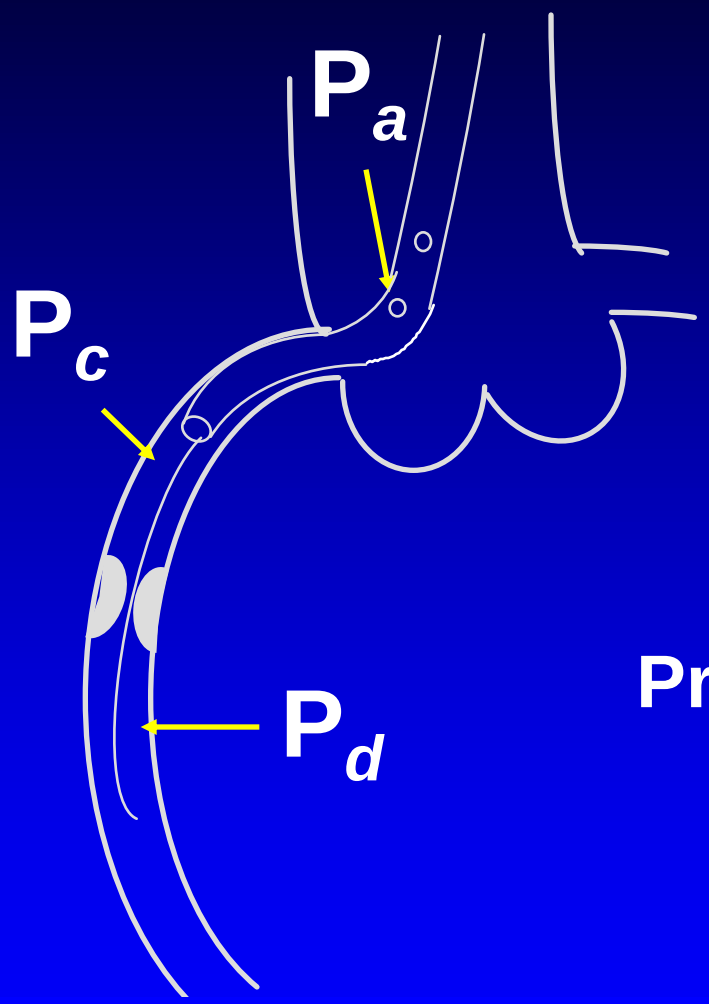
45
46

FFR and Guiding catheter with Sideholes

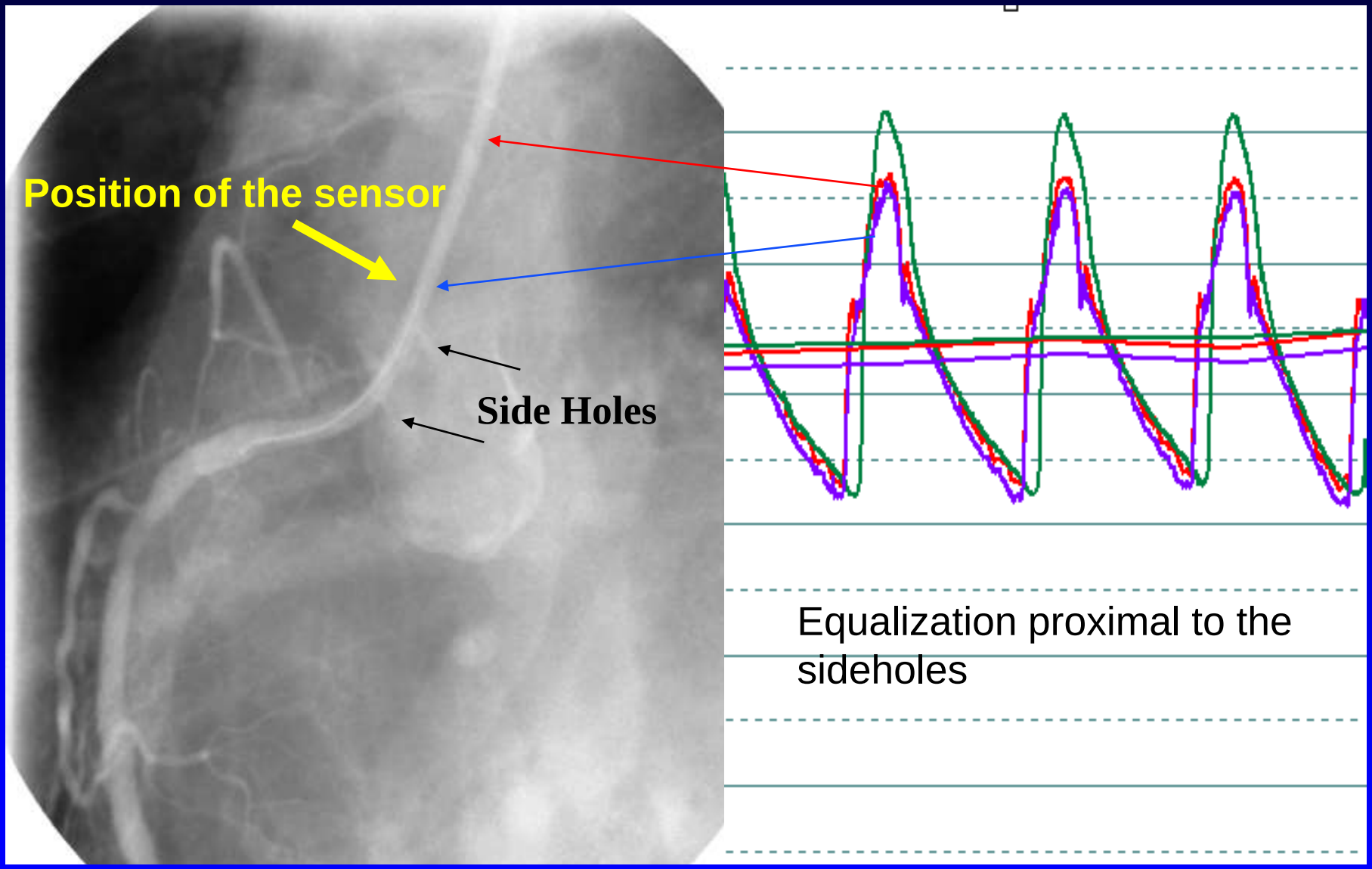


$P_c \neq P_a$

Pressure recorded by guiding

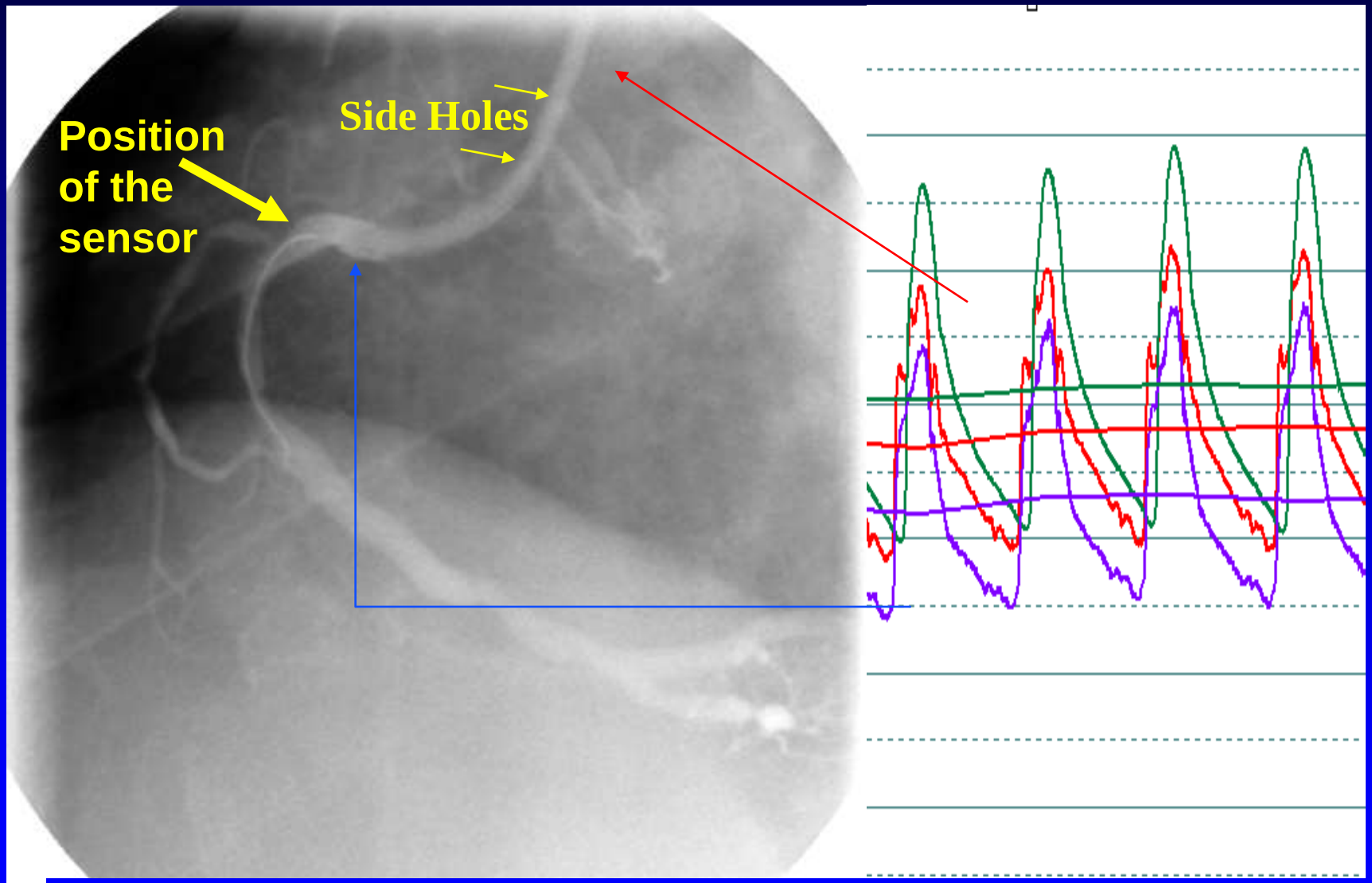
When wedging of the catheter or guiding cath with sideholes, dislodge guiding from ostiumduring the measurement

Guiding Catheter With Sides Holes



Sensor proximal to side holes

Guiding Catheter With Sides Holes



Sensor in the proximal RCA + hyperemia

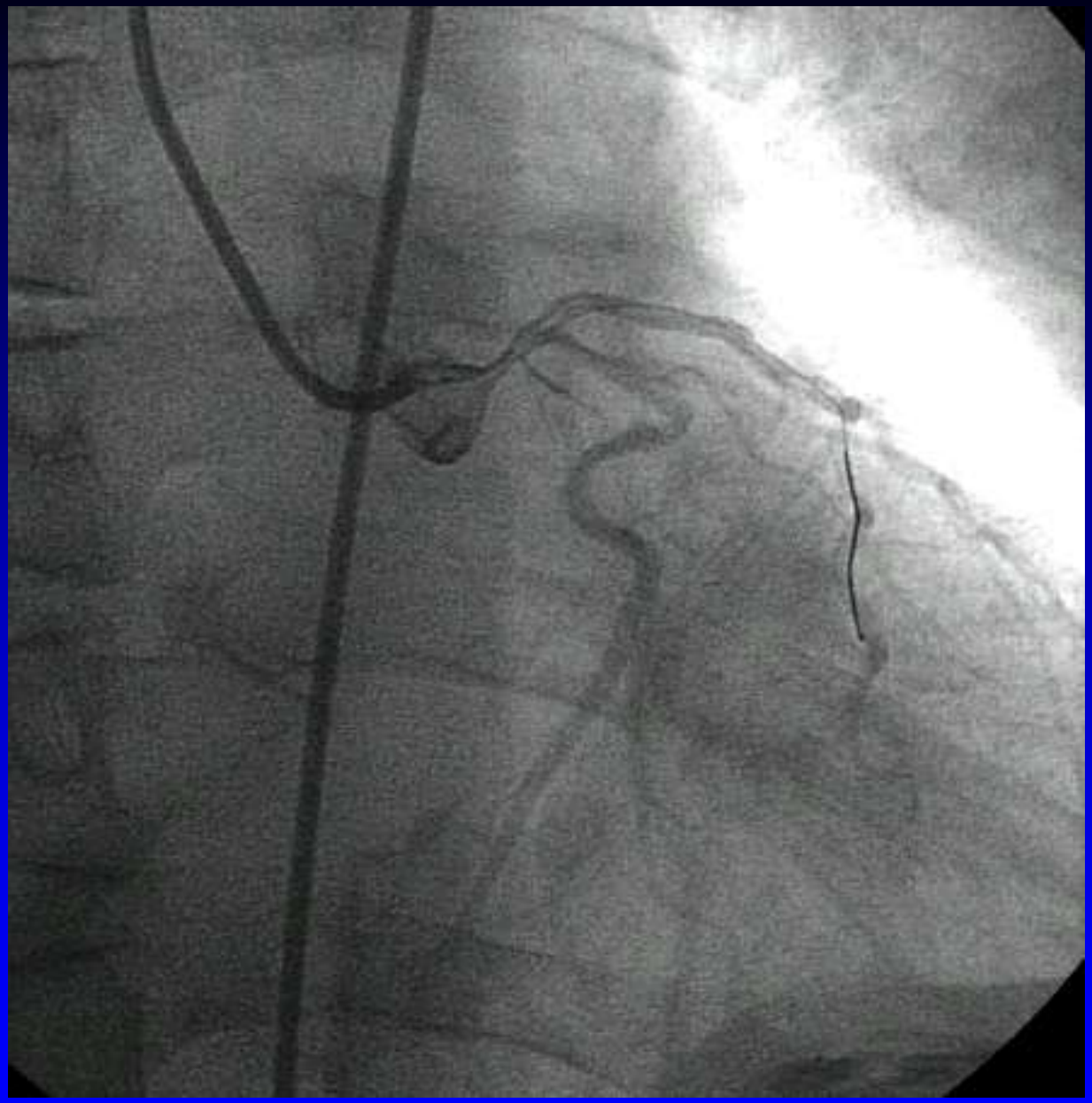
Coronary Pressure: Pittfalls and Artifacts:

If there is "damping" , small ostium, or if you are using guiding catheter with sideholes:

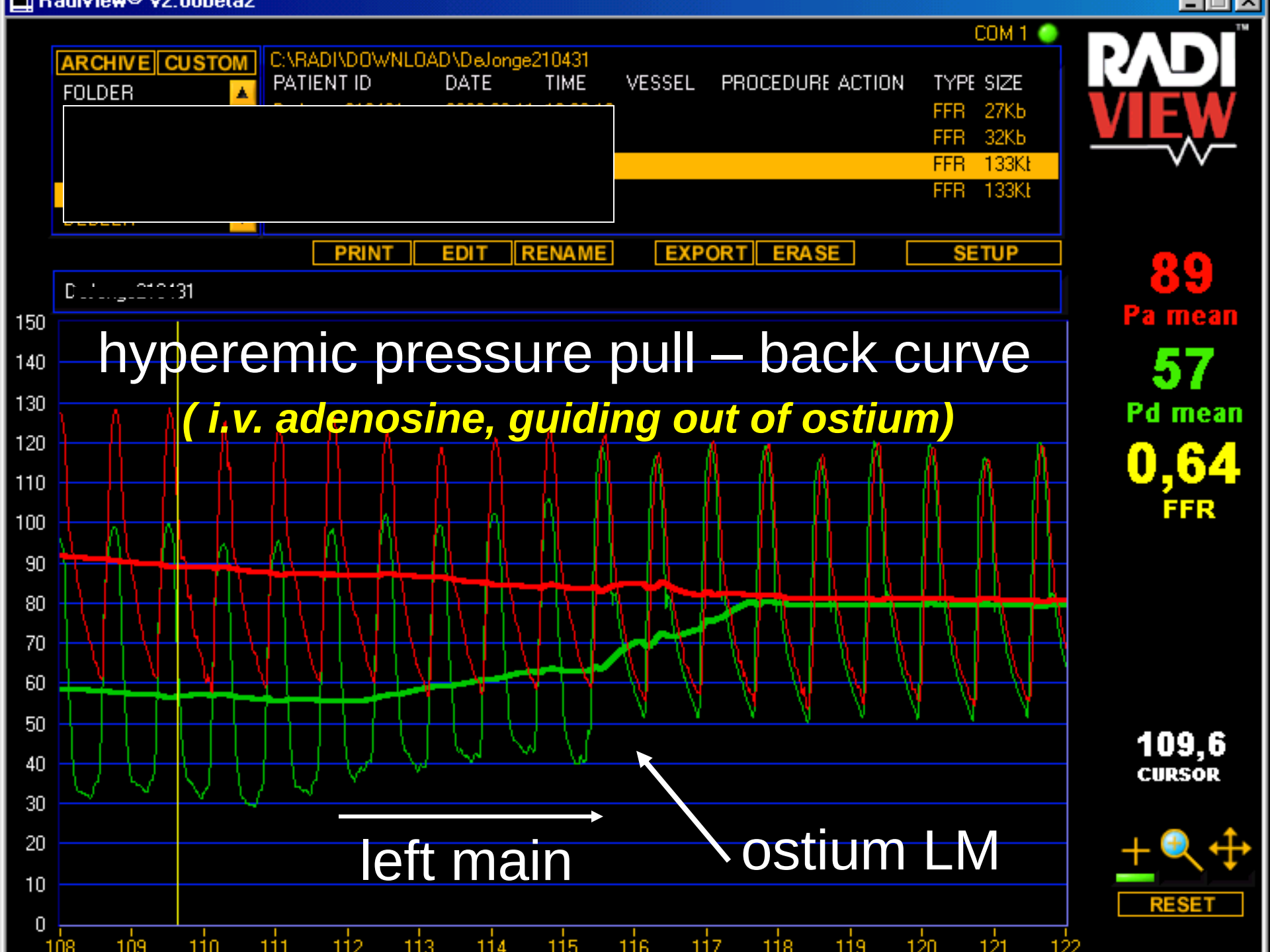
→ ***use i.v. adenosine and withdraw guiding slightly from ostium during measurement***

(often most convenient by pushing up the PW)

Note: also i.v. regadenoson bolus enables reliable interrogation of ostial stenosis



PressureWire in LAD, guiding catheter dis-engaged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PRINT
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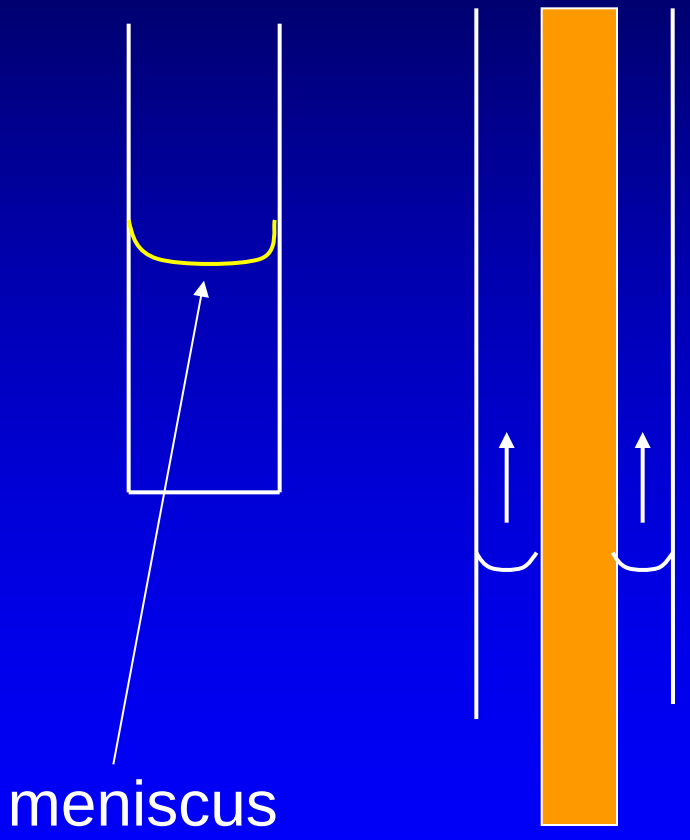
RENAME
EXPORT
ERASE
SETUP
RADI VIEW
89
Pa mean
57
Pd mean
0,64
FFR
109,6
CURSOR
RESET
hyperemic pressure pull – back curve
(i.v. adenosine, guiding out of ostium)
left main
ostium LM
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122

A LAST PITFALL ASSOCIATED WITH GUIDING CATHETER (especially at end of procedure and easily Interpreted as drift of the PW) :

- pressure artifacts by the guiding

  → *vigorous flushing*

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

Importance of Maximum Hyperemia (1):

MAXIMUM HYPEREMIA IS OF IMPORTANT

Insufficient hyperemia

↓

Underestimation of gradient

↓

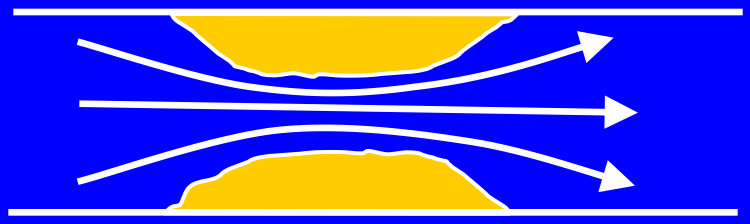
Overestimation of FFR

↓

Underestimation of stenosis severity

$\Delta P = f.Q + s.Q^2$

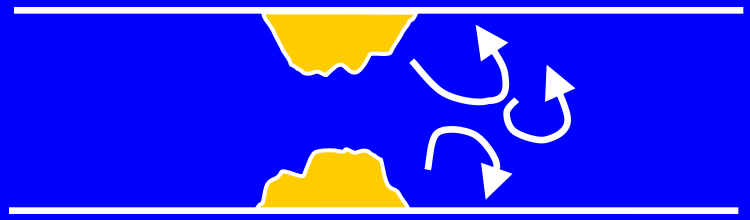
f = friction coefficient



Moderate gradient at rest

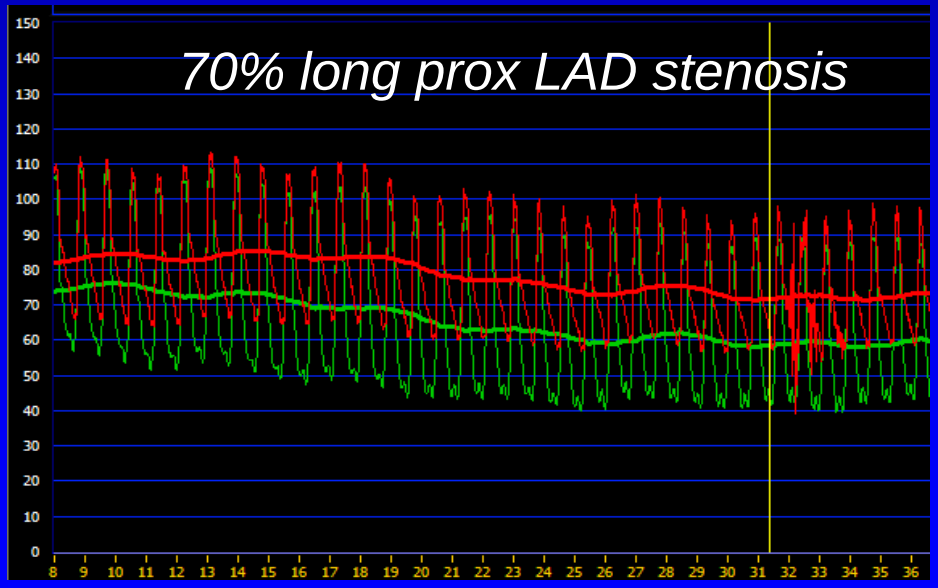
Moderate increment at hyperemia

S = separation coefficient

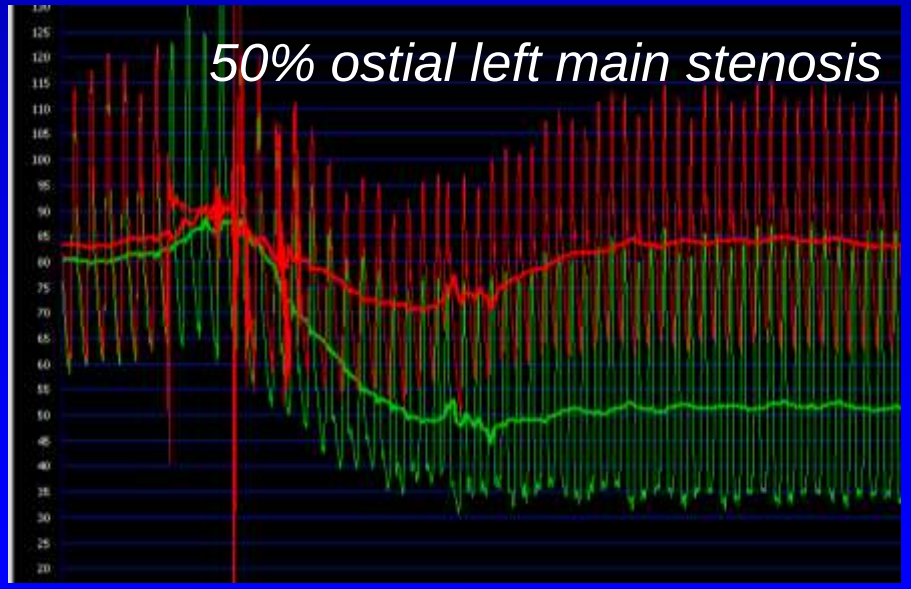


Small gradient at rest

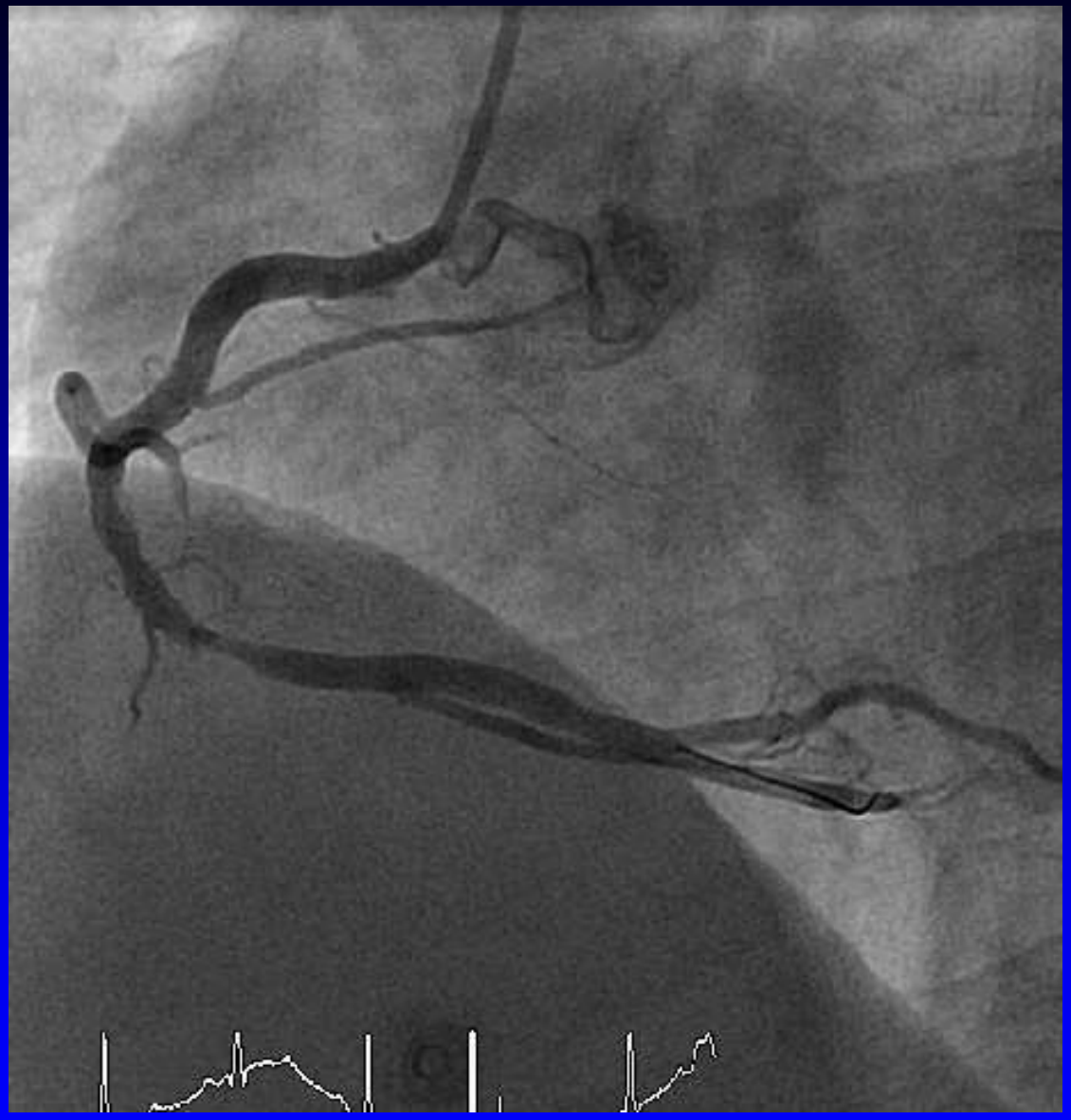
Large gradient at hyperemia



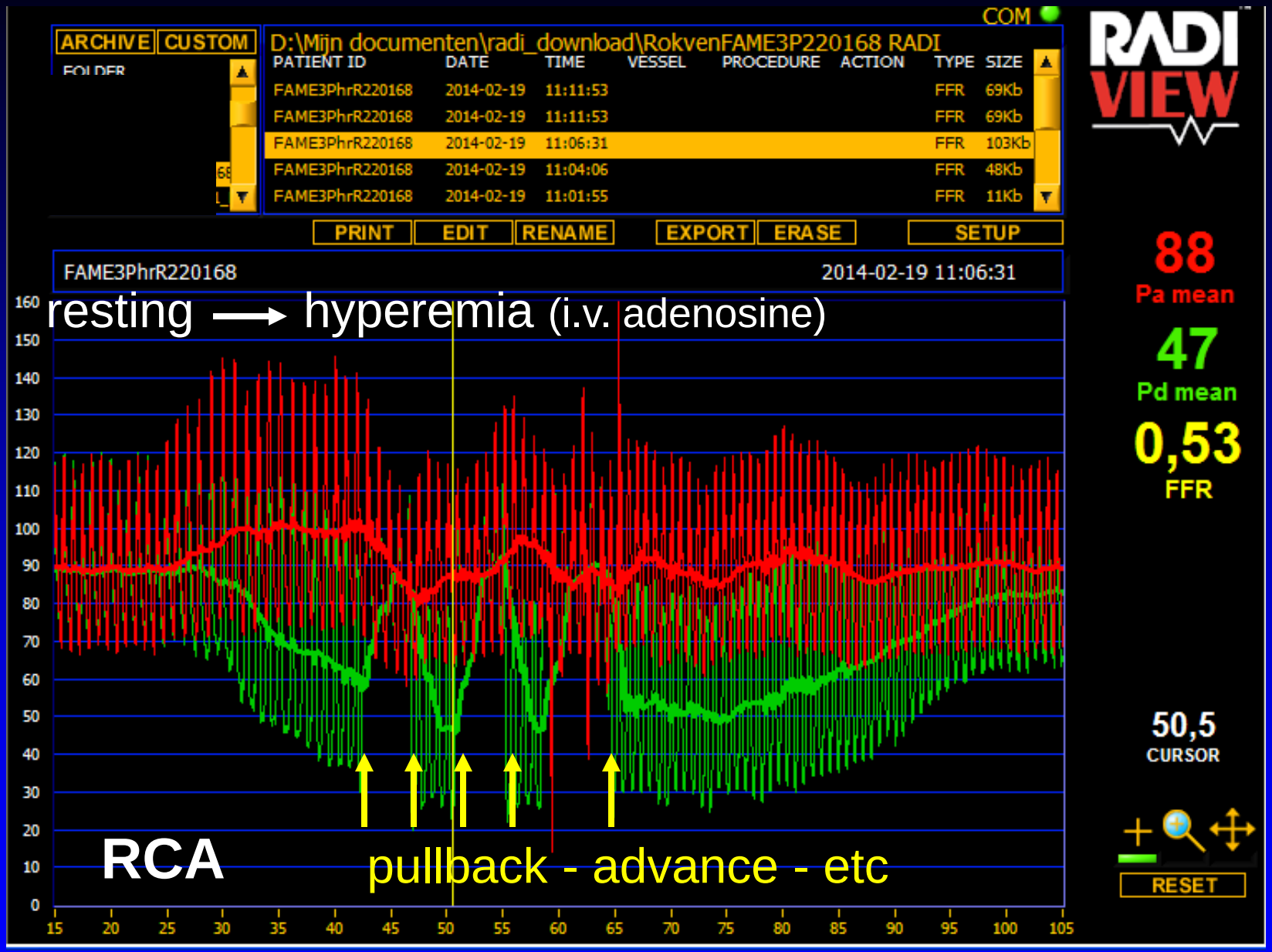
iFR = 0.89 FFR = 0.85



iFR = 0.94 FFR = 0.57



PressureWire in RCA in 46-year old male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FAME3PhrR220168 2014-02-19 11:11:53 FFR 69Kb
FAME3PhrR220168 2014-02-19 11:06:31 FFR 103Kb
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PRINT
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RADI VIEW
88
Pa mean
47
Pd mean
0,53
FFR
50,5
CURSOR
RESET
resting ⟶ hyperemia (i.v. adenosine)
RCA
pullback - advance - etc

Hyperemia necessary ?

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*

OPTIMUM FFR TECHNIQUE: *hyperemia mandatory?*

Realize that:

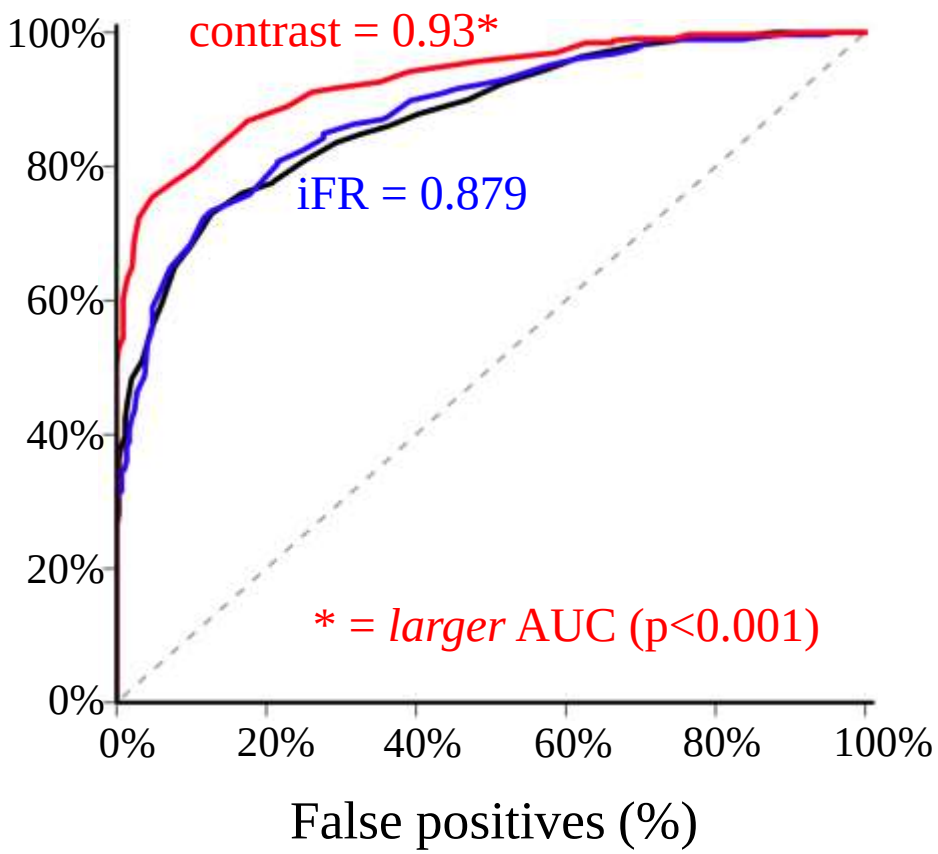
- resting indices poorly predict hyperemic measurements

- diagnostic accuracy decreases to 80%

  Verify study, N=200, prospective and consecutive
  Resolve study, N=1600, retrospective
  Advise-2 study, N = 650, prospective
  Contrast study, N= 750, prospective

- pullback recording is time-consuming and has poor resolution without hyperemia

Submaximal Hyperemia with a single routine Contrast injection: CONTRAST study (LBT at PCR)



Diagnostic accuracy of different indices compared to FFR:

iFR:	***79%***	***P < 0.001***
Pd/Pa at rest:	***80%***	
Contrast FFR (cFFR):	***85 %***	

Johnson et al, LBT at PCR, in press

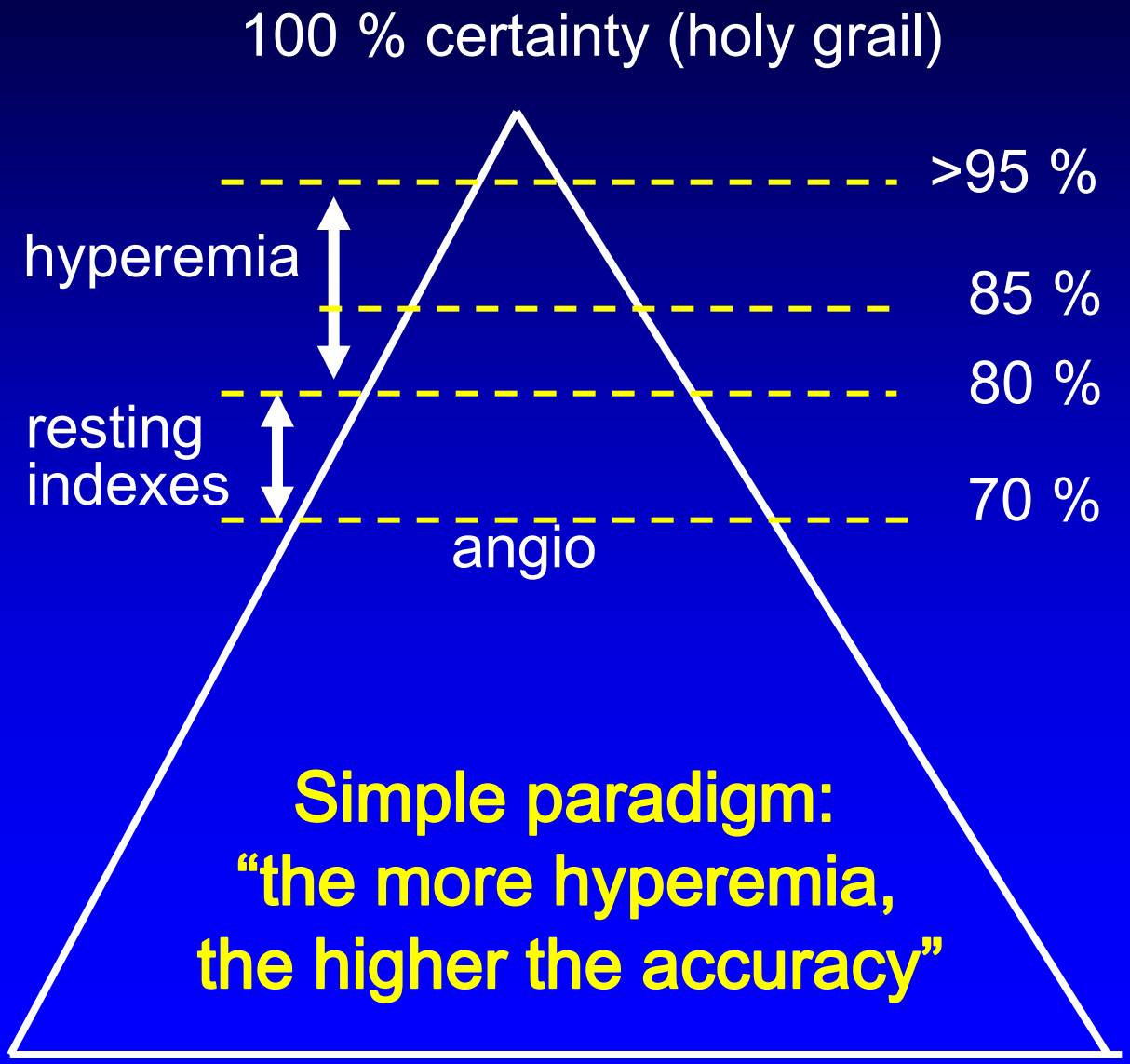
Correct Classification of Ischemic Stenosis

FFR

Contrast cFFR

resting Pd/Pa, iFR,

angiography



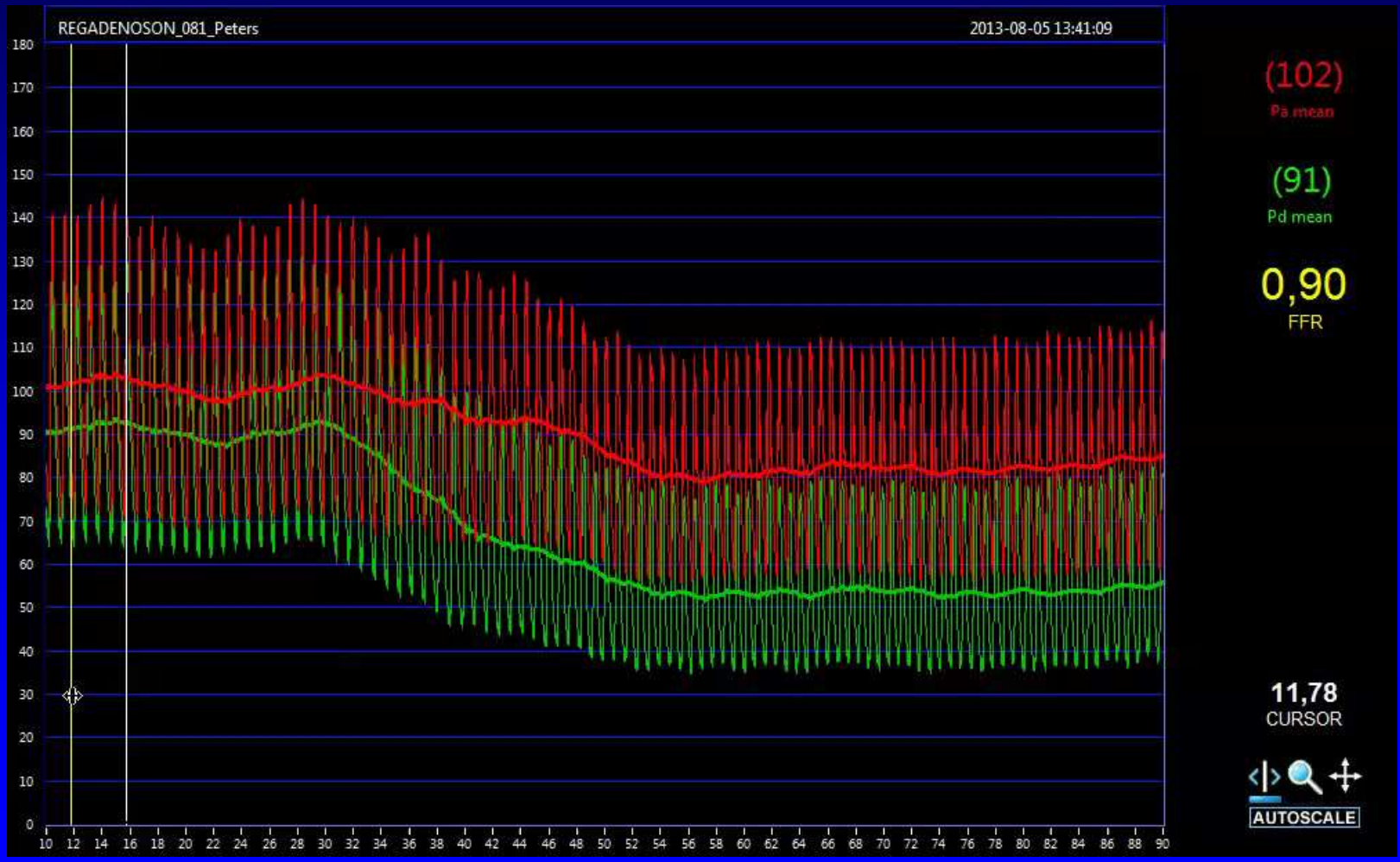
MAXIMUM VASODILATORY STIMULI

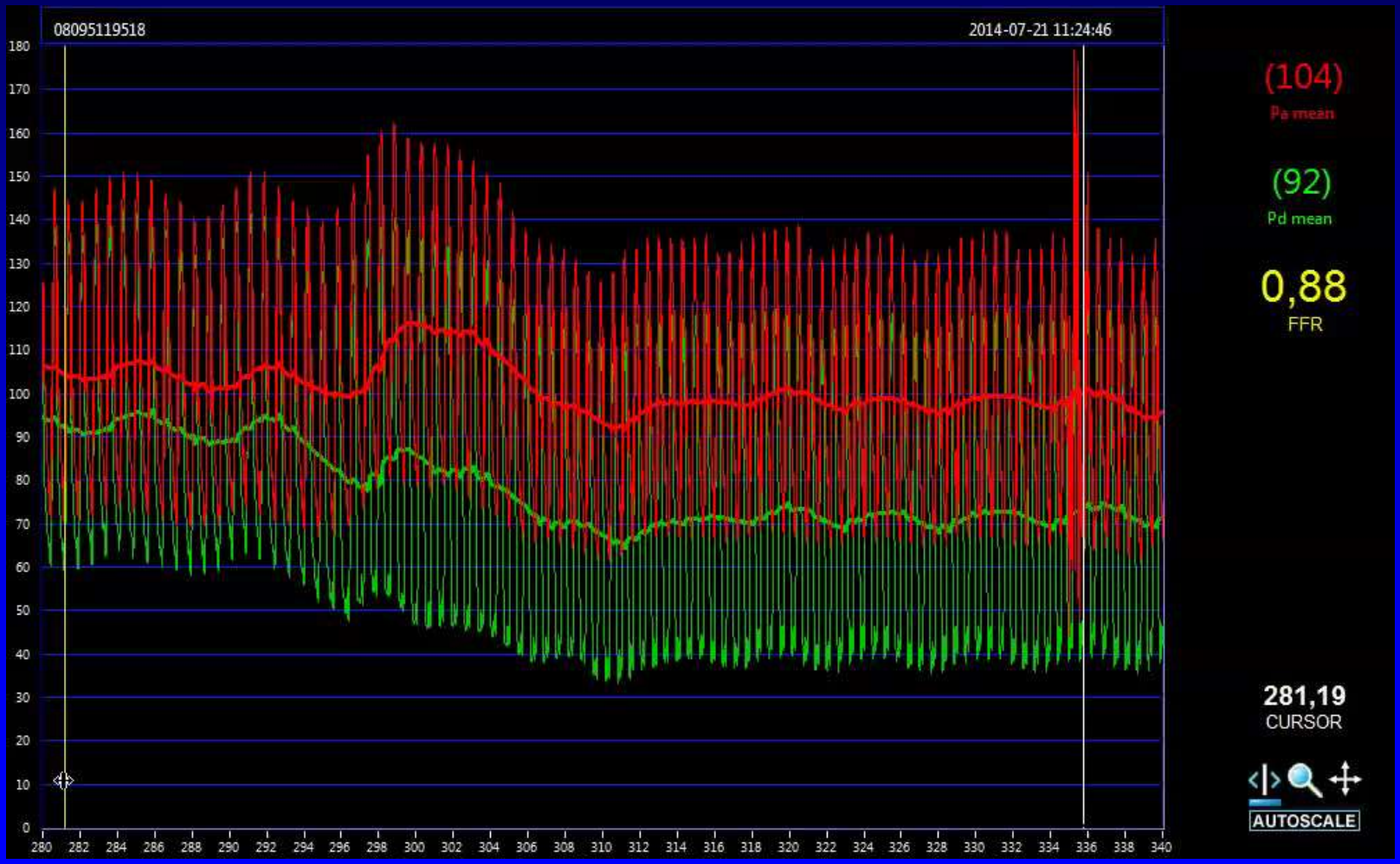
- PAPAVERINE i.c. (12 mg RCA, 20 mg LCA)
- ADENOSINE i.c. (100 µg RCA, 200 µg LCA)
- ADENOSINE i.v. (140 µg/kg/min)
- ATP i.c (idem adenosine)
- ATP i.v. (idem adenosine)
- regadenoson (400 µg as i.v. single bolus)

A few words about i.v. adenosine:

Do fluctuations occur? → *Yes, in 40 % of patients*

Are they a problem? → *No, not at all !*


REGADENOSON_081_Peters
2013-08-05 13:41:09
(102)
Pa mean
(91)
Pd mean
0,90
FFR
11,78
CURSOR
AUTOSCALE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(104)
Pa mean
(92)
Pd mean
0,88
FFR
281,19
CURSOR
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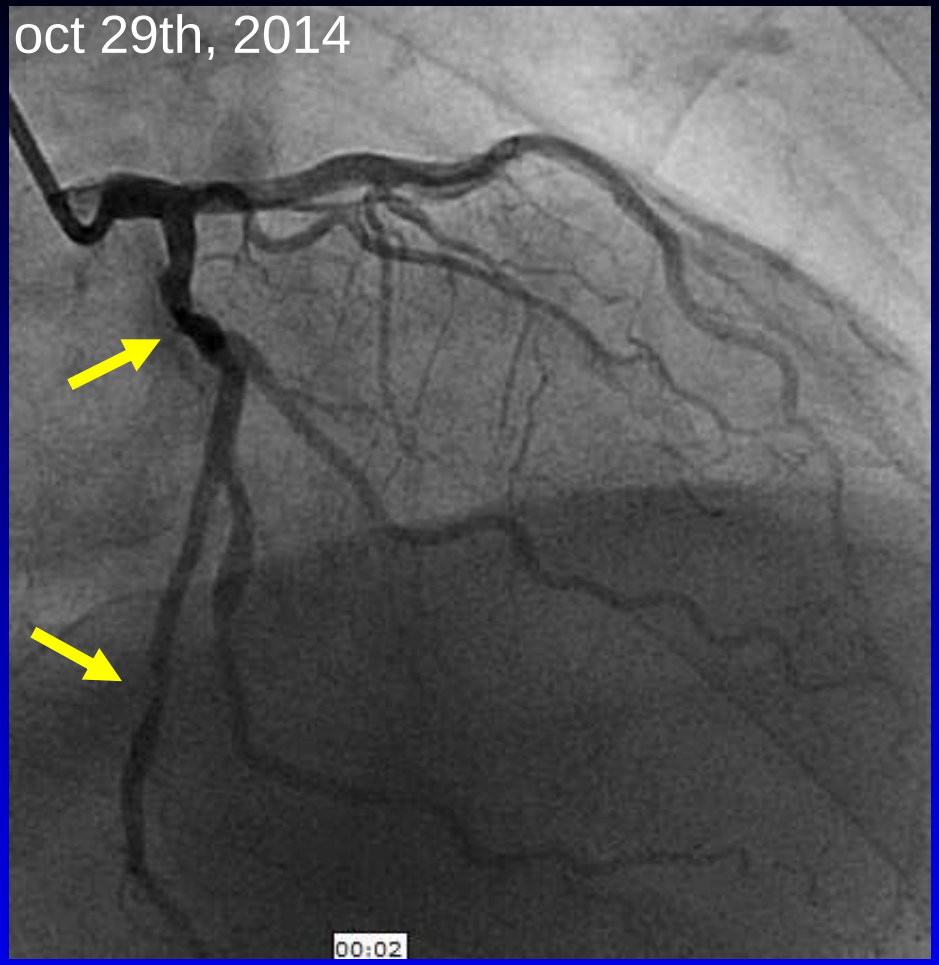
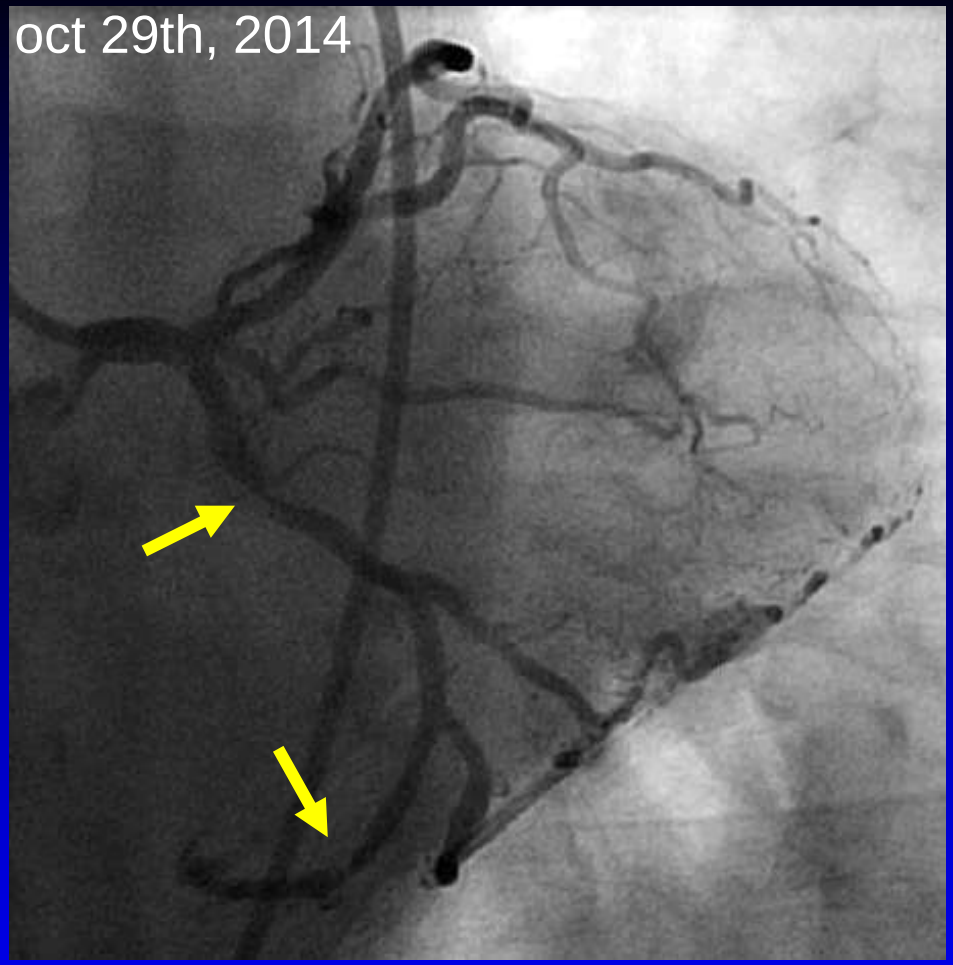
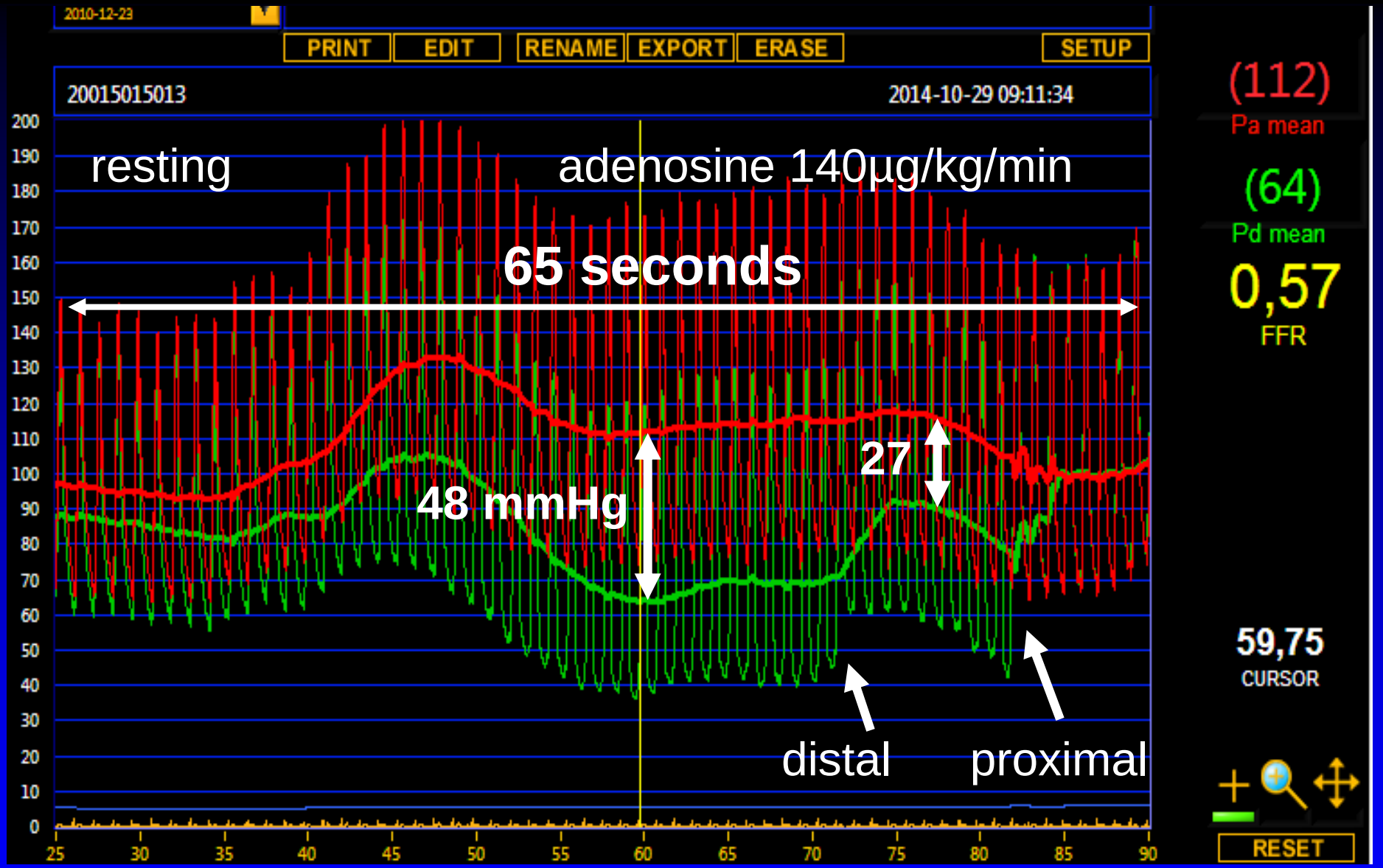
CAVEAT:
Resolution of resting vs hyperemic measurements

also the resolution of the pull-back recording is 2-3 x lower with iFR (“iFR-scout”) compared to FFR



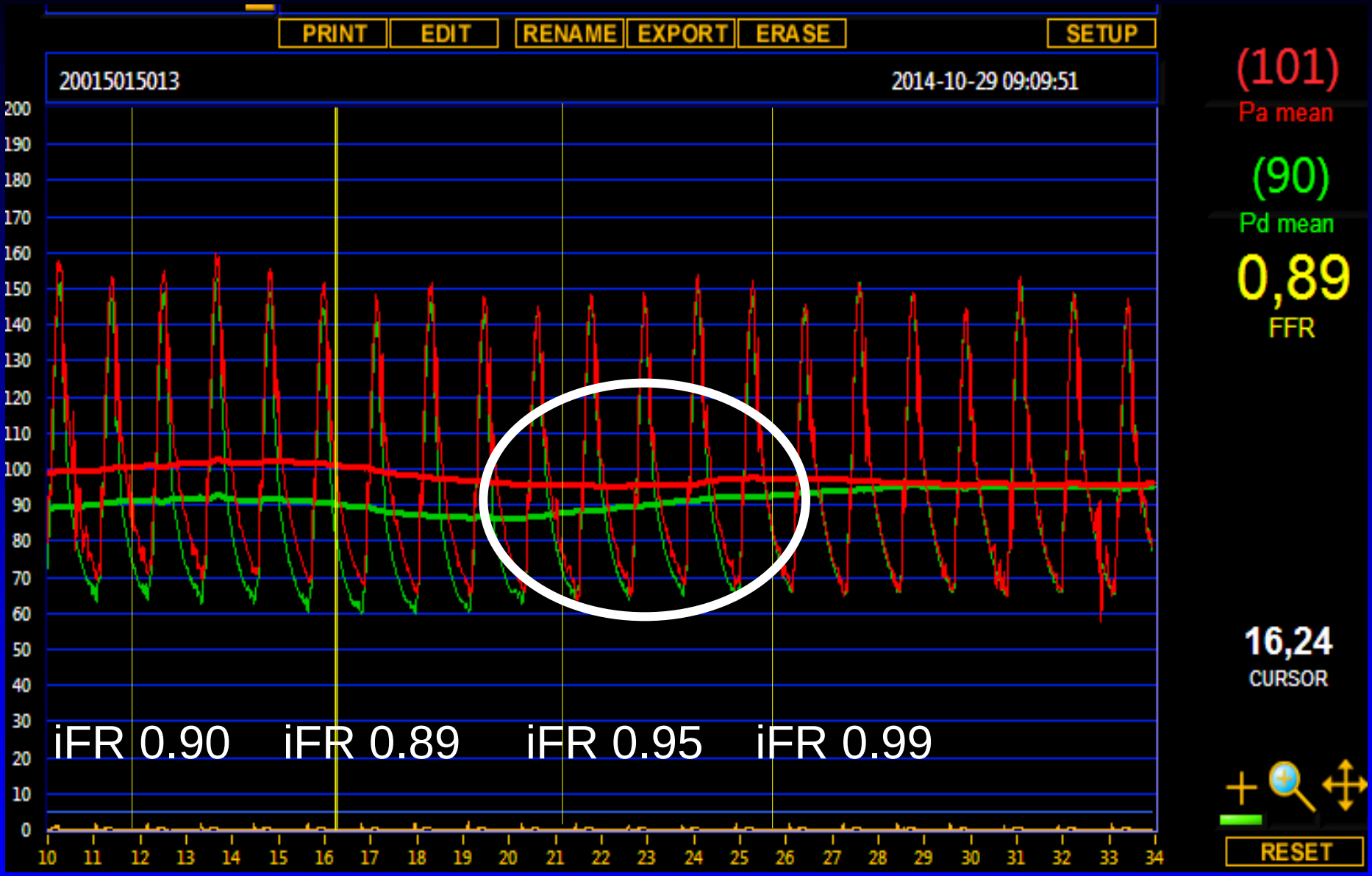


Male, 65-year-old, typical angina,
inferolateral reversible defect at MIBI-SPECT
70% lesions in proximal & distal dominant LCX



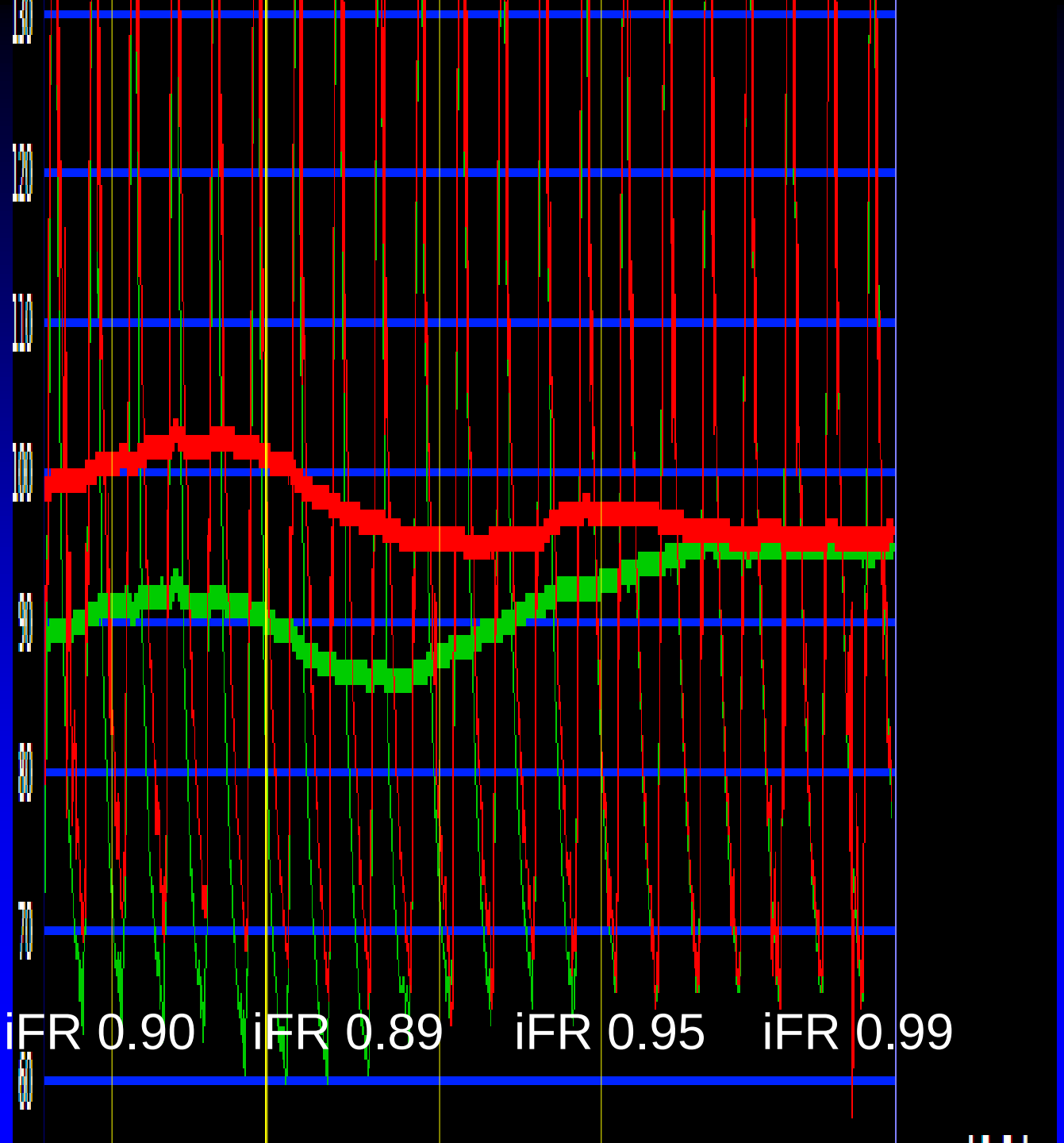
hyperemic pullback recording:

rapid, reliable, detailed information within seconds



"resting" pullback recording with multiple iFR:

time-consuming, less reliable, less detailed information



Blowing up the scale does not add more information

7 mmHg

iFR Scout : blowing up the scale does not improve precision !

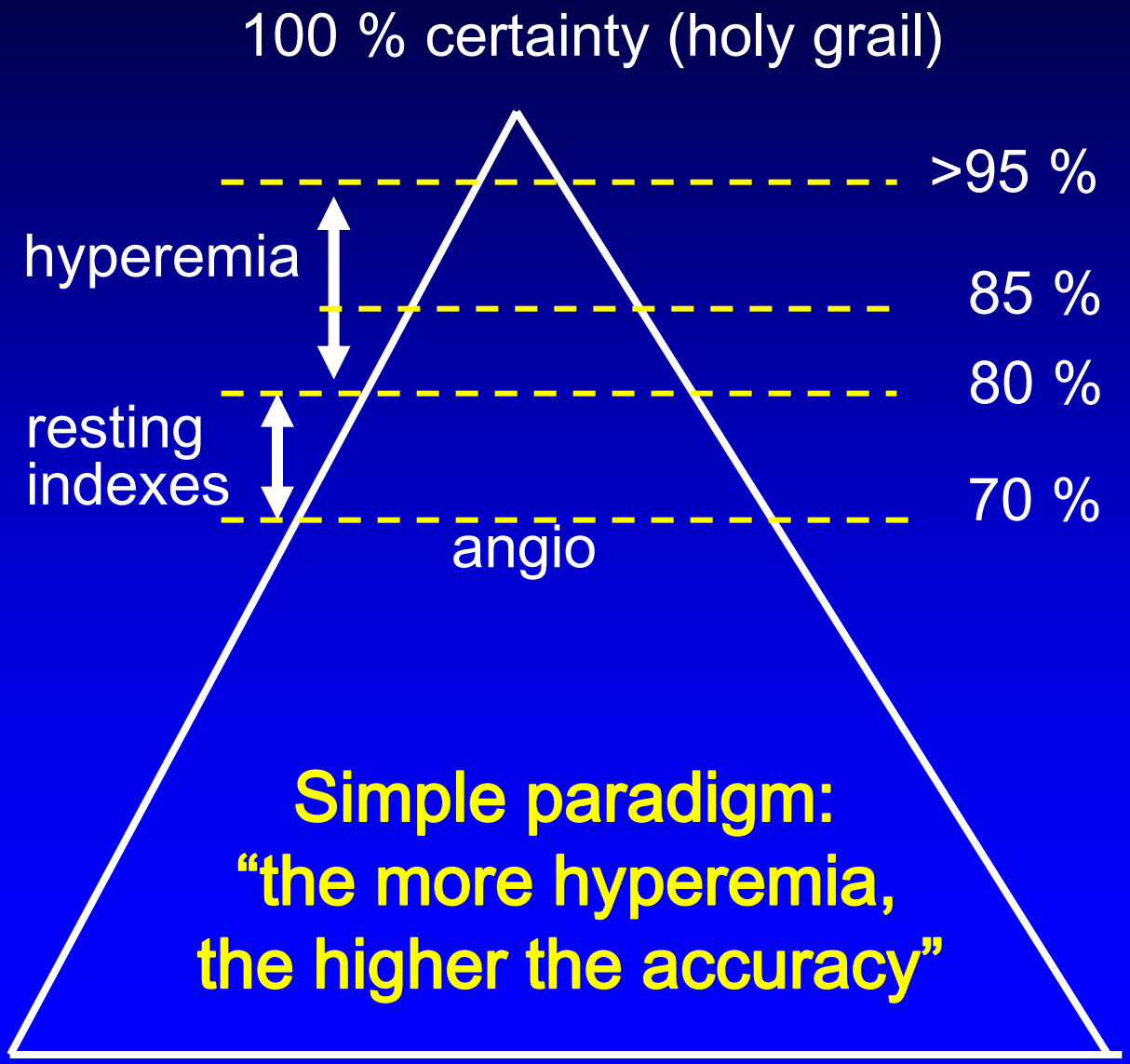
Correct Classification of Ischemic Stenosis

FFR

Contrast cFFR

resting Pd/Pa, iFR,

angiography



RECOGNIZING PITFALLS DURING FFR MEASUREMENTS

Part 1: "technical pitfalls", related to practicalities during the procedure

(avoidable by practical tips & tricks and skills)

related to introducer, drift, guiding catheter, wire manipulations, practicalities of hyperemia

Part 2: "physiologic" pitfalls & interpretation errors

(avoidable by knowledge of physiology)

Misinterpretation of correct signals:

high FFR and (apparently !) severe stenosis:

- small perfusion territory, old infarction
- abundant collaterals
- deceiving angio, look for other culprit lesion !

Diffuse disease:

detectable by hyperemic pullback recording

Severe Microvacular Disease:

- IMR, CFR
- Absolute flow and Resistance measurement by new technique

  (keynote lecture tomorrow afternoon 2 pm)

IN SUMMARY:

- *Nothing is perfect, not even FFR….*
- *…..but false positive or false negative FFR is extremely rare*
- *However, some pitfalls must be recognized and avoided.*
- *In most cases of presumed "false negative FFR", there is either a technical, physiological, or interpretational point explaining the case*