CORONARY PHYSIOLOGY IN THE CATHLAB:

PRACTICAL SET-UP OF FFR

Educational Training Program ESC
European Heart House
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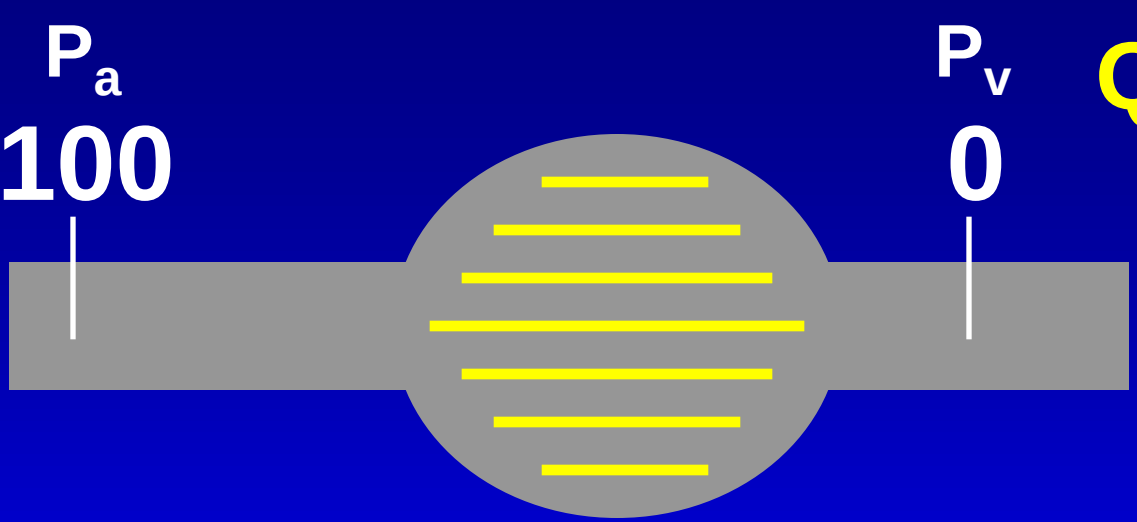
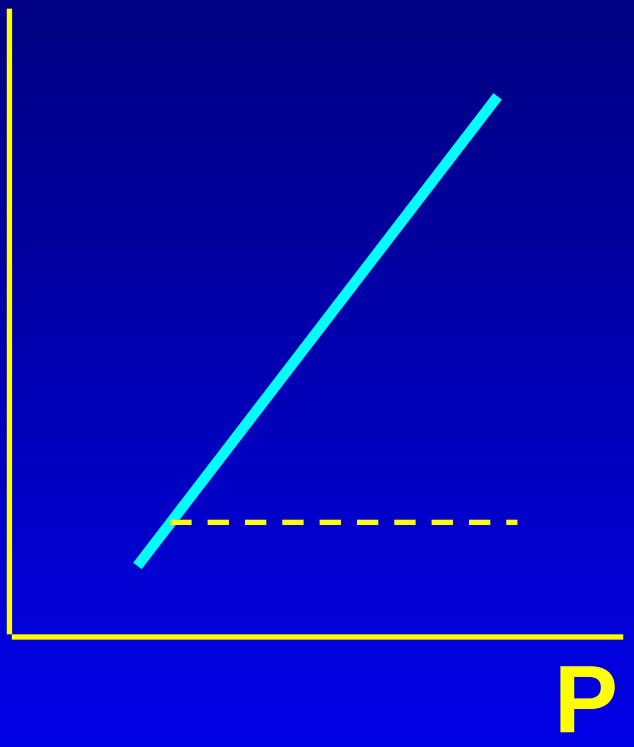
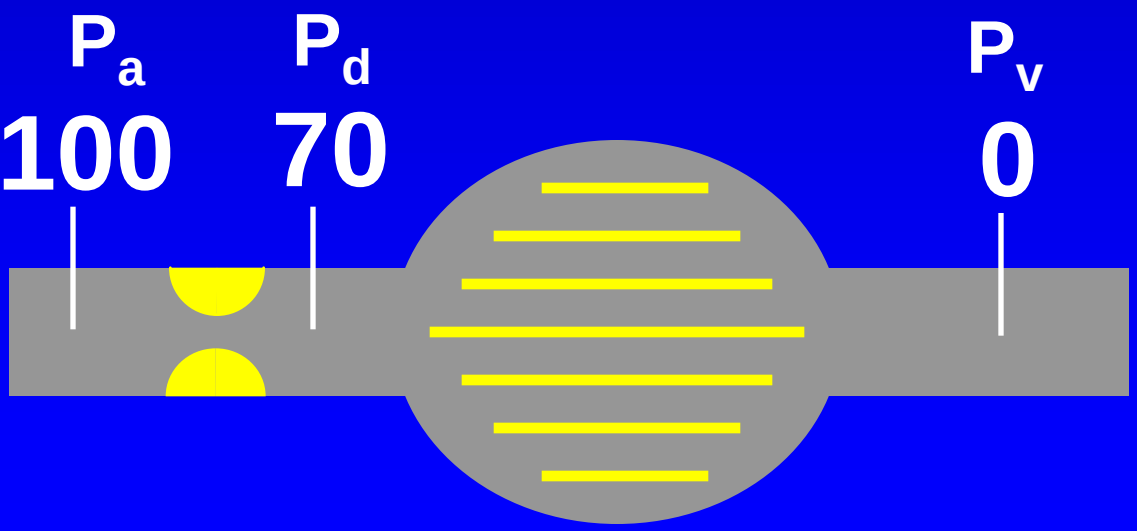
During Maximal Vasodilatation







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

$$= 0.70$$

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

P_a = mean aortic pressure at maximum hyperemia

P_d = mean distal coronary pressure at maximum hyperemia

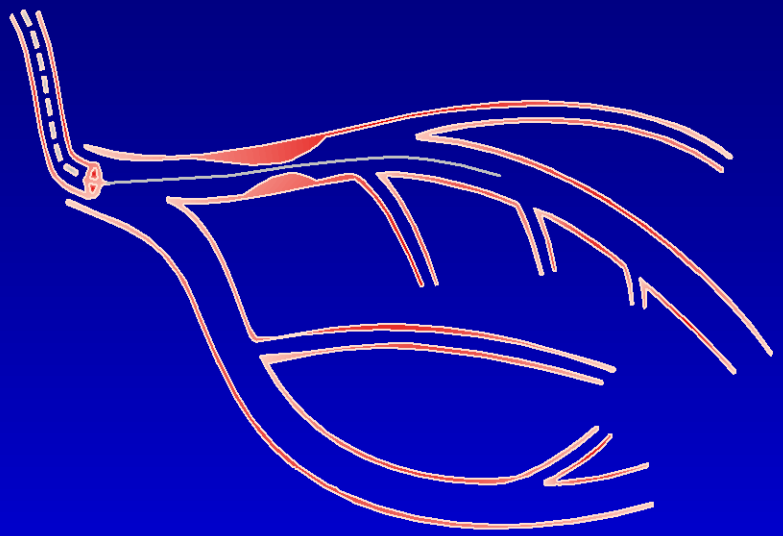
FFR = 0.6 means:

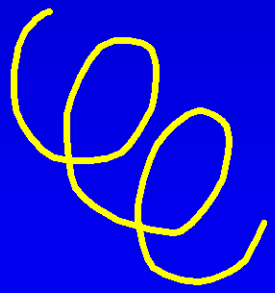
"Due to this particular stenosis, maximum achievable blood flow to the myocardium supplied by this artery, is only 60 % of what it would be if this coronary artery were completely normal"

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"

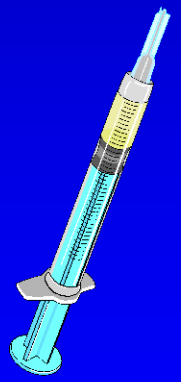
Application in catherization laboratory





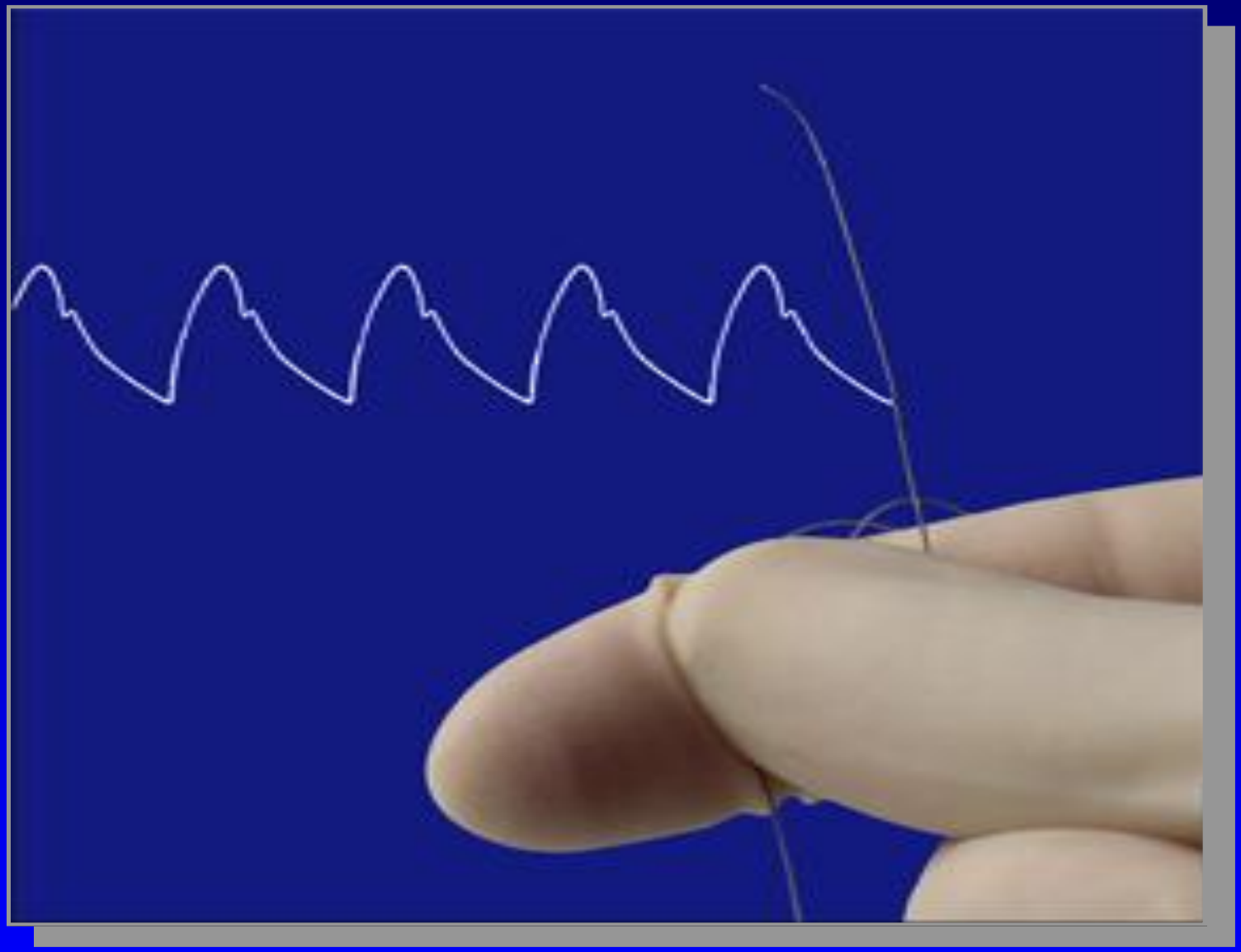
pressure wire

+



hyperemic stimulus

= **FFRmyo**



0.014 sensor-tipped PTCA guidewire (St Jude Medical & Volcano)

MAXIMUM VASODILATORY STIMULI

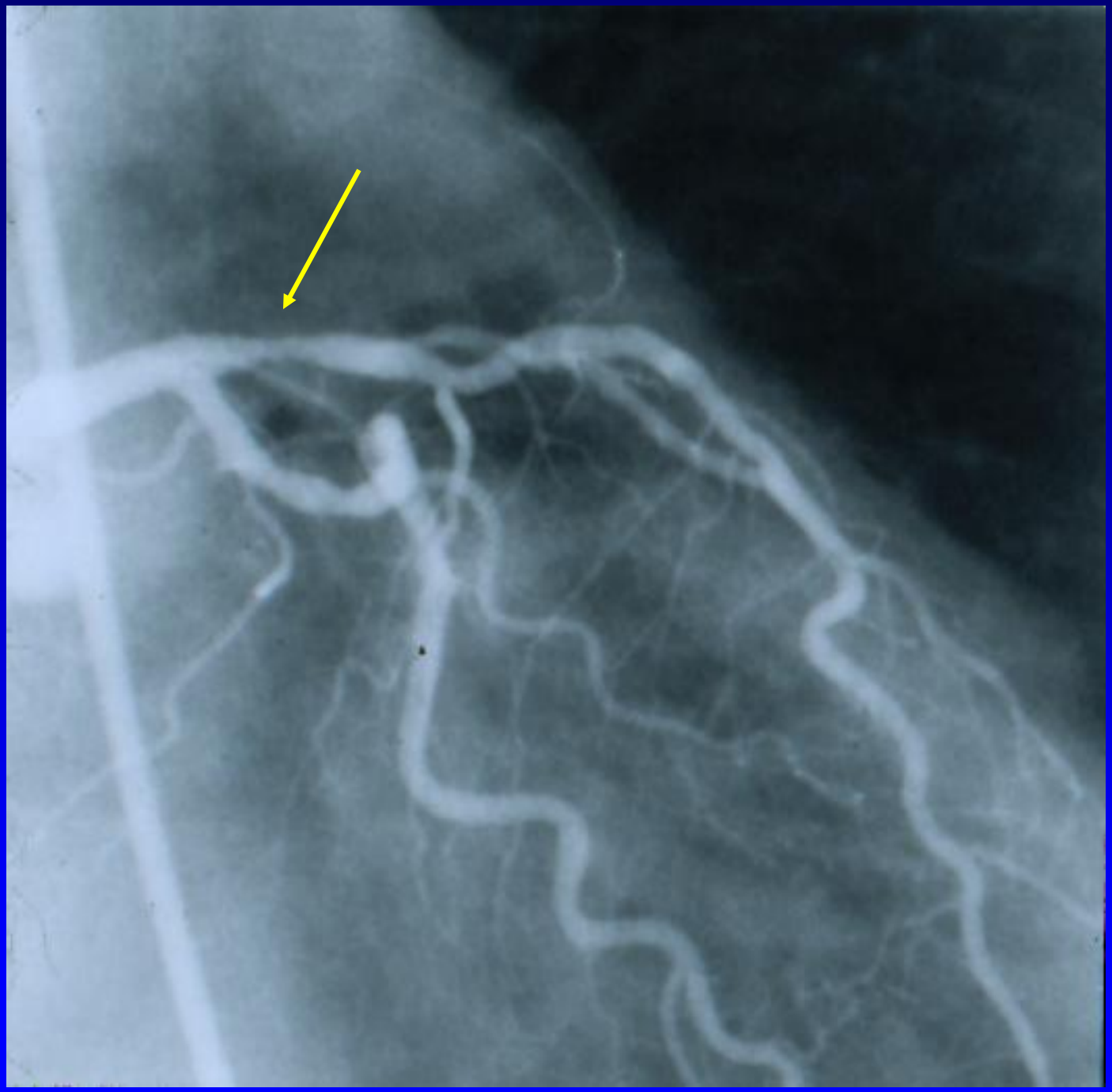
!! Maximum hyperemia is paramount !!

- **PAPAVERINE i.c.**
- **ADENOSINE i.c.**
- **ADENOSINE i.v.**
- **ATP i.c**
- **ATP i.v.**

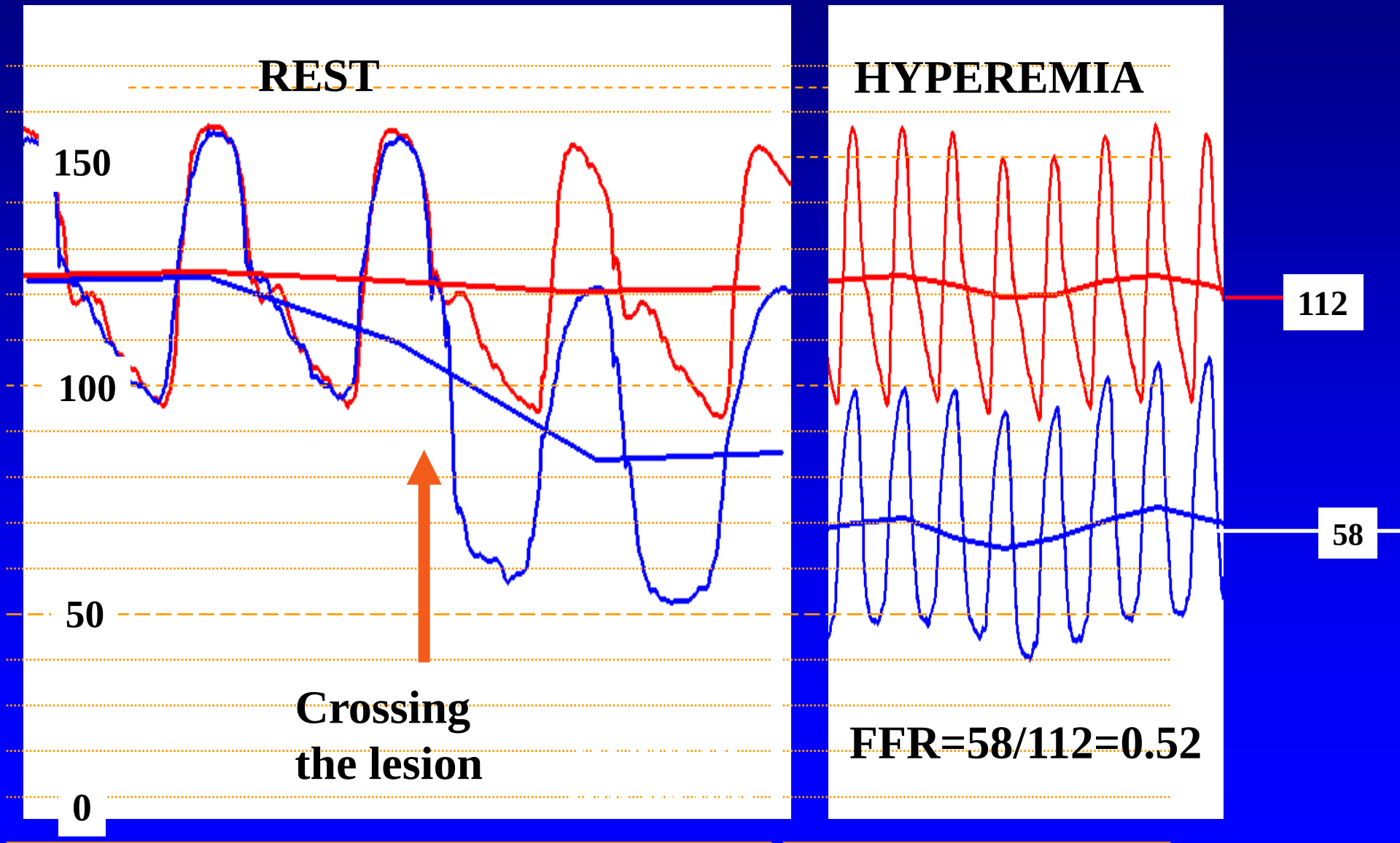
} Bernard De Bruyne

- ***regadenoson ?*** → Lokien Van Nunen

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



Fractional Flow Reserve in Clinical Practice

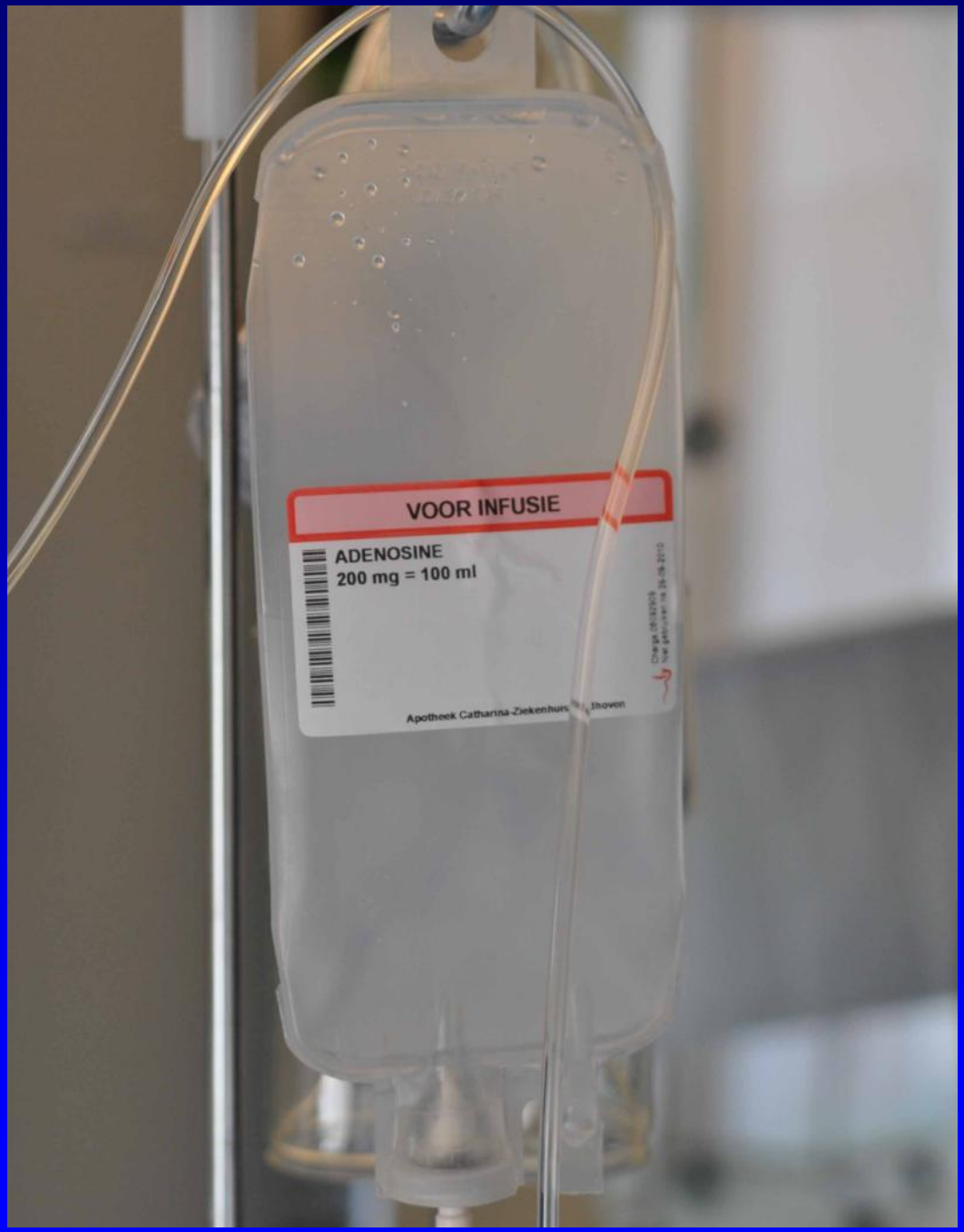


Catharina Hospital, Eindhoven, NL

1800 FFR cases per year

95 % = central venous adenosine by femoral sheath

Venous sheath into femoral vein



Adenosine for
i.v. infusion

(standard bag
200 mg = 100 ml)

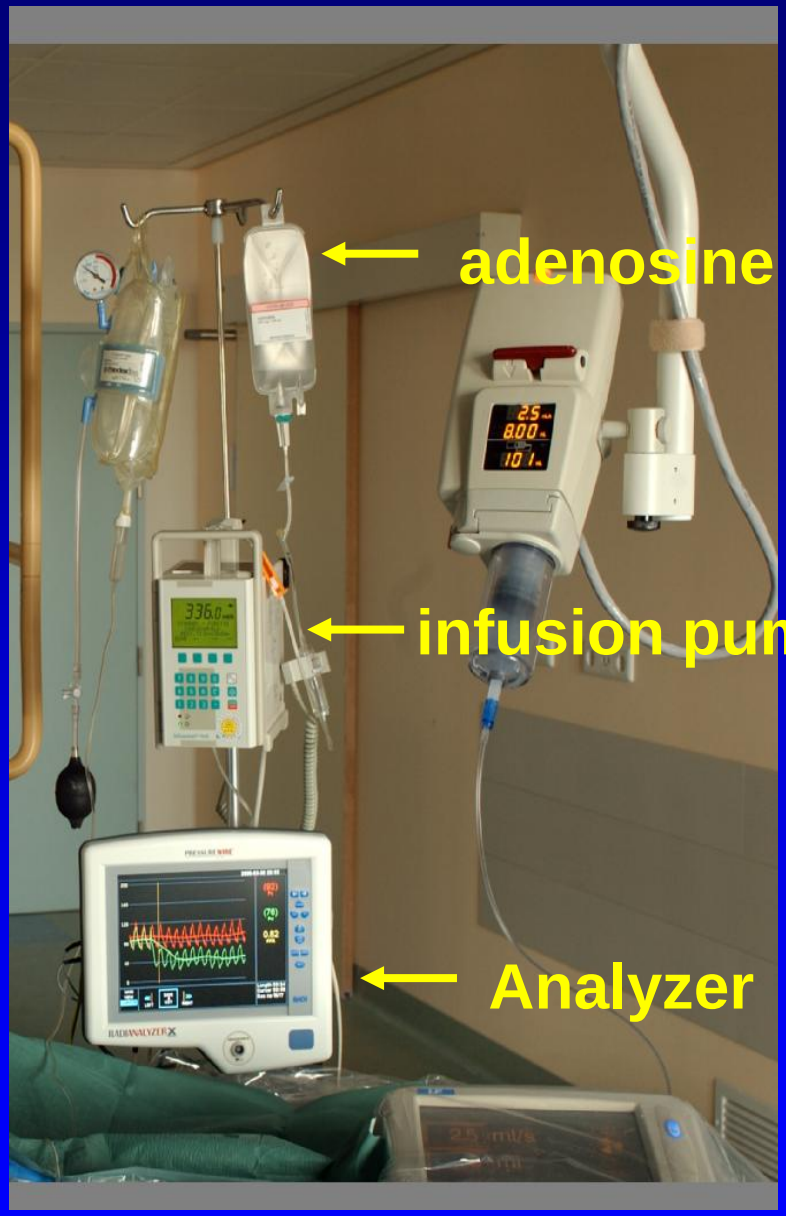
price: Euro 2,=
per bag

prepared by
hospital pharmacy

manifacturing
protocol available
at carias@cze.nl

Infusion pump for adenosine (140 µg/kg/min)

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



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

Some notes on your sheaths

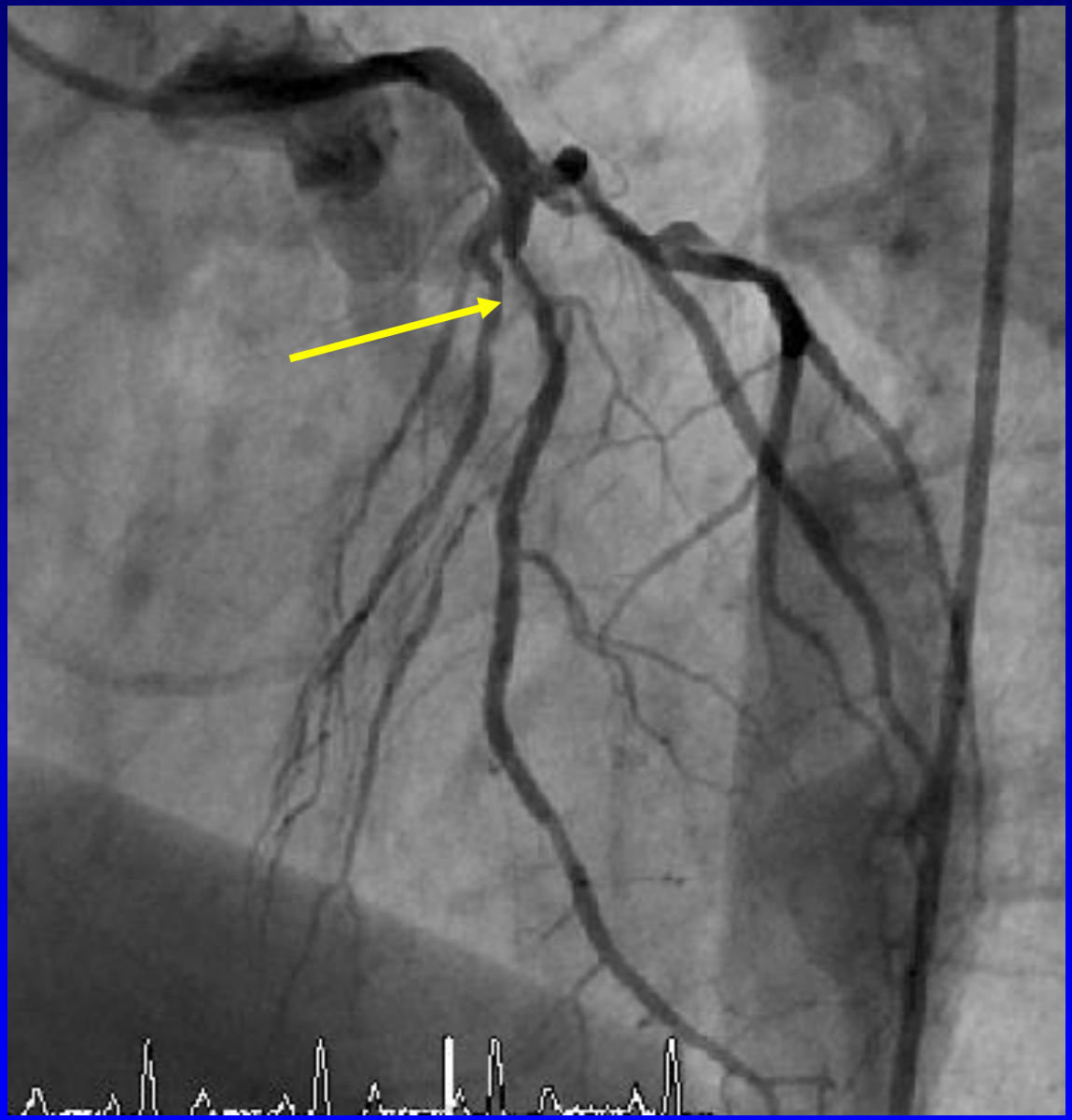
MAXIMUM HYPEREMIA IS OF PARAMOUNT IMPORTANCE:

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

PRACTICAL PERFORMANCE OF FFR - MEASUREMENT



Nitroglycerine

Note !

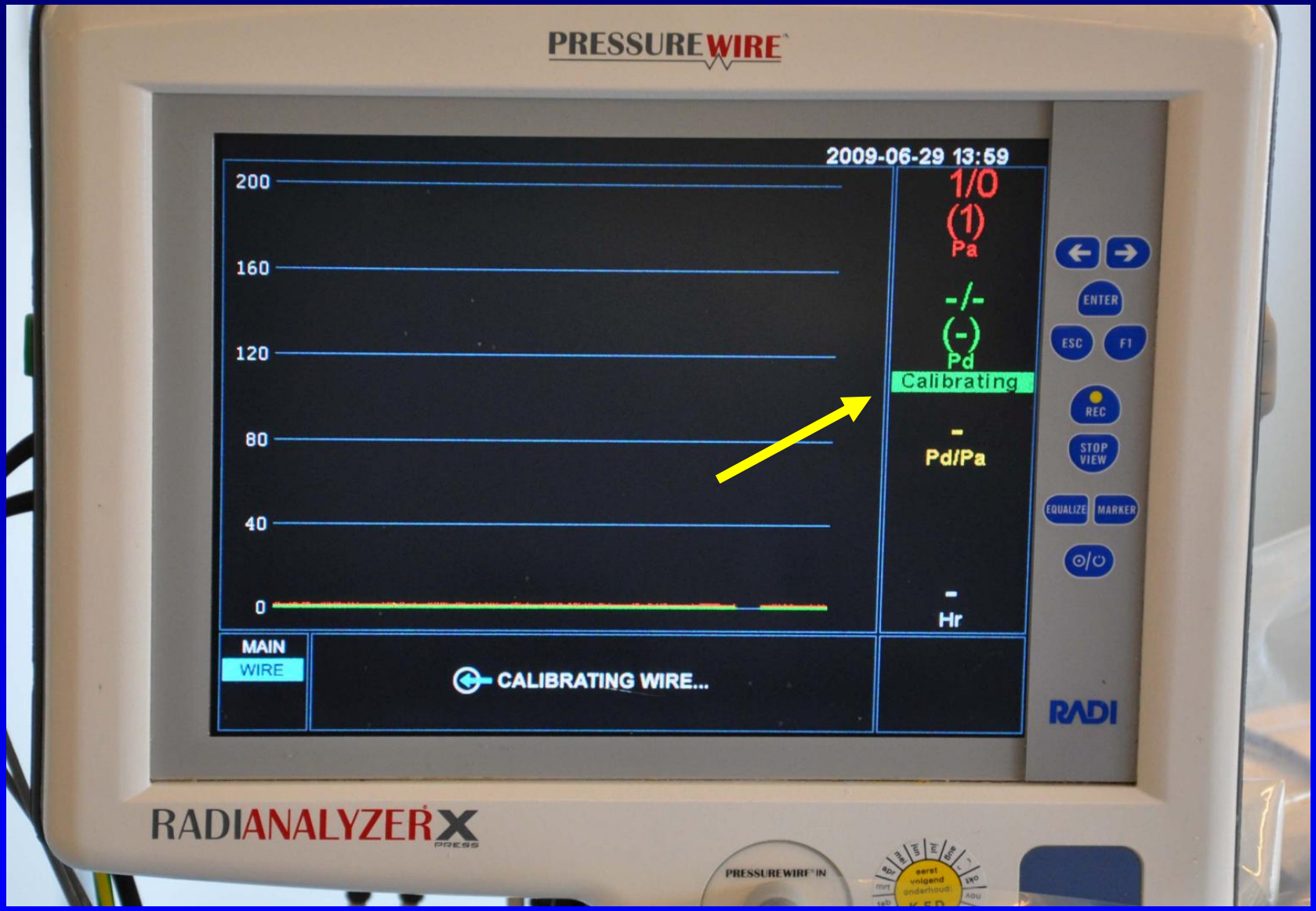
As in any intracoronary manipulation, before entering the coronary circulation, administer *200-300 µg NTG i.c.*

200 – 300 µg NTG i.c.

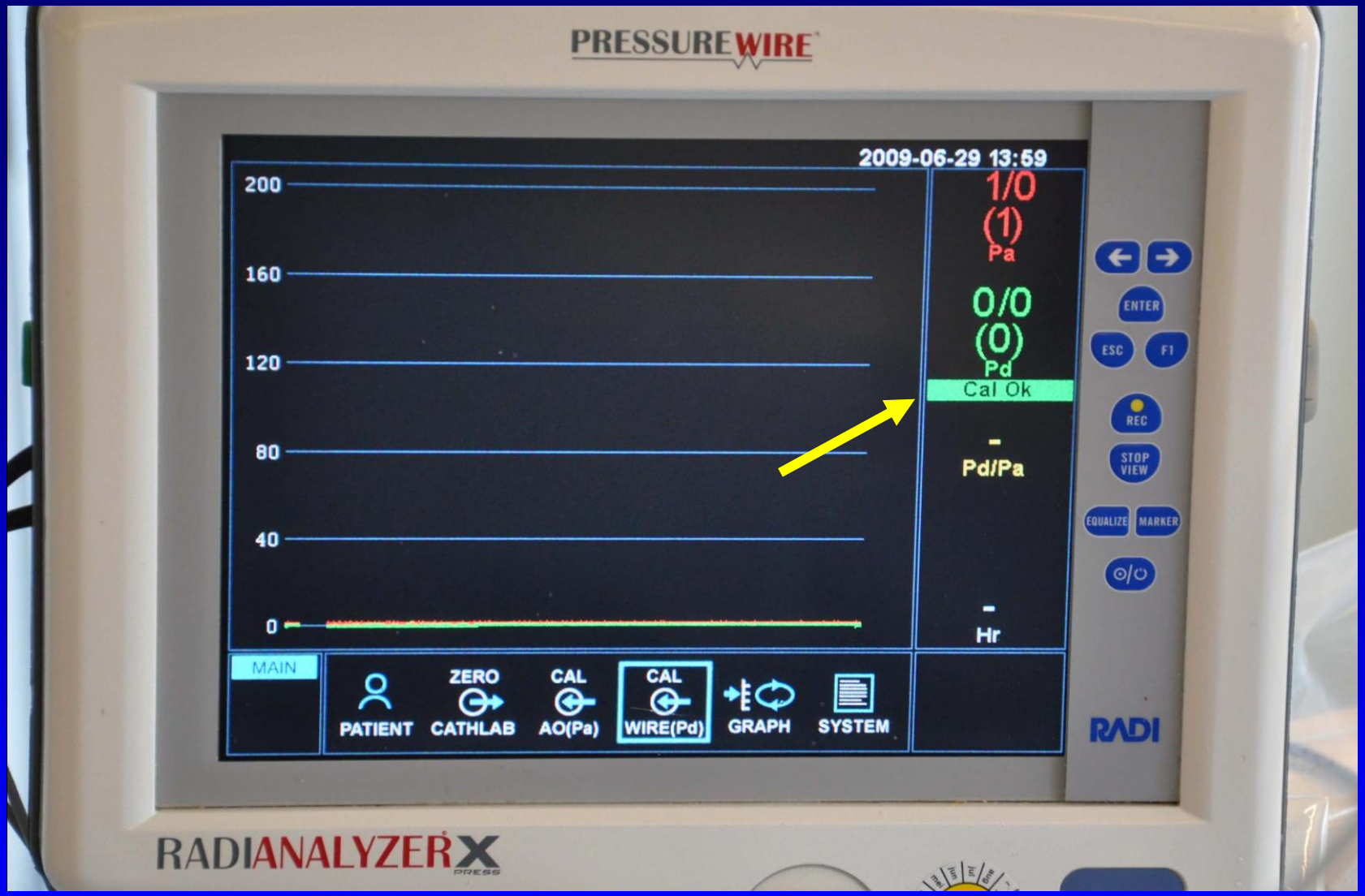
Unpacking of the Pressure Wire

Flushing the Pressure Wire

Connecting the Pressure Wire to Analyzer



Calibrating Pressure Wire

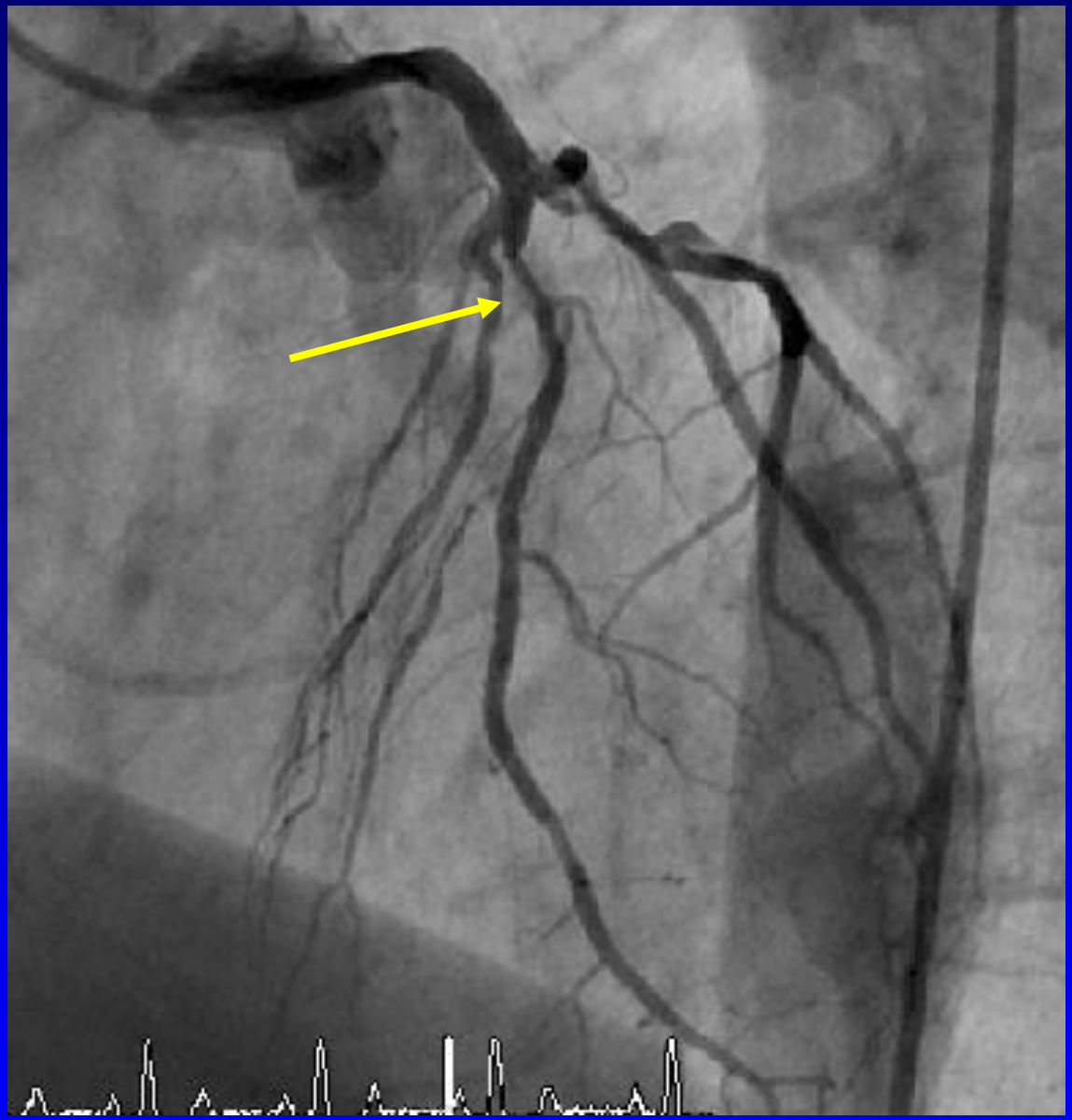


Pressure Wire Calibrated: Ok

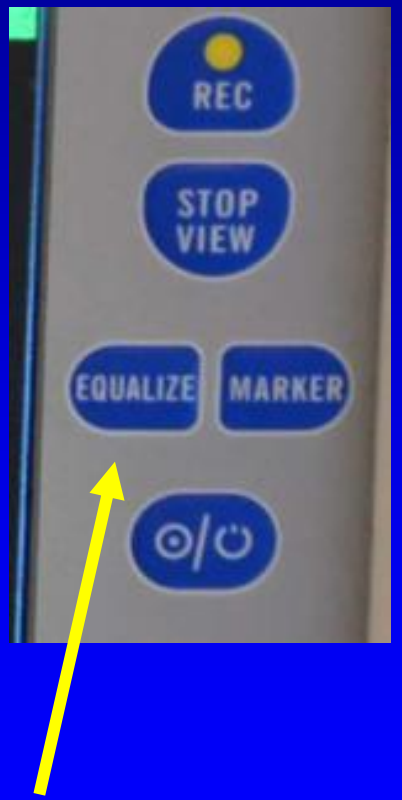
Pressure Wire introduced into Y-connector

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



NOTE:

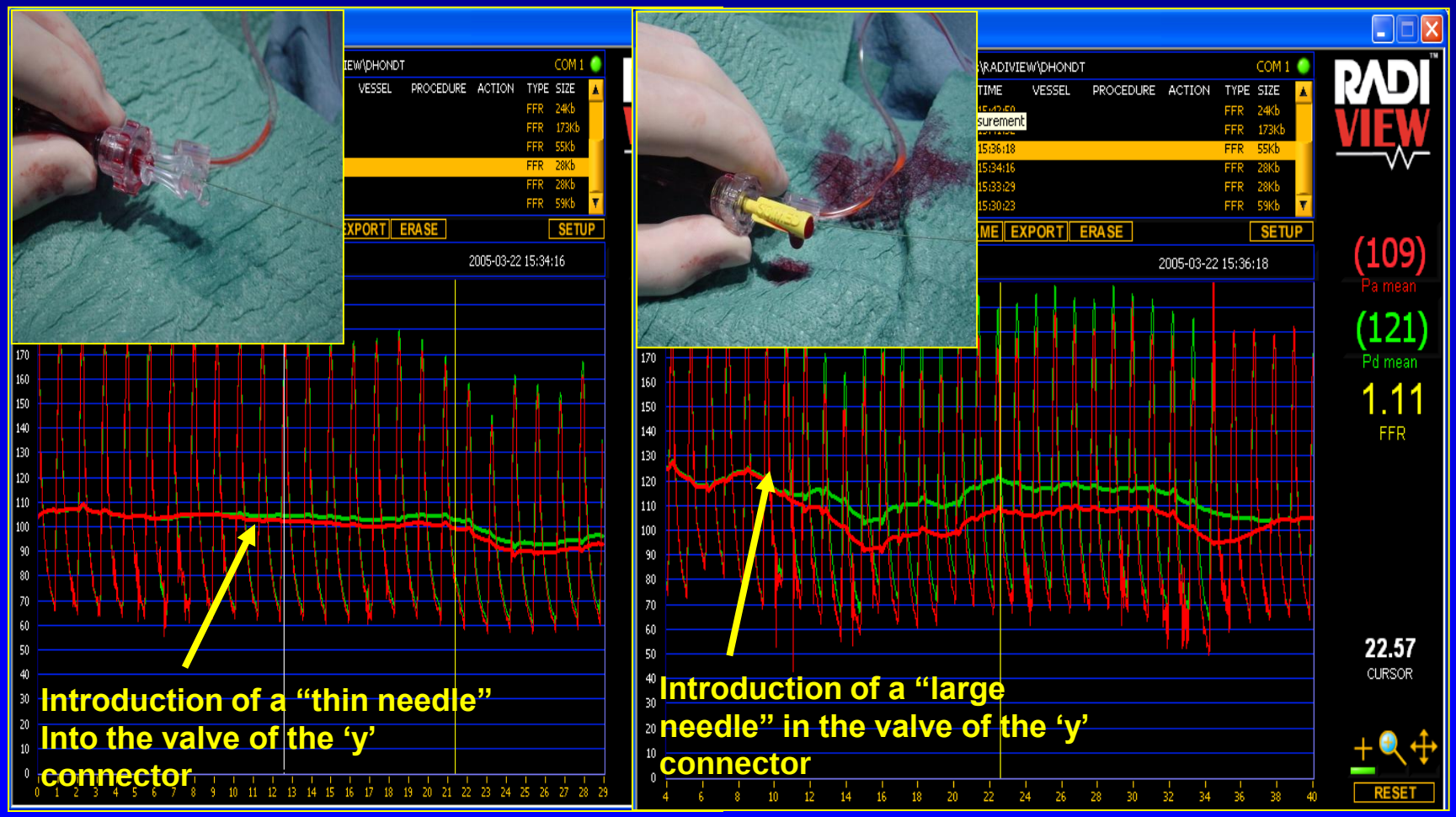
introducer needle in or out !?!

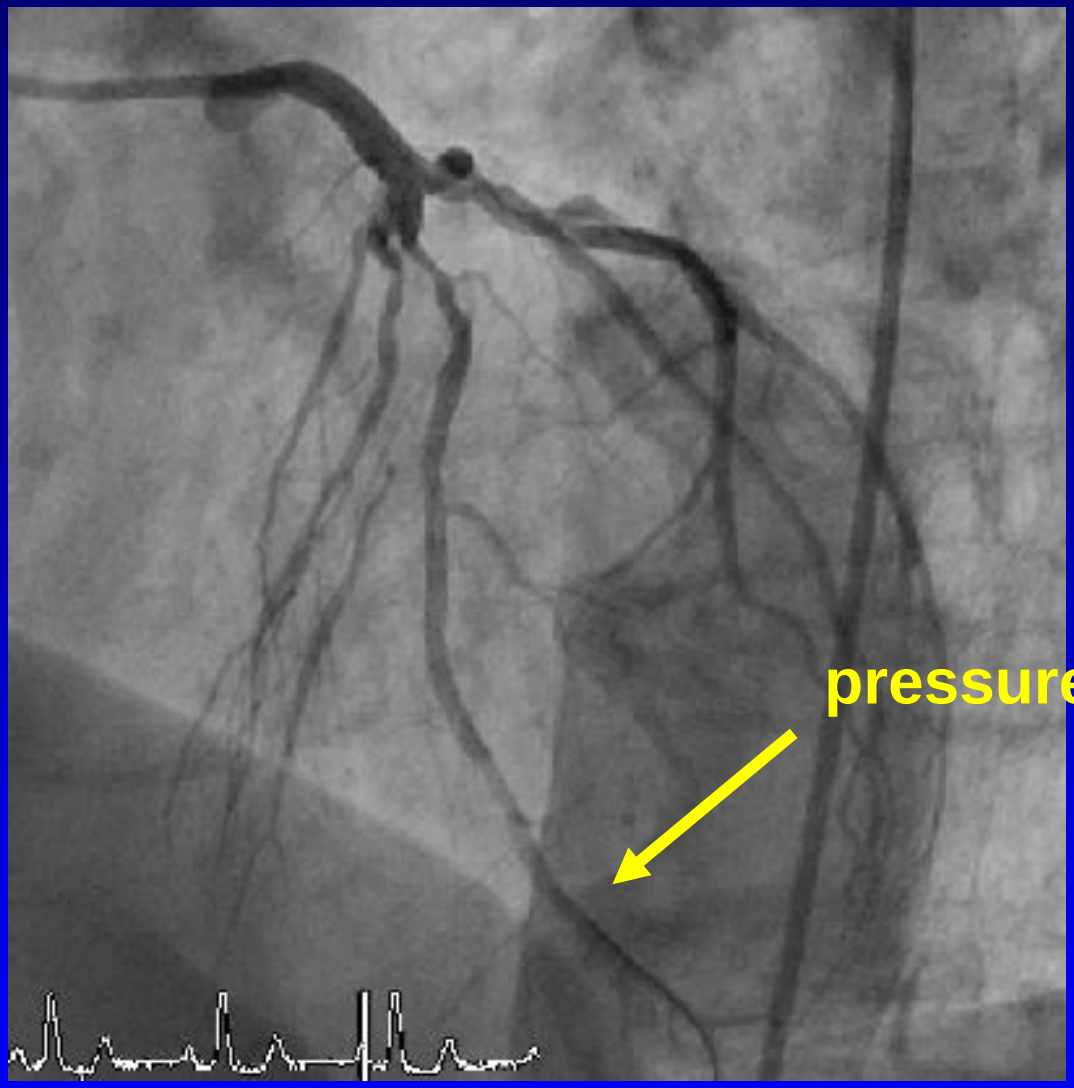
→ ***doesn't matter as long as you realize what you are doing***

1. ***Know your needle***

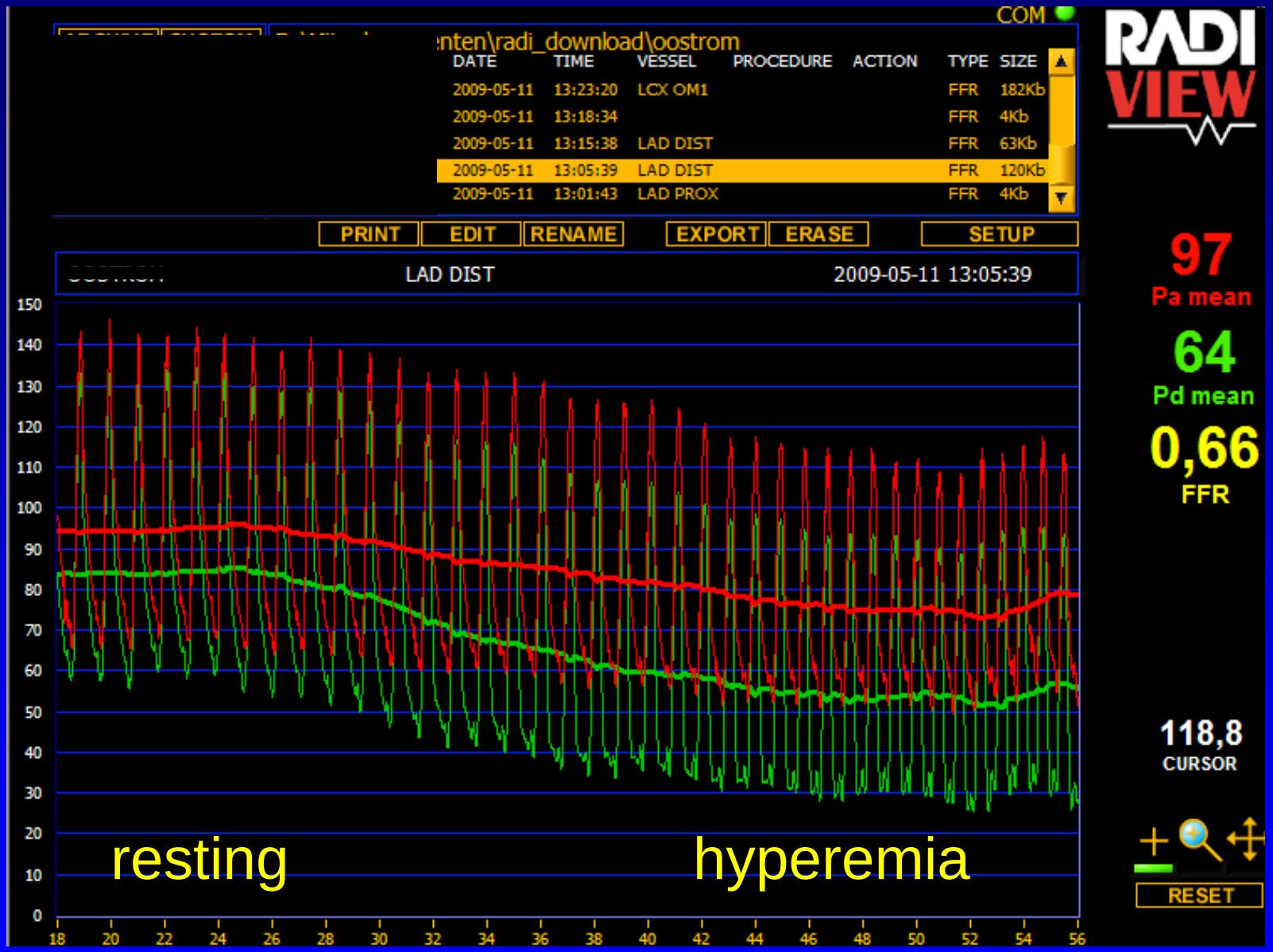
2. ***Realize that some apparent "drift" at the end is not drift per se but can be caused by the presence of the introducer when doing the initial measurement and absence of the (removed) introducer at the end***

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

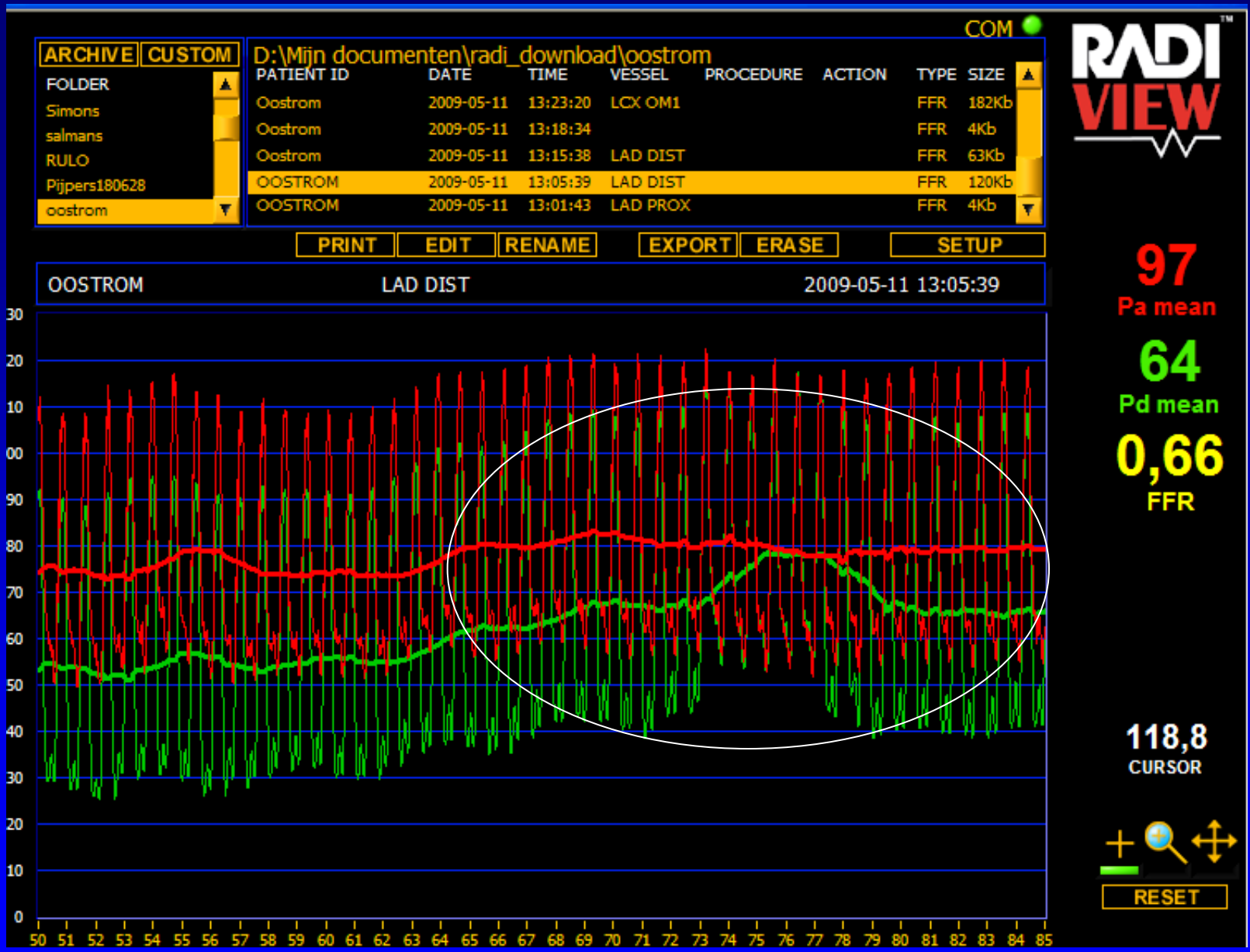




advance pressure wire through stenosis
and ***induce hyperemia*** ⟶ **FFR**



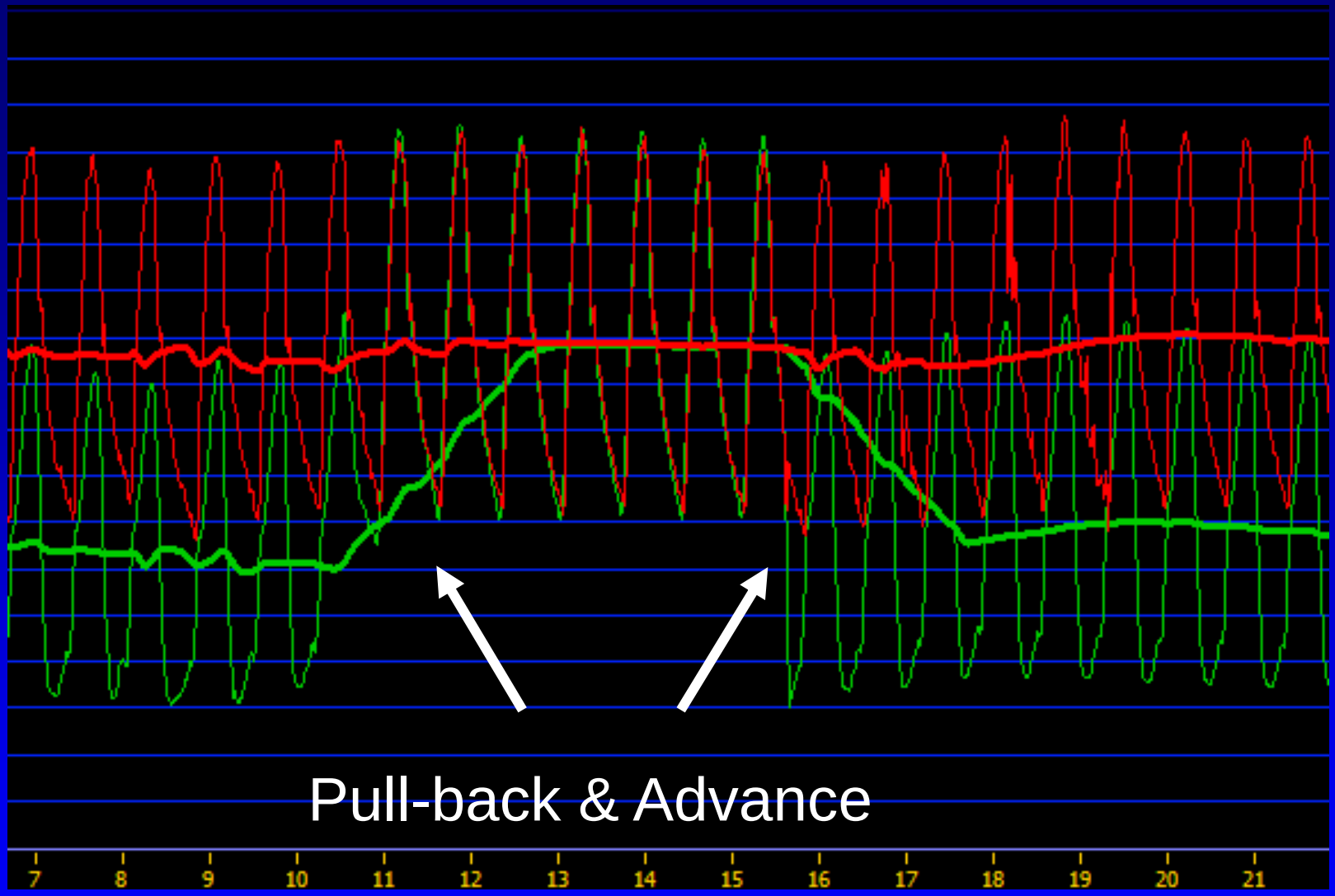
FFR LAD (i.v. adenosine) = 0.66 ⟶ *need for stent*



Make pullback recording for optimal information

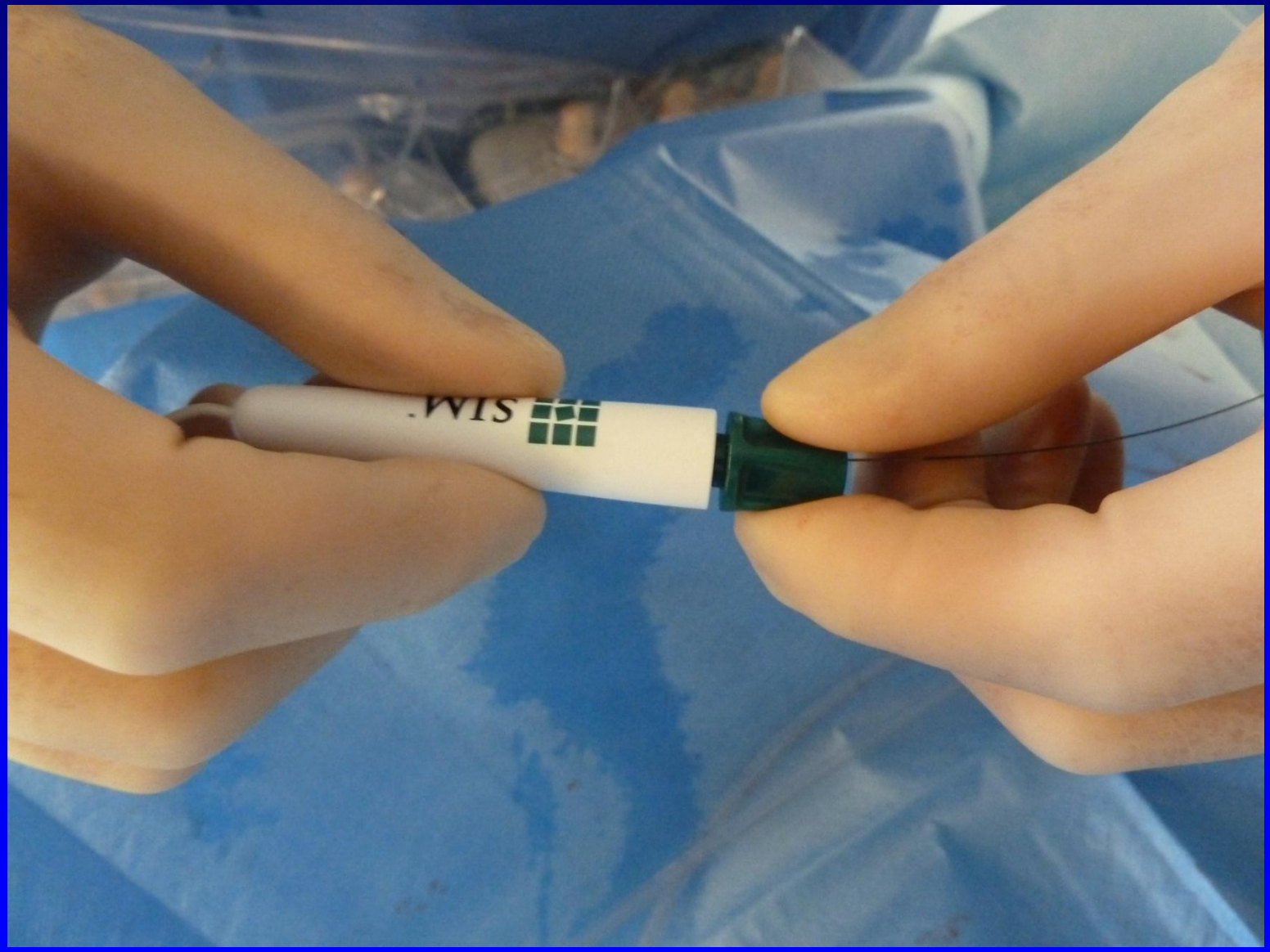
Because sensor is 3 cm from tip, easily pull-back and push-up for exact spatial information.

If desirable, perform pull-back recording for exact location of pressure drop / stent deposition

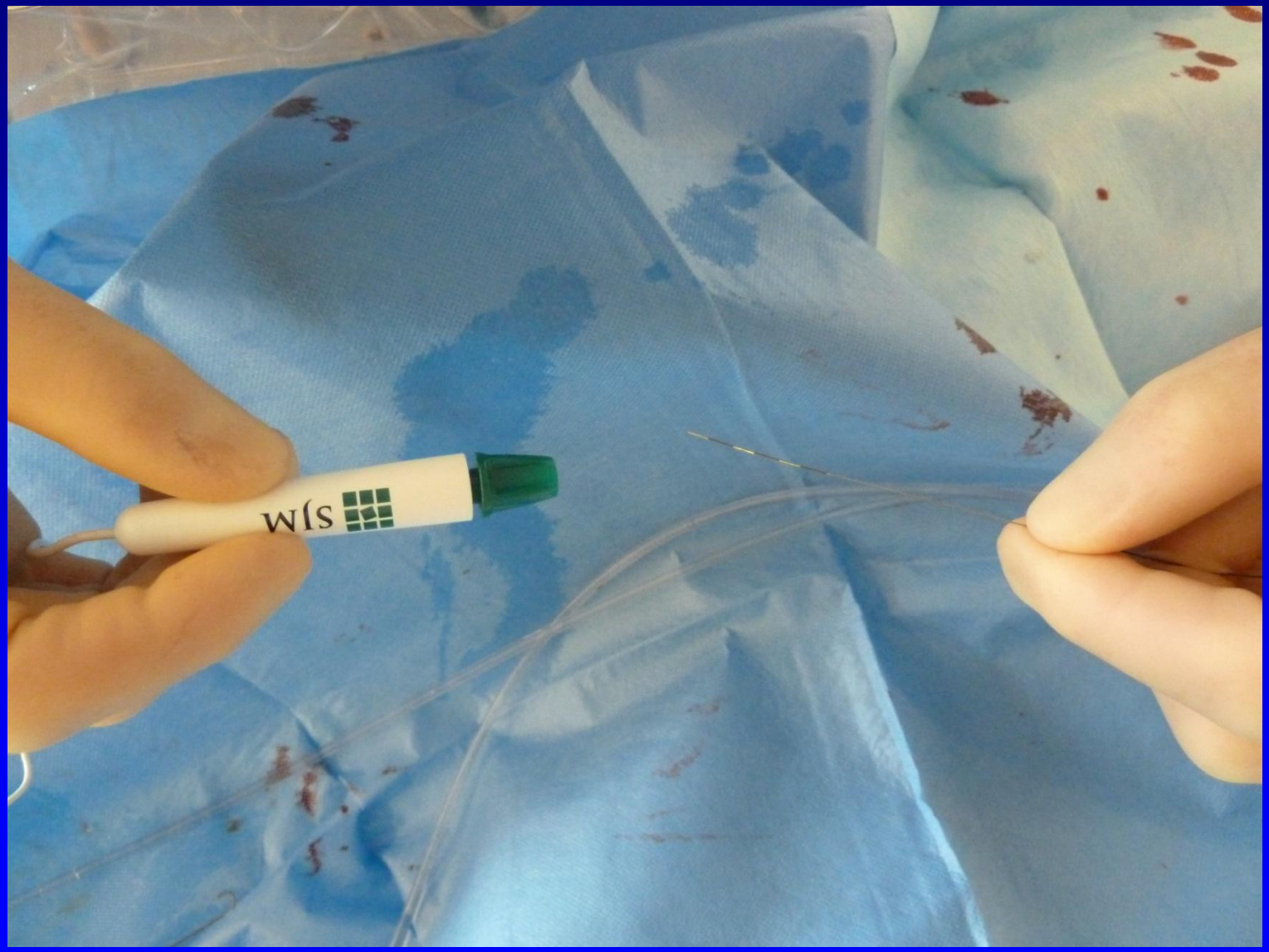


Pull-back recording for detailed spatial information about distribution of lesions along the complete artery

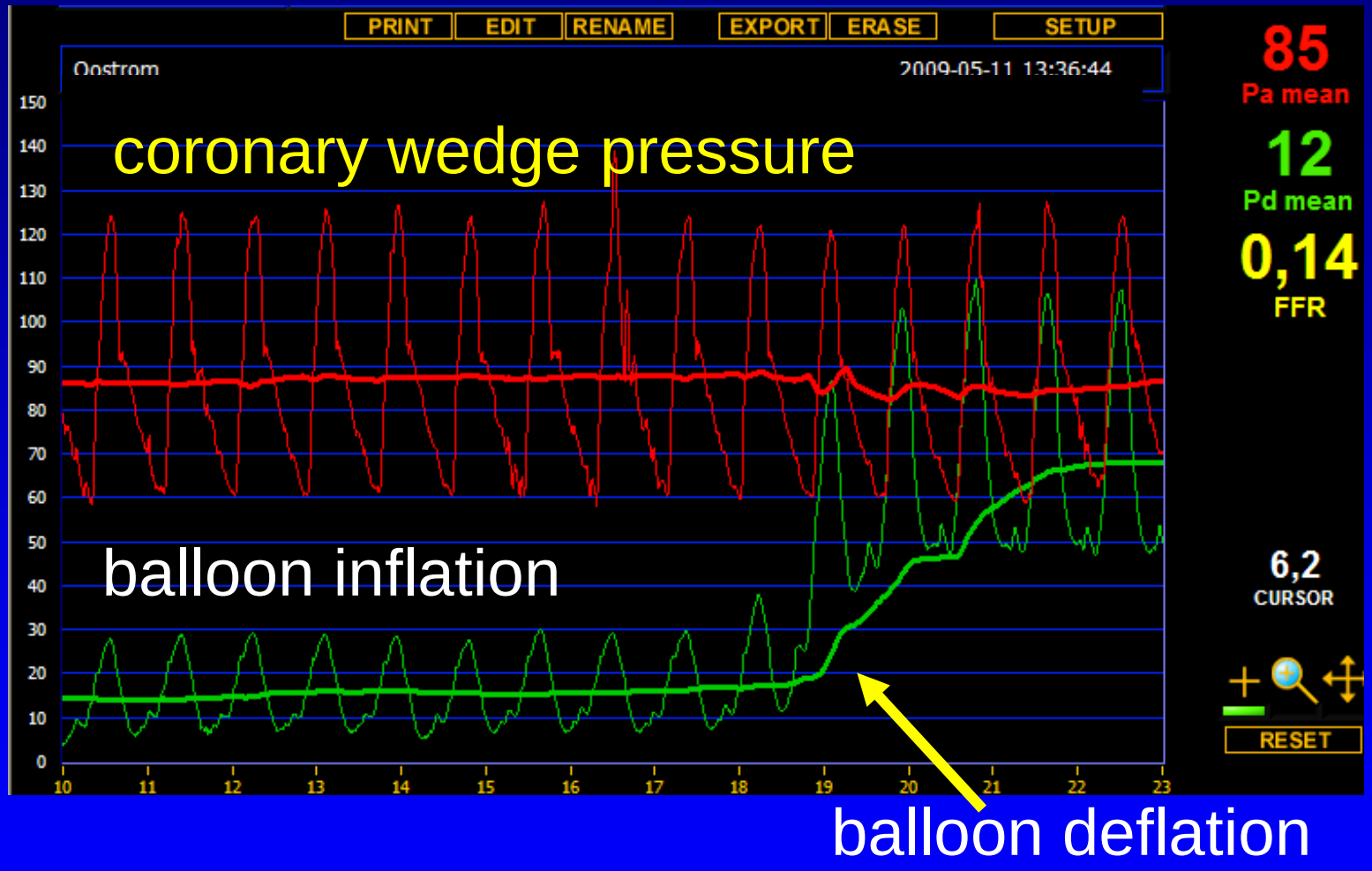
If you need to treat, disconnect pressure wire



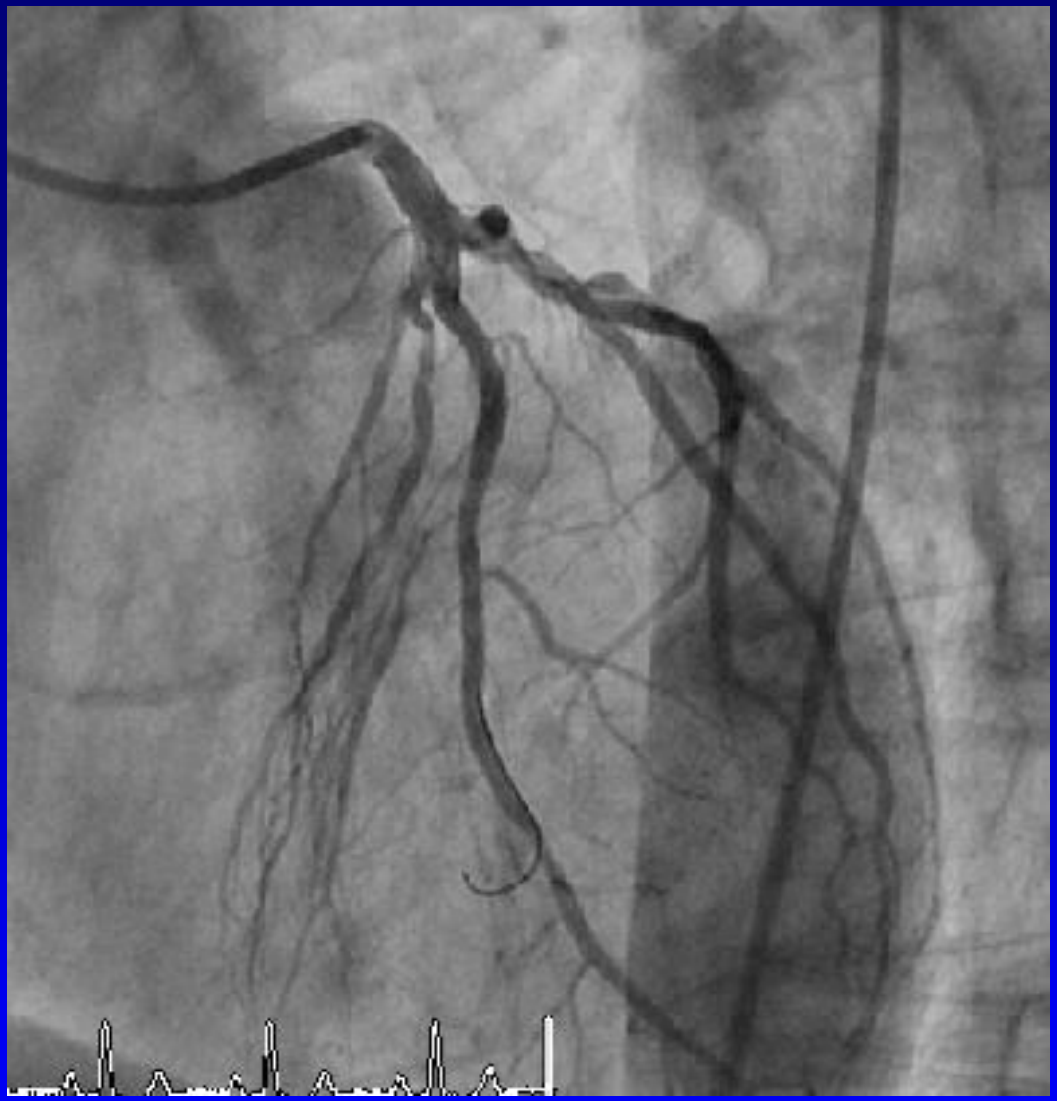
disconnecting the pressure wire…….



to assess ***collateral flow***: measurement of coronary wedge pressure during balloon inflation can be done

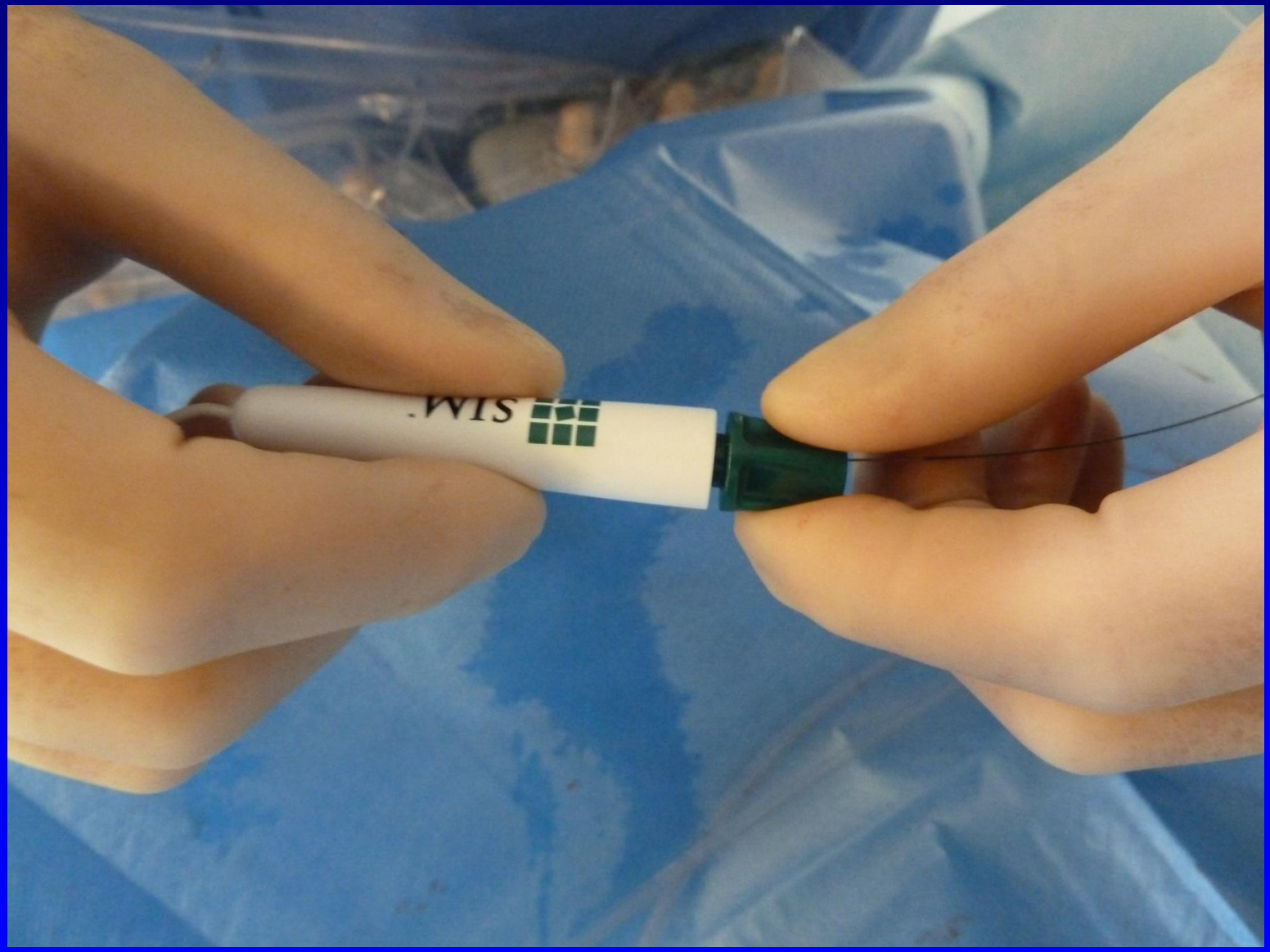


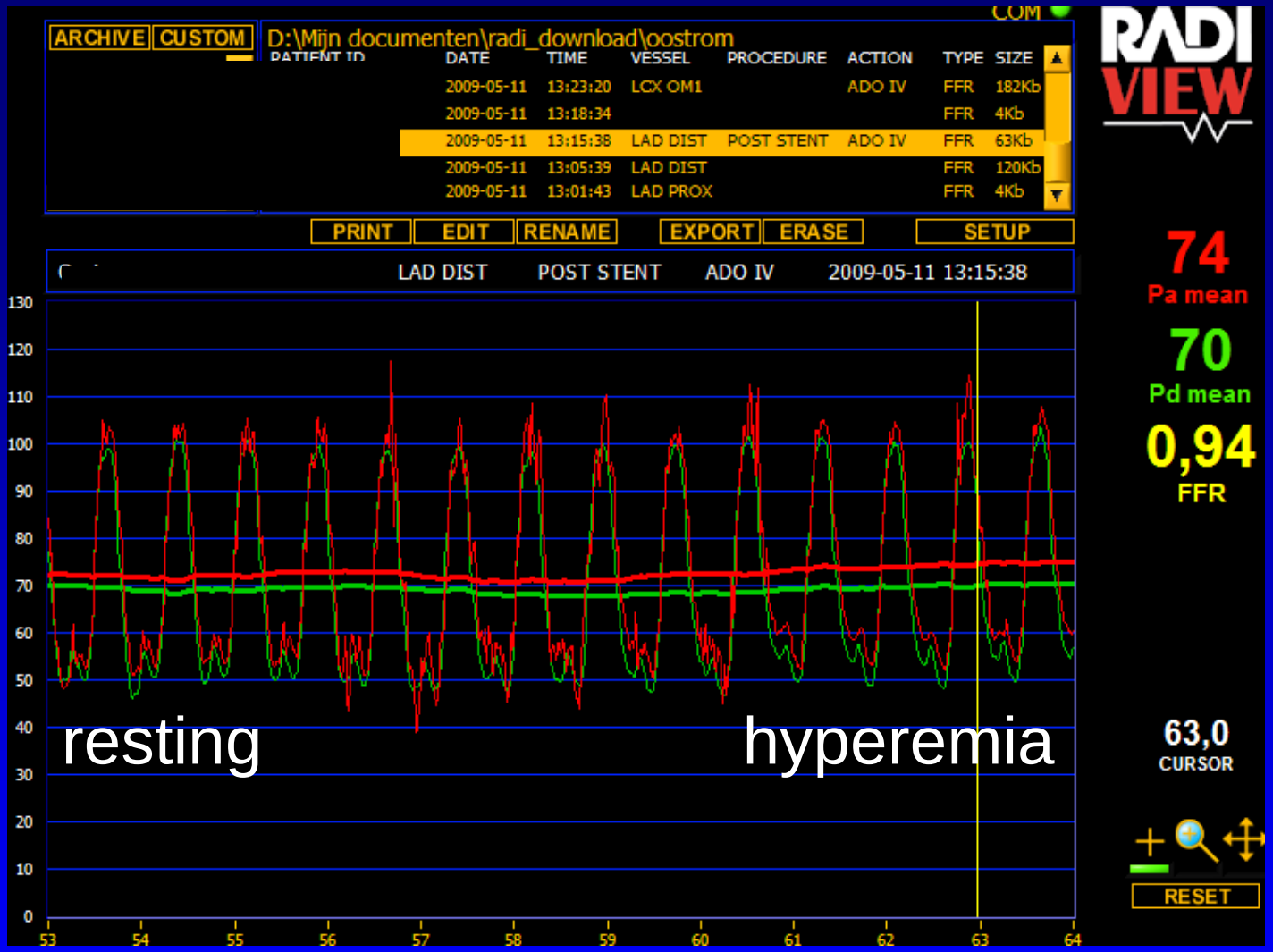
Fractional collateral flow = (Pd-Pw) / (Pa-Pw)



Stent has been placed: LAD after stenting

If you like to evaluate post-stent result, connect again





measurement of *FFR after stenting* to assess result

FFR = 0.94

NOTICE:

After stenting, in the majority of patients no resting conditions are obtained anymore and “semi-hyperemic” status persists, with a lot of inter-individual variation.

It often takes > 30 minutes to achieve “baseline” again

As a consequence, “resting” Pd/Pa (and iFR) are often *lower after stenting than before.*

To evaluate improvement by stenting, you need to compare FFR after and before stenting
(e.g. ⟶ FFR from 0.6 to 0.9 means increase of maximum achievable myocardial flow by 50 %)

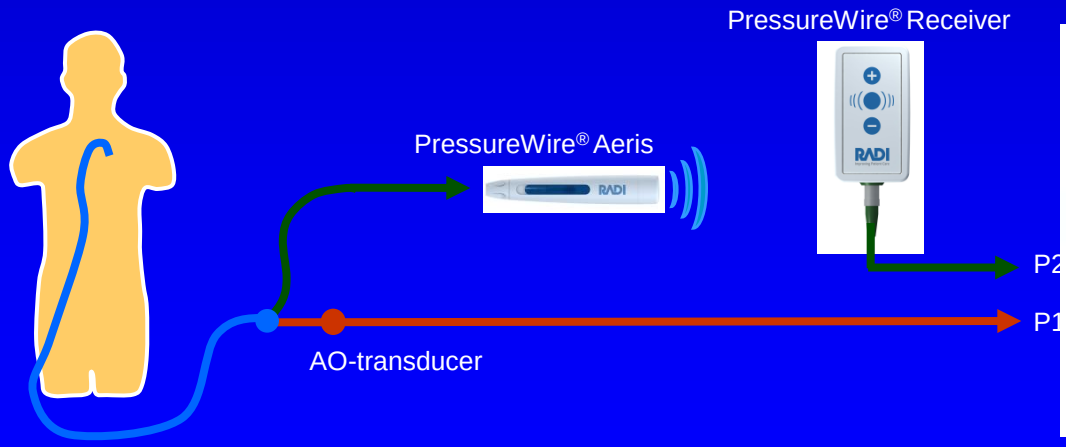
At the end, when sensor is back at tip of guiding catheter, verify *absence of drift*

Complete Integration of FFR Measurement in the Regular Environment of the Cathlab

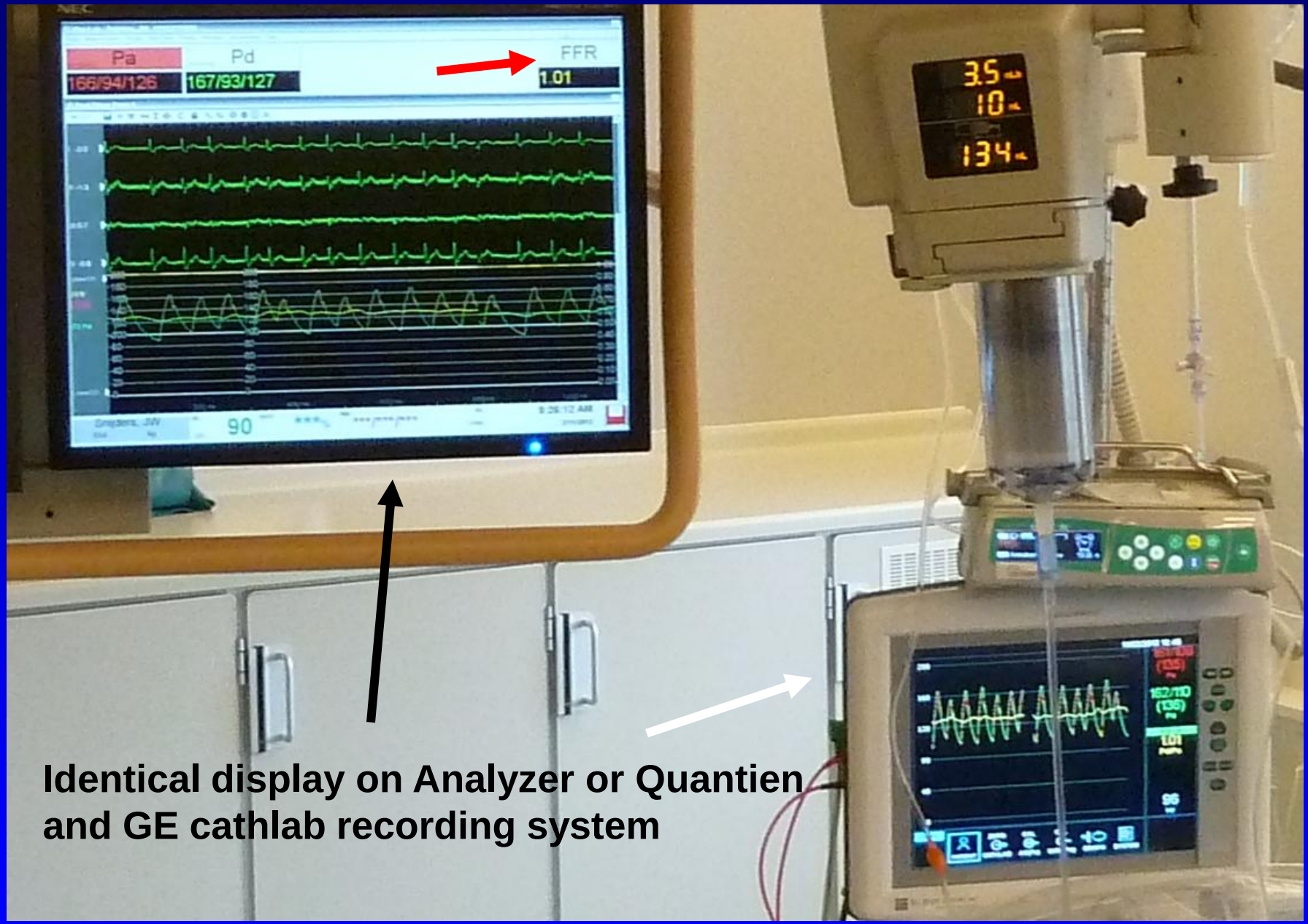
PressureWire® Aeris

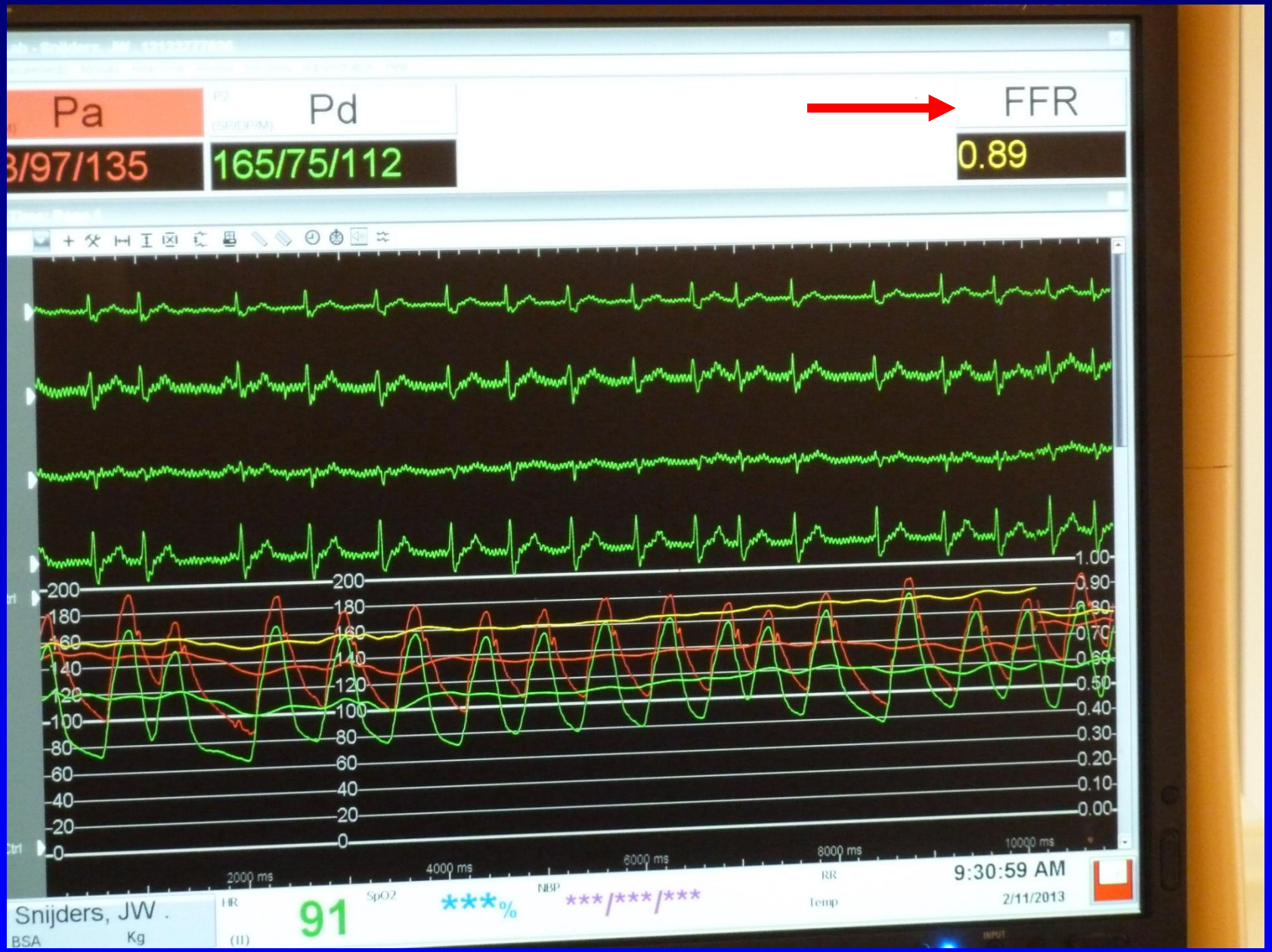
True FFR Integration (St Jude Medical)

- Receiver connects directly to any hemodynamic recording system.
- Used directly in the cathlab with no additional instrumentation.
- Utilizes the standard blood pressure transducer ports without any extra cabling.
- Requires FFR software upgrade from cathlab manufacturers General Electric, Philips, etc
- No calibration, ready in 1 second



Hemodynamic recording system

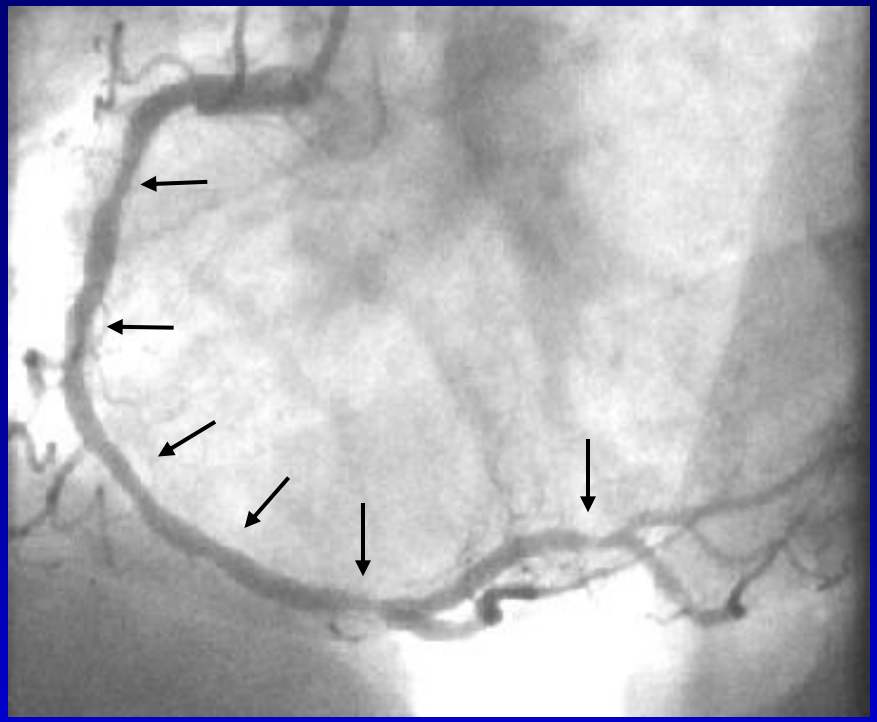

Pa
Pd
FFR
166/94/126
167/93/127
1.01
90
Identical display on Analyzer or Quantien
and GE cathlab recording system

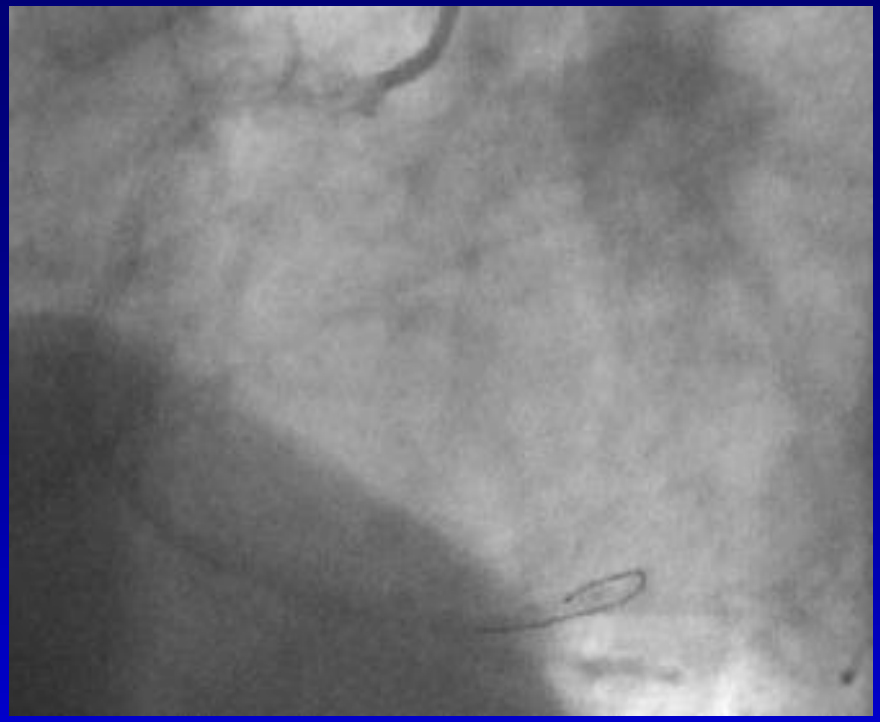


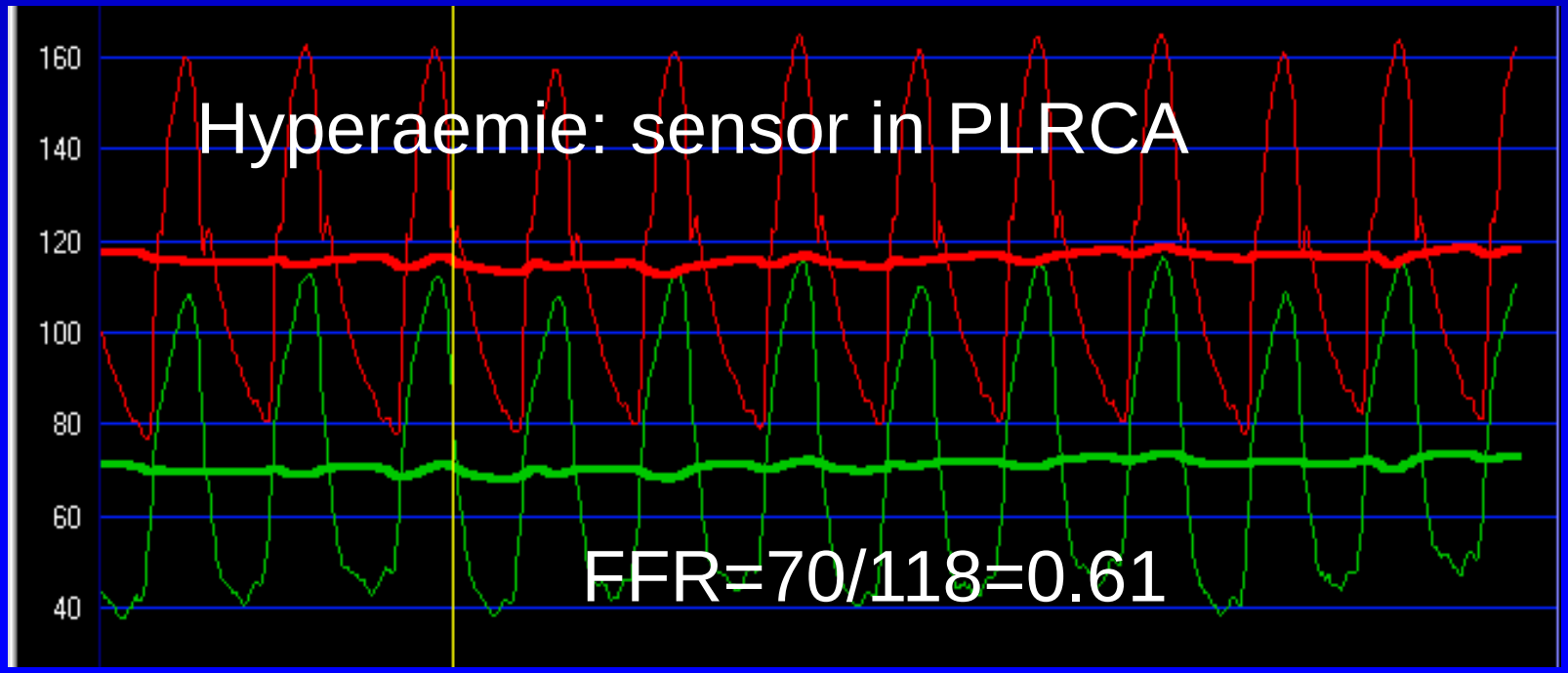
GE catlab recording system: full integration of FFR

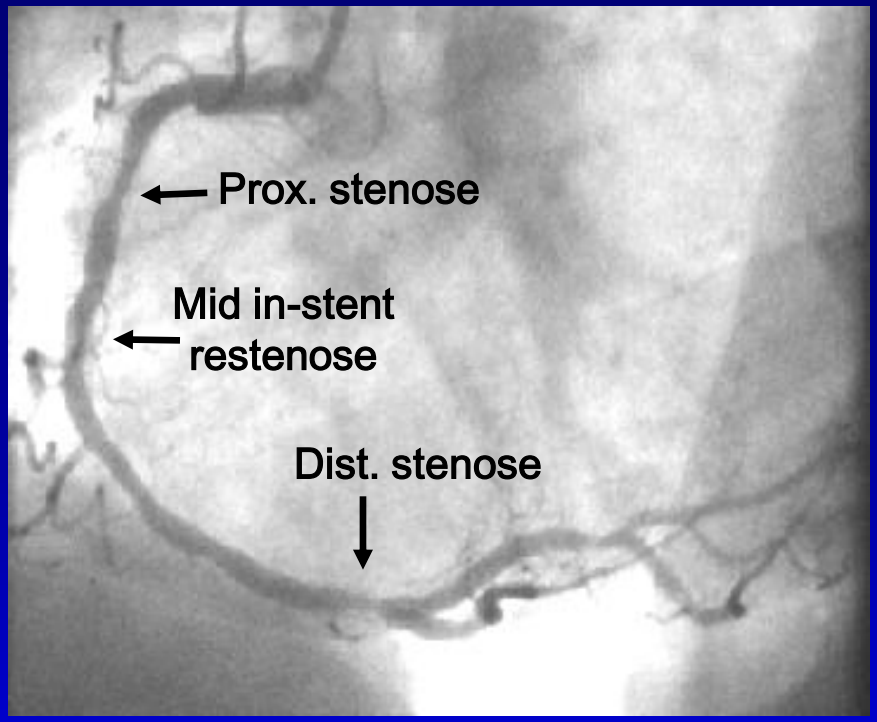
A few final issues:

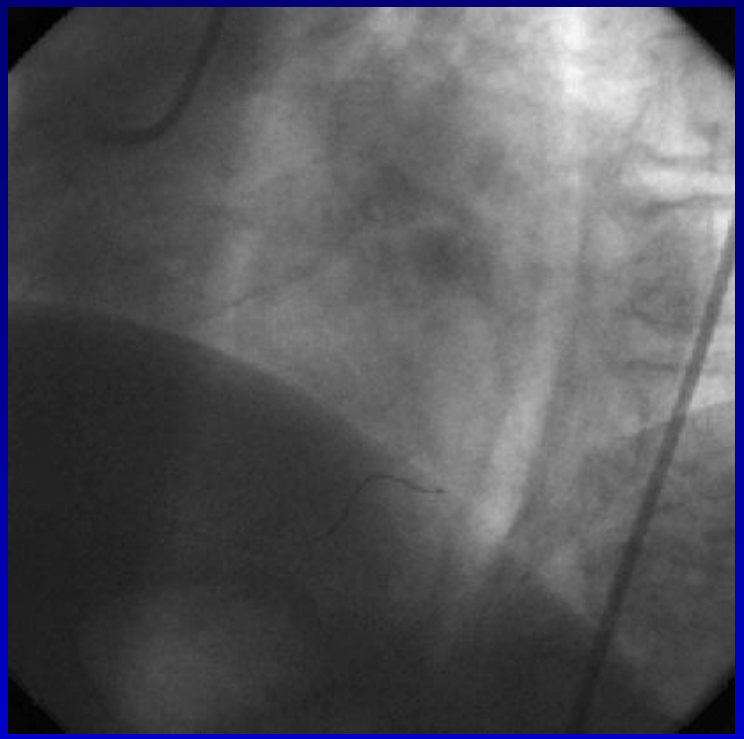
- **pressure pullback recording**
- **always necessary to induce hyperemia ?**
- **regadenoson**

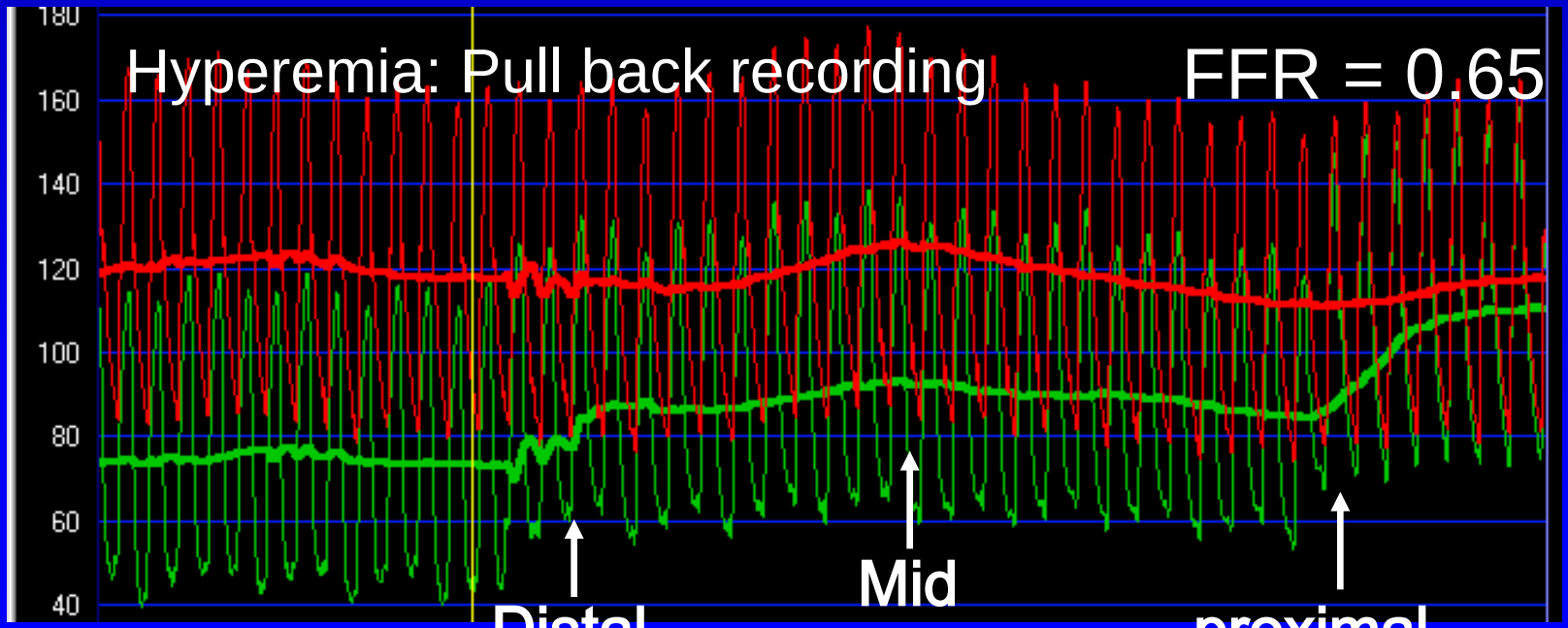


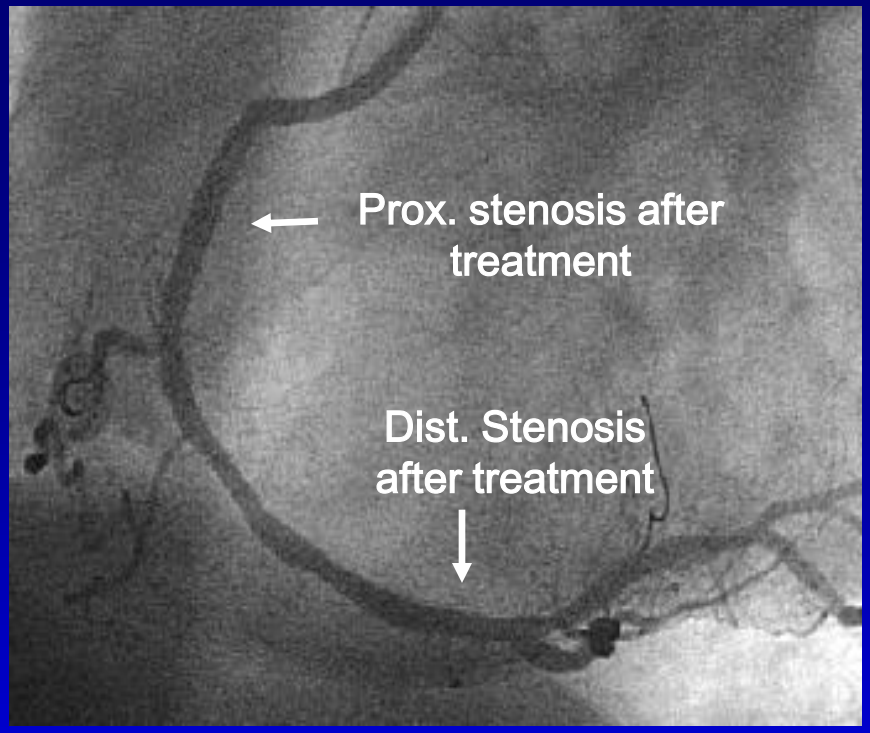


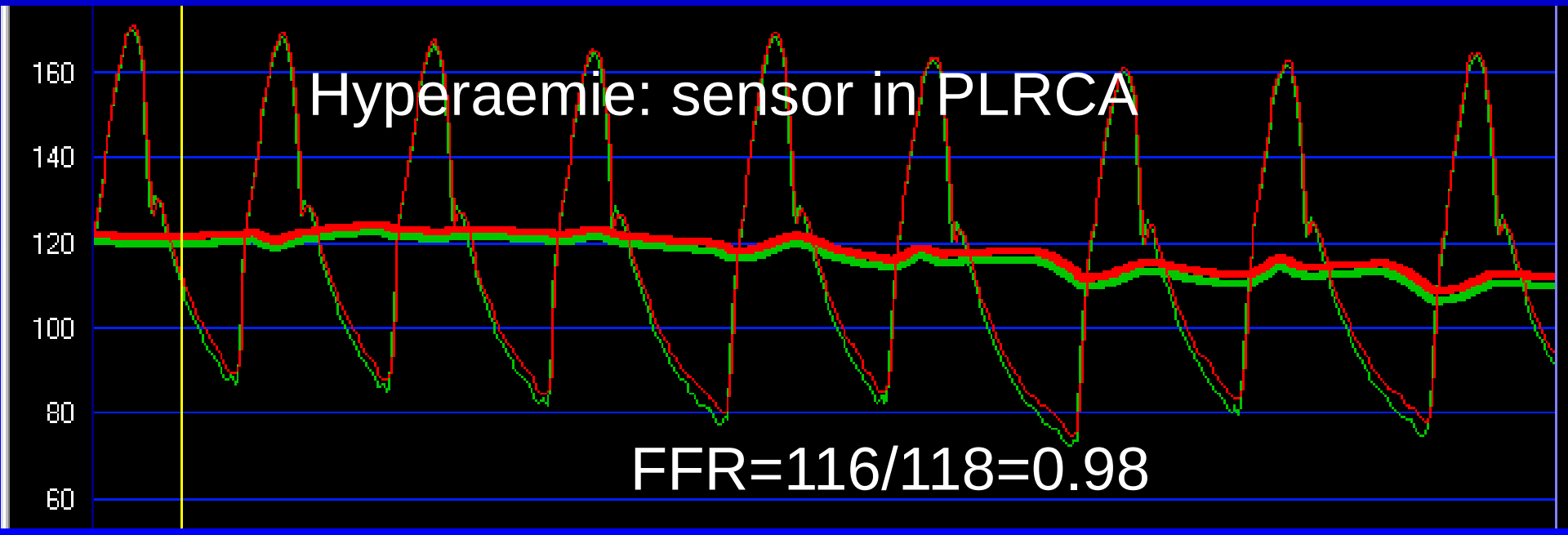

160
140
120
100
80
60
40
Hyperaemie: sensor in PLRCA
FFR=70/118=0.61


Prox. stenose
Mid in-stent restenose
Dist. stenose




Hyperemia: Pull back recording
FFR = 0.65
180
160
140
120
100
80
60
40
Distal
Mid
proximal


Prox. stenosis after treatment
Dist. Stenosis after treatment


160
140
120
100
80
60
Hyperaemie: sensor in PLRCA
FFR=116/118=0.98

A few final issues:

- **pressure pullback recording**
- ***always necessary to induce hyperemia ?***
- **regadenoson**

FFR - light

A bunch of older and newer resting indexes:
Pd/Pa at rest, diastolic Pd/Pa, iFR, i-iFR, bSRv,
(“**FFR-light**”) ,
which have in common that they all avoid hyperemia
and only have a moderate accuracy (70% -80%)

necessity of hyperemia

- If Pd/Pa at rest (or comparable indices, like iFR) is < 0.80 , as a matter of fact FFR will also be < 0.80 and hyperemia in itself is not strictly mandatory to decide upon inducible ischemia

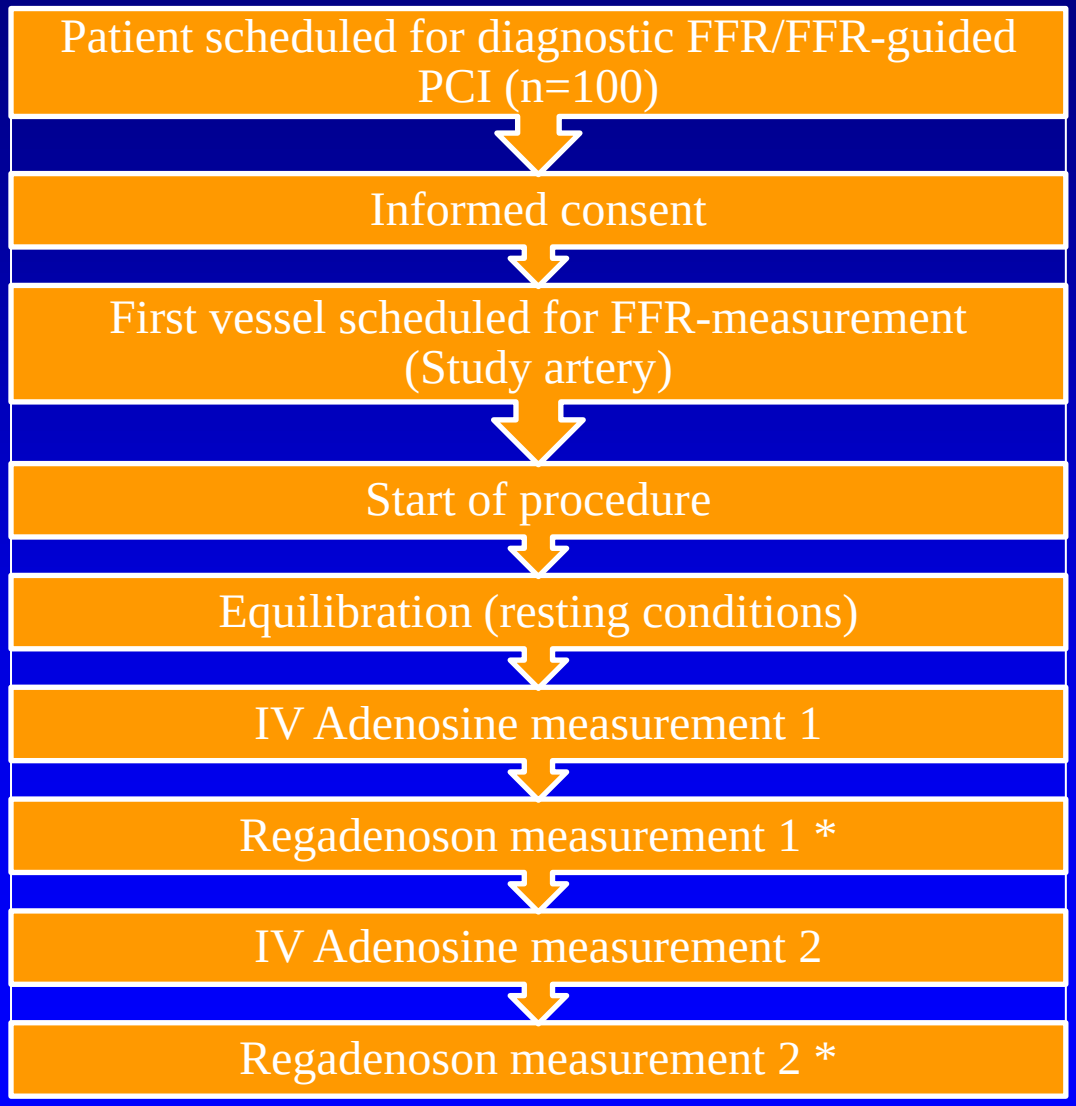
- but without hyperemia, you cannot make a meaningful *pull-back recording* and you are loosing a lot of valuable information

- and without hyperemia and FFR , you cannot judge how much a patient improved by stenting:
  you don't know where you came from
  (*"did FFR go from 0.78 to 0.91 or from 0.65 to 0.91 ?"*)
  and no resting conditions exist after PCI
  (paradoxical deterioration of resting indexes)

A few final issues:

- **pressure pullback recording**
- **necessity of hyperemia**
- ***regadenoson*** ⟶ *Lokien Van Nunen*

Adenosine (central venous infusion) vs Regadenoson

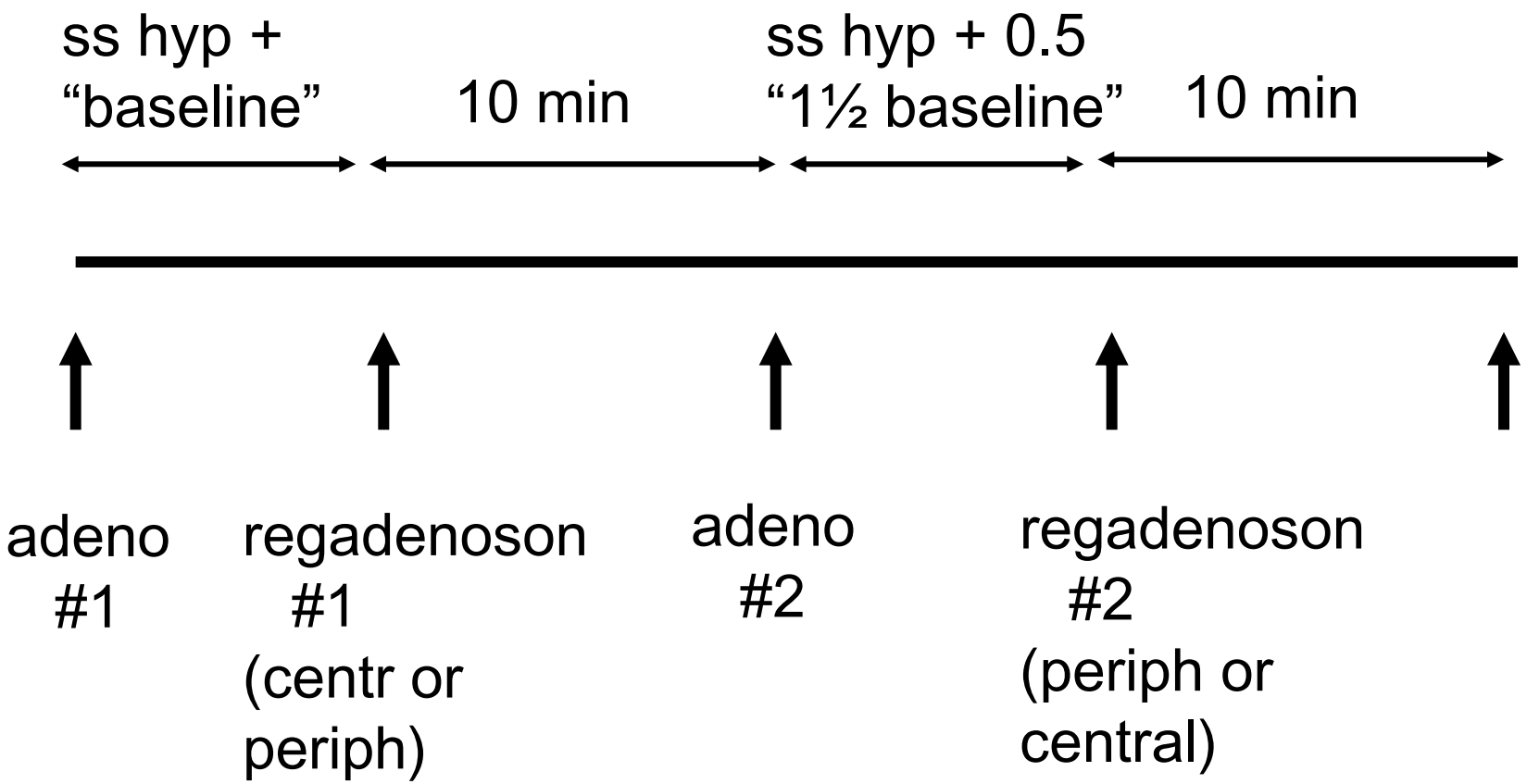


Adenosine (central venous infusion) vs Regadenoson for maximum hyperemia

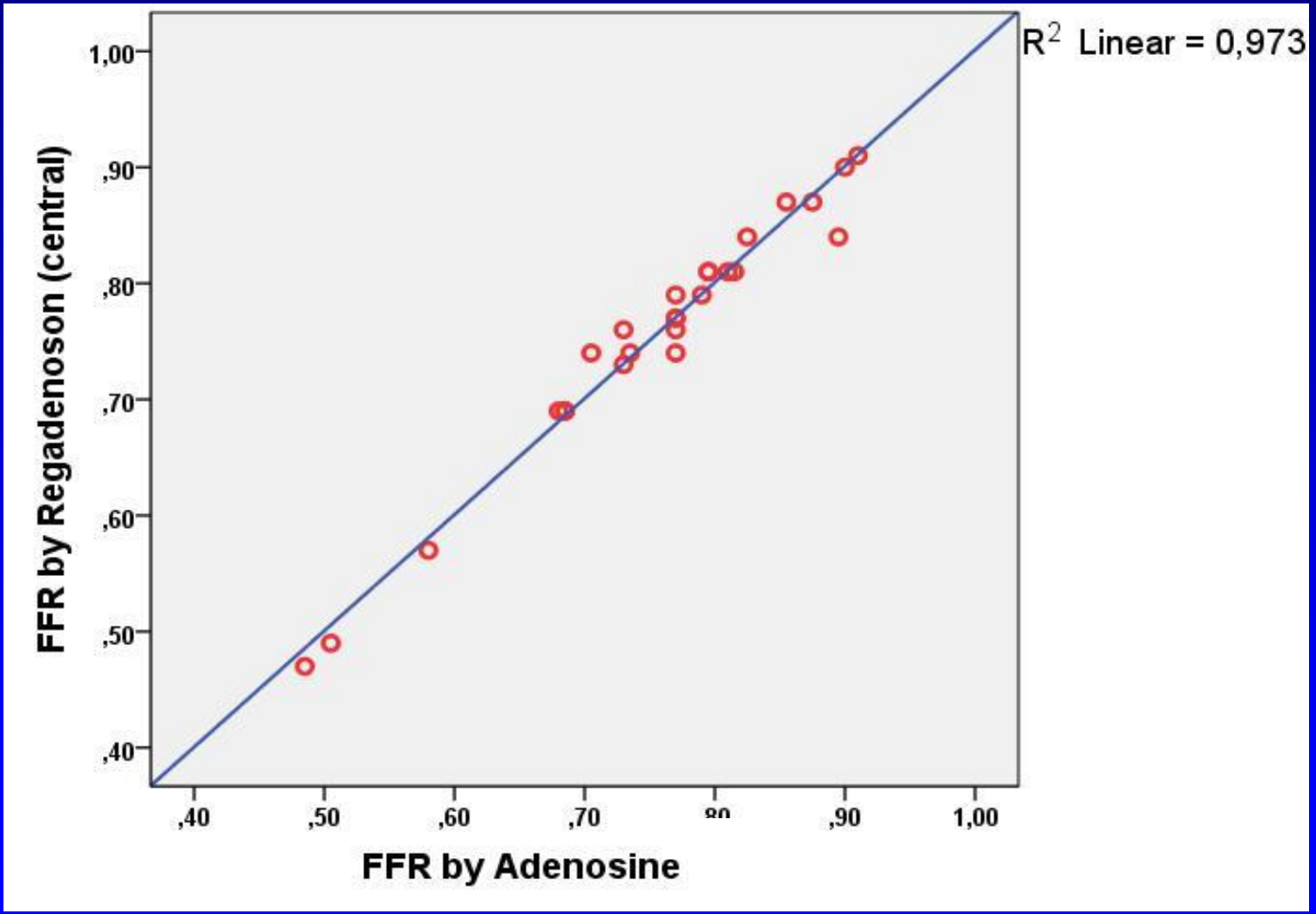
- 100 arbitrary patients admitted for FFR measurement
- central venous line (femoral sheath) and peripheral line
- adenosine 140 µg/kg/min as central venous infusion vs single bolus of 400 µg regadenoson in central or peripheral vein
- adenosine #1, regadenoson #1, adenosine#2, regadenoson #2
- randomization with respect to regadenoson:

central/central (N=25)
peripheral/central (N=25)
central/peripheral (N=25)
peripheral/peripheral (N=25)

Adenosine (central venous infusion) vs Regadenoson for maximum hyperemia



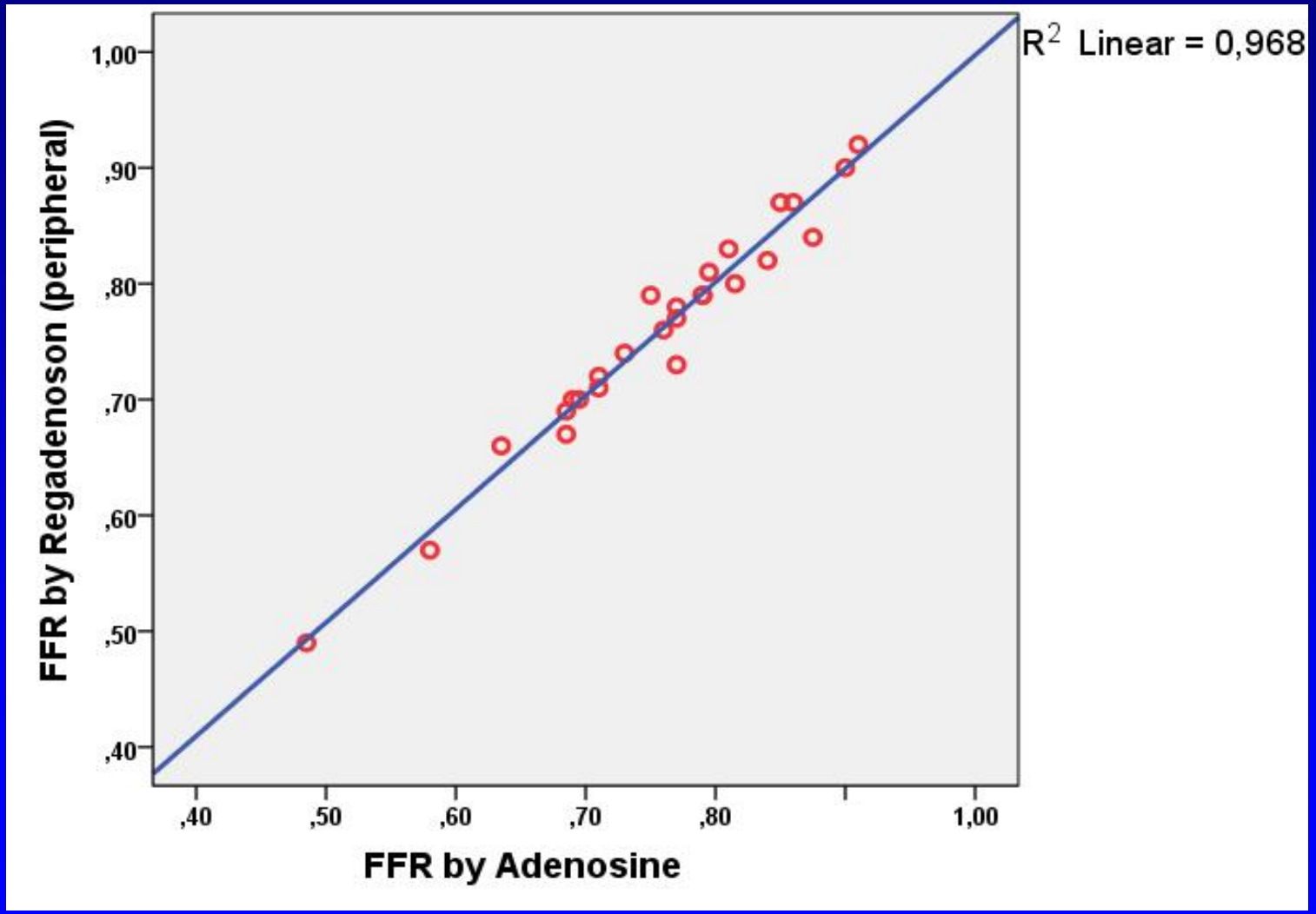
Adenosine (central venous infusion) vs Regadenoson (central venous single bolus injection 400 µg)



N=30

courtesy of Dr Lokien van Nunen

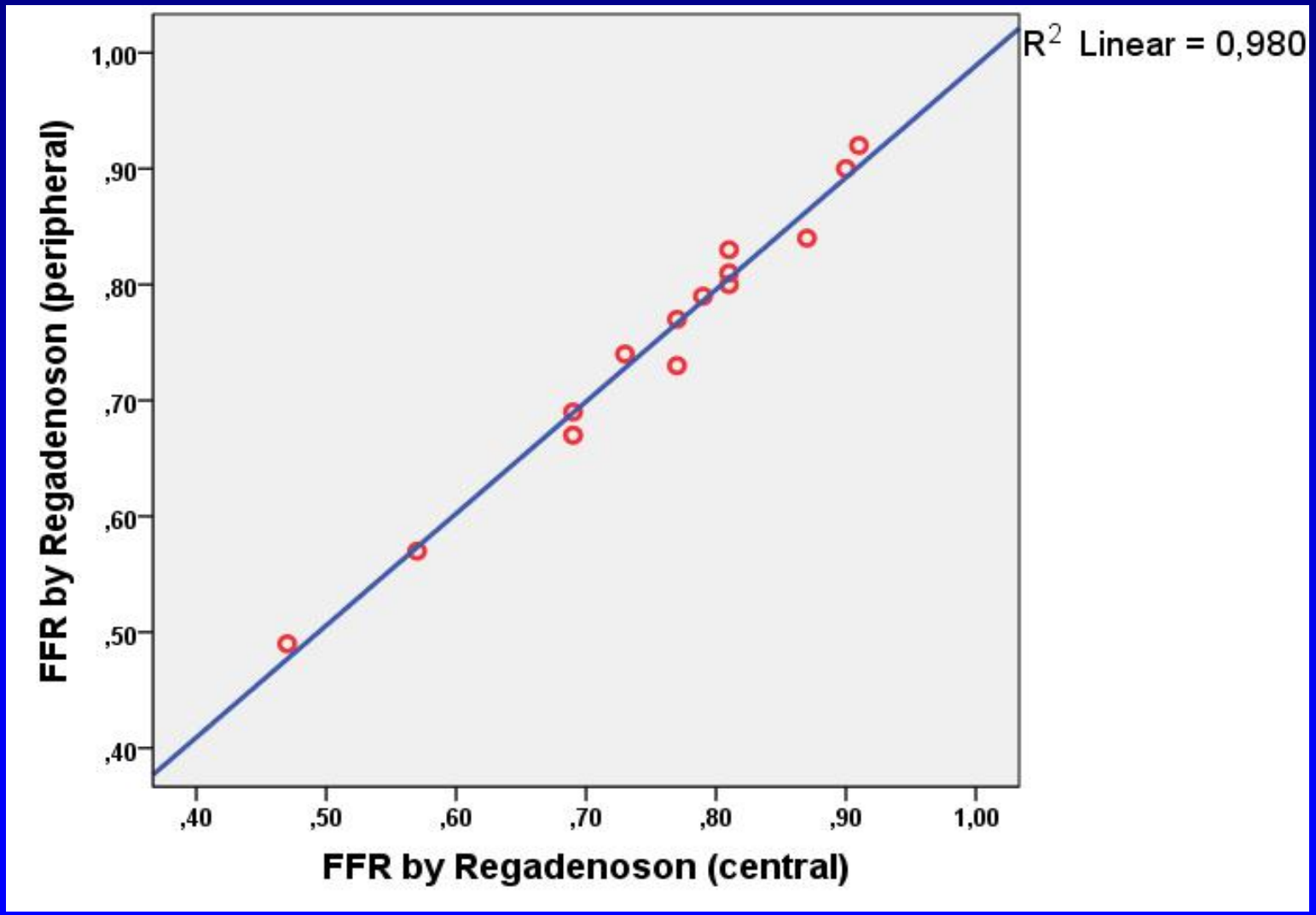
Adenosine (central venous infusion) vs Regadenoson (peripheral venous single bolus injection 400 µg)



N=30

courtesy of Dr Lokien van Nunen

Regadenoson
(central venous single bolus injection 400 µg vs peripheral single bolus 400 µg)



N=20

courtesy of Dr Lokien van Nunen

Results of first 47 Patients

- Maximum hyperemia achieved by regadenoson in ALL patients (difference compared to central venous adenosine 0.00 +/- 0.02)
- No difference between central and peripheral regadenoson
- Hyperemic plateau reached ≤ 40 sec in all patients both for central and peripheral regadenoson
- Duration of hyperemic plateau varied from 75 sec to 9 minutes (sufficient for pull-back recording in all patients)
- Zero complications or side-effects both for adenosine *(94 runs*) or (repeated) regadenoson (94 injections), except the well-known and innocent chest discomfort (graded 6/10 vs 5/10, respectively) and a few skipped beats in 2 patients (adeno) without necessity to interrupt administration

Adenosine (Central Venous Infusion)
versus
Single Bolus Injection ofRegadenoson For Maximum Hyperemia

Logo
CAZI

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Aims of this study:

- To investigate if the hyperemic effect of single bolus regadenoson injection is equal to the present gold standard i.e. central venous adenosine infusion
- To determine time intervals to onset of maximum hyperemia and the duration of steady state hyperemia if present
- To compare central venous vs peripheral venous administration of regadenoson
- To investigate side-effects as well as safety of repeated regadenoson injections, if desired

Conclusions (halfway this study)

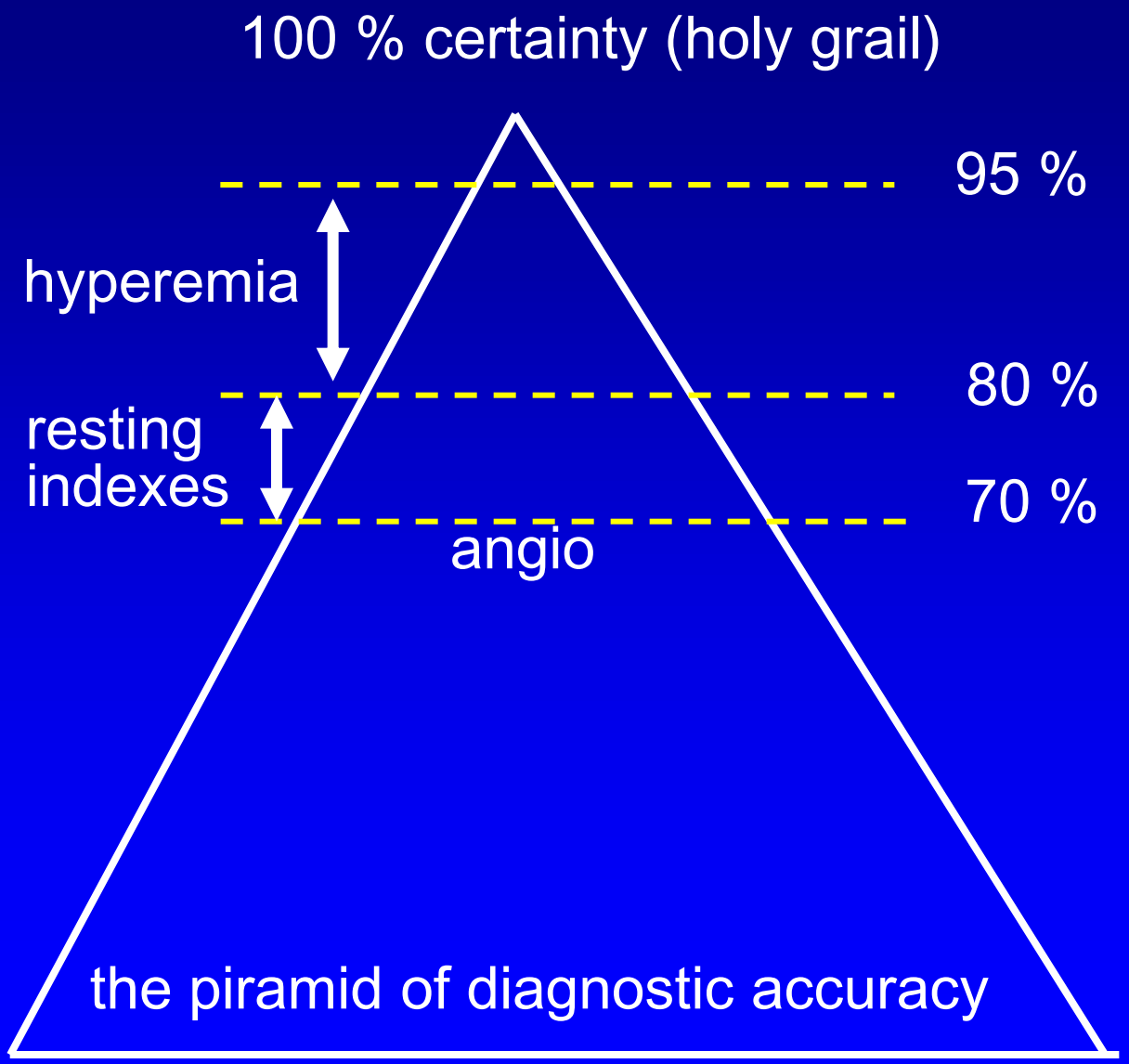
- Regadenoson as a single bolus injection of400 µg, is an excellent alternative for central venous adenosine infusion to induce maximum hyperemia
- Rapid onset (~ 30 sec) and steady state long enough (at least 75 sec) to perform pressure pullback recording,
- In case multiple arteries need to be investigated, repeated injection can be performed and is safe
- No noticeable side effects of regadenoson or adenosine, except the harmless chest discomfort

Correct Classification of Ischemic Stenosis

FFR

resting Pd/Pa, iFR, bSVr (“FFR-light”)

angiography



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*

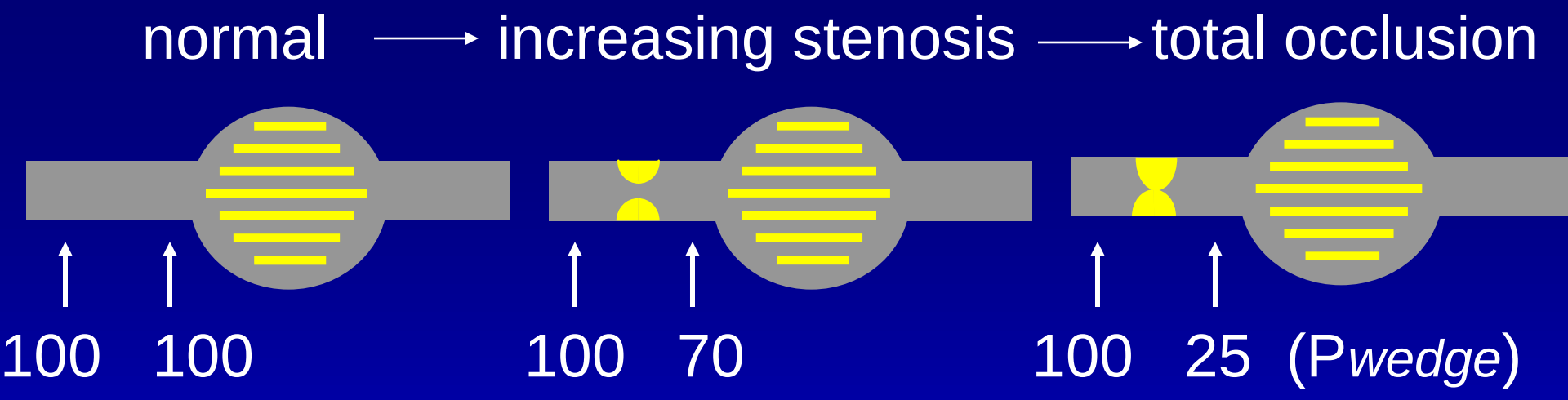
- *At maximum vasodilation (corresponding with maximum hyperemia or with maximum exercise), blood flow to the myocardium is proportional to **myocardial perfusion pressure***
  *(**~hyperemic distal coronary pressure**)*

FRACTIONAL FLOW RESERVE =

MAXIMUM FLOW IN THE PRESENCE OF A STENOSIS

NORMAL MAXIMUM FLOW

$$\approx \frac{\text{Distal coronary pressure at maximum hyperemia}}{\text{Aortic pressure}}$$



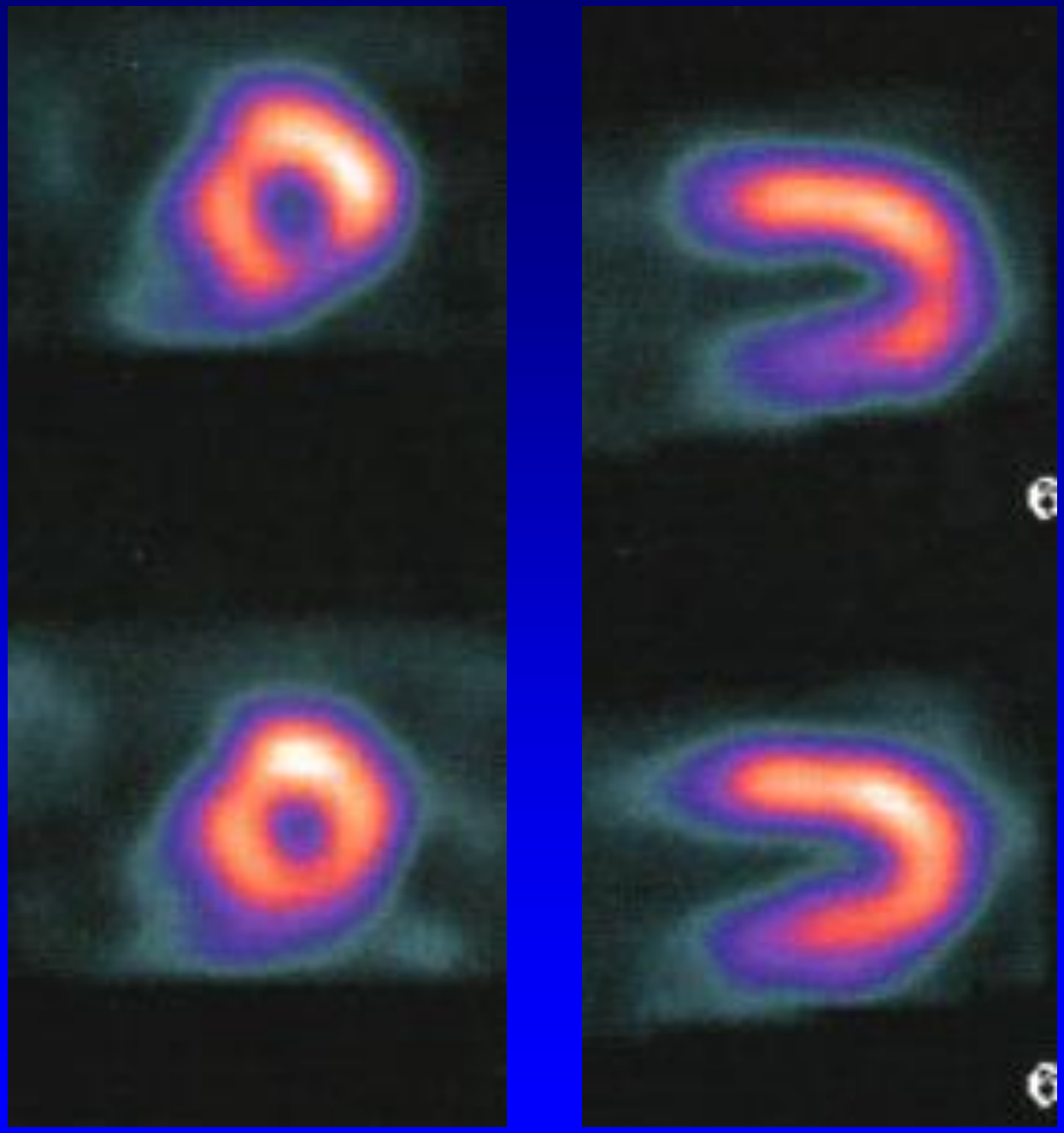
Maximum myocardial perfusion:

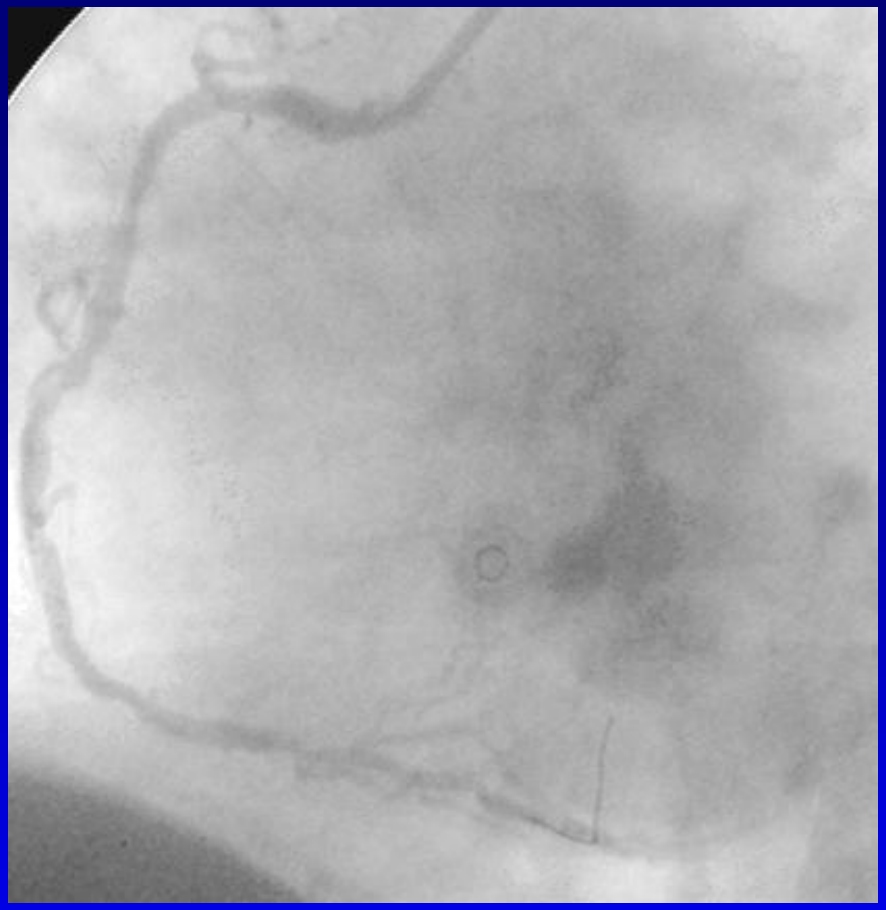
100% ⟶ ***70%*** ⟶ ***25%***

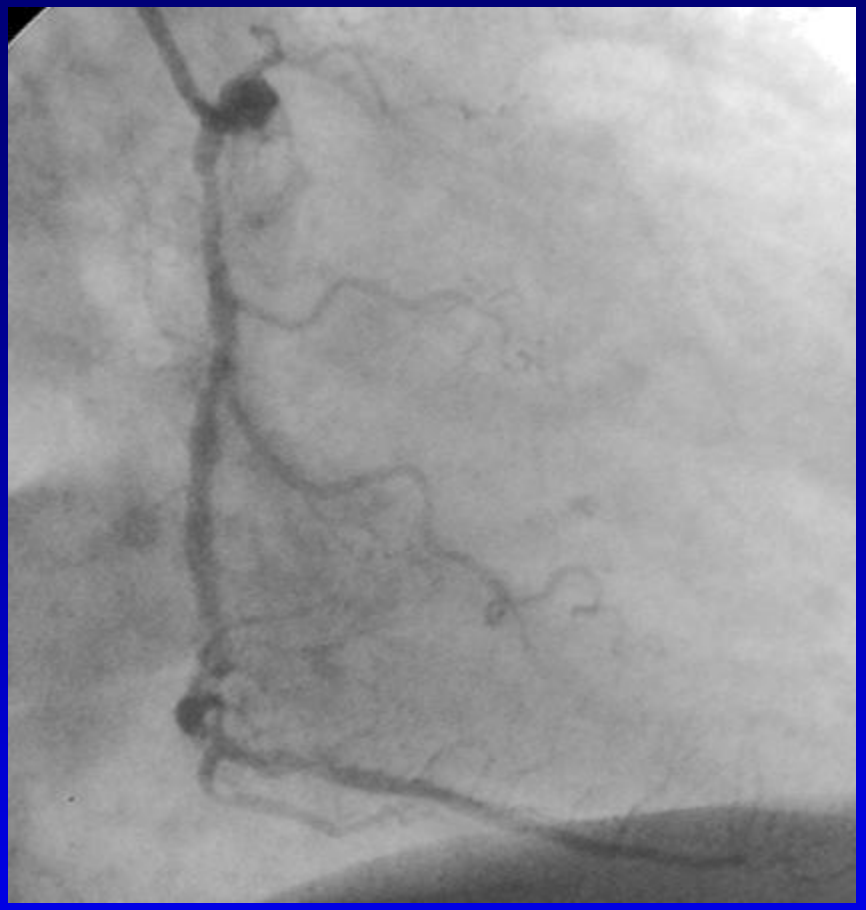
FFR: **1.0** ⟶ **0.7** ⟶ **0.25**

In other words: FFR is linearly related to maximum achievable blood flow

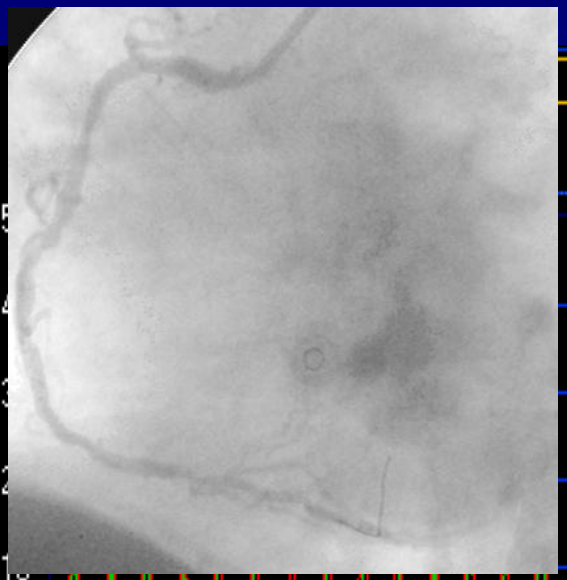
Angina
Pectoris
&
Pos MIBI:







Typical chest pain; positive MIBI-Spect inferior wall



EDIT RENAME EXPORT ERASE SETUP

2004-06-14 15:55:19

109
Pa mean

84
Pd mean

0,77
FFR

7,9
Cursor

RESET

Hyperemic pull-back recordingalong the RCA

FFR: The Pressure Pull-back Curve

Pressure pull-back curve at maximum hyperemia:

- place sensor in distal coronary artery
- induce sustained maximum hyperemia by i.v. adenosine, or i.c. papaverine
- pull back the sensor slowly under fluoroscopy
- the individual contribution of every segment and spot to the extent of disease can be studied in this way

Coronary pressure is unique in this respect and such detailed spatial information cannot be obtained by any other invasive or non-invasive method