Physiologic Assessment of Coronary Artery

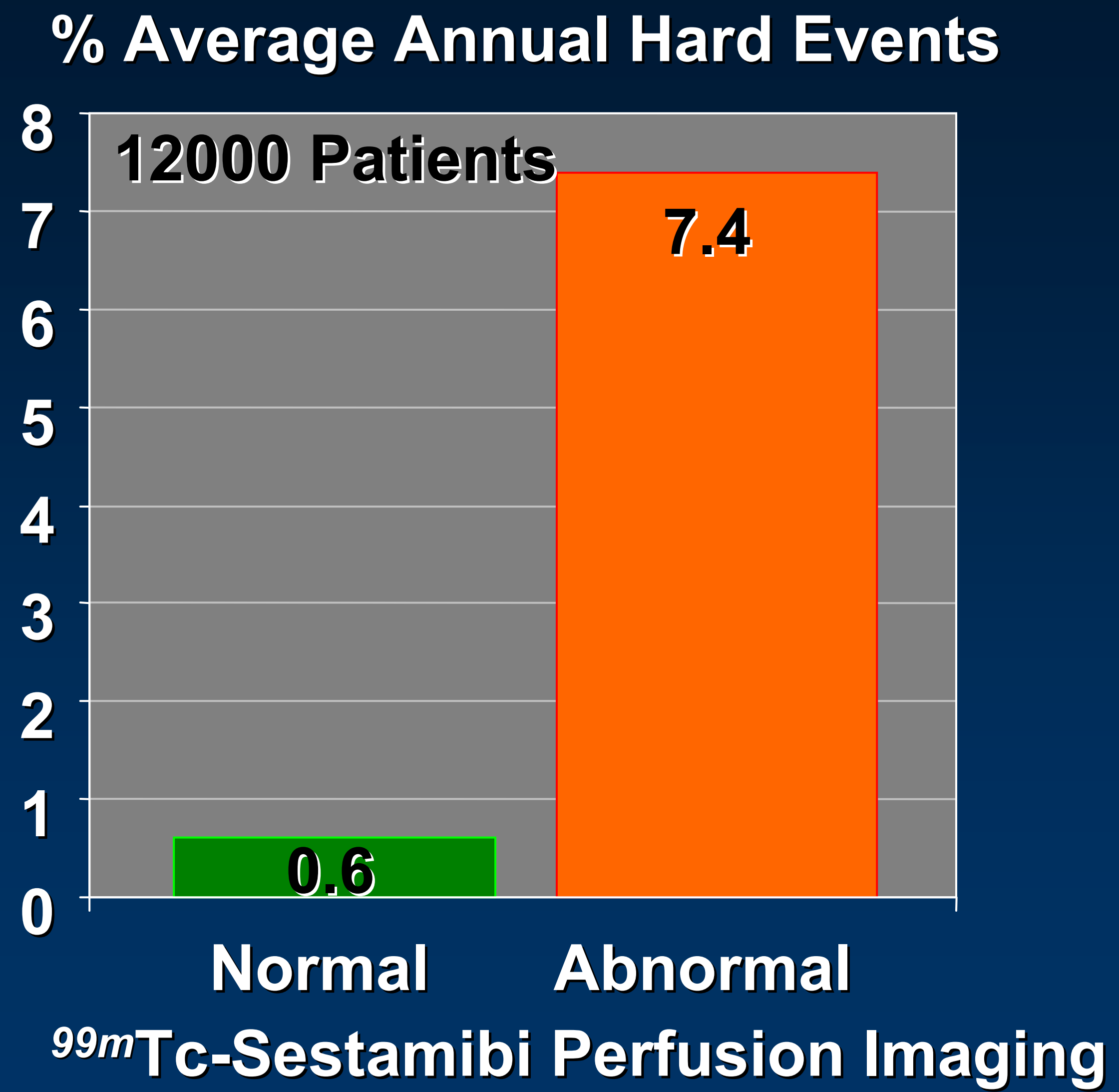
Myeong-Ho Yoon

**Ajou University, School of Medicine,
Department of Cardiology,
Suwon, Korea**

Concept of FFR

related to
pressure measurements

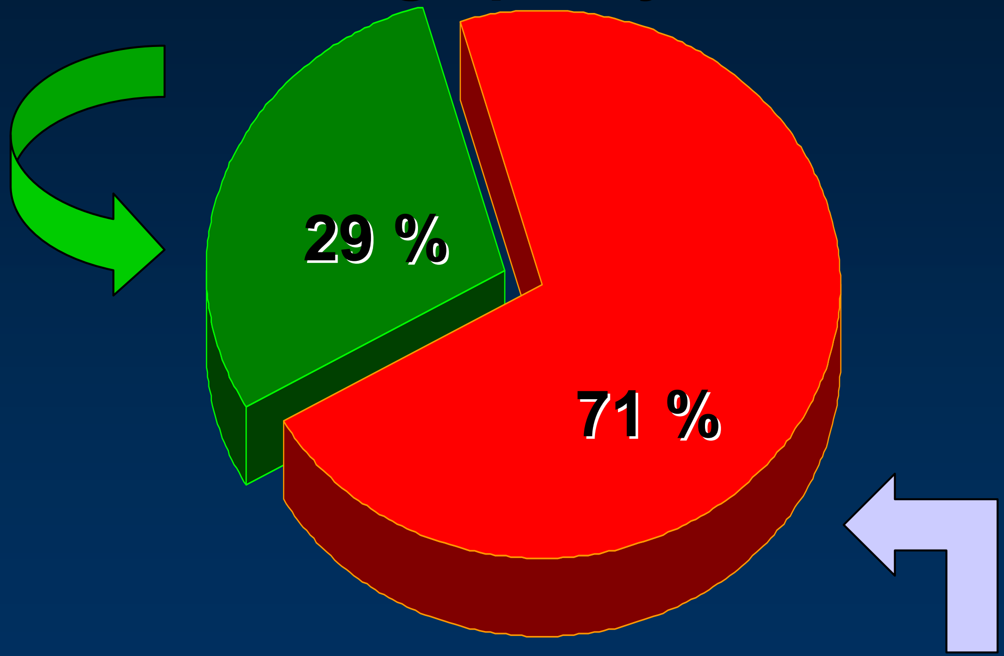
Prognostic significance of reversible ischemia at MIBI-Spect



Iskander S et al, JACC 1998

Non-Invasive Stress Testing and PCI

Exercise Test Performed Before Angioplasty



NO Exercise Test Performed Before Angioplasty

Topol et al. Circulation 1993

Conceptual limitations of non-invasive testing:

- ***Diagnostic accuracy not optimal***, especially not in intermediate stenosis

- ***Limited spatial resolution***, *especially in patients with more complex disease* (unfortunately quite common nowadays) :
  - *multivessel disease*
  - *several stenoses within the same artery*
  - *uncertainty about exact perfusion territories*

- No discrimination between ***epicardial vs microvascular disease*** or ***local stenosis vs diffuse epicardial disease***

Practical reasons ***why non-invasive testing is often not performed:***

- Needs to be performed in *another department* (MIBI-Spect)

- *Patient is already on the table* for diagnostic angiography and the interventionalist wants to proceed immediately

- Increasing numbers of *acute patients* in the cathlab (with often multiple lesions)

- *Financial considerations, shortening of hospital stay*

Assessing Stenosis Severity in the Catheterization Laboratory

Quantitative Coronary Angiography

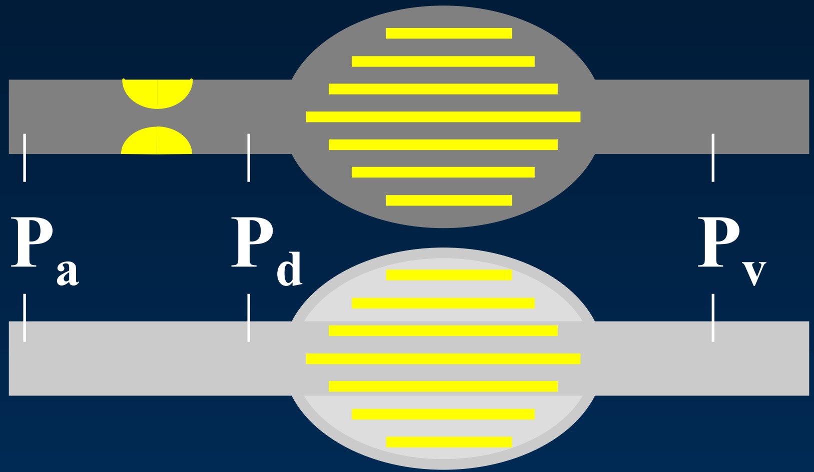
Limitations

- ***applicable in only a minority of stenoses***
- ***reference segment = normal***
- ***not all dimensions taken into account***
- ***physiologic parameters not taken into account***
- ***collaterals not taken into account***

→ **Not very helpful for clinical decision making.**

FFR (Myocardial Fractional Flow Reserve):

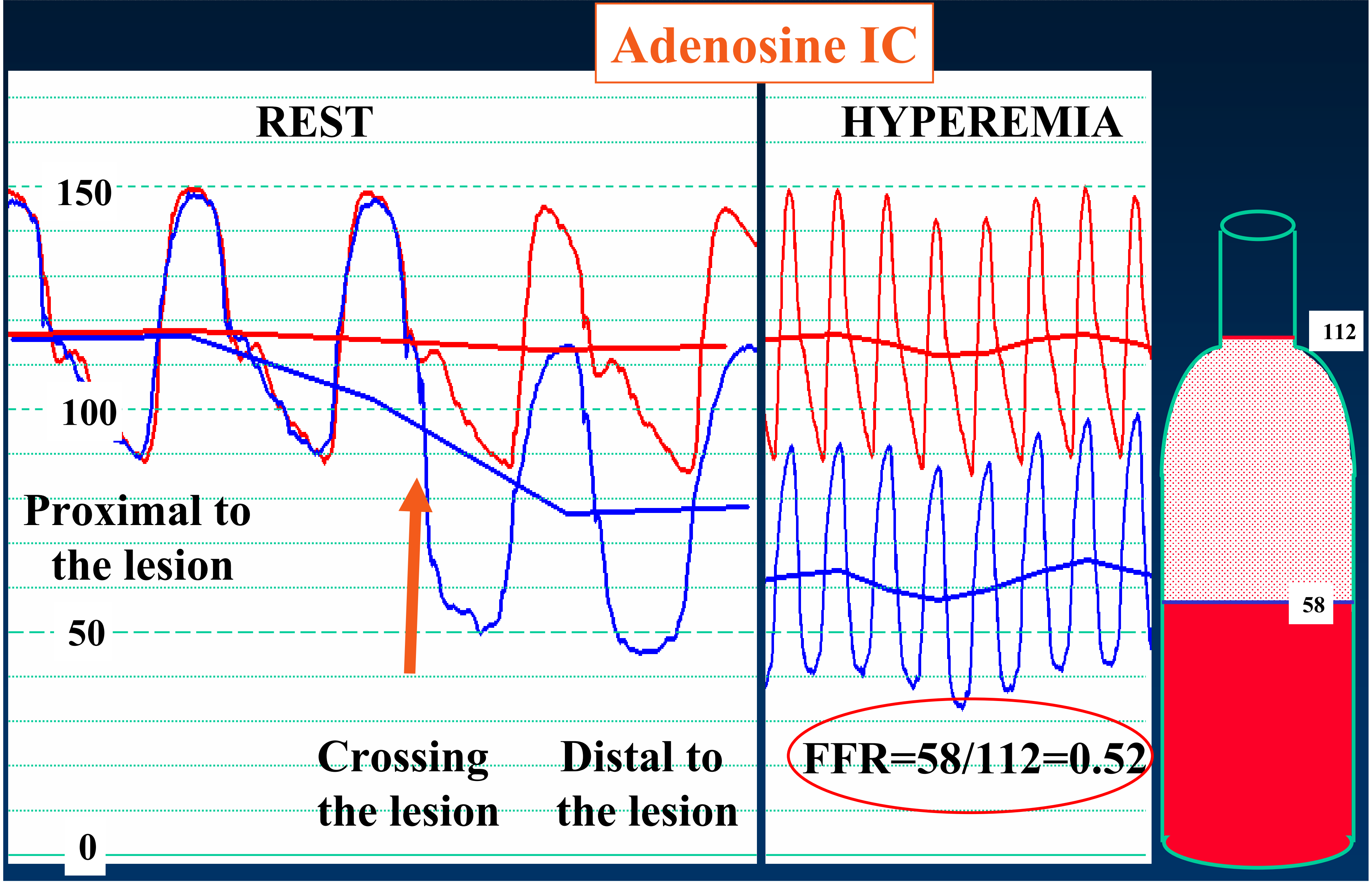
a Flow Index Derived from Pressures



$$\frac{Q^{S}_{max}}{Q^{N}_{max}} = FFR$$

$$FFR = \frac{(P_d - P_v) / R_{myo}}{(P_a - P_v) / R_{myo}} = \frac{P_d}{P_a}$$

Fractional Flow Reserve in Clinical Practice

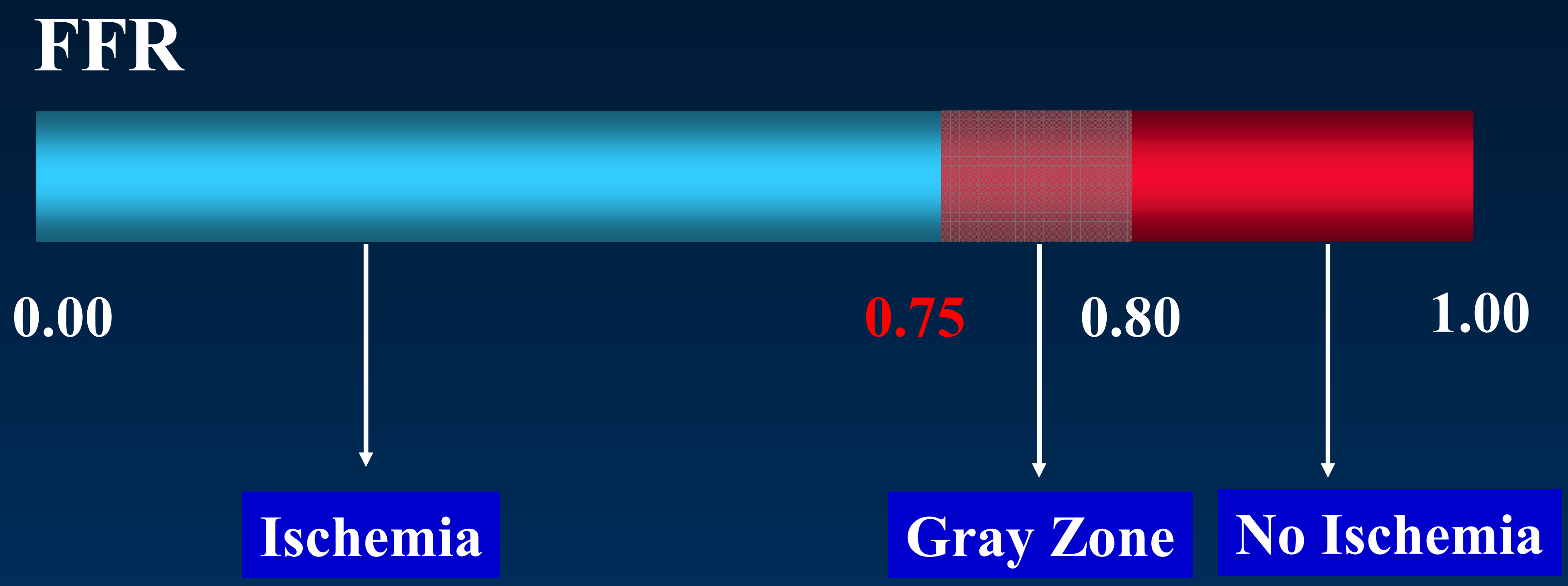


Normal Value of FFR

$$FFR = \frac{P_d}{P_a}$$

Normal FFR = 1

Ischemic Value of FFR



Ischemic FFR = 0.75

Coronary Pressure Measurements

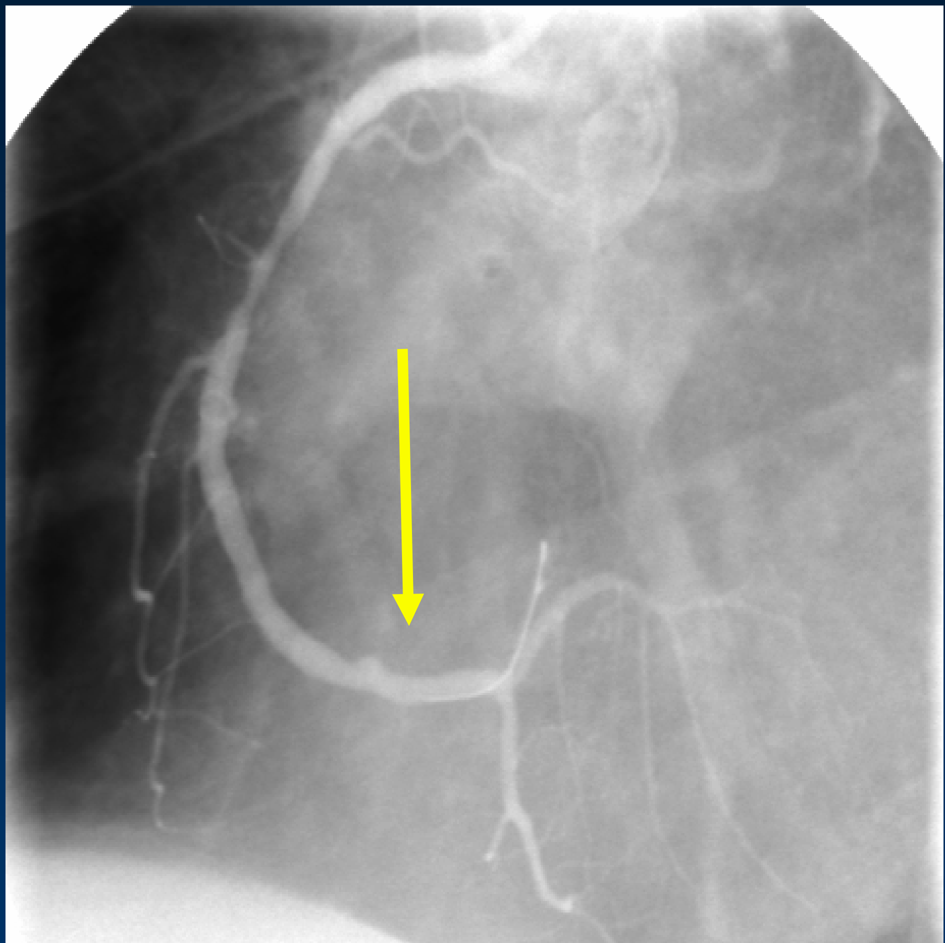
Prerequisits

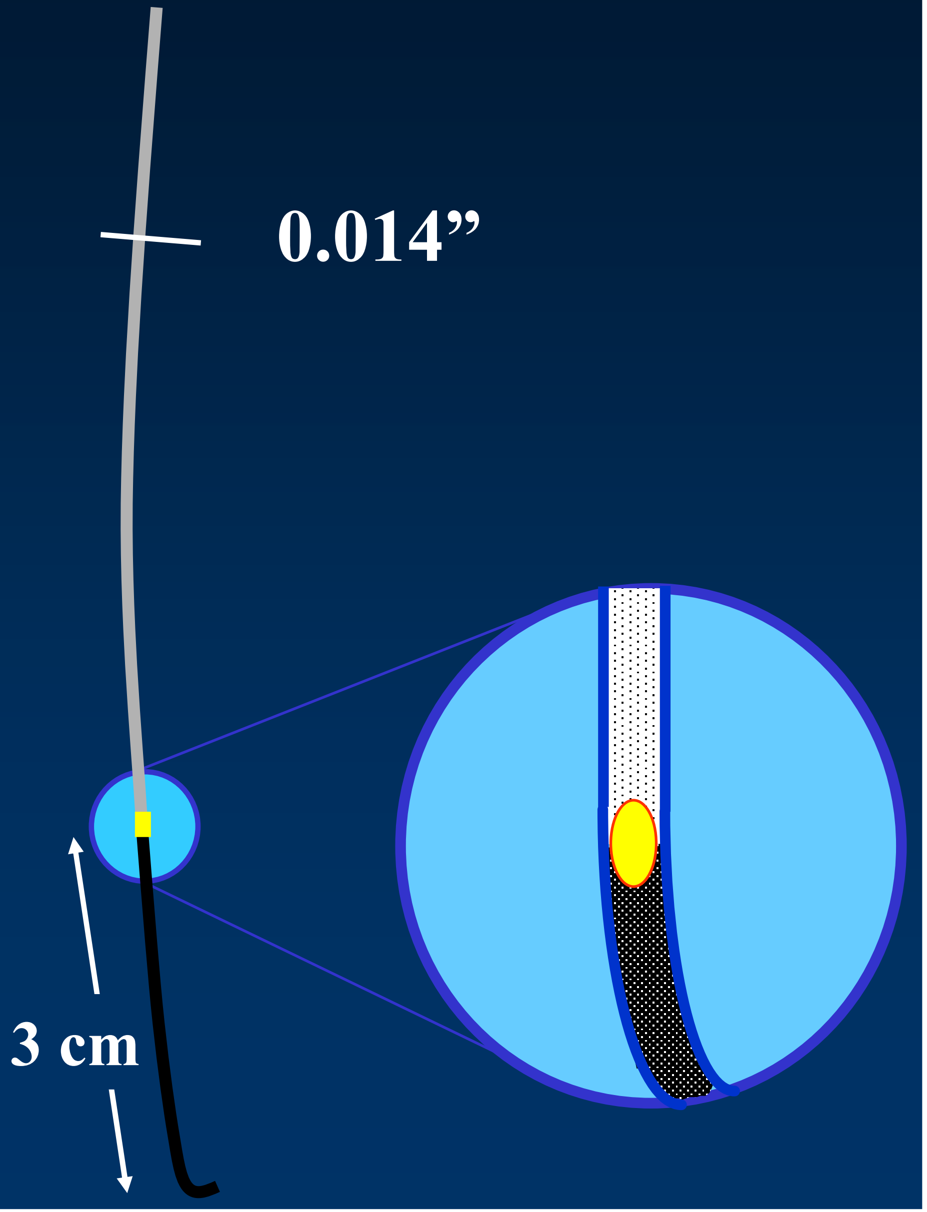
1. Pressure Measuring Guide Wire

2. Maximal Hyperemia

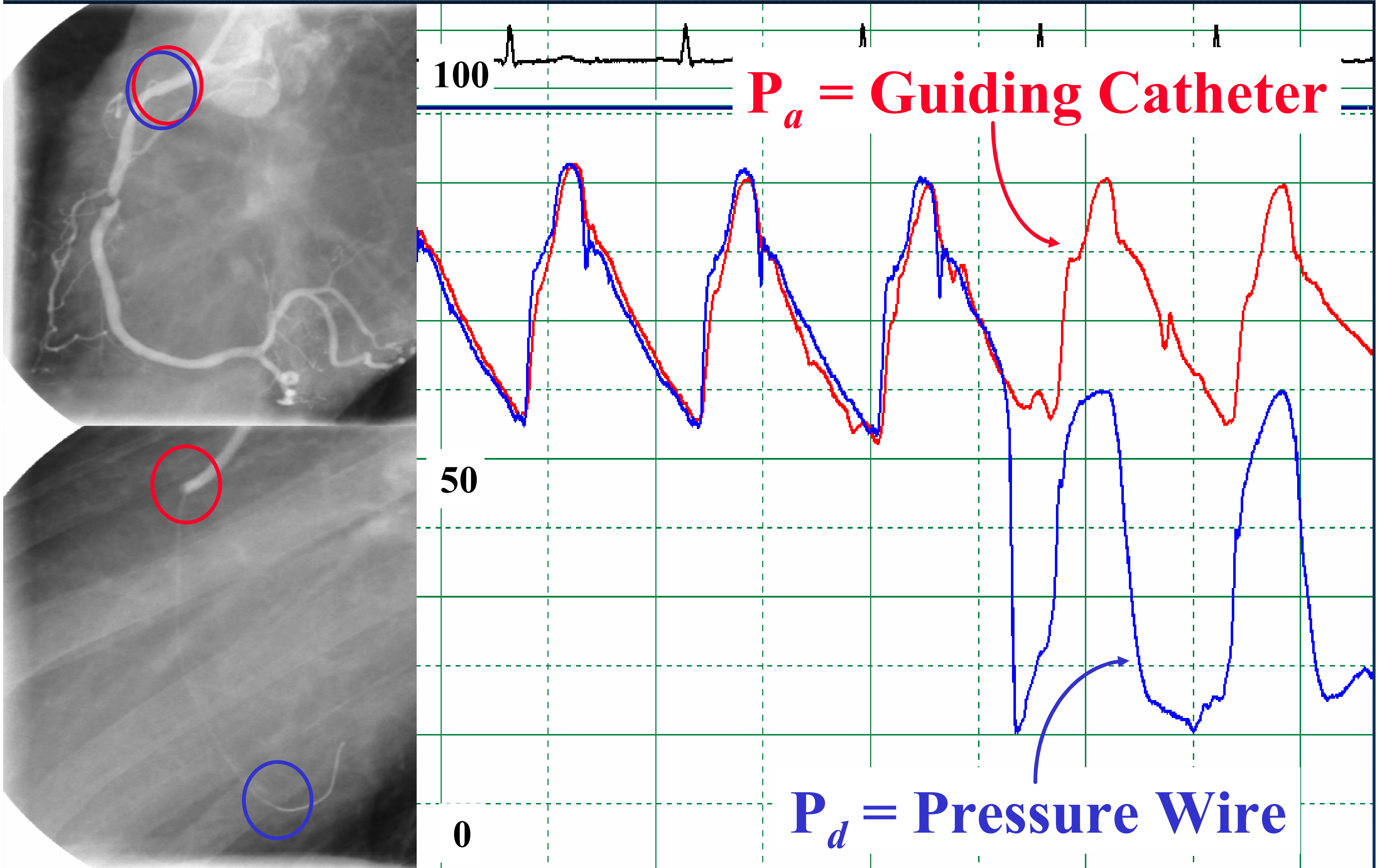
3. FFR instead of $\triangle$P

Pressure Monitoring Guide Wire





Pressure Monitoring Guide Wire

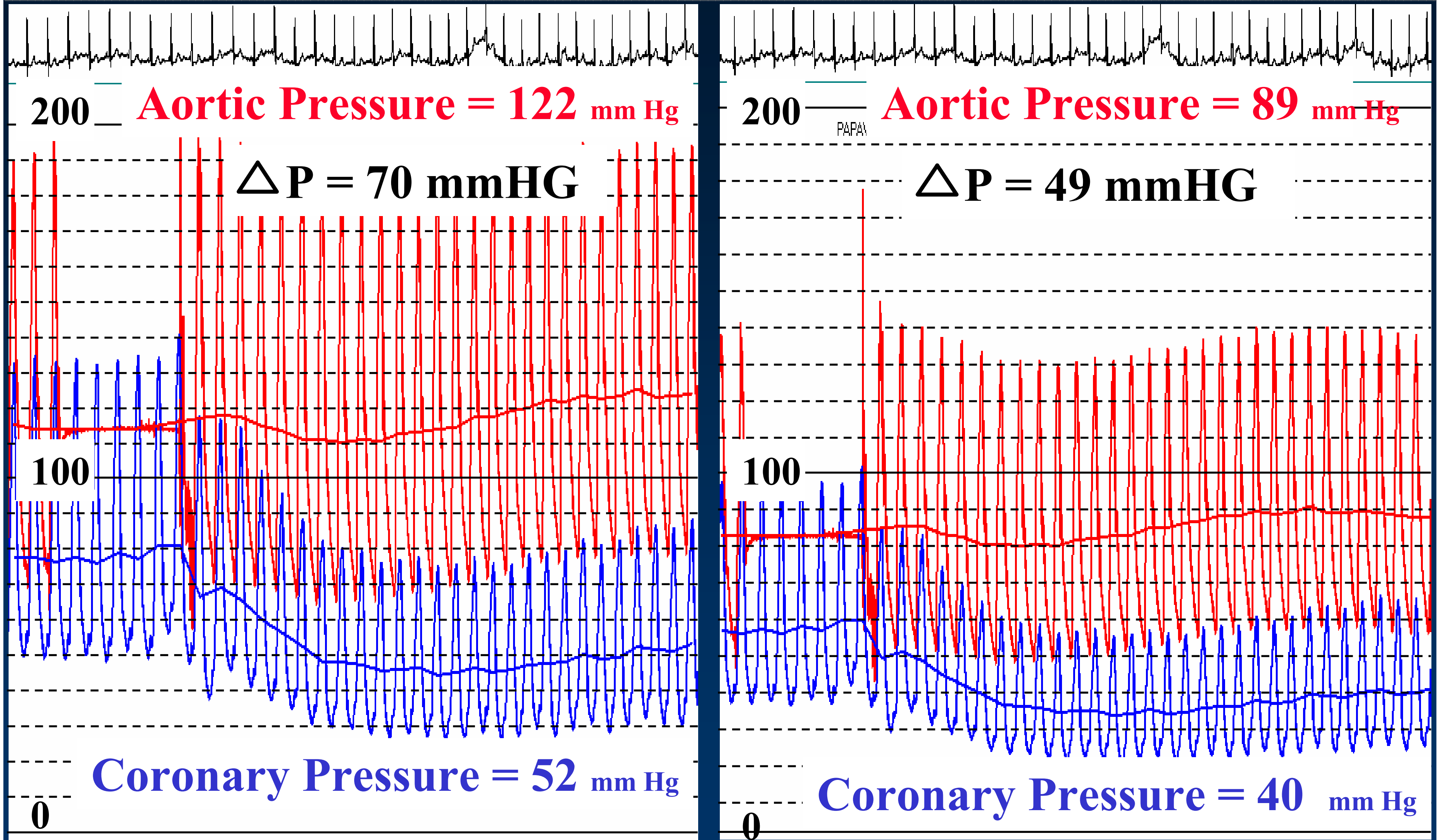


Hyperemia - administration

- Hyperemic stimuli
  - Intravenous Adenosine 140-160 μg/kg/min
  - Intracoronary Adenosine LCA: 20-40 μg

    RCA: 15-30 μg
  - Intracoronary Adenosine Infusion

Influence of Systemic Pressure on Trans-stenotic Gradient



FFR = 52/122 = 0.43

FFR = 40/89 = 0.45

FFR: Unique Features

FFR_{myo} ...

- is a **lesion specific index**
- is **independent** of hemodynamic parameters
- has a **normal value of 1.0**
- takes into account collateral flow
- has **no need** for a normal **control artery**
- can be **easily obtained**: $FFR_{myo} = P_d / P_a$

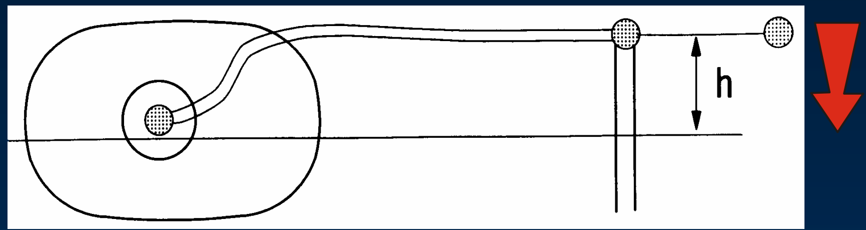
Pitfalls

related to
pressure measurements

Pitfalls, The "Height effect"

- The proximal pressure is normally measured through the liquid column in a guiding catheter

! External pressure sensor must be fixed level with the heart

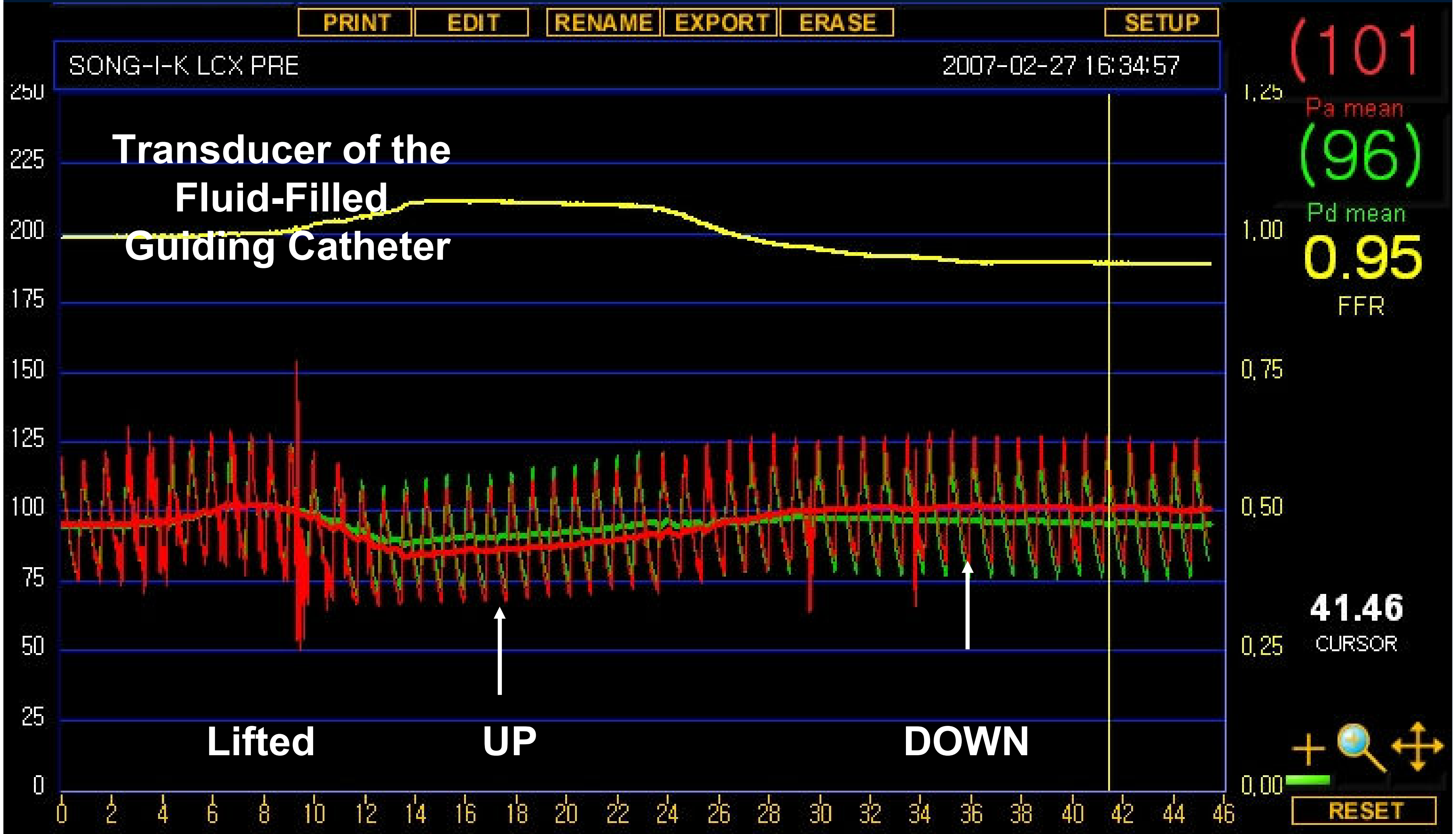


- 13 mm difference in height (h) will produce an error of 1 mm Hg.

- **Place the sensor close to the tip of the guide catheter.**
- **Adjust the height of the external pressure transducer, until signals are equal.**

Pijls and De Bruyne "Coronary Pressure" Kluwer Academic Publishers 1997, pp110.

Importance of the Height of the Transducer



Pressure leakage
through RHV / Guidewire Introducer

Cause

Minimal leakage from RHV = pressure loss from guiding catheter (typically 5-8 mmHg)

Can occur if RHV is tightened with g.w. introducer still in place

Effect

Pa under-estimated

FFR over-estimated

Recommendations, Guiding Catheter Size

Diagnostic case:	6 F or 7 F
Interventional case:	7 F

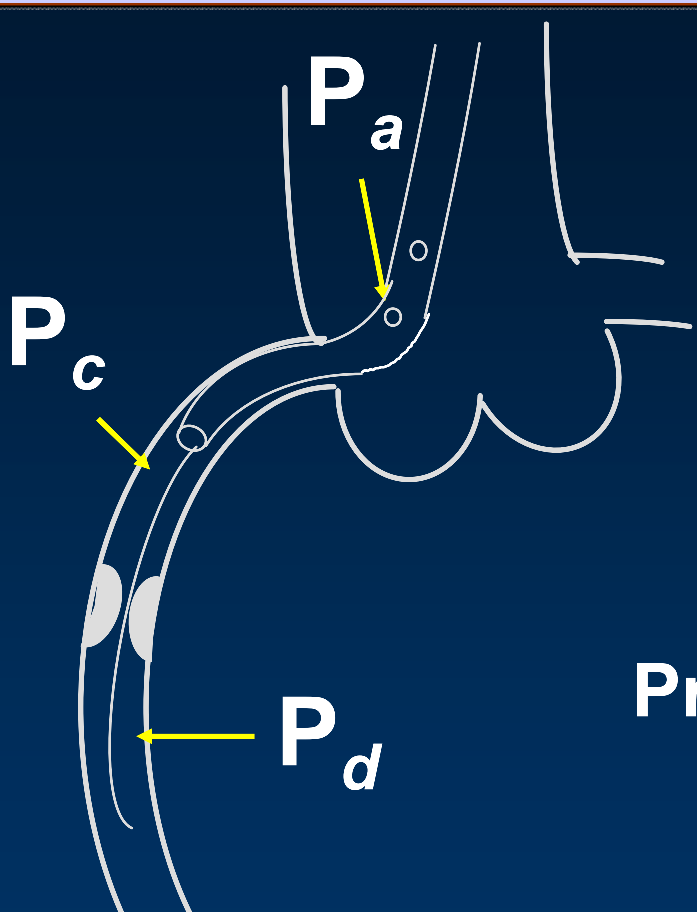
Too small

damped aortic signal through the guiding catheter

Too big

partial occlusion/restriction of coronary blood flow

FFR and Guidings with Side-Holes



$P_c \neq P_a$

↓ ↓

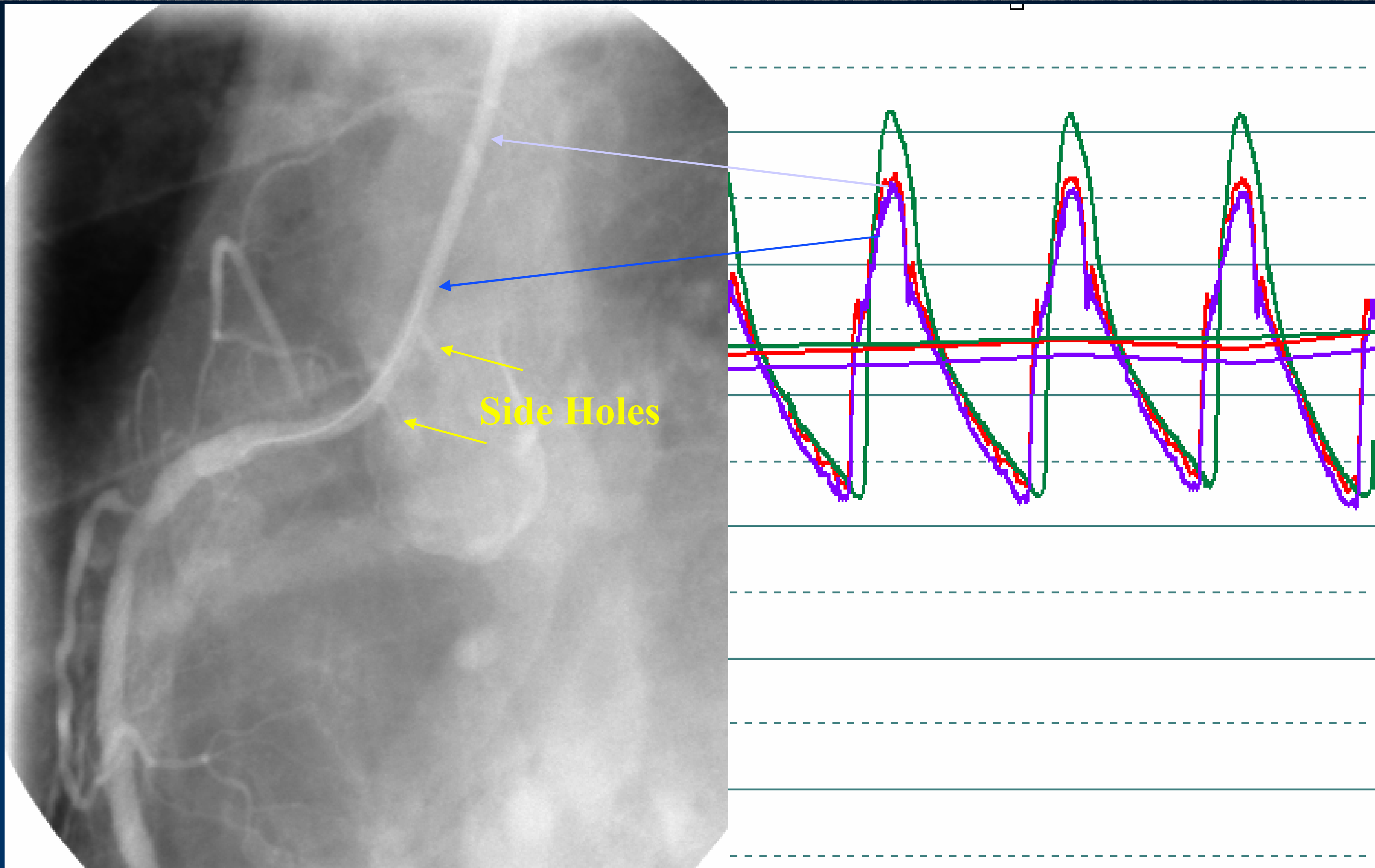
Pressure recorded by guiding

When wedging of the catheter, withdraw guiding from ostium

For flow or pressure measurements:

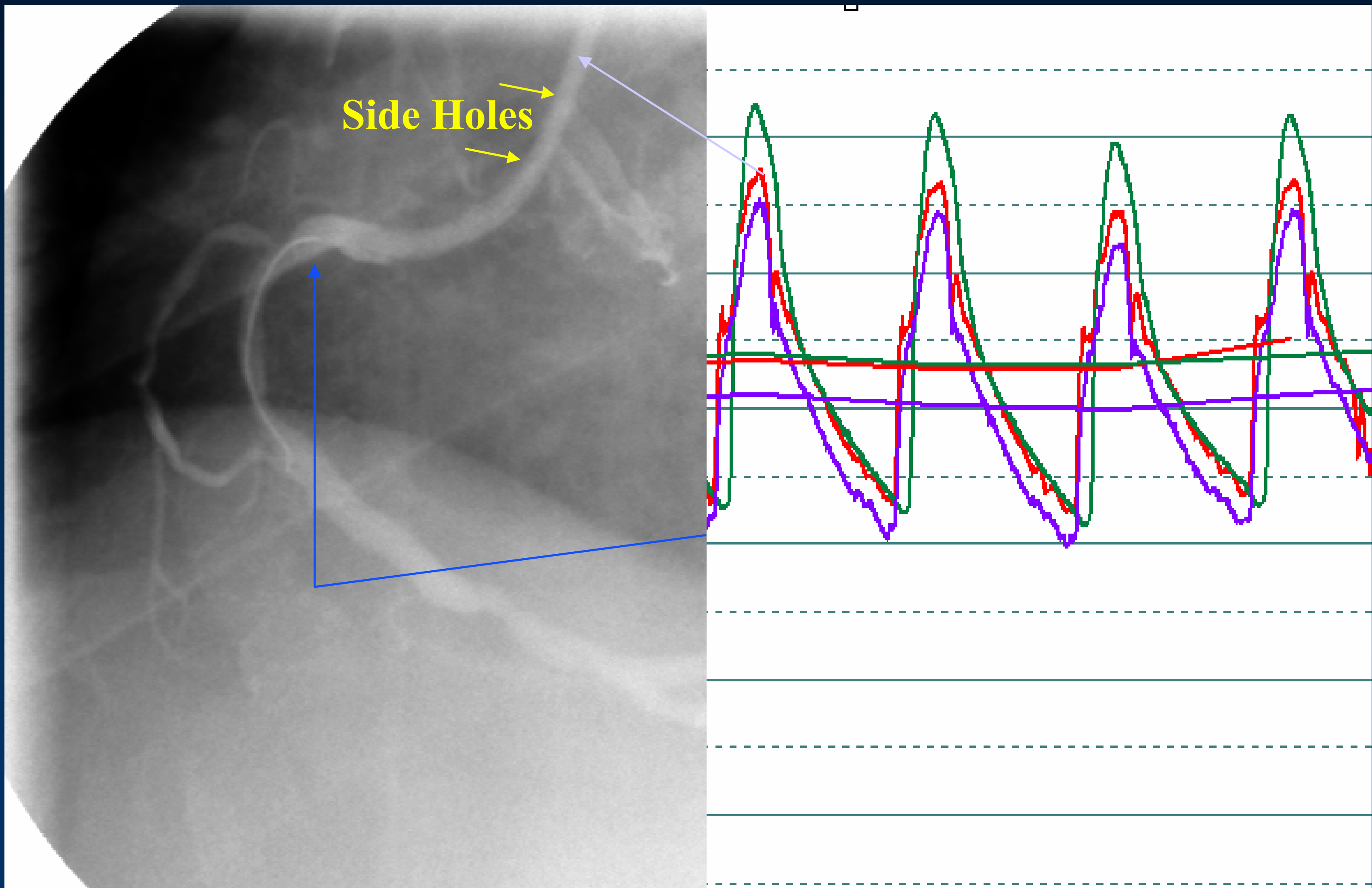
NO SIDE-HOLES

Guiding Catheter With Sides Holes



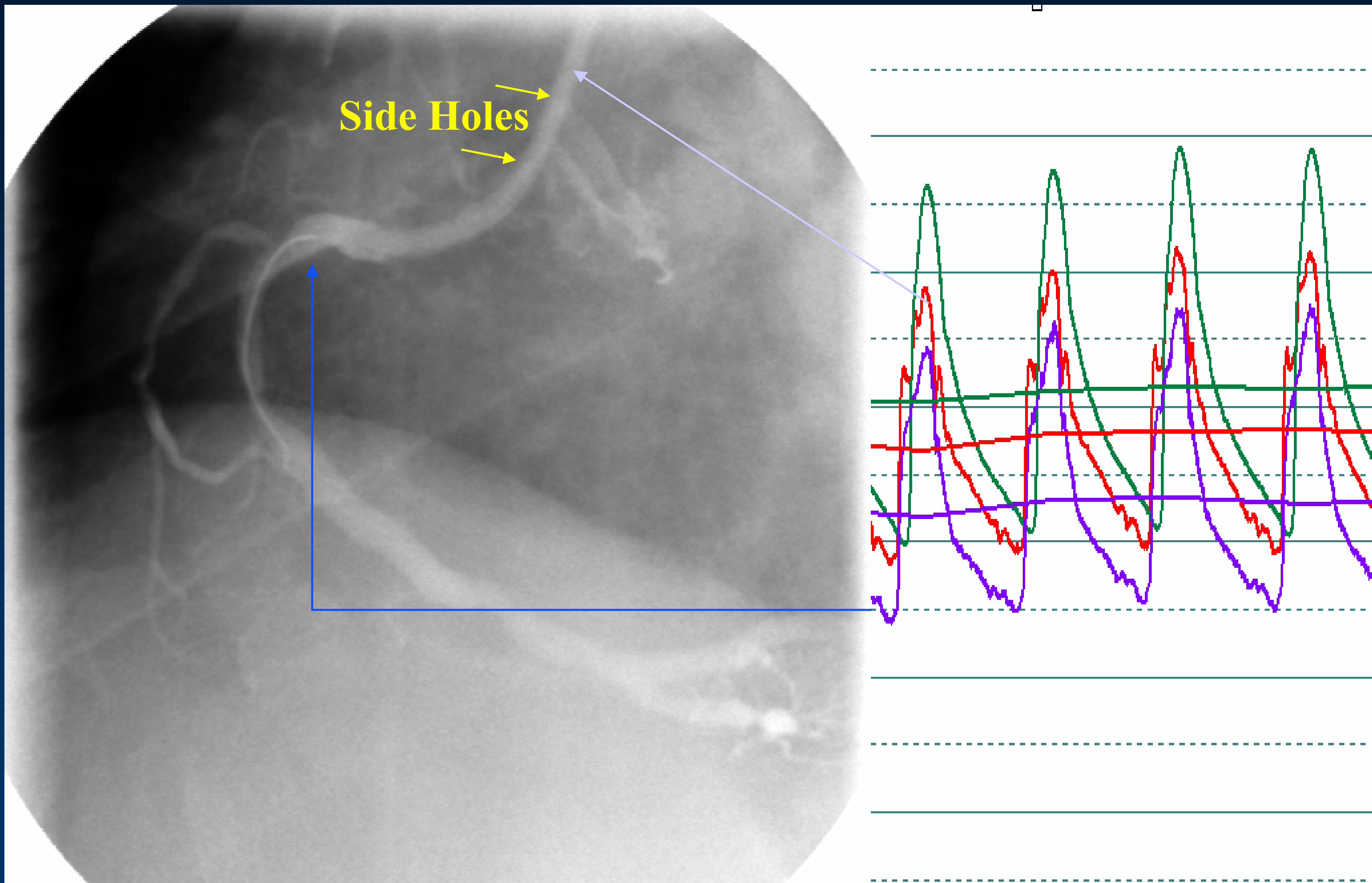
Sensor proximal to side holes

Guiding Catheter With Sides Holes



Sensor in the proximal RCA

Guiding Catheter With Sides Holes



Sensor in the proximal RCA + Papaverine

Guiding Catheters with Sideholes

If it is essential ...

- Beware of signal misinterpretation
- Withdraw guiding catheter from ostium during measurements
- Do not use i.c. hyperemic stimulus

Use i.v. hyperemia stimulus and withdraw the guiding catheter from the ostium during measurement.

Choice of hyperemic stimuli

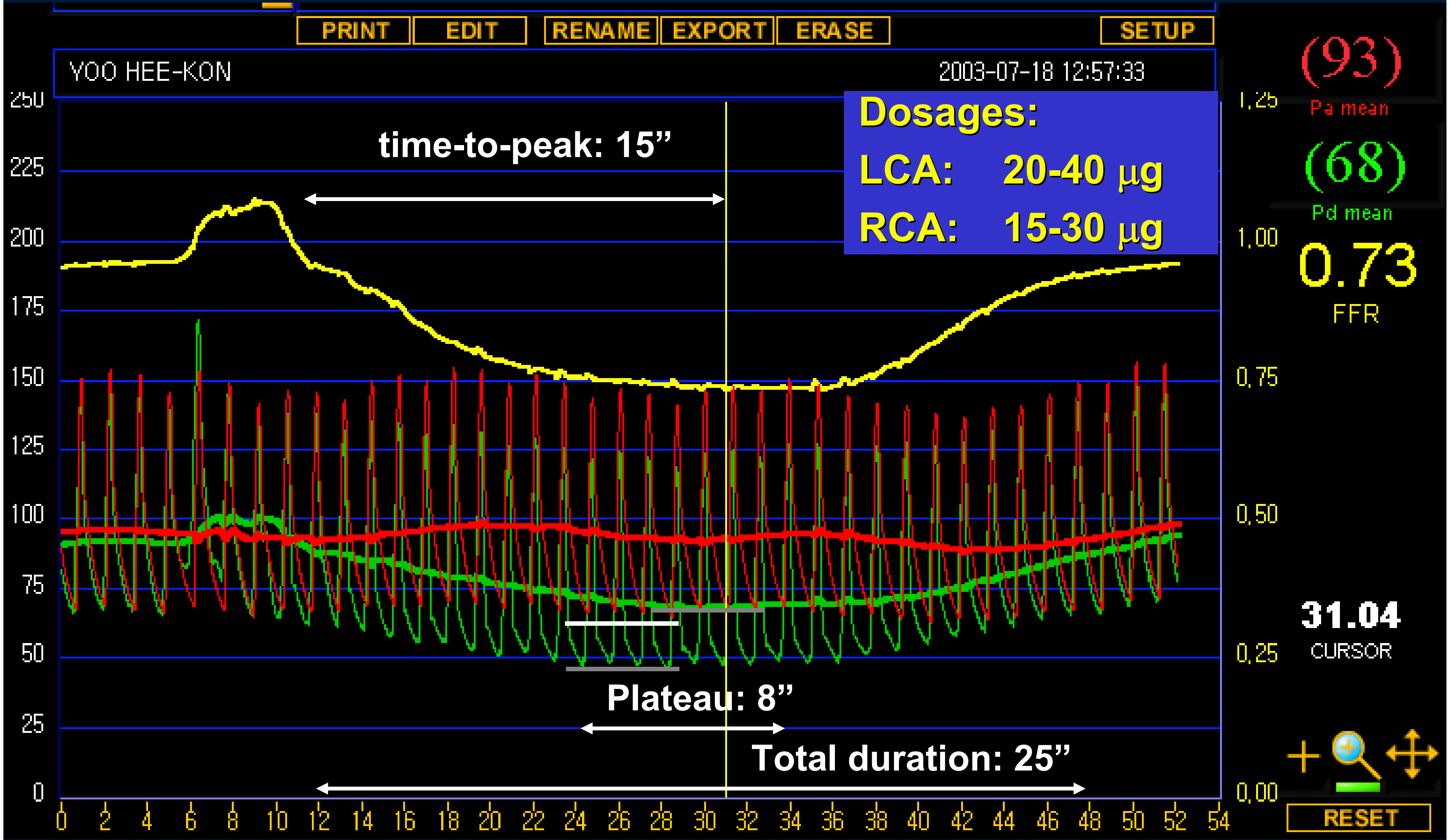
Intra coronary

- Guiding catheter position
- Guiding catheter side-holes
- Too quick (3^{rd} pressure line)

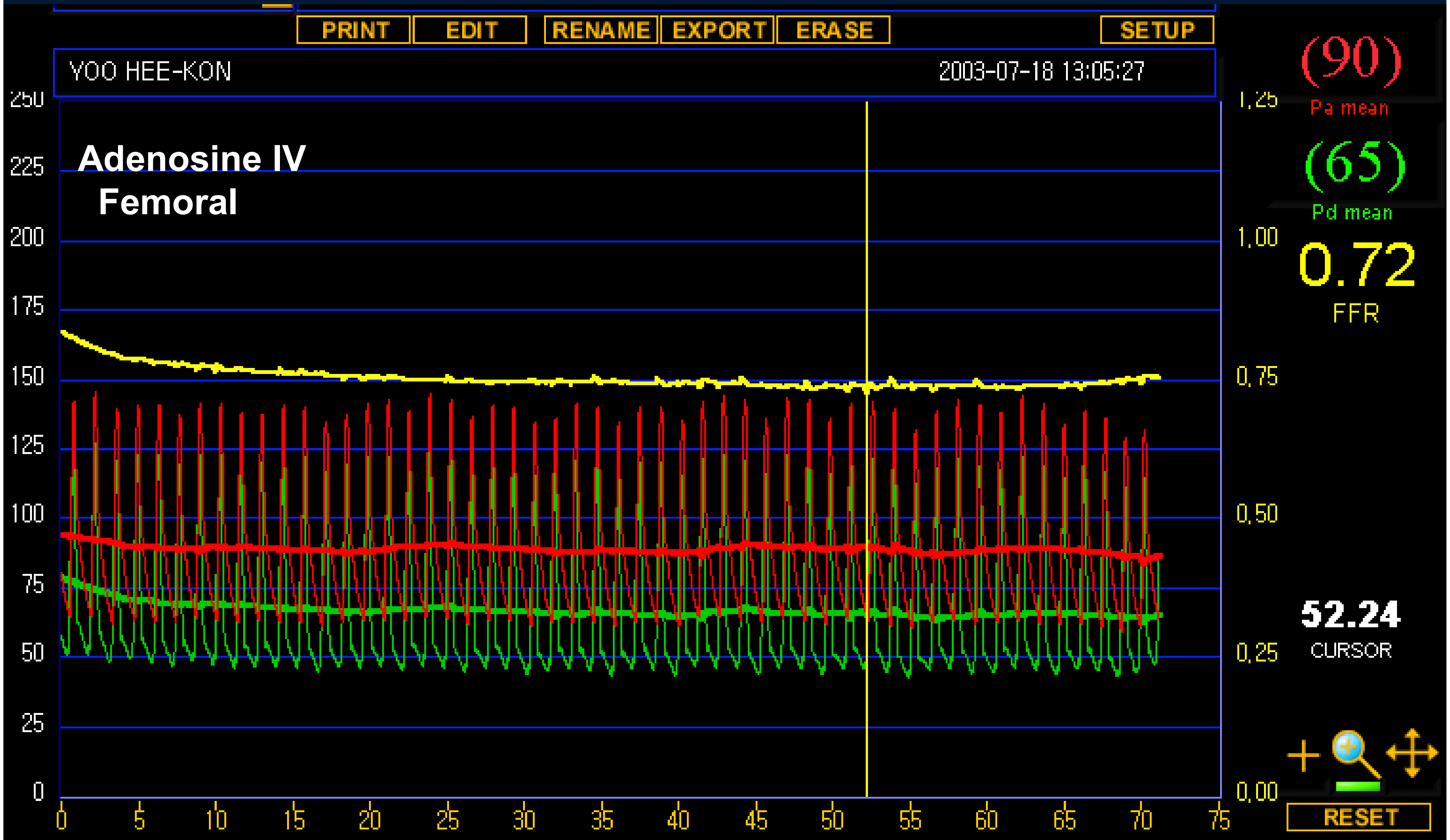
Intra venous

- Femoral vein only
- High volume infusion pump

Intracoronary Bolus of Adenosine



Intravenous Infusion of Adenosine 140 μg/kg/min



Intravenous Infusion of Adenosine

Pull-back Curve

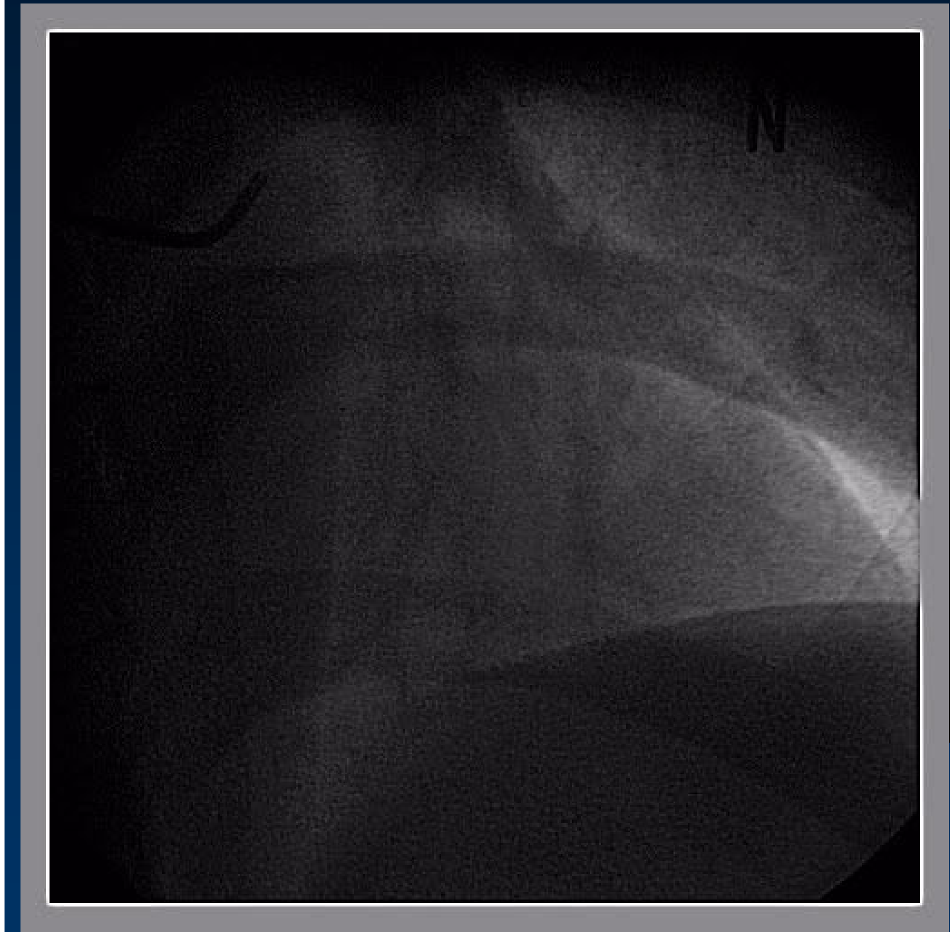
Slow pull-back of sensor across stenosis during steady state maximum hyperemia

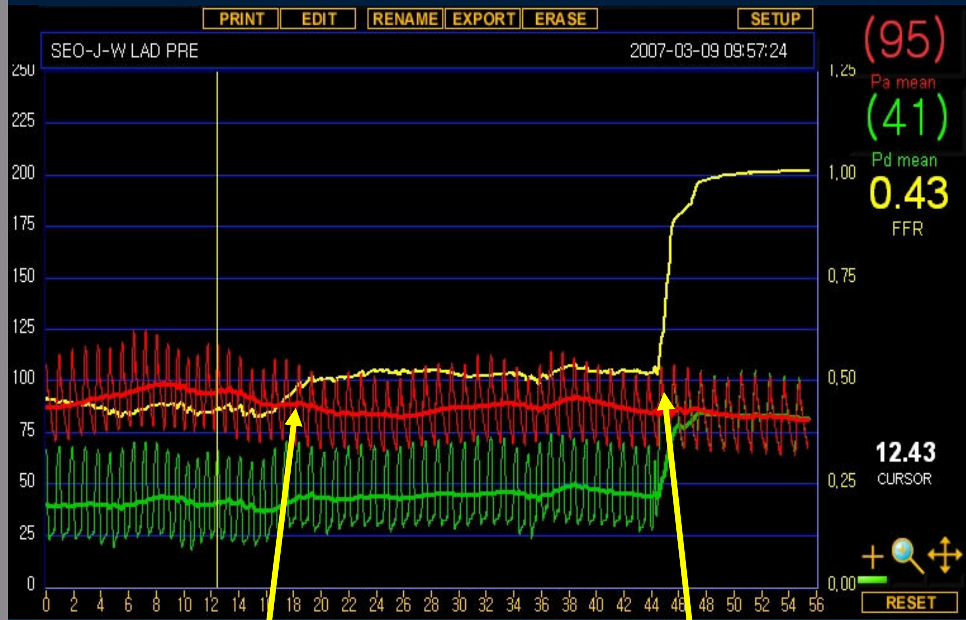
Most reliable and reproducible way to determine exactly the physiologic significance

Reproducible, without withdrawing the wire from the stenosis

(only the sensor moves across the lesion, the tip of the wire remain distally)

Example of Pullback Curve

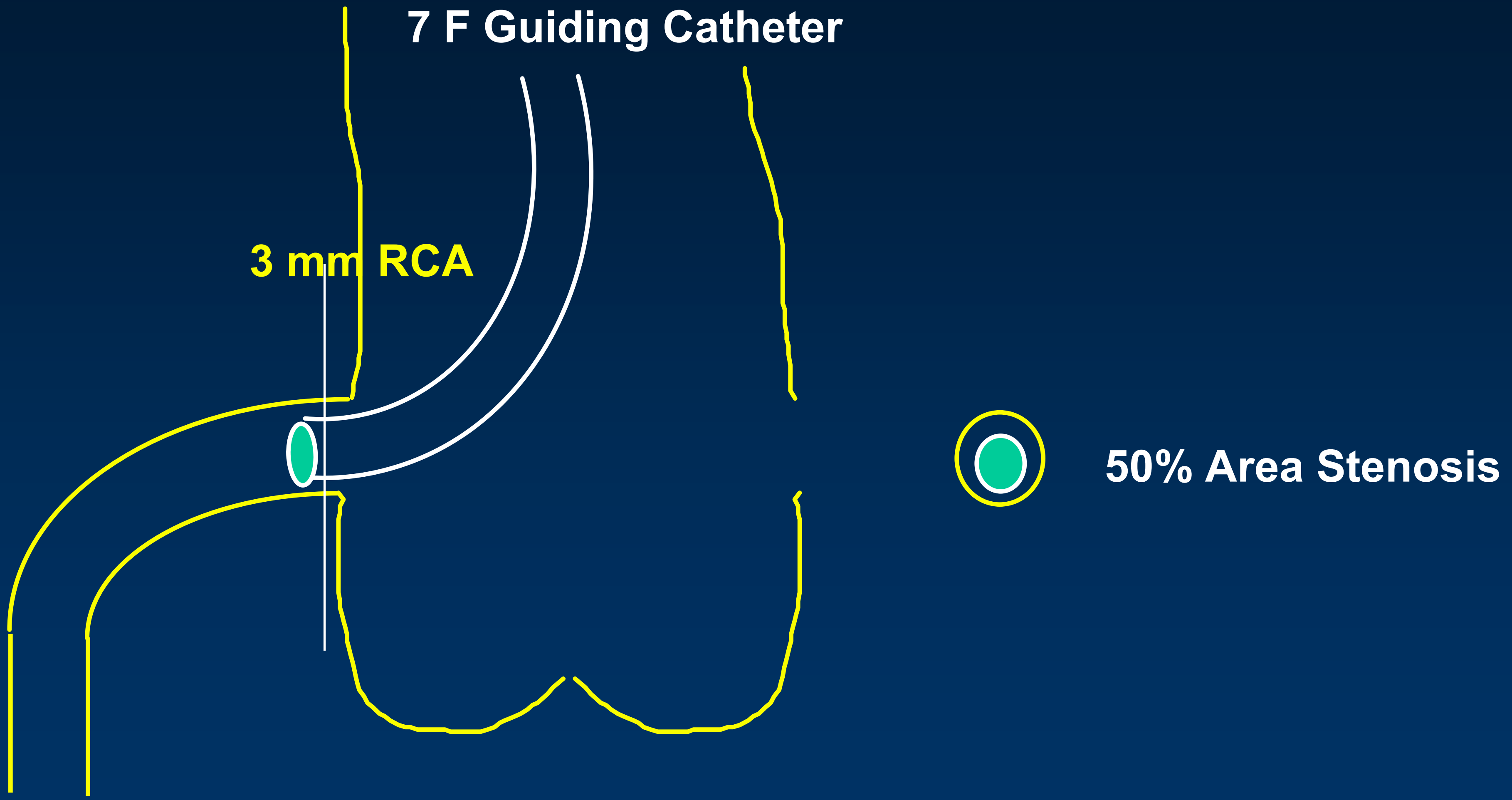




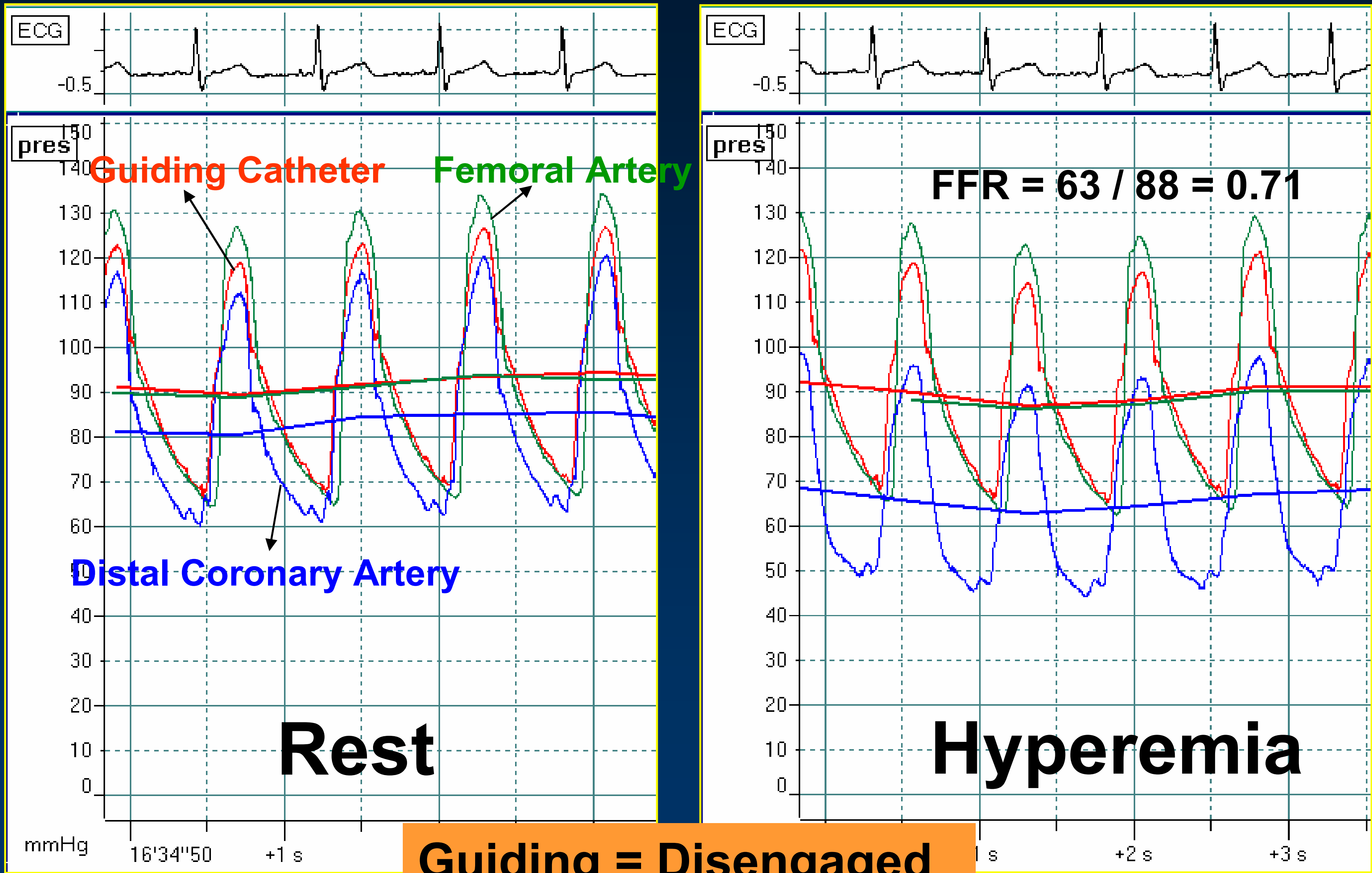
distal stenosis proximal stenosis

Pull-back curve at maximum hyperemia
(i.v. adenosine infusion)

Wedging of the Guiding Catheter: Importance of Flow

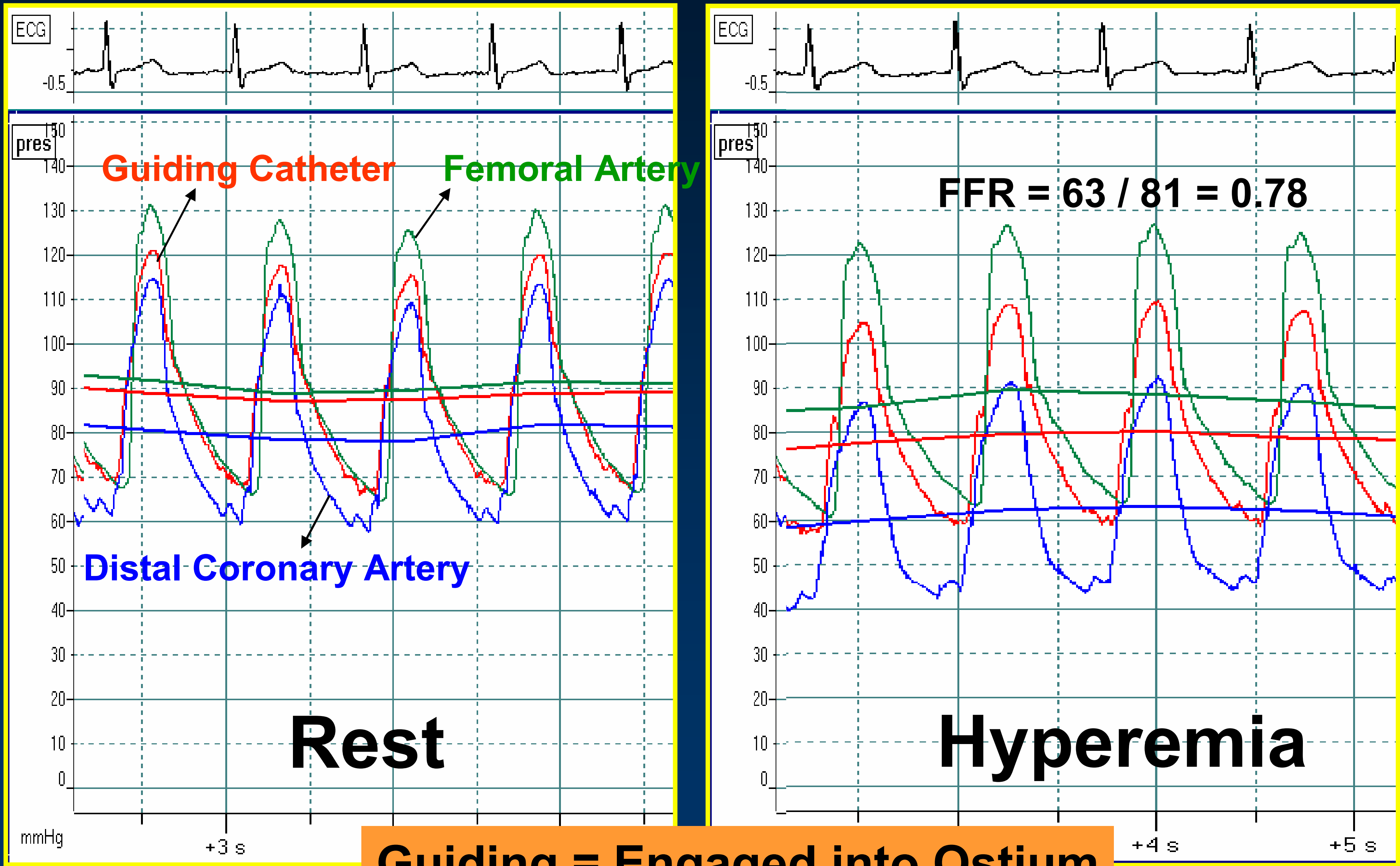


Influence of the Guiding in the Ostium



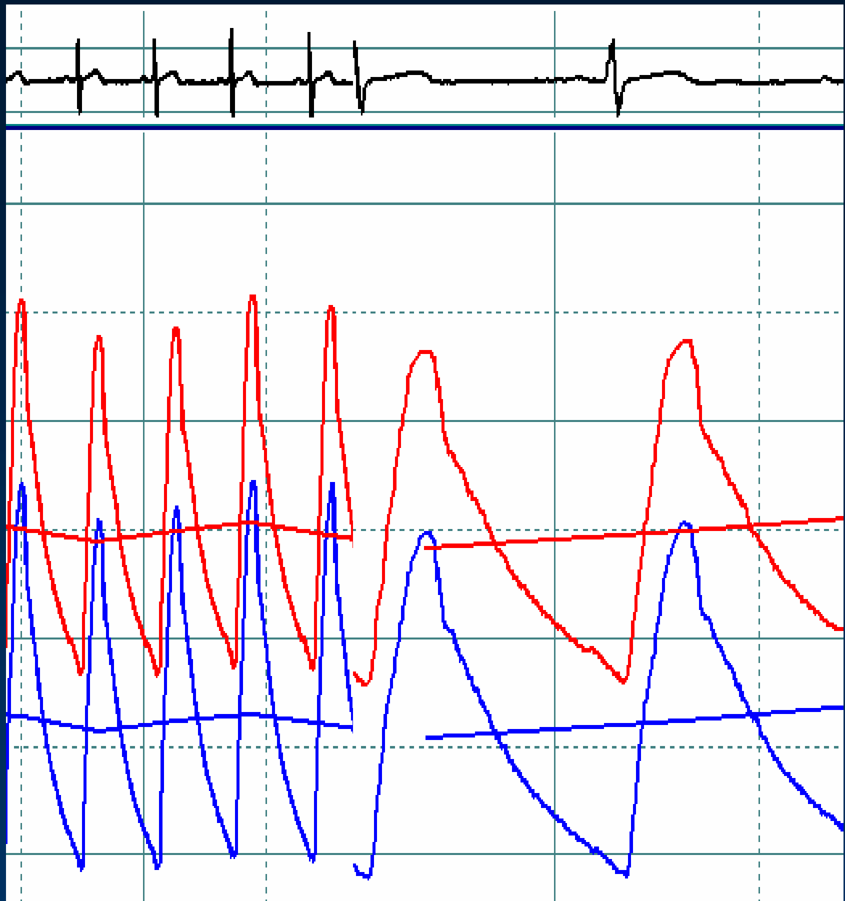
Guiding = Disengaged

Influence of the Guiding in the Ostium

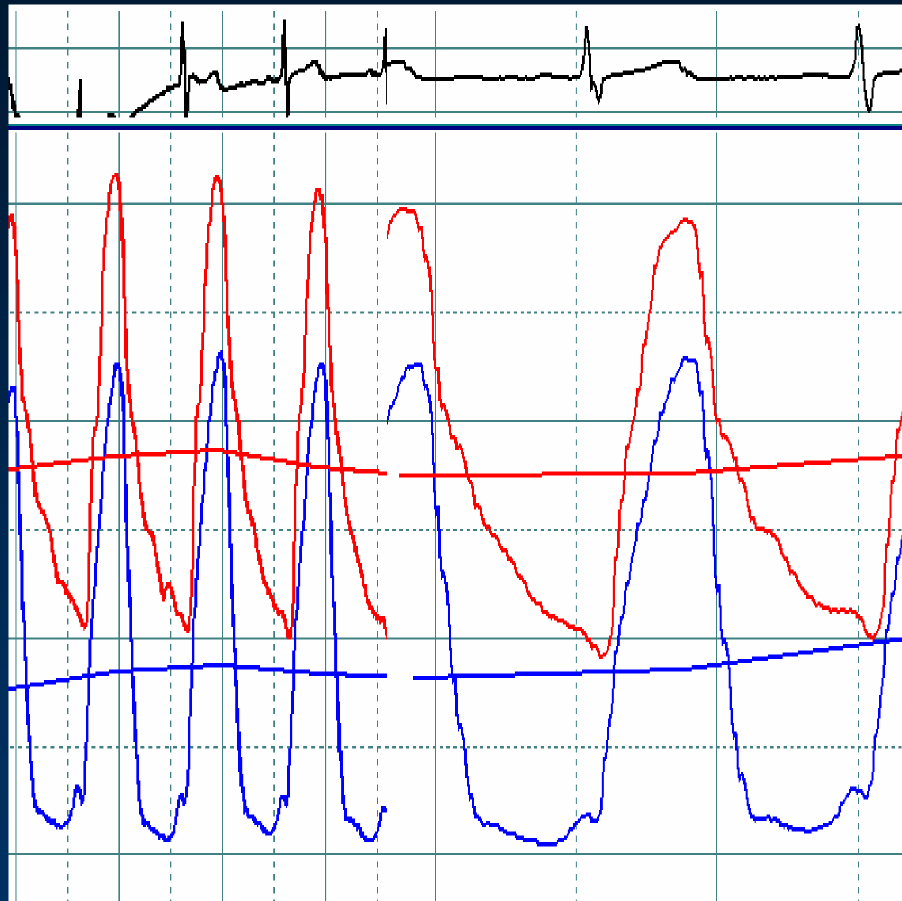


Guiding = Engaged into Ostium

Drift of the Pressure Sensor



Drift: morphology of the pressure tracings is *identical*

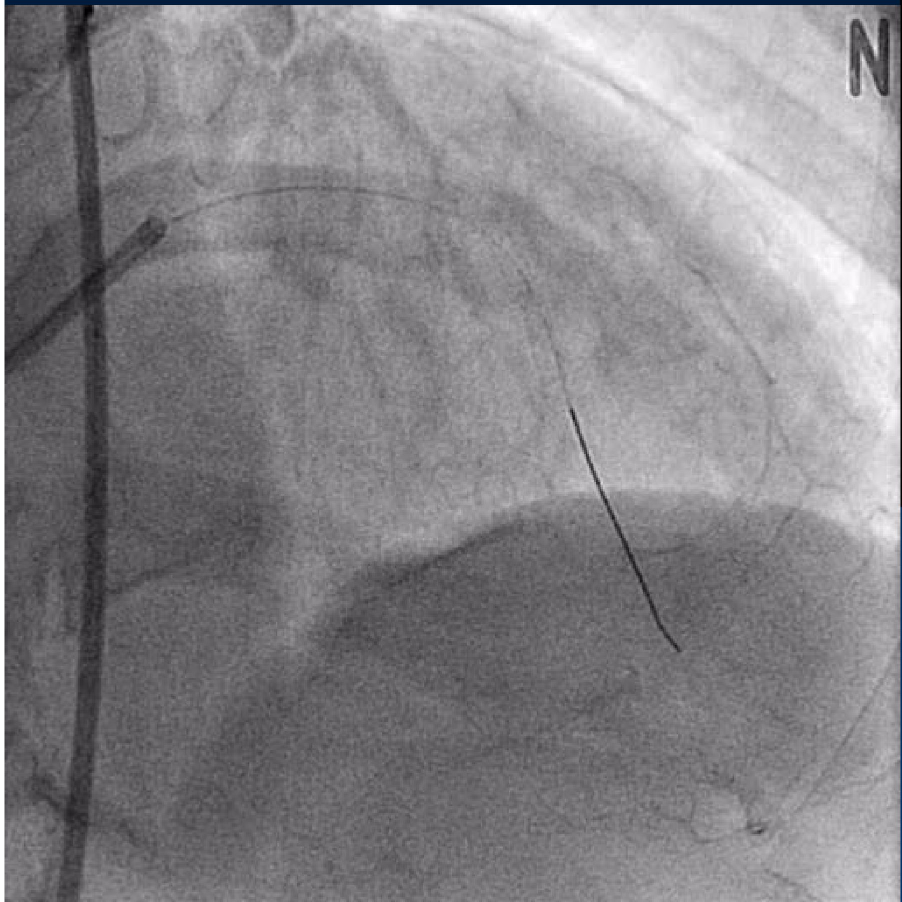


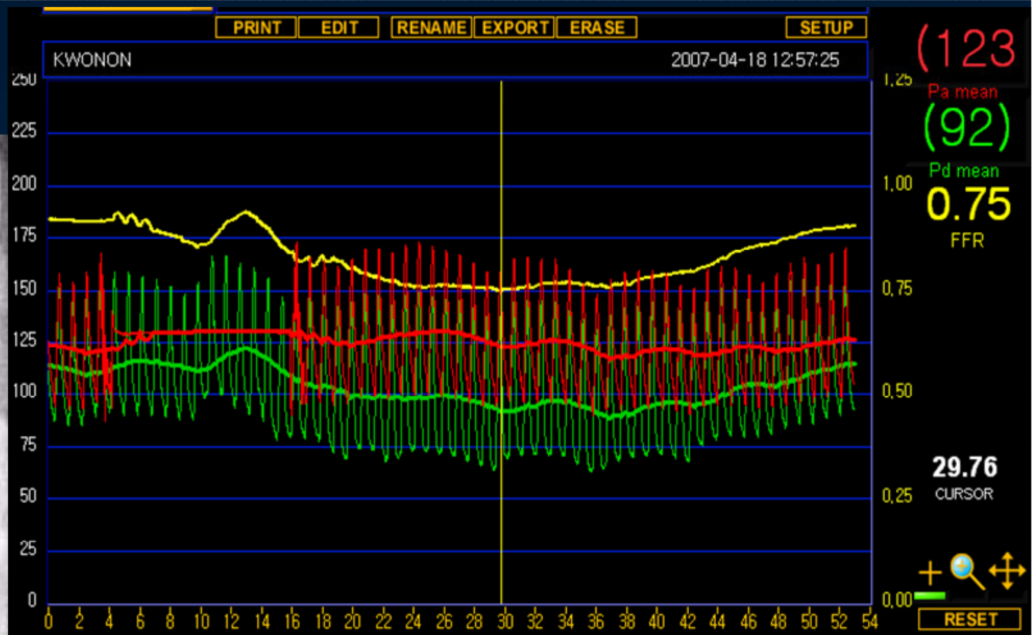
Pressure Gradient: morphology of the pressure tracings is *different*

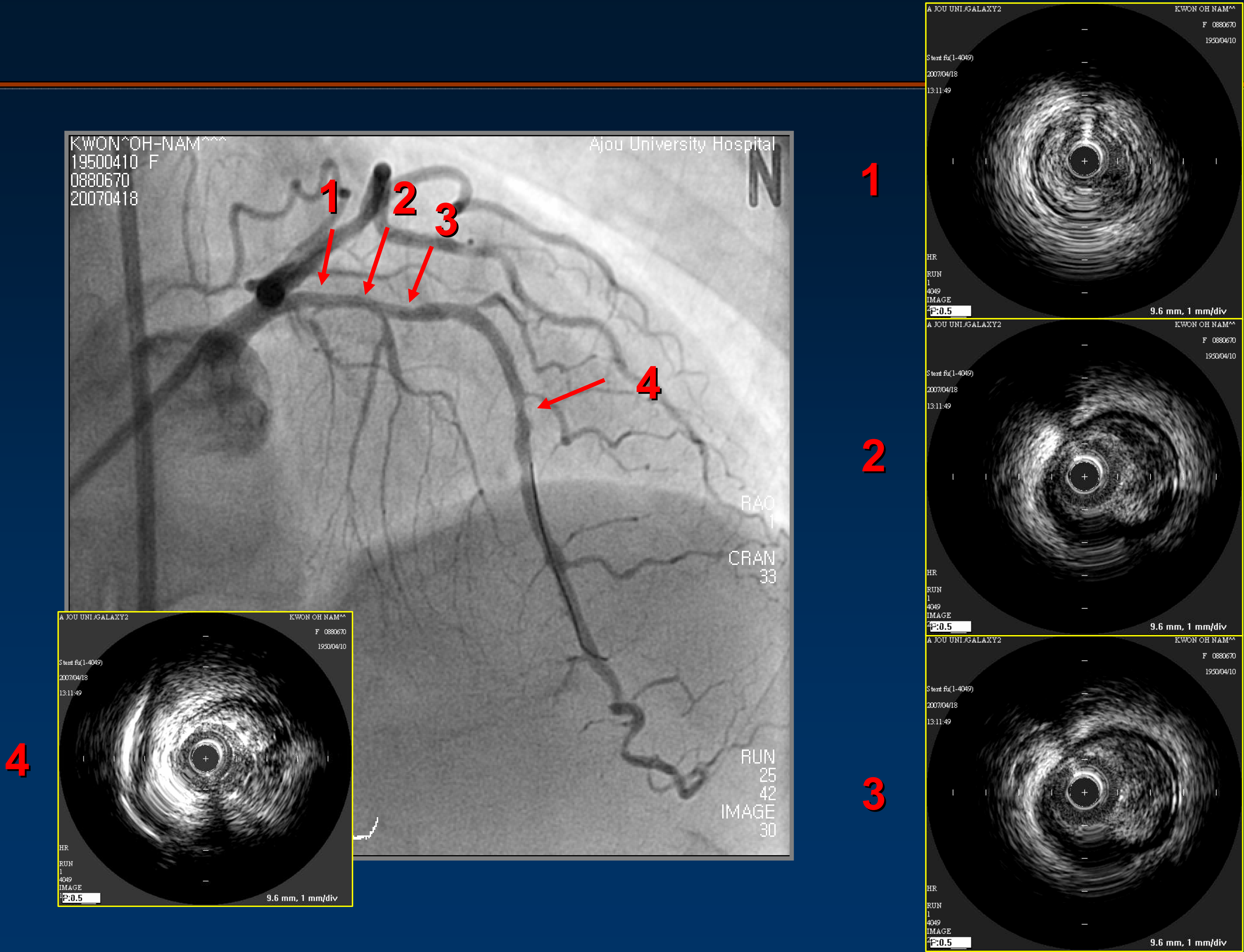
Clinical Applications of FFR

related to pressure measurements

Clinical Applications





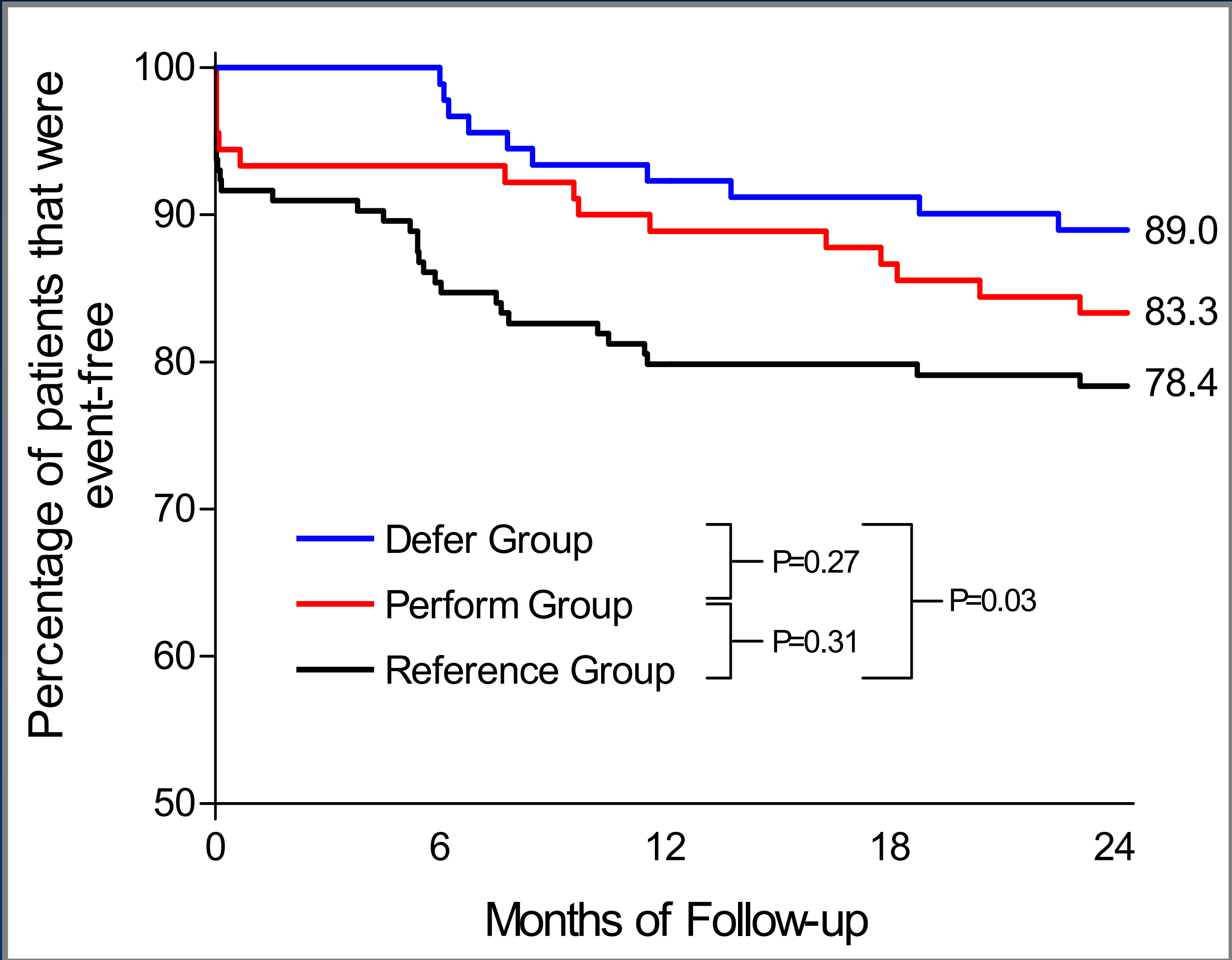


KWON^OH-NAM^^^
19500410 F
0880670
20070418
Ajou University Hospital
N
RAO
1
CRAN
33
RUN
25
42
IMAGE
30
1
2
3
4
A JOU UNI./GALAXY2
KWON OH NAM^^
F 0880670
1950/04/10
Stent fu(1-4049)
2007/04/18
13:11:49
HR
RUN
1
4049
IMAGE
F:0.5
9.6 mm, 1 mm/div

DEFER STUDY

DEFER Study: 2 year Event-free Survival

Event rate per year for non-significant lesion is 5 %



Bech GJ, *Circulation 2001; 103 : 2928-34*

Fractional Flow Reserve: Cut-Off Values

1. Before PTCA: *Should we dilate?*

≥ 0.75: NO
< 0.75: YES

2. After balloon angioplasty: *Is this result sufficient?*

< 0.90: NO
≥ 0.90: YES

3. After stenting: *Is the stent well deployed?*

< 0.94: NO
≥ 0.94: YES

Coronary Pressure Measurement in Complex PCI

This means:

Detailed spatial and segmental information on the functional impact of the disease is paramount for optimum benefit of PCI :

- Which of several arteries are culprit?
- Selection of culprit spots and segments within a unparticulary artery
- Is it focal epicardial or diffuse or microvascular disease that causes the ischemia

→ Coronary Pressure Measurement

Clinical Implication of FFR

	IVUS	FFR
Native CAD	MLD ≥1.8 mm MLA ≥4.0 mm^2	≥0.75–0.8
Left main	MLD ≥2.8 mm MLA ≥5.9 mm^2	≥0.75
Serial lesions	Assesses anatomic severity along the length of the artery	Relative contribution of each stenosis on pullback method
SVG	Identifies severe lesion and tissue characteristics. Helps identify when to use distal protection device	No data for FFR in SVG; data correlating rCFR with SPECT available
Ostial lesions	Helps locate ostial-aorta juncture and correct stent position	≥0.75
Acute MI	Demonstrates plaque burden	Limited data
Bifurcation lesions	Assesses size of main and side branch, adequacy of results	≥0.75

Conclusion

1. FFR can be measured **successfully** in most cases and **extremely reproducible**.

2. **FFR < 0.75** always indicates inducible ischemia and >0.80 excludes ischemia in 91 % of the cases - FFR assessment can be used direct PCI only ischemic, flow-limiting lesions.

3. FFR has a **prognostic value** in post-stenting and normalization of FFR after stenting was accompanied by a restenosis rate of <5% at six-month follow up.

4. FFR can be useful in **more complex and extensive coronary disease**.