Imaging & Physiology Summit, FFR Workshop

BASIC CONCEPTS OF FRACTIONAL FLOW RESERVE (FFR)

Seoul, Korea, december 6th, 2013

CATHARINA-ZIEKENHUIS

Nico H. J. Pijls, MD, PhD
Catharina Hospital,
Eindhoven, The Netherlands

catharina ziekenhuis

Disclosures:

Dr Pijls received institutional research grants from St Jude Medical and Maquet
and is consultant for St Jude Medical
and for Heartflow

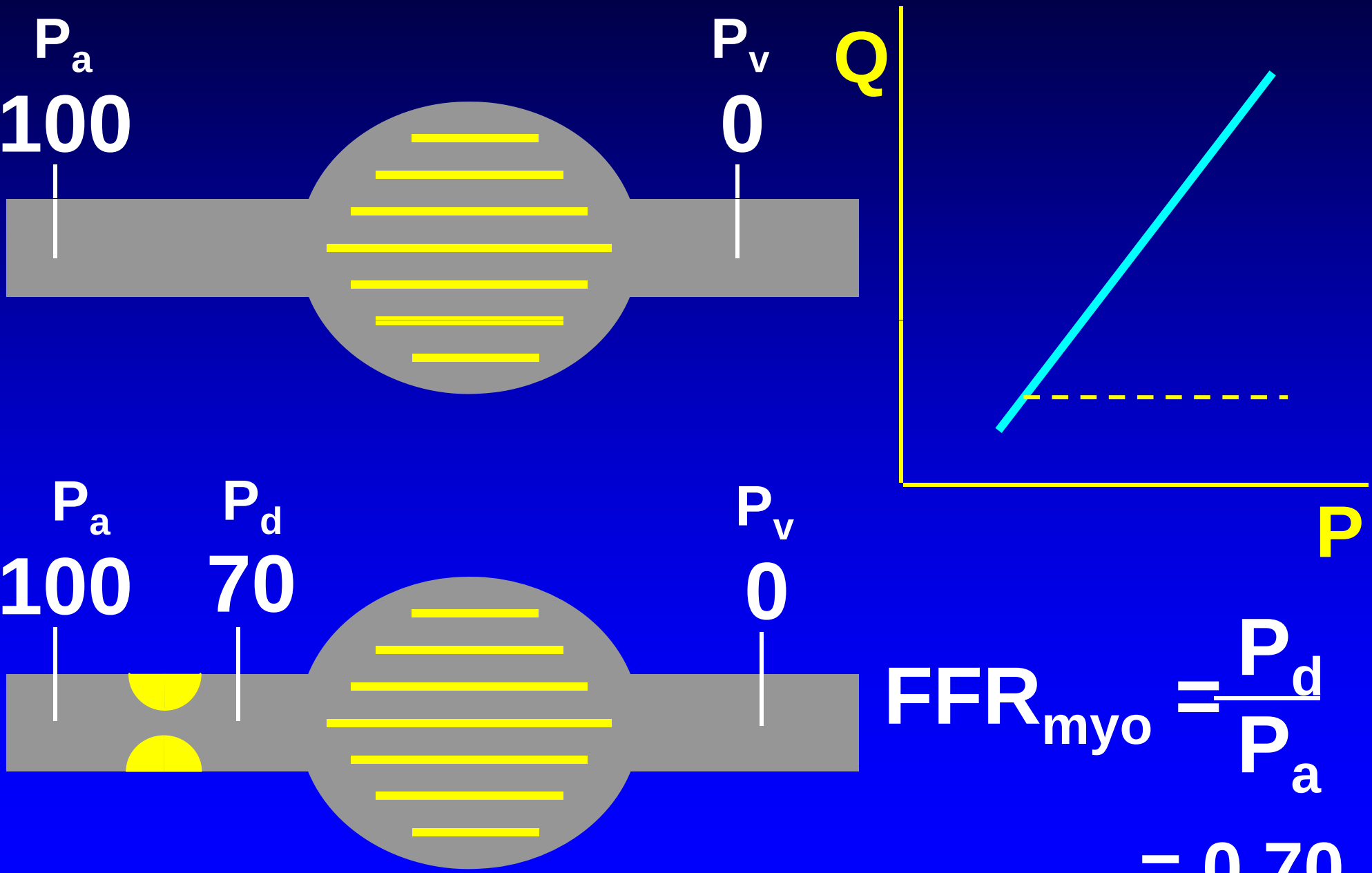
FRACTIONAL FLOW RESERVE:

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



FRACTIONAL FLOW RESERVE =

MAXIMUM FLOW IN THE PRESENCE OF A STENOSIS

NORMAL MAXIMUM FLOW

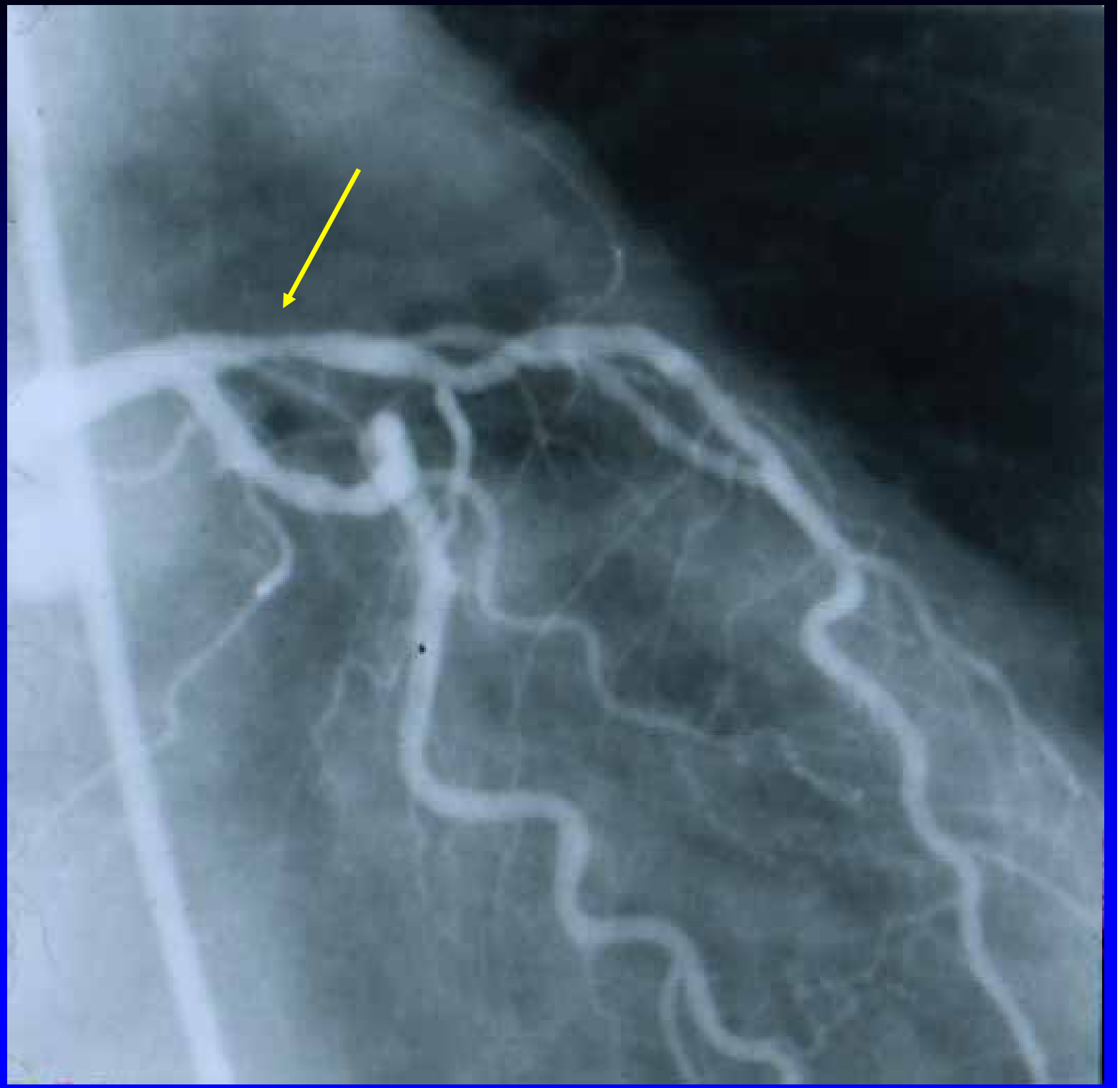
~

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

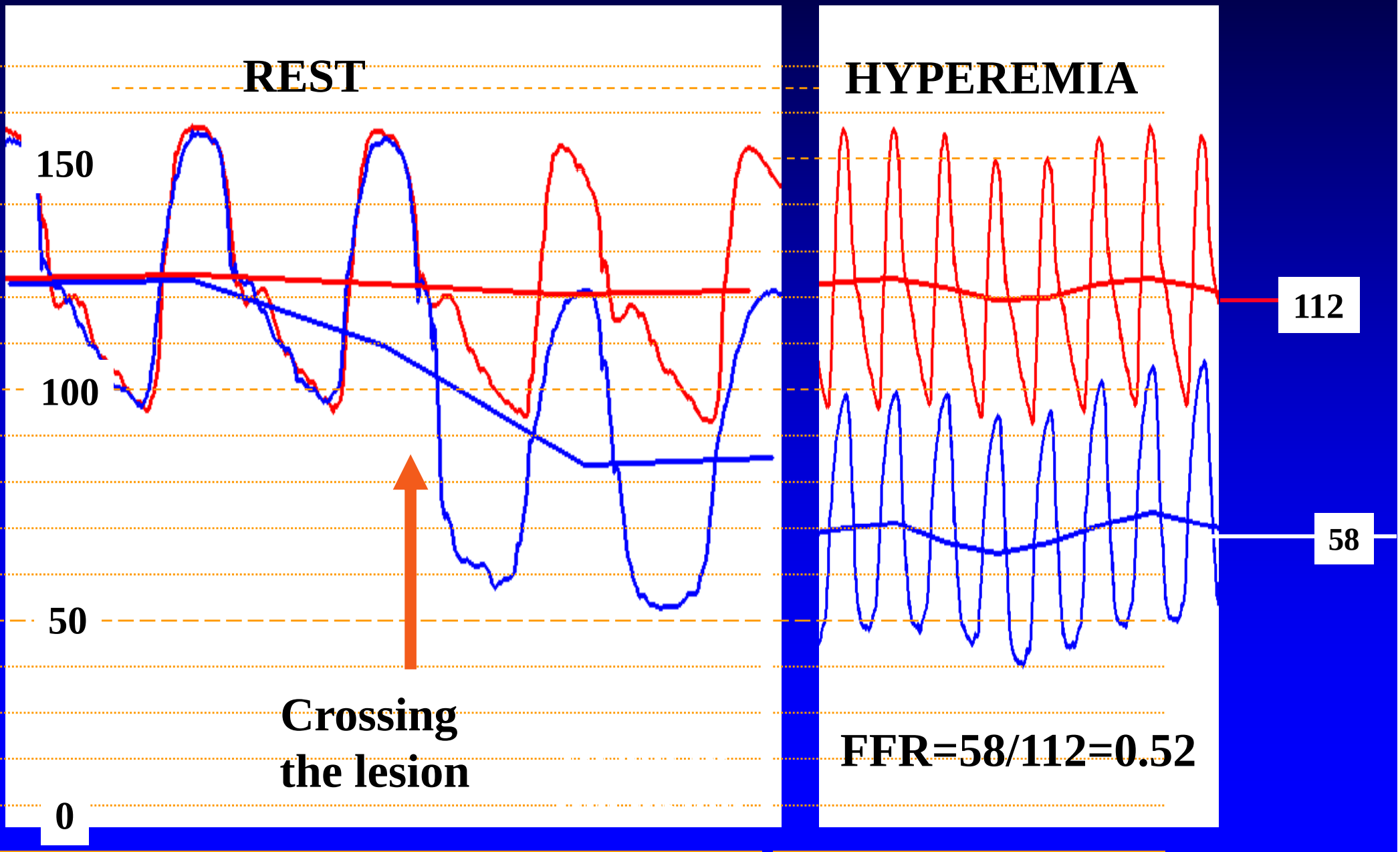
P_a = mean aortic pressure at maximum hyperemia

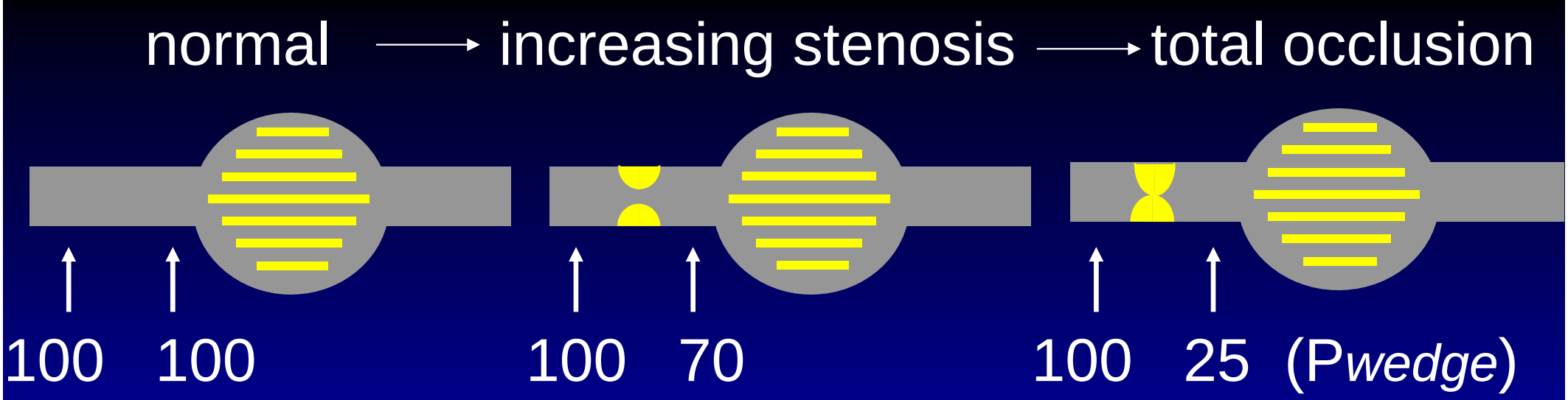
P_d = mean distal coronary pressure at maximum hyperemia

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



Fractional Flow Reserve in Clinical Practice





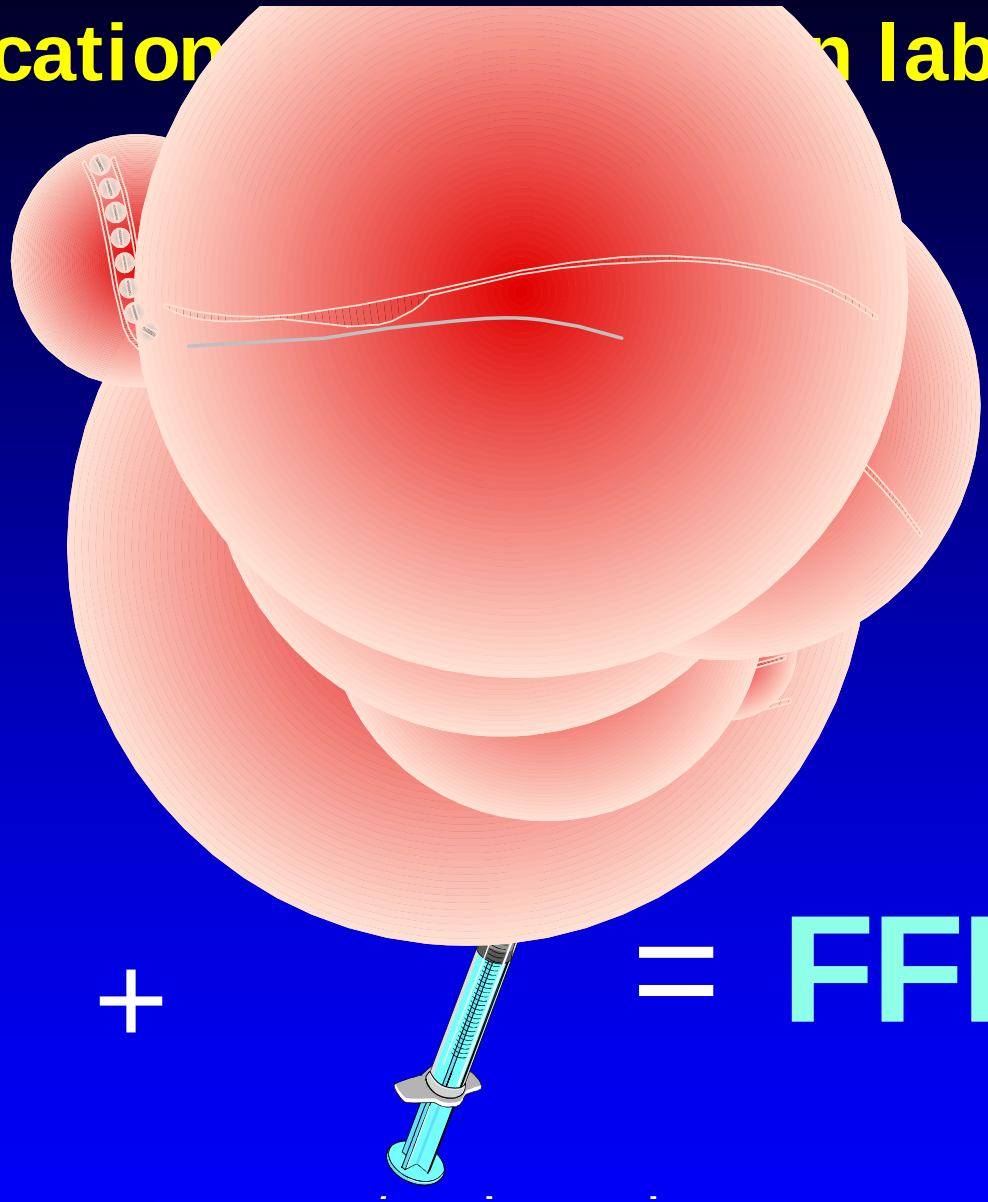
Maximum myocardial perfusion:

100% ⟶ ***70%*** ⟶ ***25%***

FFR: **1.0** ⟶ **0.7** ⟶ **0.25**

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

Application n laboratory

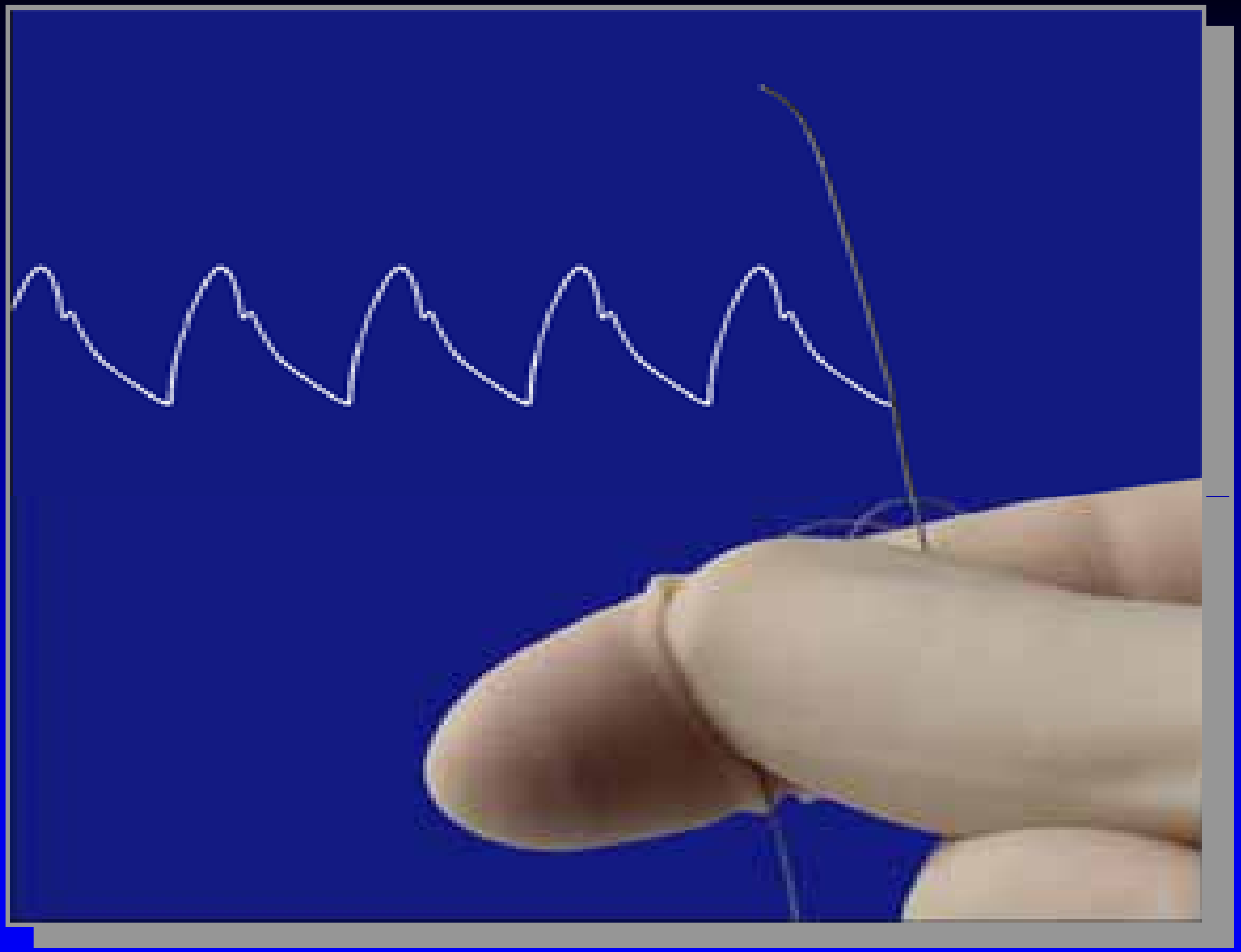


pressure wire

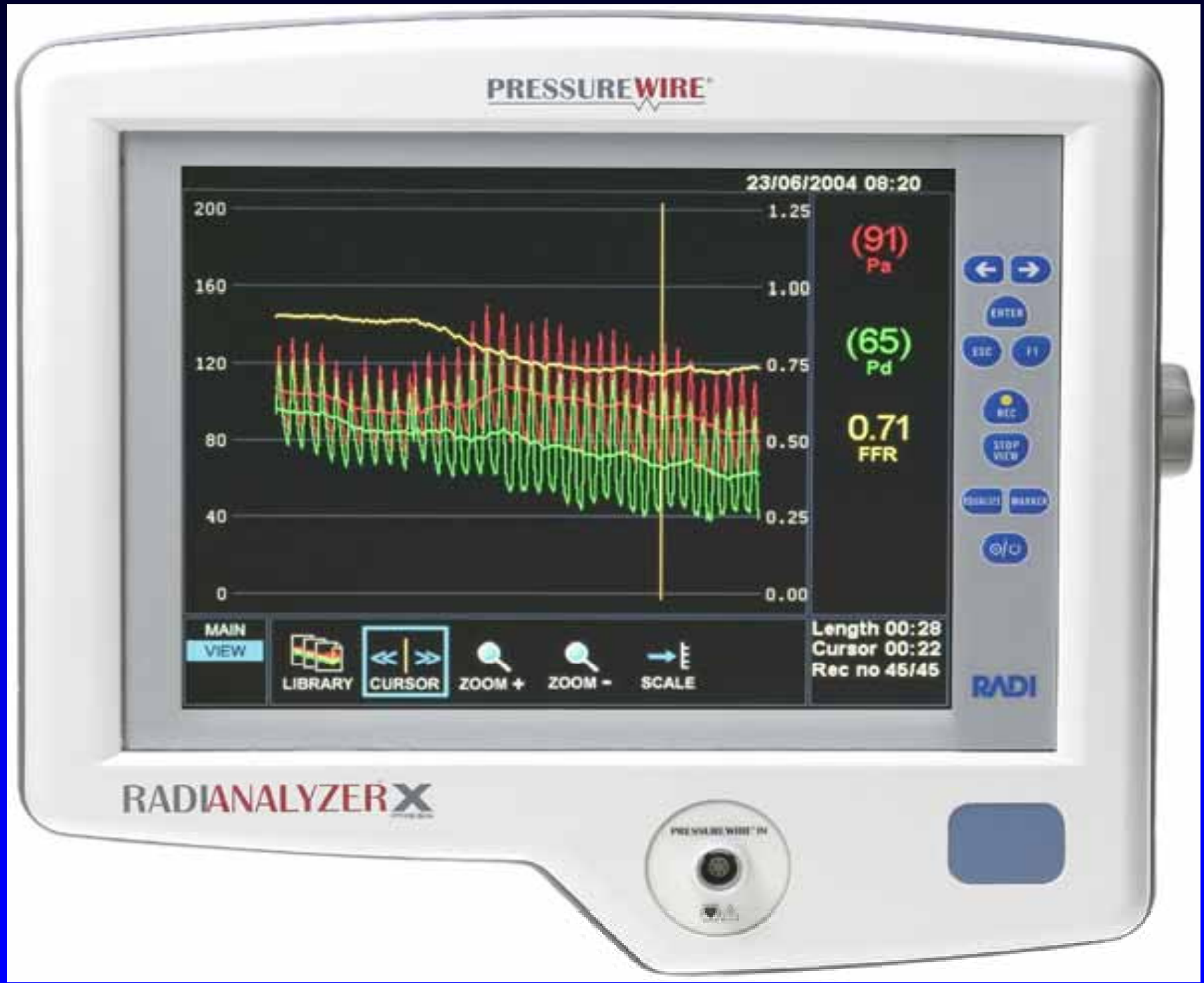
+

hyperemic stimulus

= **FFRmyo**



0.014 sensor-tipped PTCA guidewire


PRESSUREWIRE
23/06/2004 08:20
200
160
120
80
40
0
1.25
1.00
0.75
0.50
0.25
0.00
(91)
Pa
(65)
Pd
0.71
FFR
MAIN
VIEW
LIBRARY
CURSOR
ZOOM +
ZOOM -
SCALE
Length 00:28
Cursor 00:22
Rec no 45/45
RADI
RADIANALYZER X

MAXIMUM VASODILATORY STIMULI

!! Maximum hyperemia is paramount !!

- **PAPAVERINE i.c.**
- **ADENOSINE i.c.**
- **ADENOSINE i.v. infusion**
- **ATP i.c**
- **ATP i.v.**
- **REGADENOSON i.v. bolus**

BASIC FEATURES OF FFR

- ***Normal value = 1.0* for every patient and every artery**
- FFR is *not influenced by changing hemodynamic conditions* (heart rate, blood pressure, contractility)
- FFR specifically relates the influence of the epicardial stenosis to myocardial perfusion area and blood flow
- FFR accounts for collaterals
- FFR has a *circumscript threshold value* (~ 0.75 – 0.80) to indicate ischemia
- FFR is *easy* to measure (success rate 99 %) and extremely *reproducible*
- Pressure measurement has un *unequaled spatial resolution*

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:

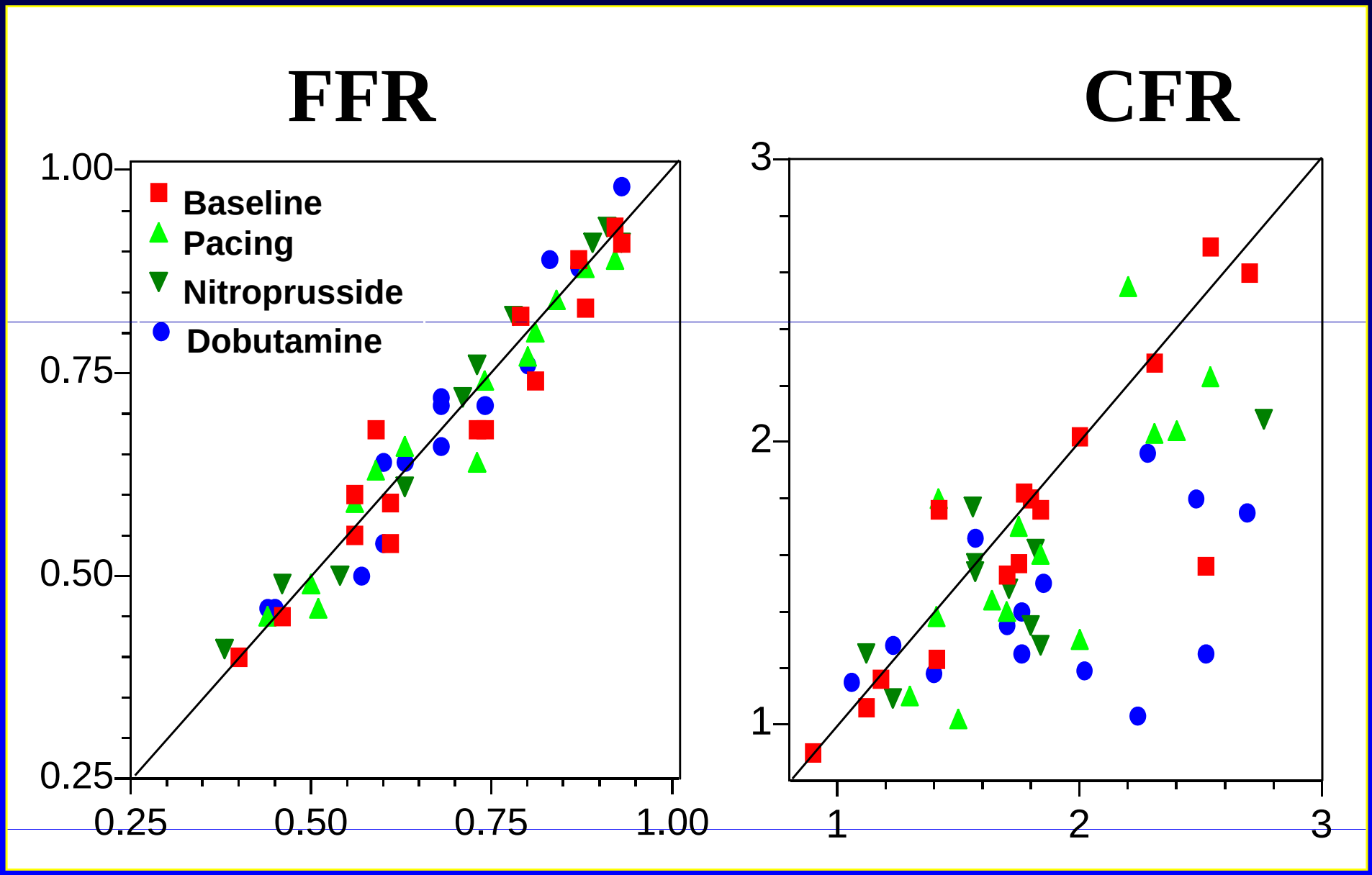
FFR = 0.87 +/- 0.09 (range 0.64 – 0.97)

De Bruyne, Circulation 2001; 104:2401-2406

BASIC FEATURES OF FFR

- Normal value = 1.0 for every patient and every artery
- ***FFR is not influenced by changing hemodynamic conditions*** (heart rate, blood pressure, contractility)
- FFR specifically relates the influence of the epicardial stenosis to myocardial perfusion area and blood flow
- FFR accounts for collaterals
- FFR has a *circumscript threshold value* (~ 0.75 – 0.80) to indicate ischemia
- FFR is *easy* to measure (success rate 99 %) and extremely *reproducible*
- Pressure measurement has un *unequaled spatial resolution*

Hemodynamic Variability of FFR_{myo} and CFR



B. De Bruyne et al Circulation 1996

BASIC FEATURES OF FFR

- Normal value = 1.0 for every patient and every artery
- FFR is *not influenced by changing hemodynamic conditions* (heart rate, blood pressure, contractility)
- FFR specifically relates the influence of the epicardial stenosis to myocardial perfusion area and blood flow
- FFR accounts for collaterals
- ***FFR has a circumscript threshold value with small gray zone (~ 0.76 – 0.80) to indicate ischemia***
- FFR is *easy* to measure (success rate 99 %) and extremely *reproducible*
- Pressure measurement has un *unequaled spatial resolution*

Threshold value of FFR to detect significant stenosis

→ Lecture tonight at 6 pm

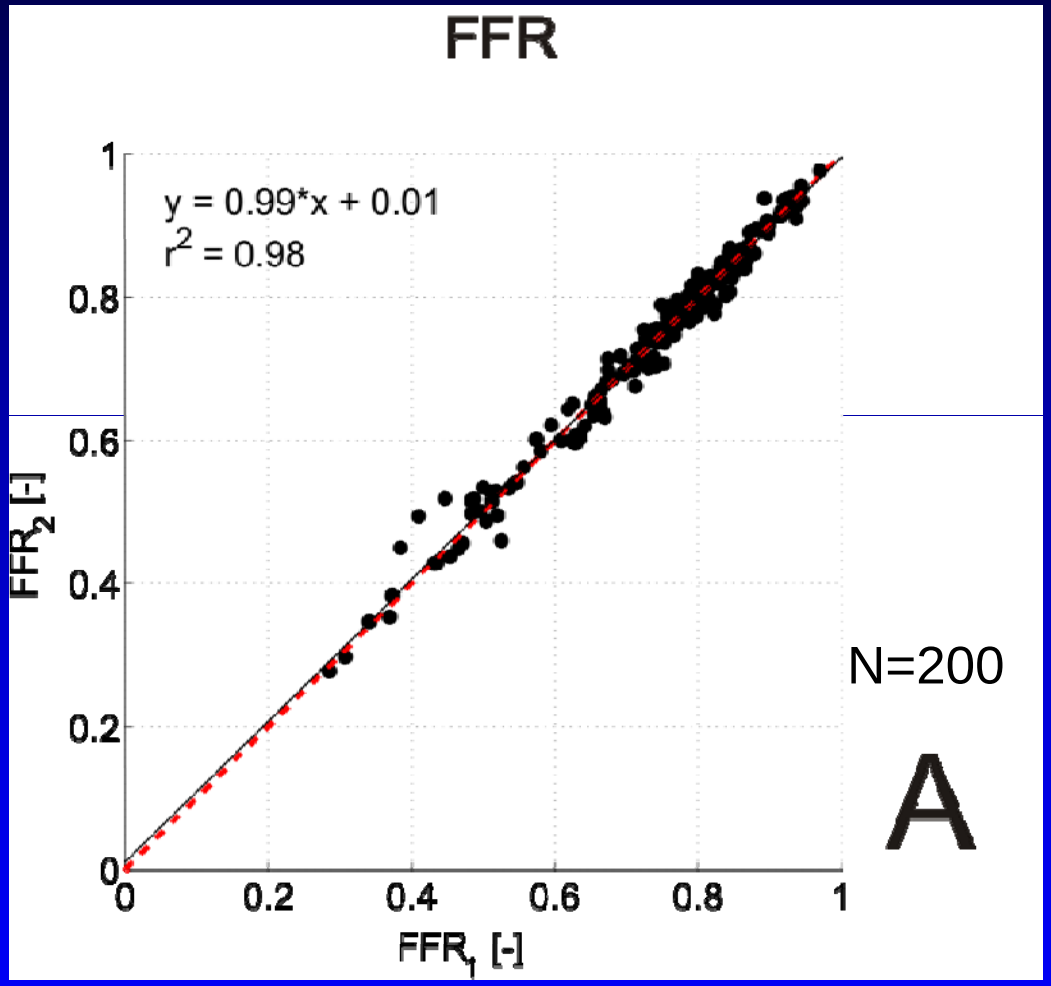
FFR is the ***only*** functional index which has ever been validated versus a **true gold standard**.
(Prospective multi-testing Bayesian methodology) → *Lecture tomorrow*

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

Sensitivity : 90%
Specificity : 100%

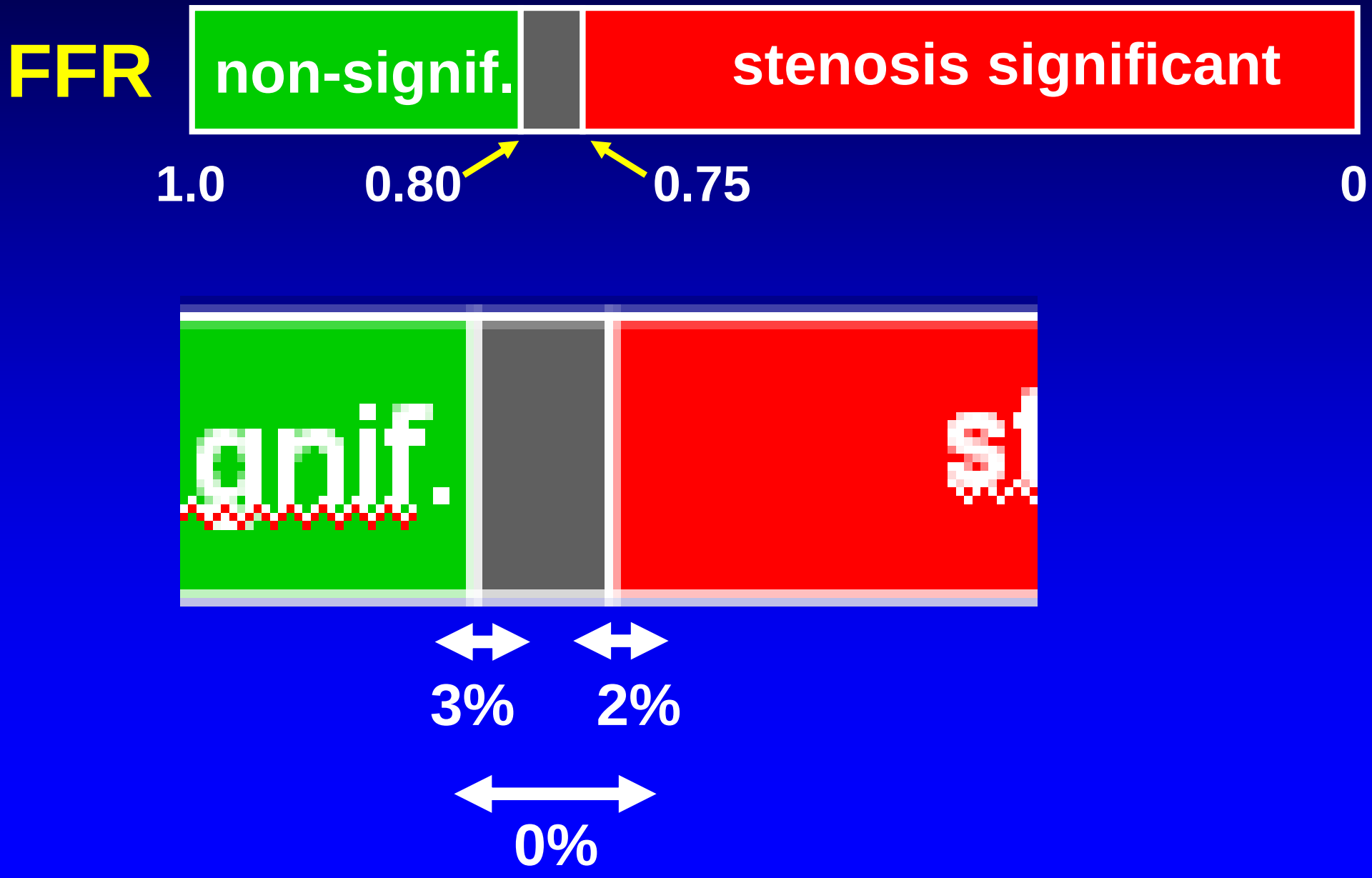
N Engl J Med 1996; 334:1703-1708

Reproducibility of FFR



VERIFY study, Berry et al, JACC 2012 (in press)

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

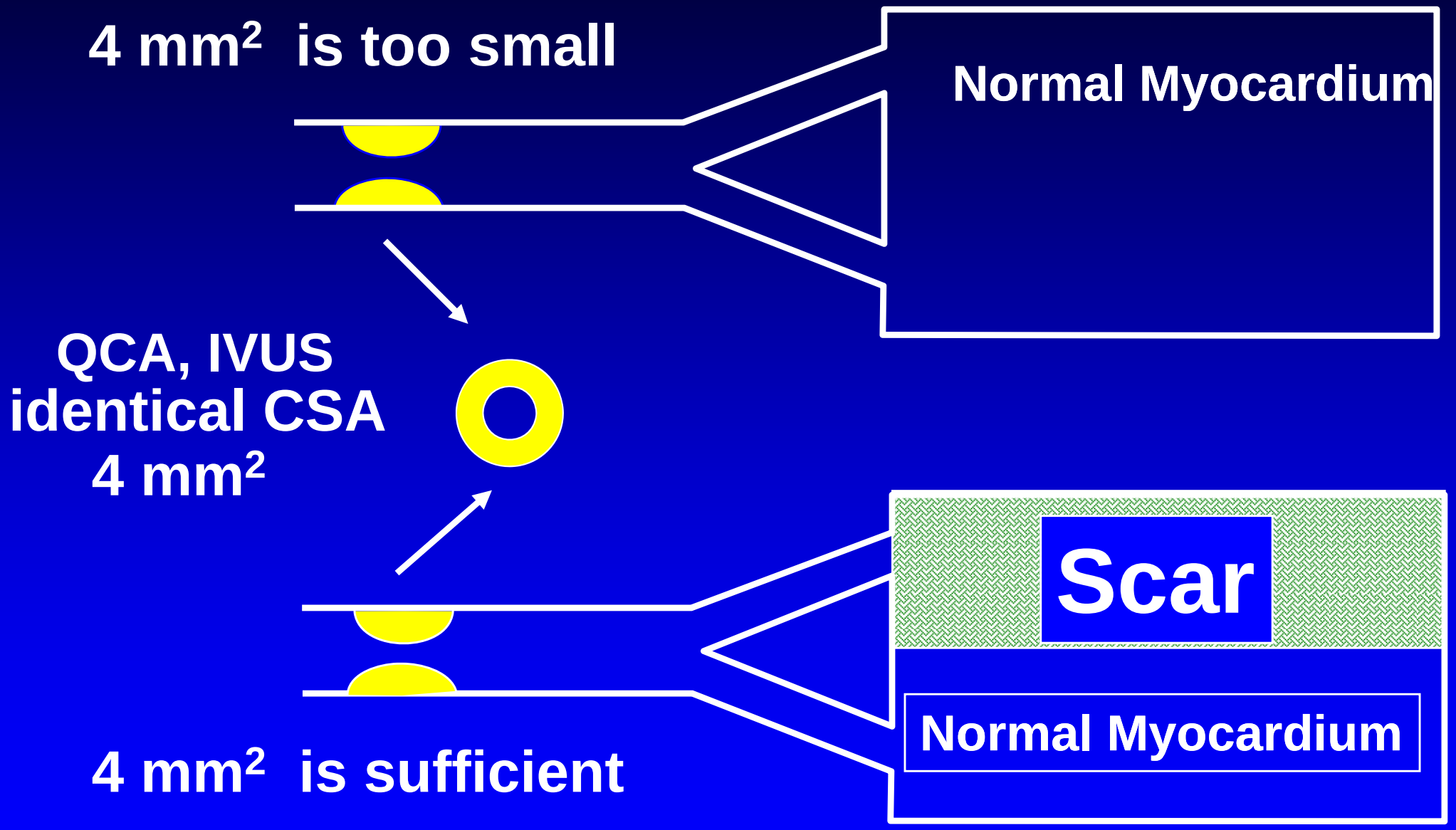


BASIC FEATURES OF FFR

- Normal value = 1.0 for every patient and every artery
- FFR is not influenced by changing hemodynamic conditions (heart rate, blood pressure, contractility)
- *FFR specifically relates the influence of the epicardial stenosis to myocardial perfusion area and blood flow*
- FFR accounts for collaterals
- FFR has a *circumscript threshold value* (~ 0.75 – 0.80) to indicate ischemia
- FFR is *easy* to measure (success rate 99 %) and extremely *reproducible*
- Pressure measurement has un *unequaled spatial resolution*

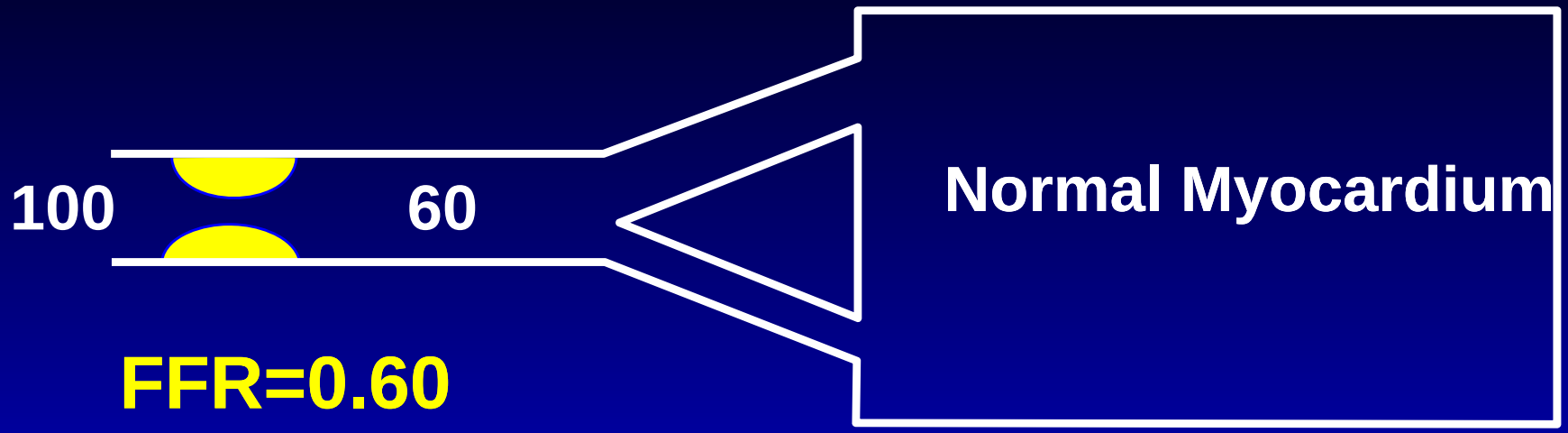
With permission of Dr Haitma Amin, Bahrain

similar stenosis but different extent of perfusion area



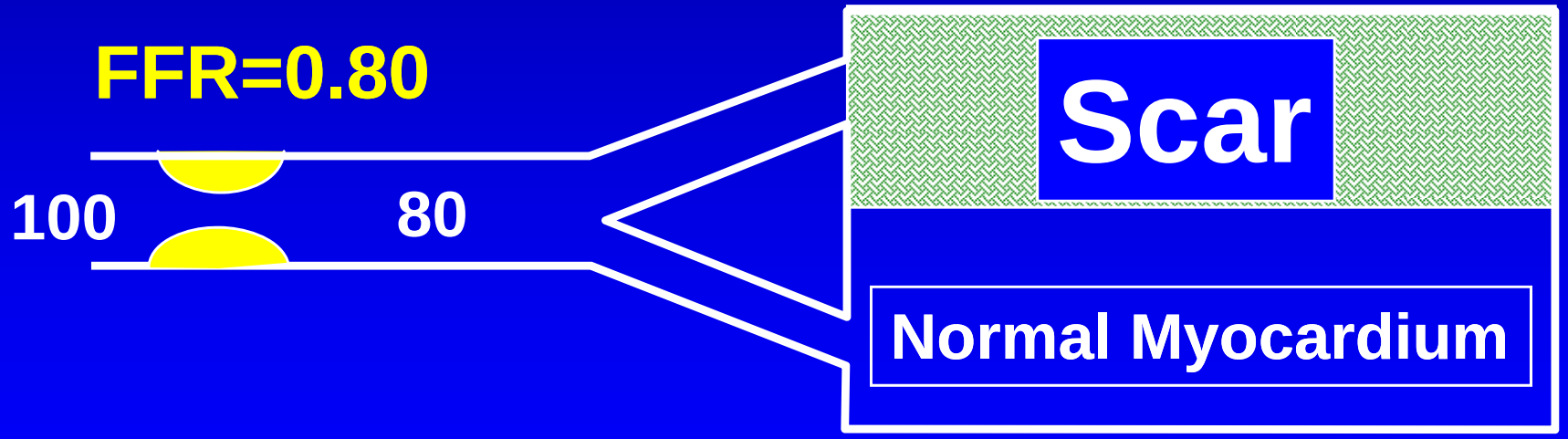
identical CSA, but different significance of stenosis

FFR accounts for the extent of the perfusion area:



FFR=0.60

FFR=0.80



Anatomic stenosis severity by IVUS or QCA is identical but physiologic severity has decreased.

→ FFR accounts for these changes !!!

FEASIBILITY OF FFR MEASUREMENT

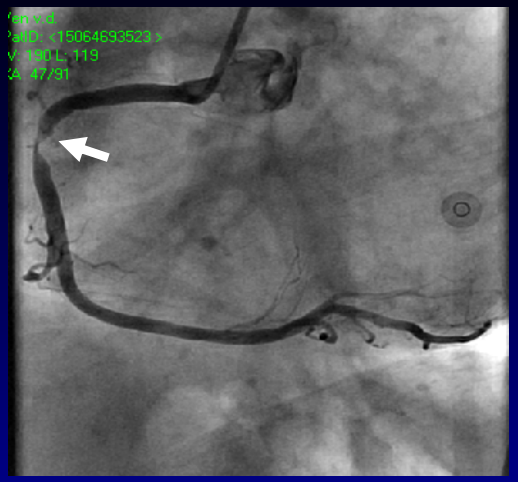
DEFER study: *(Circulation 2001;103:2928-2934)*
325 patients in 14 centers
STENT Registry: *(Circulation 2002;105:2950-2954)*
750 patients in 15 centers;
FAME STUDY
1005 patients with complex MVD
FAME-2 STUDY
1206 patients with any type of coronary artery disease

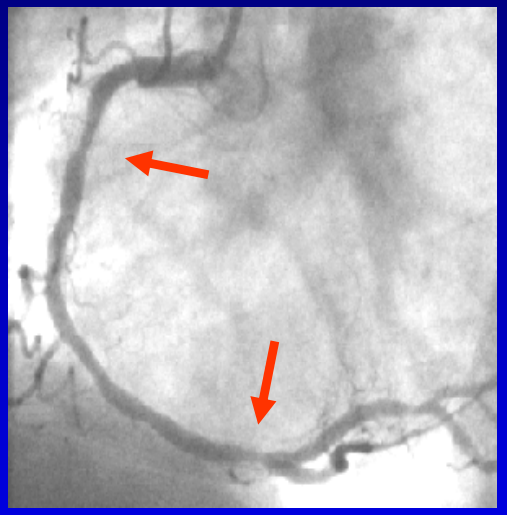
→ Successful FFR measurement in 98 – 99.5 % of all patients with minimal loss of time

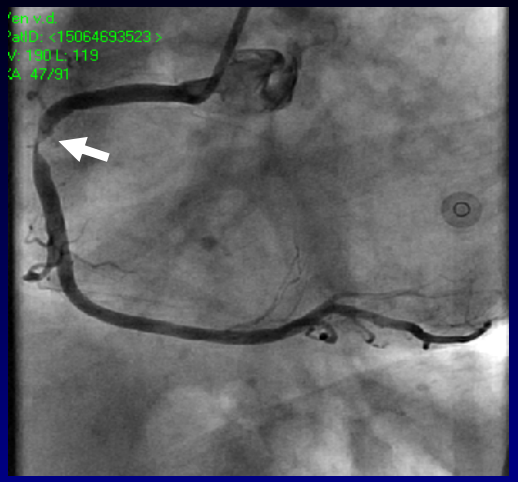
BASIC FEATURES OF FFR

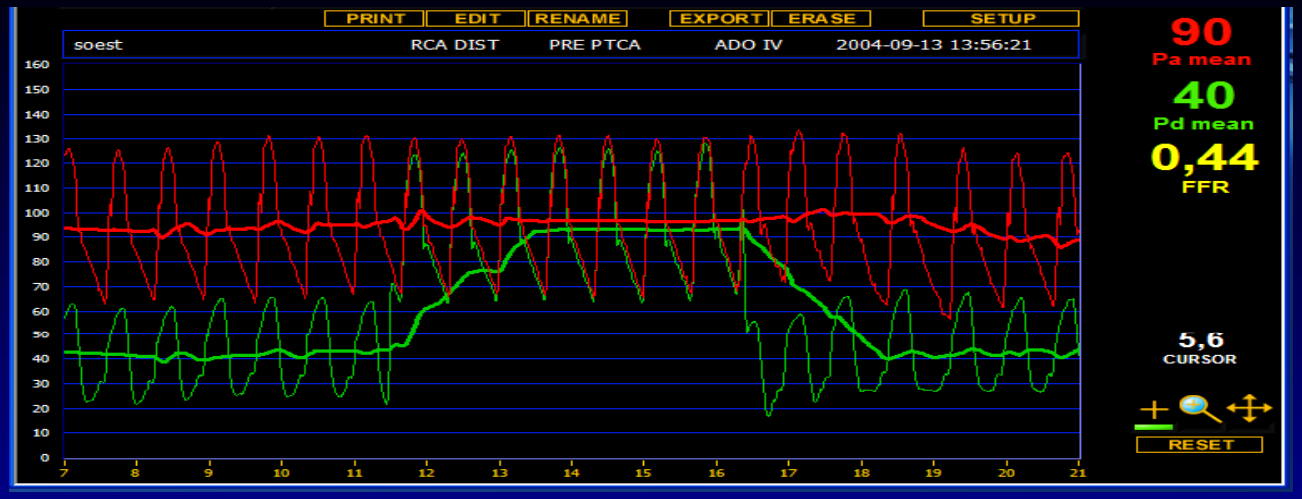
Pressure measurement has un *unequaled spatial resolution*

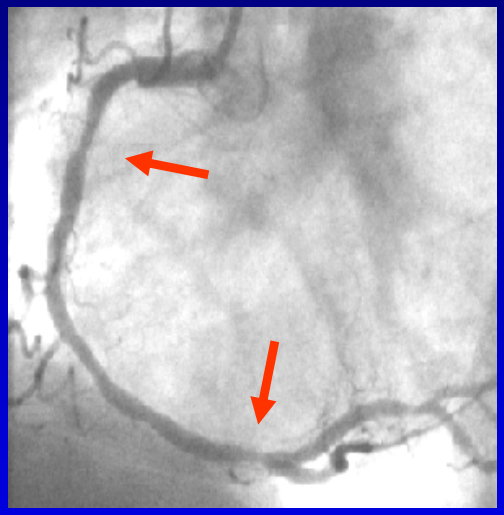
→ ***Hyperemic Pull-back Recording***

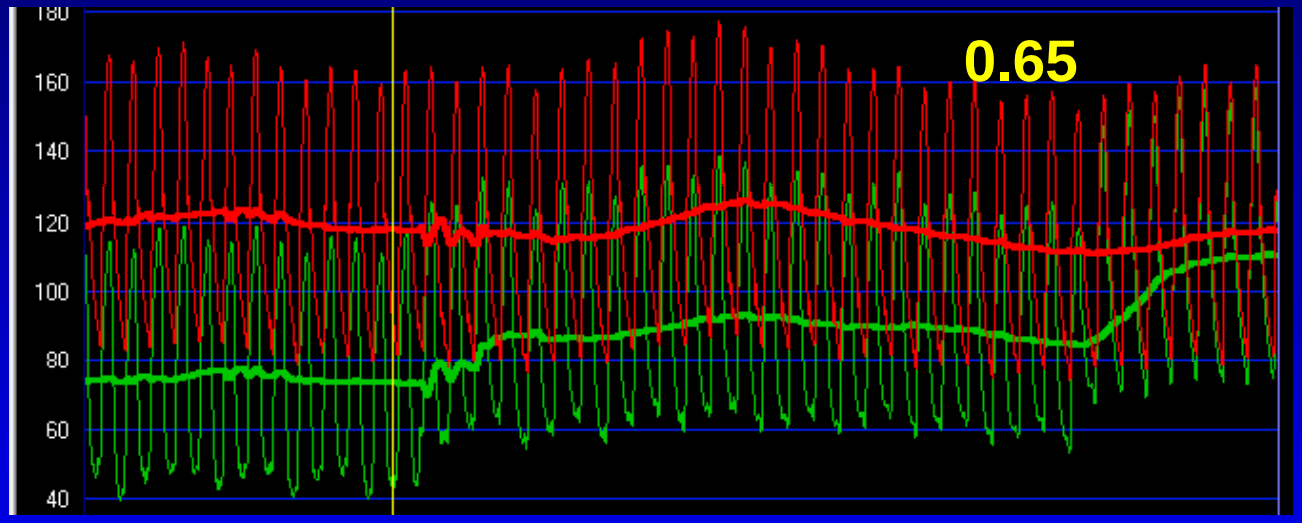


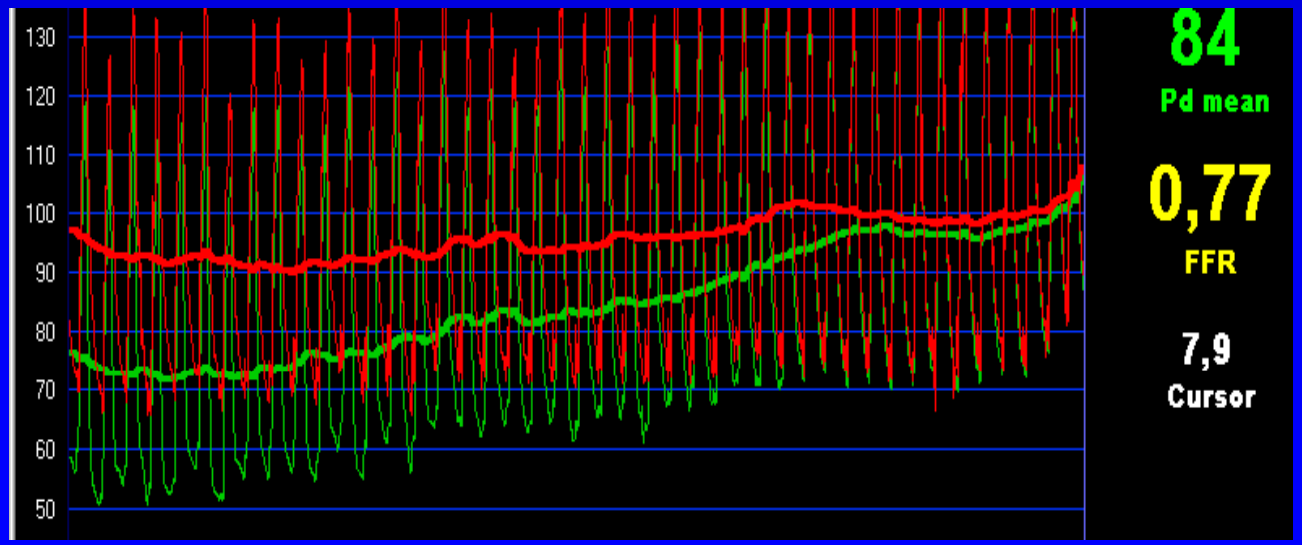





PRINT
EDIT
RENAME
EXPORT
ERASE
SETUP
soest
RCA DIST
PRE PTCA
ADO IV
2004-09-13 13:56:21
90
Pa mean
40
Pd mean
0,44
FFR
5,6
CURSOR
RESET




0.65


84
Pd mean
0,77
FFR
7,9
Cursor

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

CONCLUSIONS:

- FFR is a simple, straightforward, easy-to-perform way to evaluate the functional significance of a stenosis, with
- unequaled accuracy and reproducibility
  (special lecture tonight at evening symposium at 6 pm)
- and important implications for outcome
  (several lectures tomorrow)
- some tricks and pitfalls
  (next presentation by Dr Fearon)
- maximum hyperemia mandatory for optimum benefit
  (presentation later in this session)

EINDE

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 during 1 or 2 weeks

HOW TO OPTIMIZE FFR IN YOUR CATH-LAB (1)

If you decide to measure FFR, ***do it always in the same way and be consistent in your decision:***

FFR > 0.80 ⟶ no stent indicated, medical treatment
FFR < 0.75 ⟶ stent, if technically feasible

Measuring FFR of > 0.80 and placing a stent as yet, is ***NONSENSE***

If you are not prepared to believe your measurement, You can better not do it

“FFR never lies”

(key paper: Koolen, Cathet Cardiovasc Interv 2008: 72:248-256)

HOW TO OPTIMIZE FFR IN YOUR CATH-LAB (2)

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