Imaging and Physiology Summit
Seoul, Korea
November 20th, 2009

Measuring FFR:
Fundamentals, Tips and Tricks

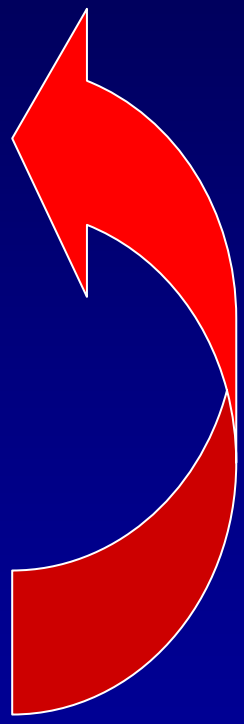
William F. Fearon, M.D.
Assistant Professor
Division of Cardiovascular Medicine
Stanford University Medical Center

Derivation of FFR

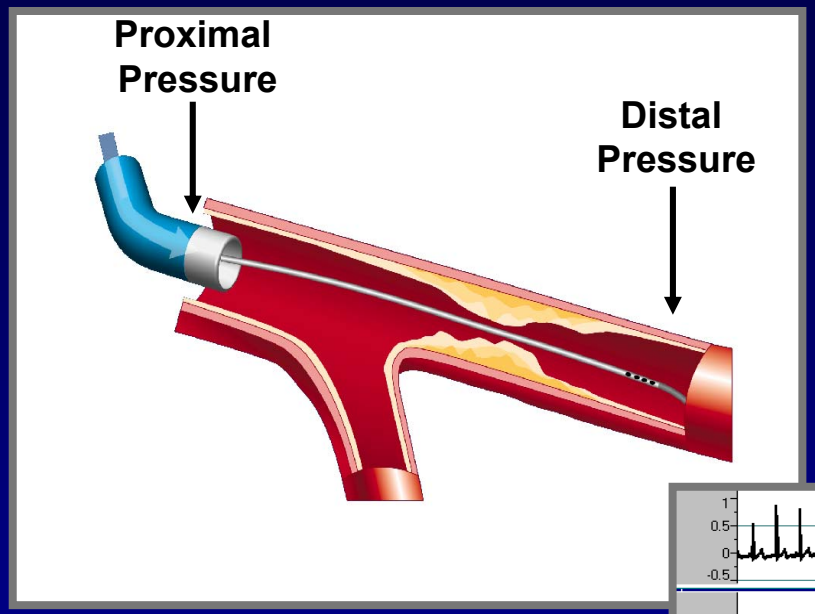
- $\text{FFR} = \dfrac{\text{Myocardial Flow (Stenosis)}}{\text{Myocardial Flow (Normal)}}$
- $\text{Flow} = \dfrac{\text{Pressure}}{\cancel{\text{Resistance}}}$
- *at maximal hyperemia* $\text{Flow} \approx \text{Pressure}$

Derivation of FFR

- FFR = $\frac{\text{Coronary Pressure (Stenosis)}}{\text{Coronary Pressure (Normal)}}$
- Flow = $\frac{\text{Pressure}}{\text{Resistance}}$
- *at maximal hyperemia* Flow ≈ Pressure

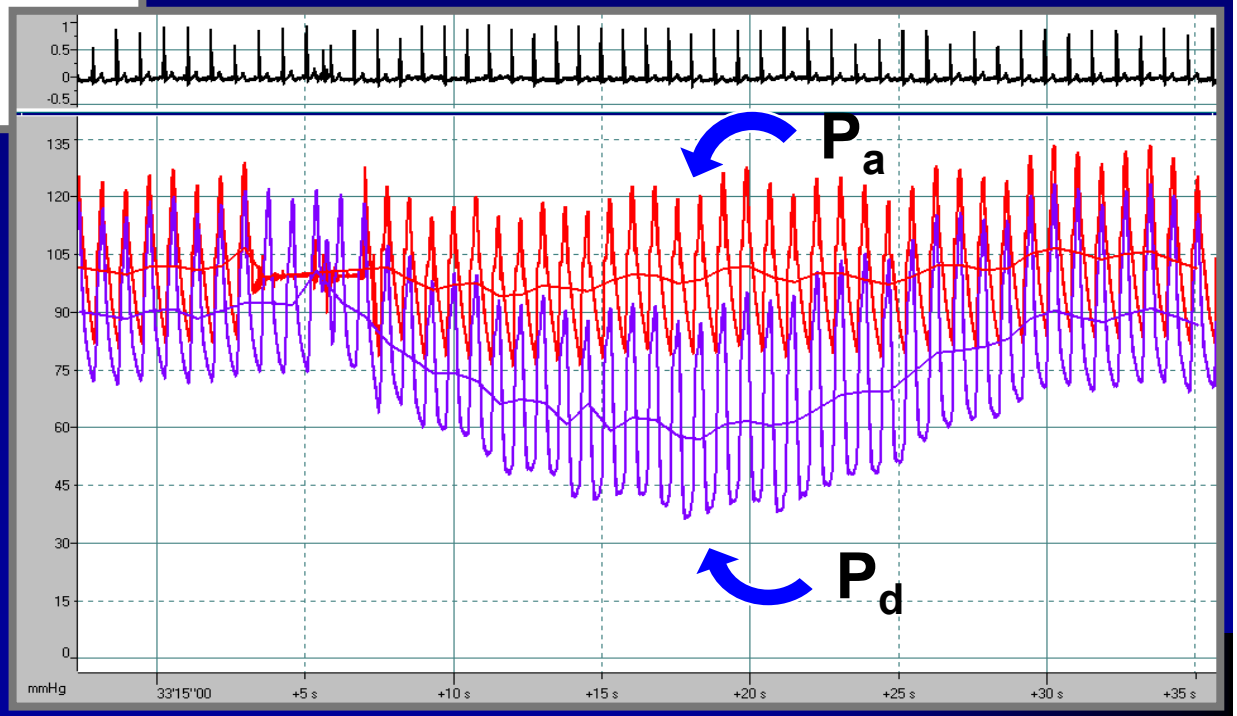


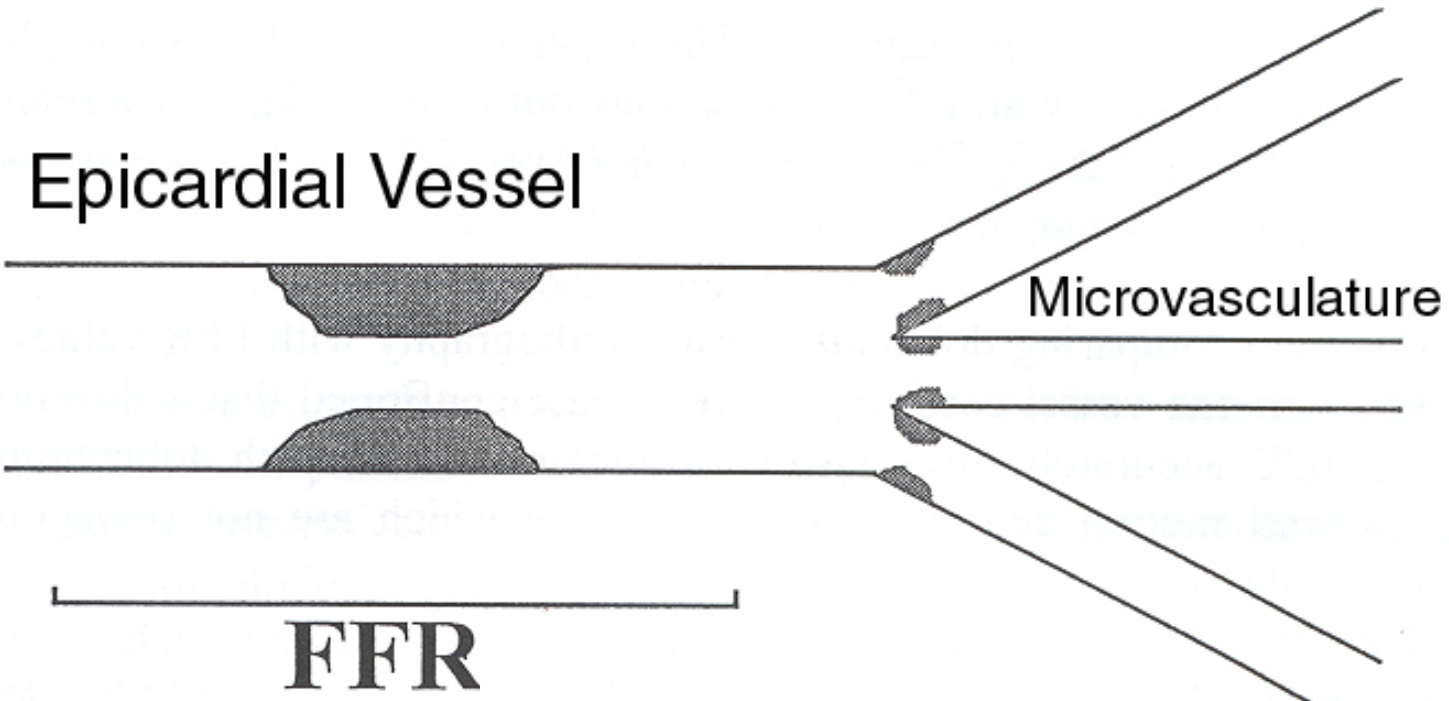
Fractional Flow Reserve



$FFR = P_d / P_a$

during maximal flow

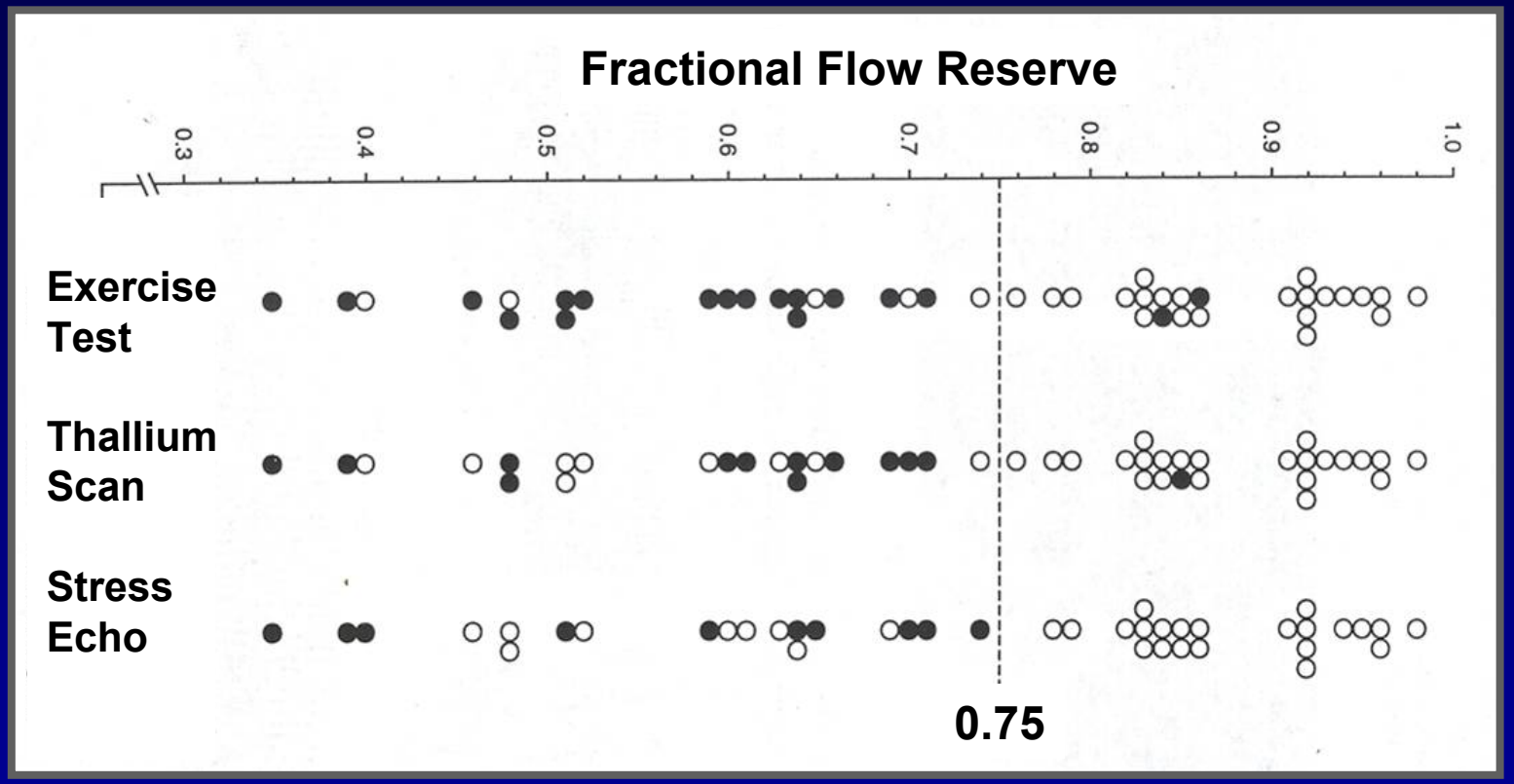




- Clearly defined normal value
- Not affected by resting hemodynamics
- Relatively easy to perform

Adapted from: Pijls and De Bruyne, Coronary Pressure
Kluwer Academic Publishers, 2000

FFR in Intermediate Lesions

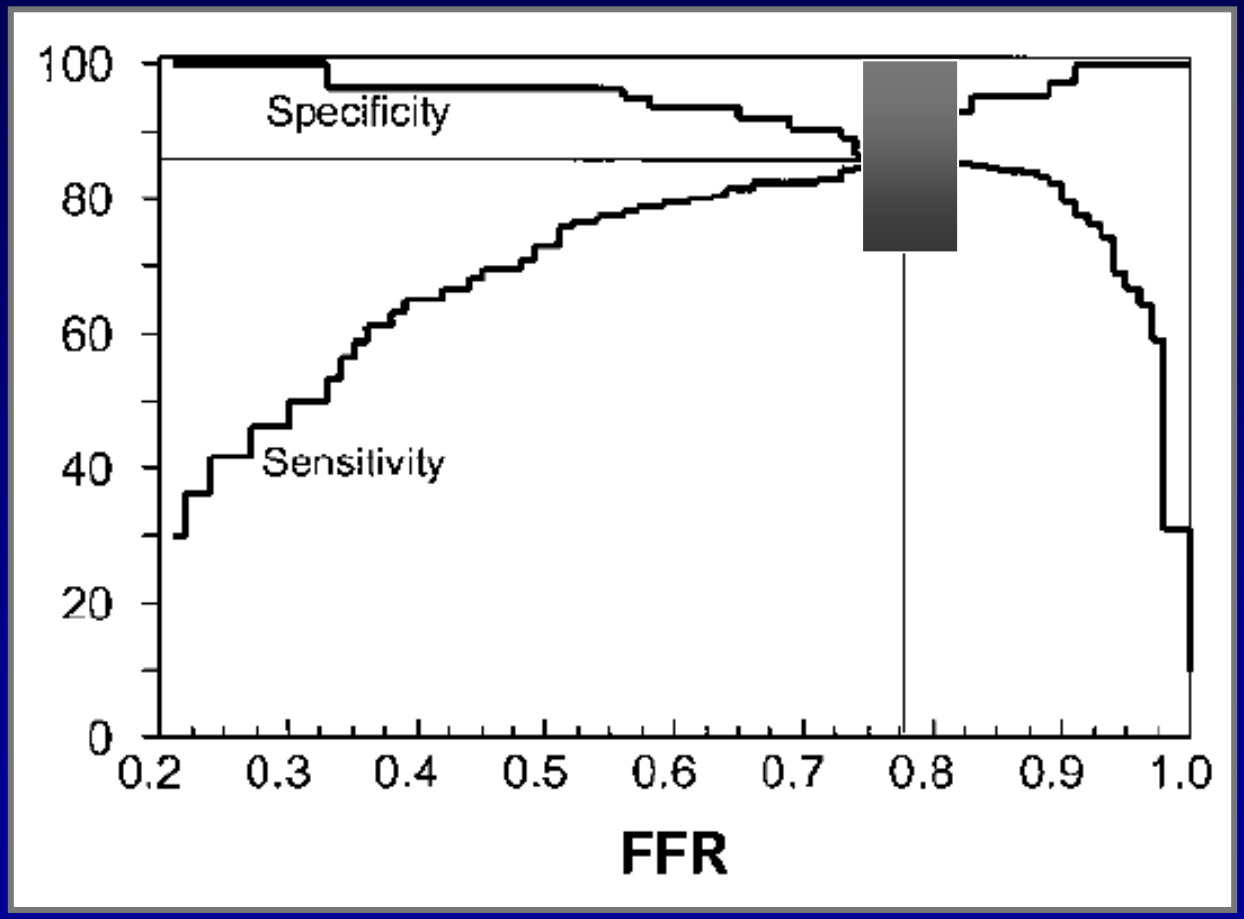


FFR < 0.75 : Sensitivity = 88%
Specificity = 100%

Pijls et al., New Engl J Med 1996;334:1703

Stanford

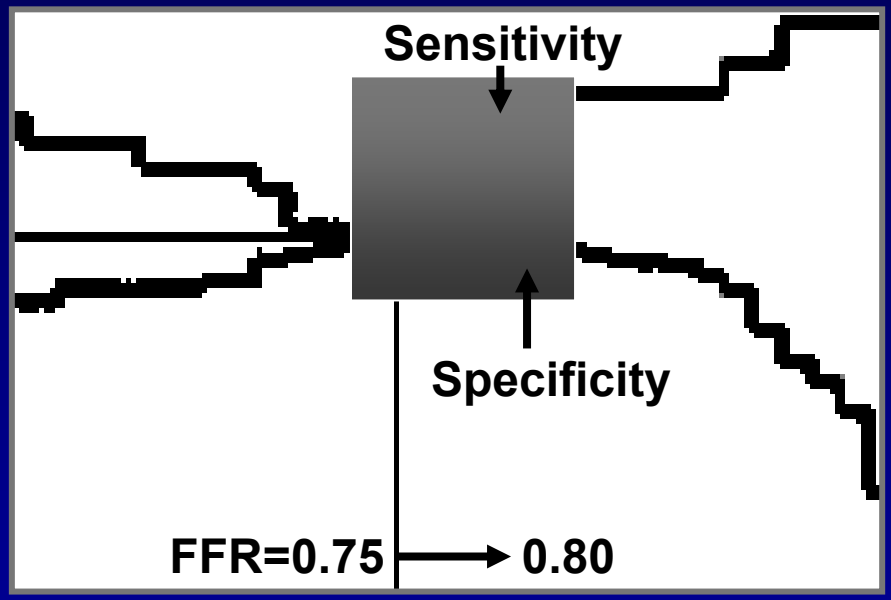
FFR and the “Grey Zone”



De Bruyne, et al. Circulation 2001;104:157-62

Stanford

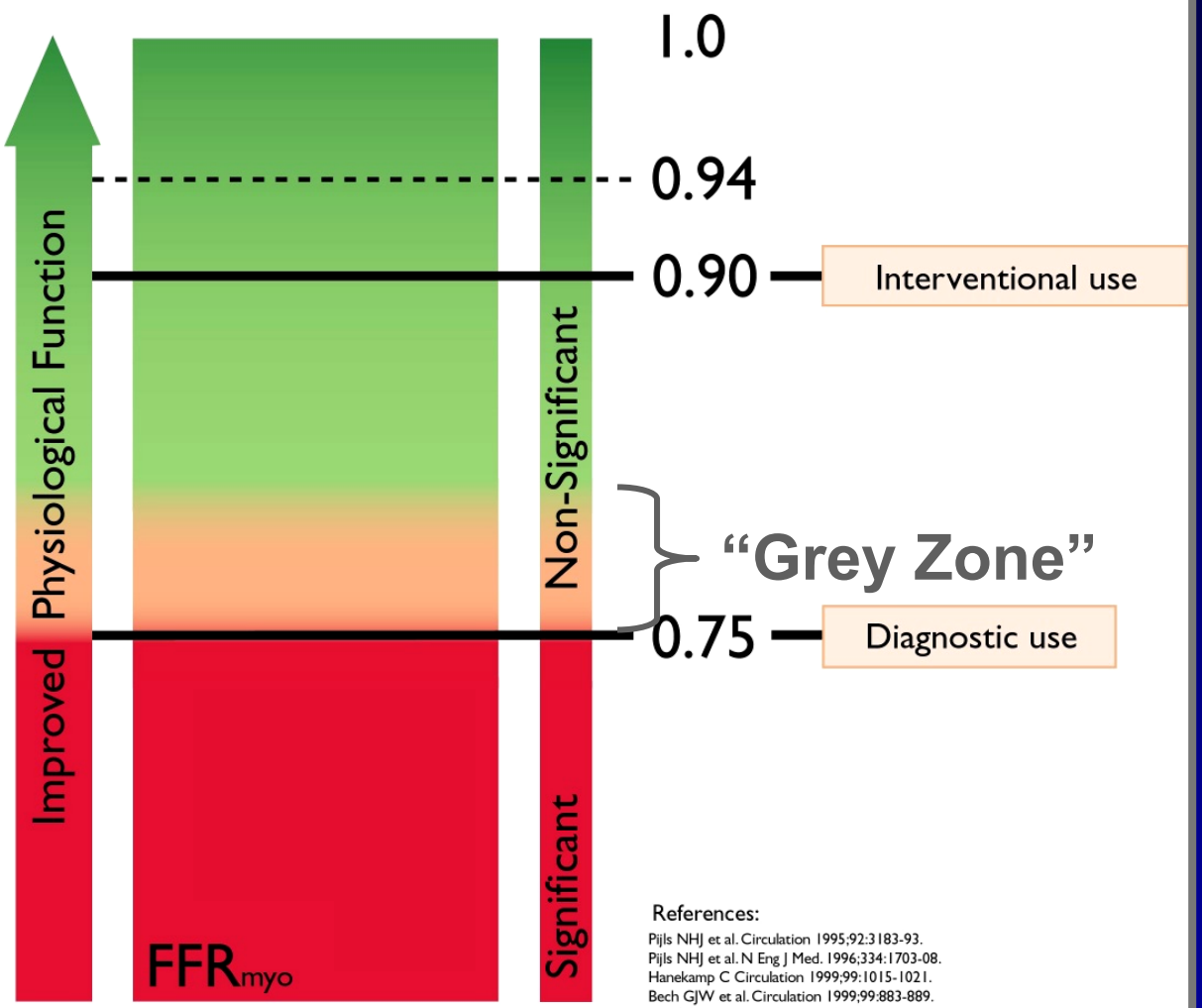
FFR and the “Grey Zone”



De Bruyne, et al. Circulation 2001;104:157-62

Stanford

FFR for decision-making in the cath lab



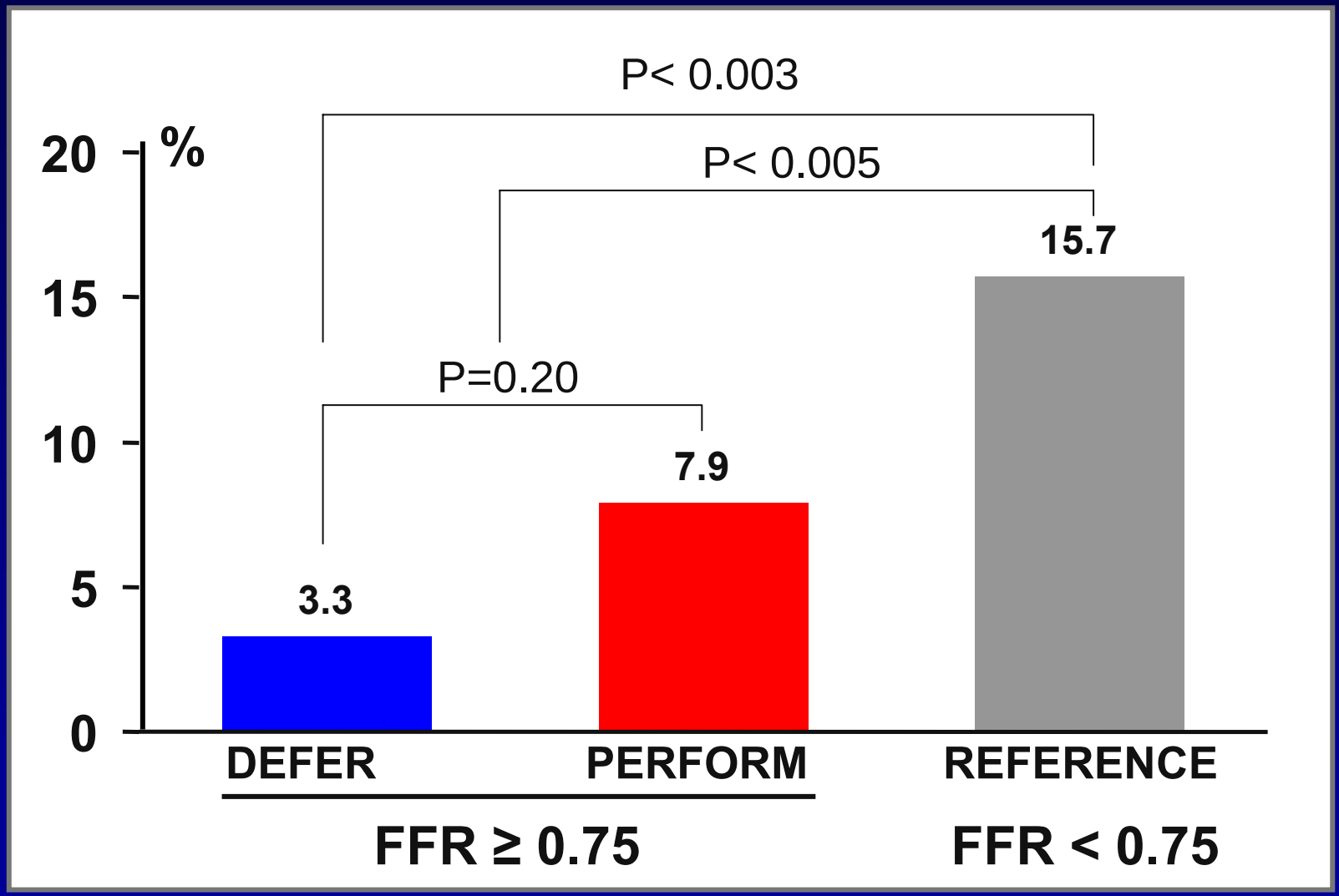
Based on the teaching file of Paul G. Yock MD, Stanford University.

Note: The specificity of this cut-off value is 100% and the sensitivity is 88%.

References:

Pijls NHJ et al. Circulation 1995;92:3183-93.
Pijls NHJ et al. N Eng J Med. 1996;334:1703-08.
Hanekamp C Circulation 1999;99:1015-1021.
Bech GJW et al. Circulation 1999;99:883-889.
Pijls NHJ and De Bruyne B. 2000.
Coronary Pressure 2nd Edition. Kluwer Academic Publishers

Cardiac Death and MI After 5 Years

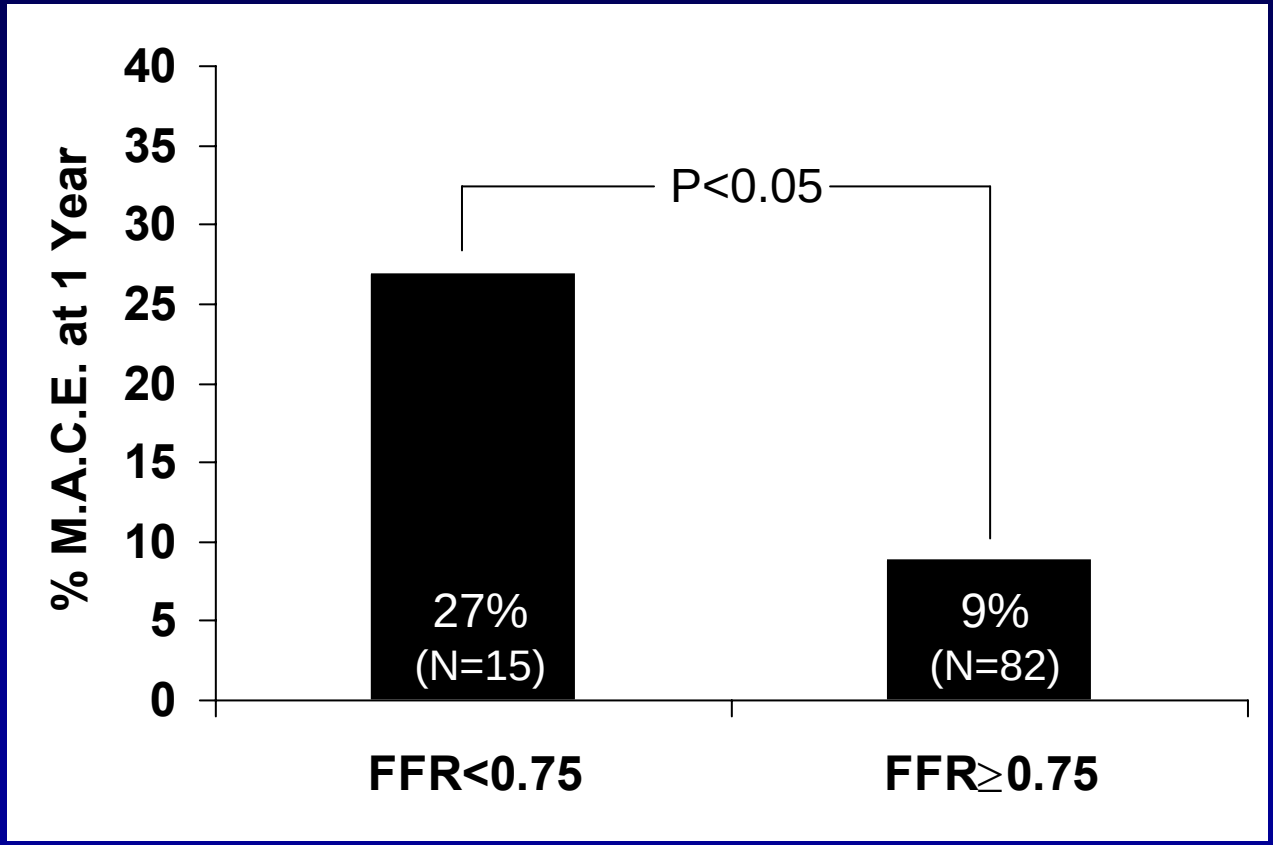


Pijls et al. J Am Coll Cardiol 2007;49:2105-11

Stanford

Danger of Deferring PCI if FFR < 0.75

97 patients with intermediate lesions and normal nuclear scans



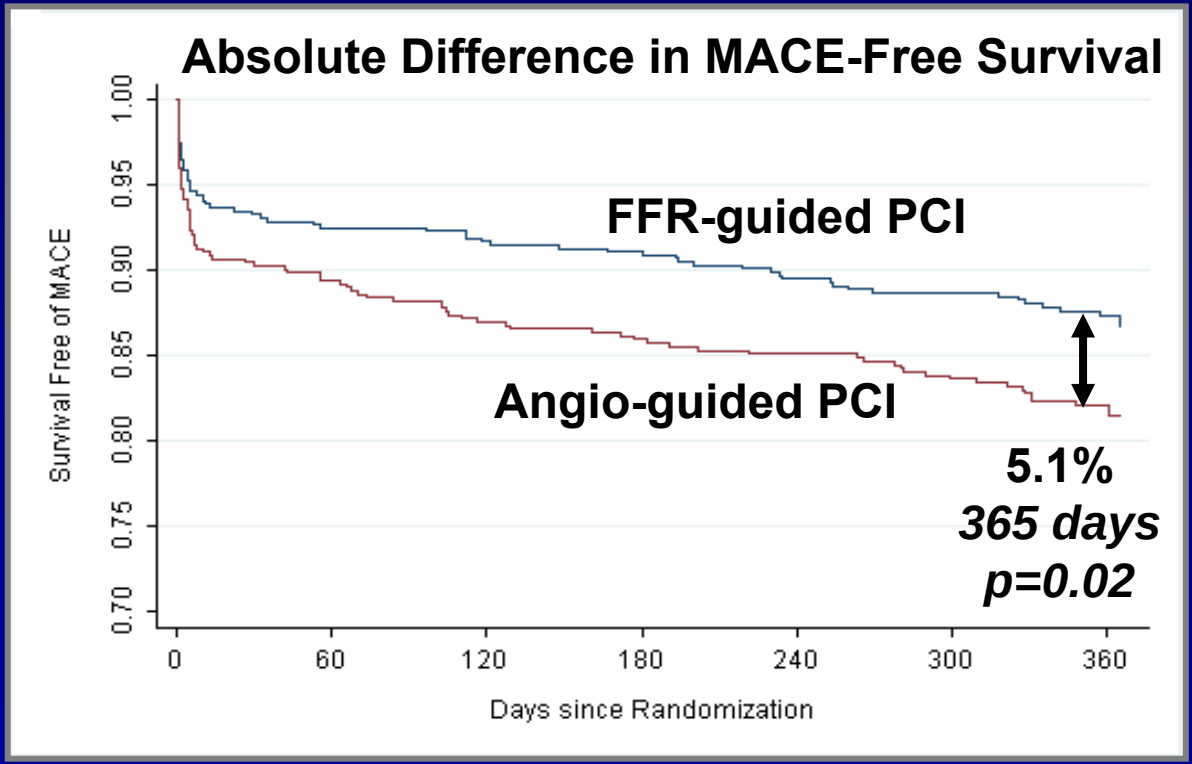
Chamuleau et al. Am J Cardiol 2002;89:377-380

Stanford

FFR-Guided PCI vs. Angio-Guided PCI in Multivessel CAD

Results of the FAME study:

1. Improved outcomes
2. Decreased cost
3. Less contrast use
4. Similar procedure time



Angio	FFR
$6,007	vs $5,332, p<0.001
302 ml	vs 272 ml, p<0.001
70 min	vs 71 min, p=0.51

New Engl J Med 2009;360:213-24

Stanford

Pitfalls / Tips & Tricks

- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice

Potential Pitfalls

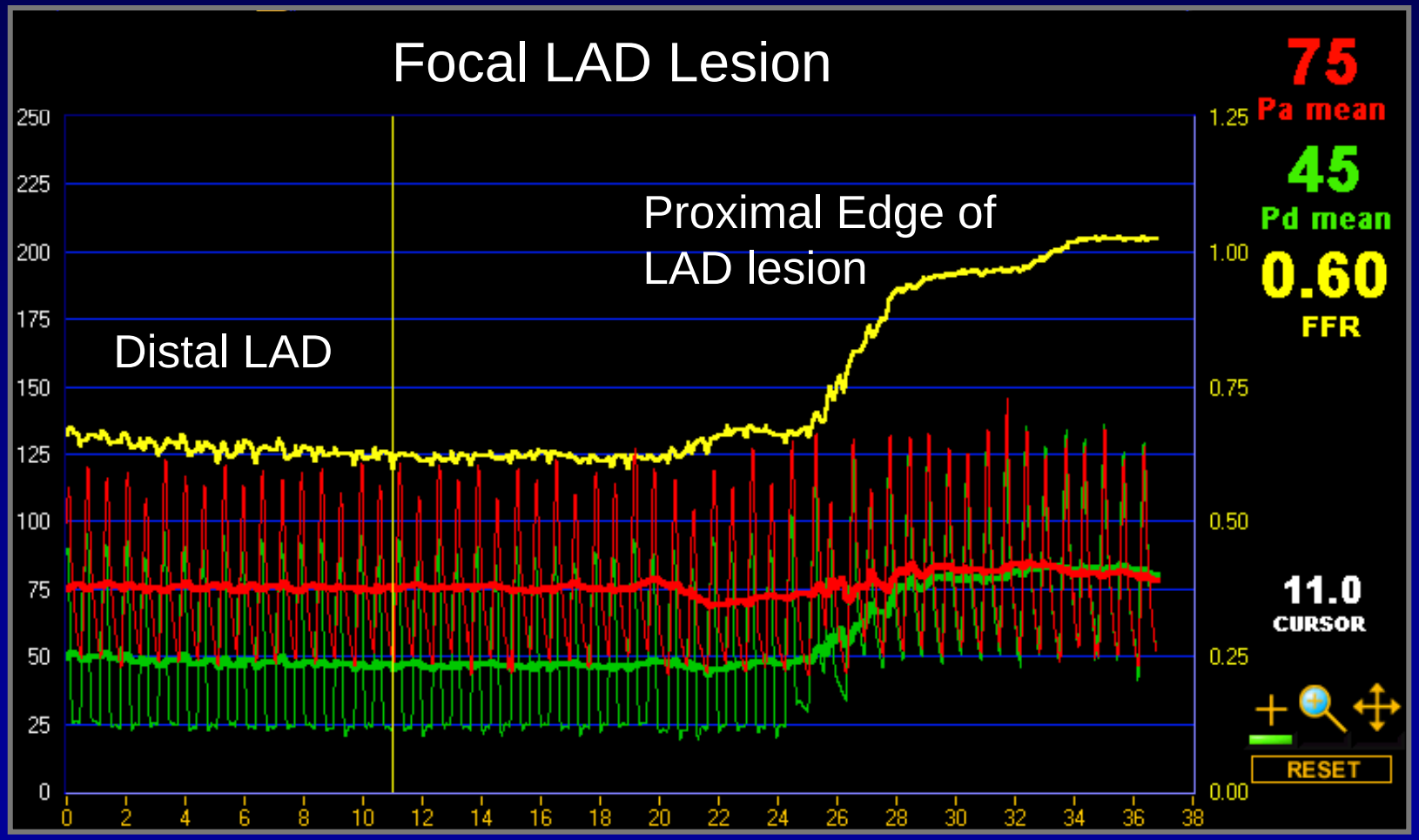
- Inadequate hyperemia
  - Intracoronary adenosine
    - Short-lasting peak effect (~5 seconds)
    - Don’t use a guiding catheter with sideholes
    - If one suspects inadequate hyperemia, then increase dose (>100 micrograms) or use intravenous adenosine

Potential Pitfalls

- Inadequate hyperemia
  - Intravenous adenosine
    - Should be administered via central vein
    - May require higher doses (>140 ug/kg/min) if given peripherally to avoid metabolism

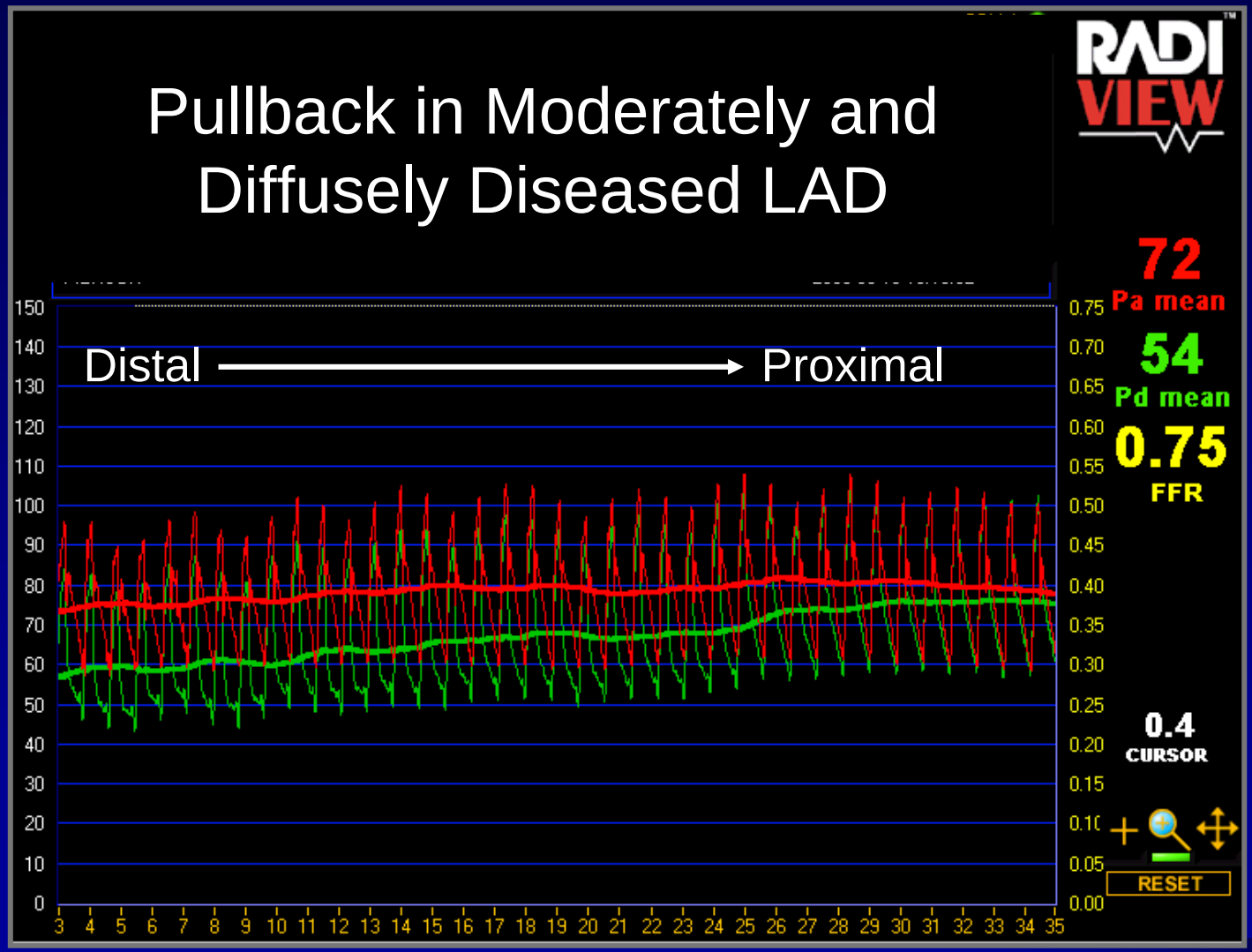
Performing FFR

Pressure Pullback



Stanford

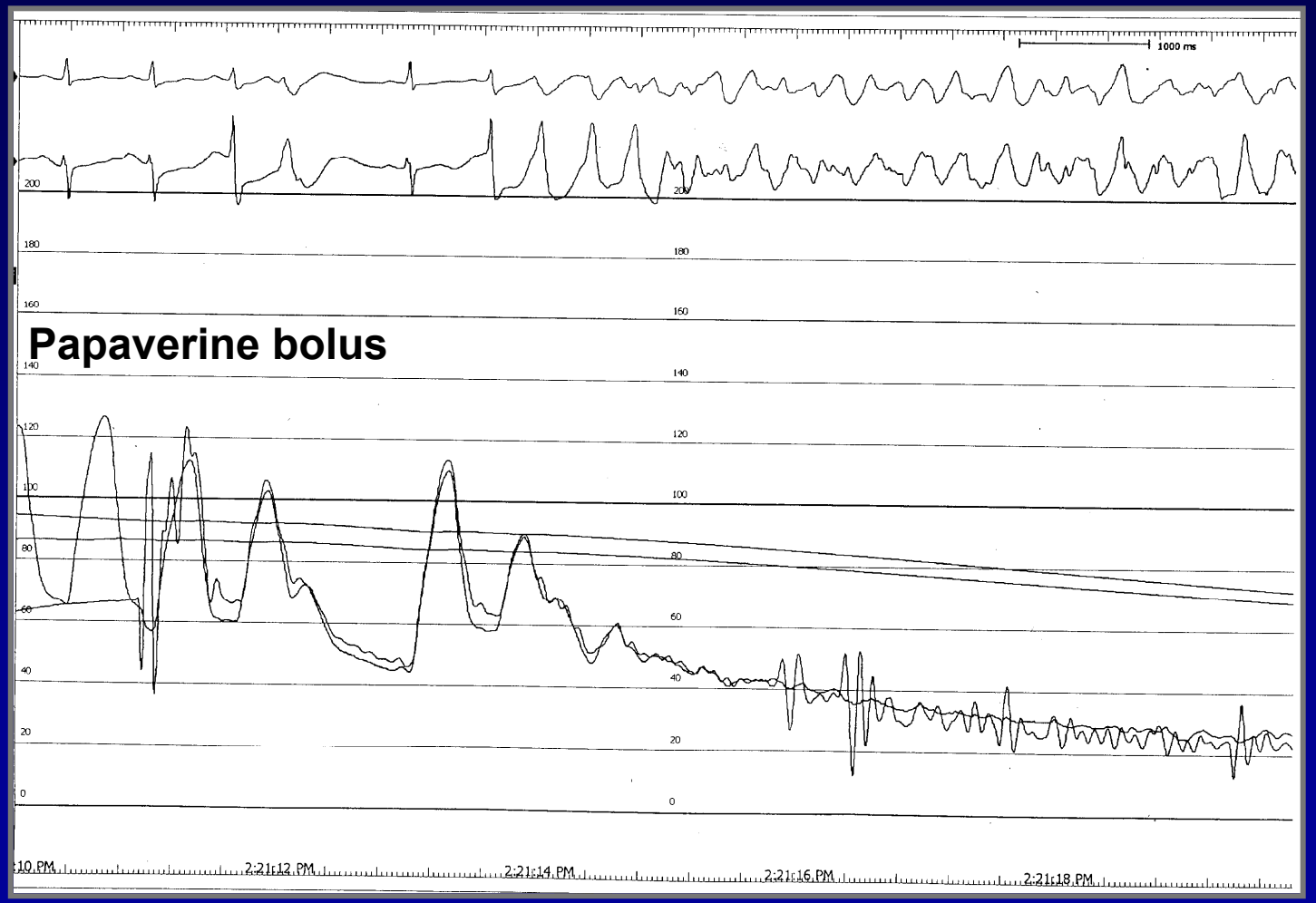
Performing FFR



Potential Pitfalls

- Inadequate hyperemia
  - Intracoronary Papaverine
    - Peak lasts 30-60 seconds, allowing pullback
    - Transient QT prolongation, T wave changes
    - Rarely causes VT / Torsade de Pointes

Papaverine-Induced Arrhythmia

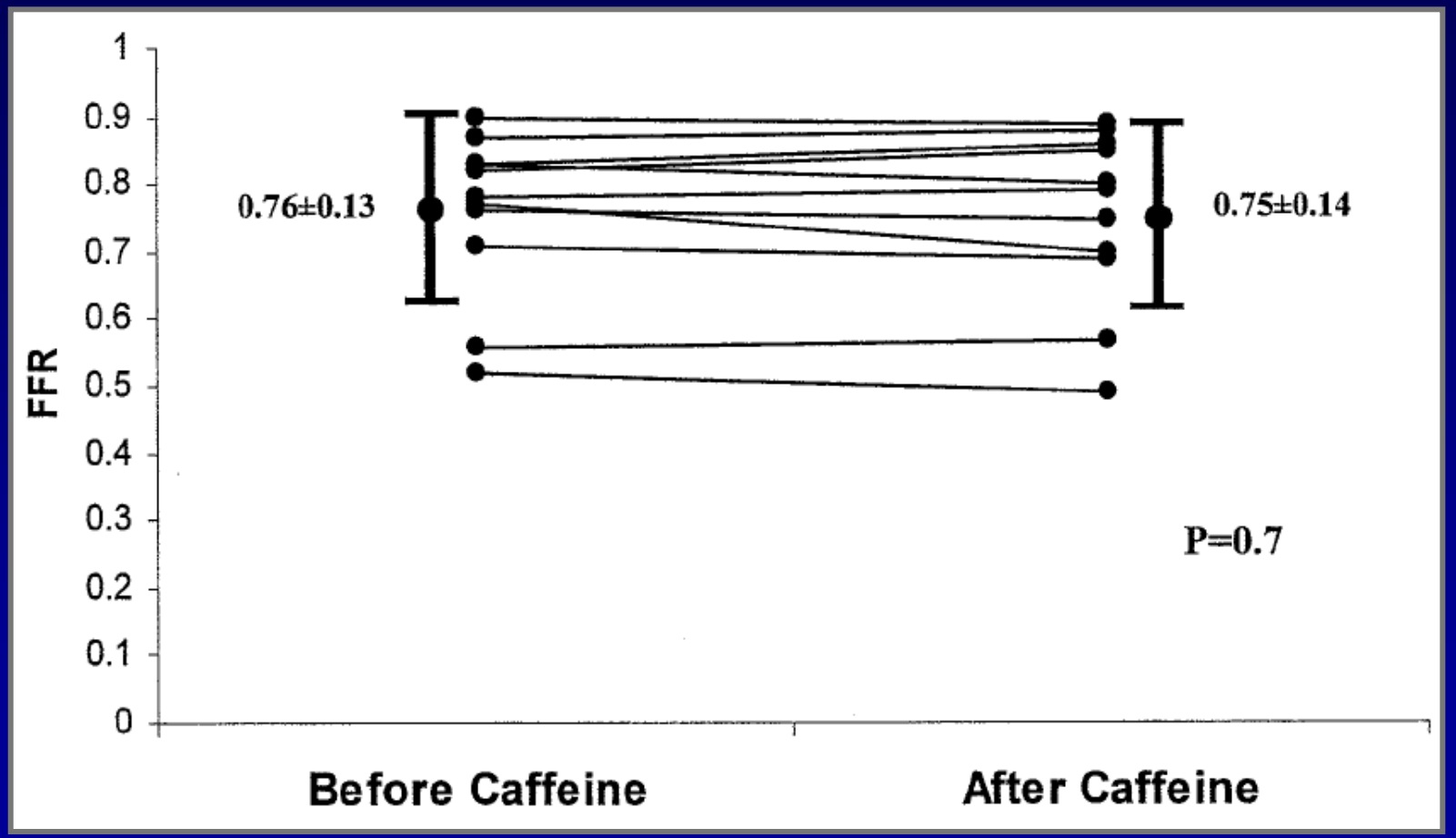


Potential Pitfalls

- Inadequate hyperemia
  - Caffeine
    - Competitive inhibitor of the adenosine A2a receptor
    - Small studies have shown that caffeine may decrease the sensitivity of dipyridamole stress tests
    - Dipyridamole indirectly increases endogenous adenosine by blocking the cellular reuptake mechanism

Caffeine and FFR

FFR measured with 30-50 ugs of IC adenosine before and after 2-3 “cups” of coffee



Aqel, et al. Am J Cardiol 2004;93:343-346.

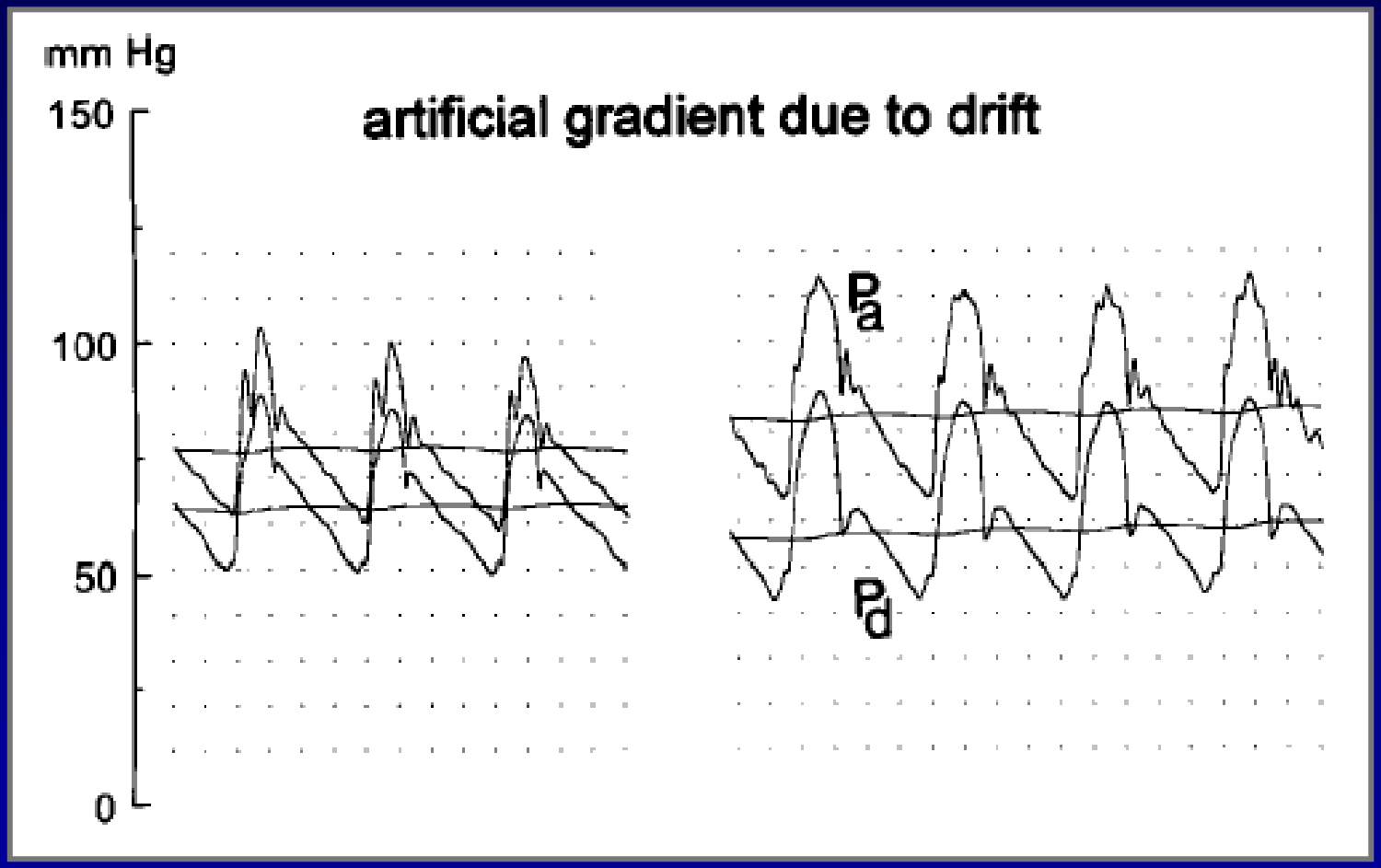
Stanford

Pitfalls / Tips & Tricks

- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice

Potential Pitfalls

Recognizing True Pressure Drift



Pijls et al. Cathet Cardiovasc Intervent 2000;49:1-16

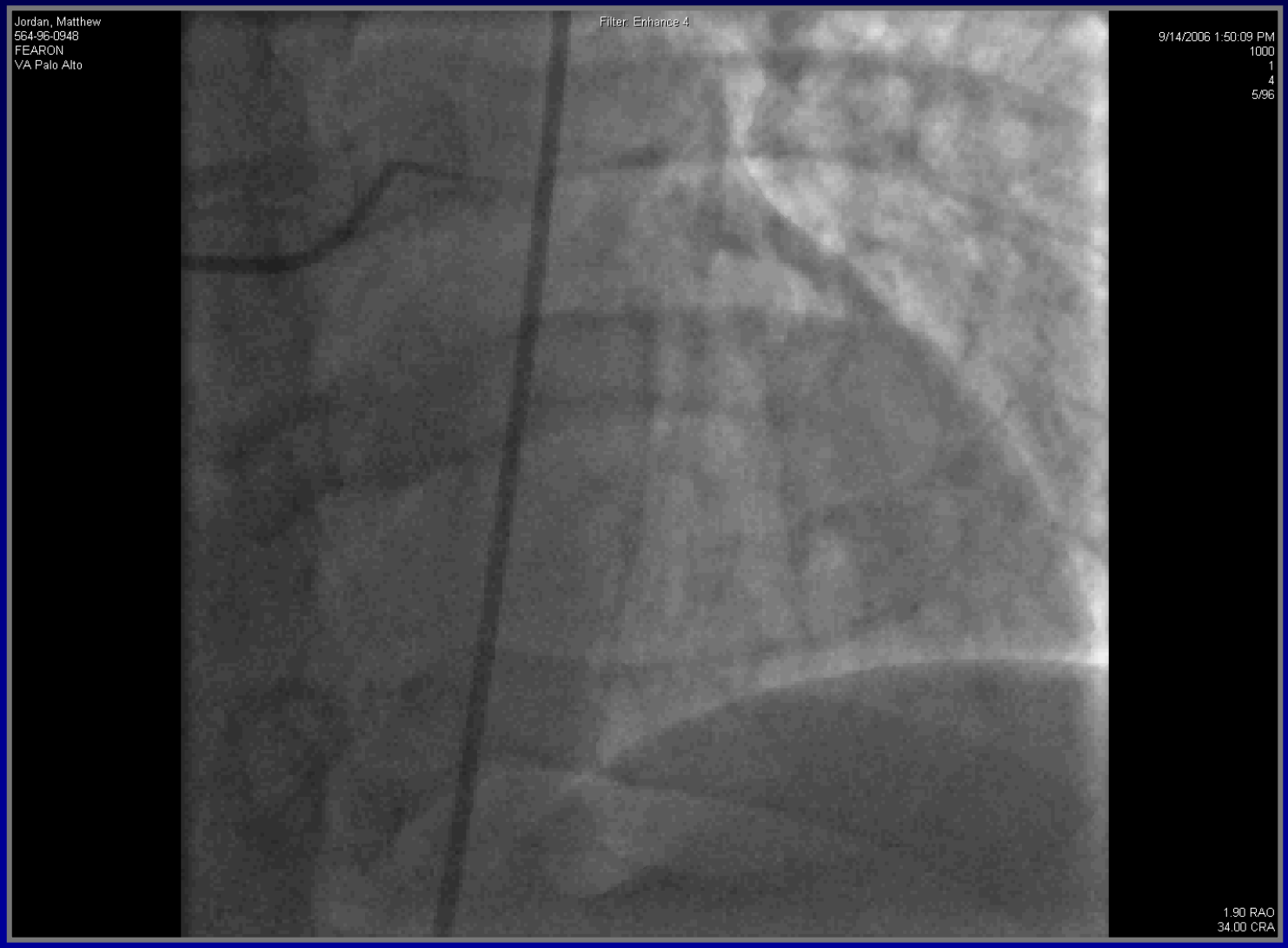
Potential Pitfalls

- Pressure Drift
  - Causes of artifactual drift
    - Wire introducer
    - Paradoxical gradient
    - Contrast in guide catheter

Pitfalls / Tips & Tricks

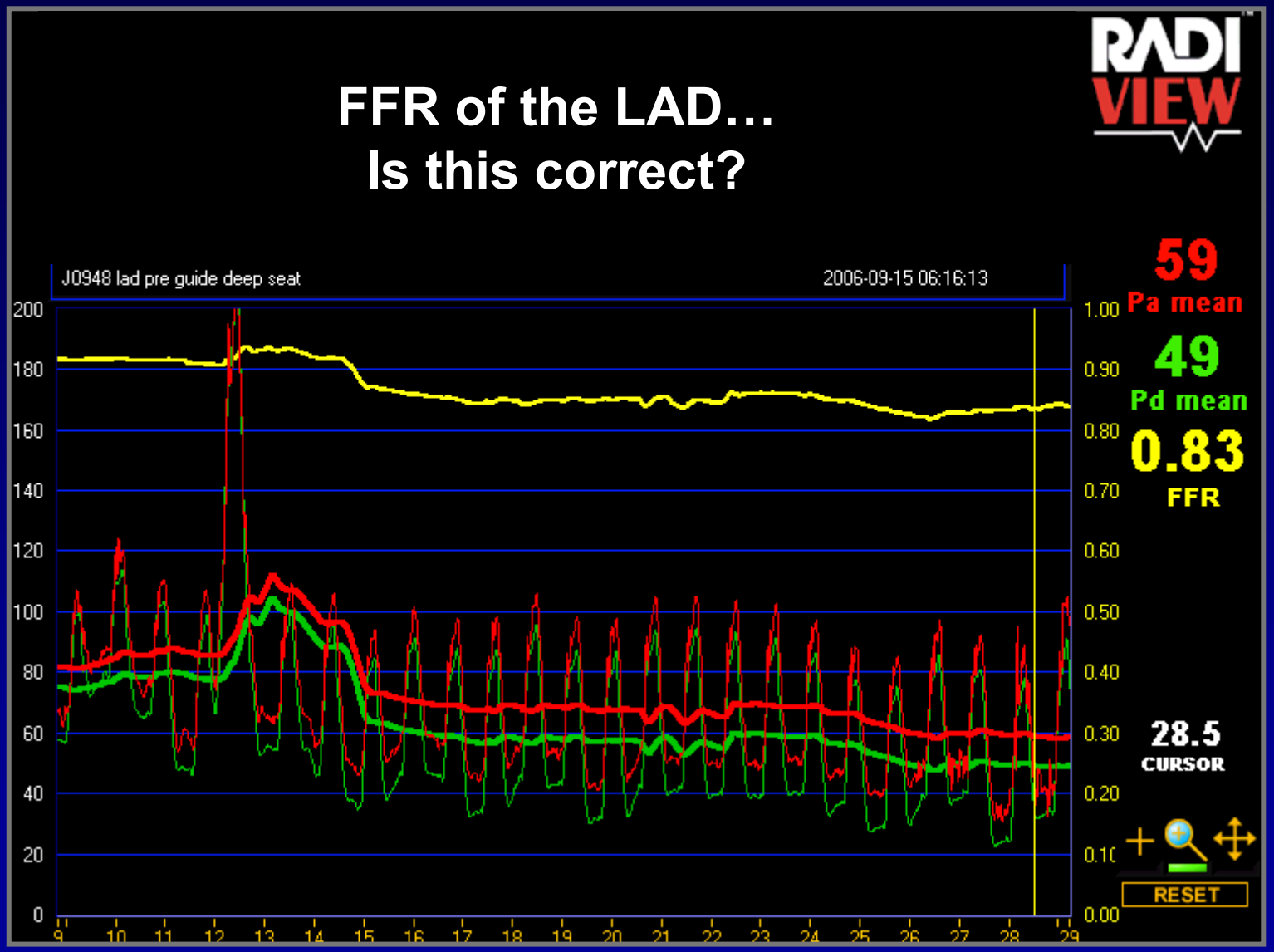
- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice

Cranial View of the LAD



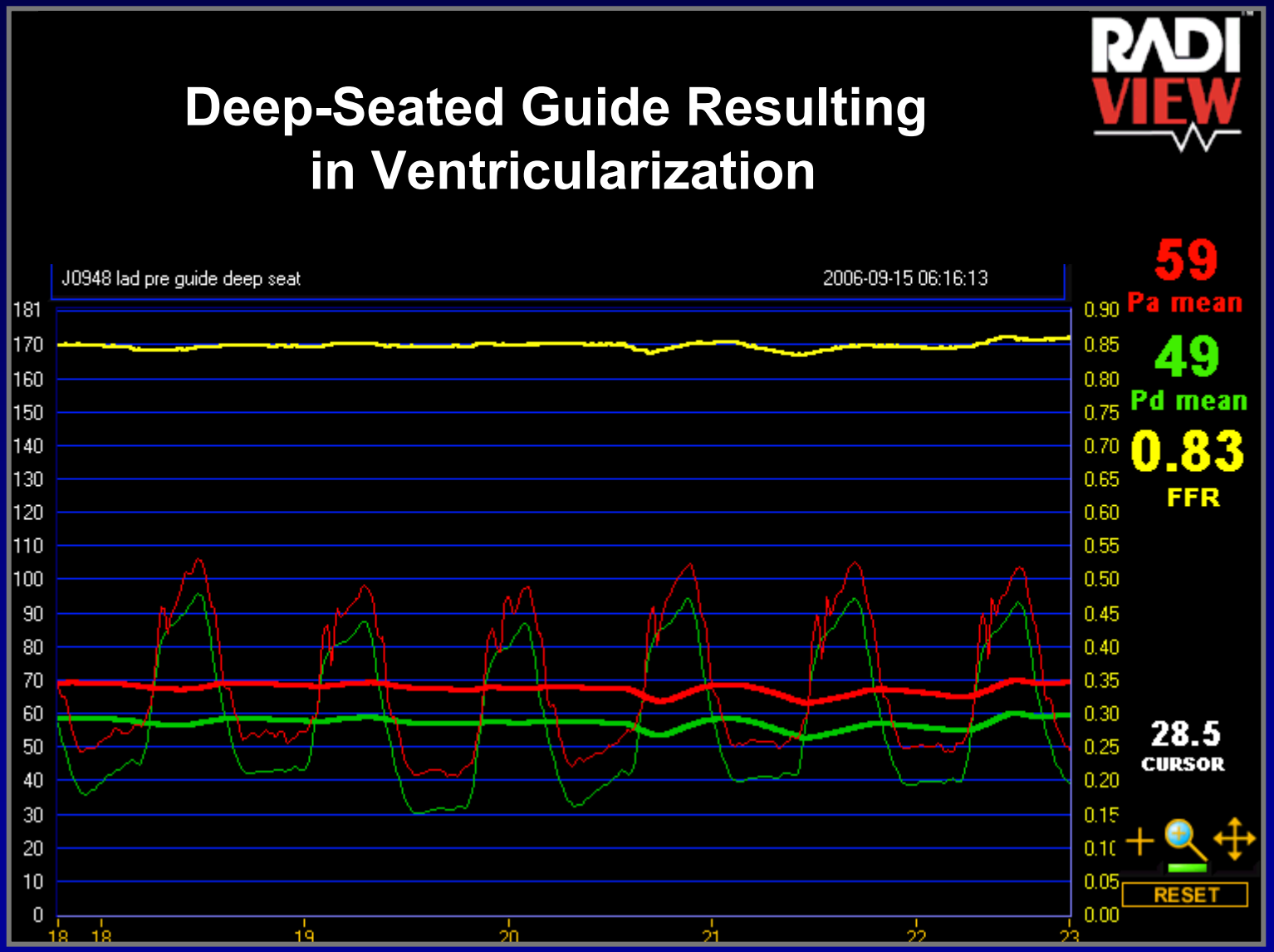
Stanford

FFR of the LAD…
Is this correct?



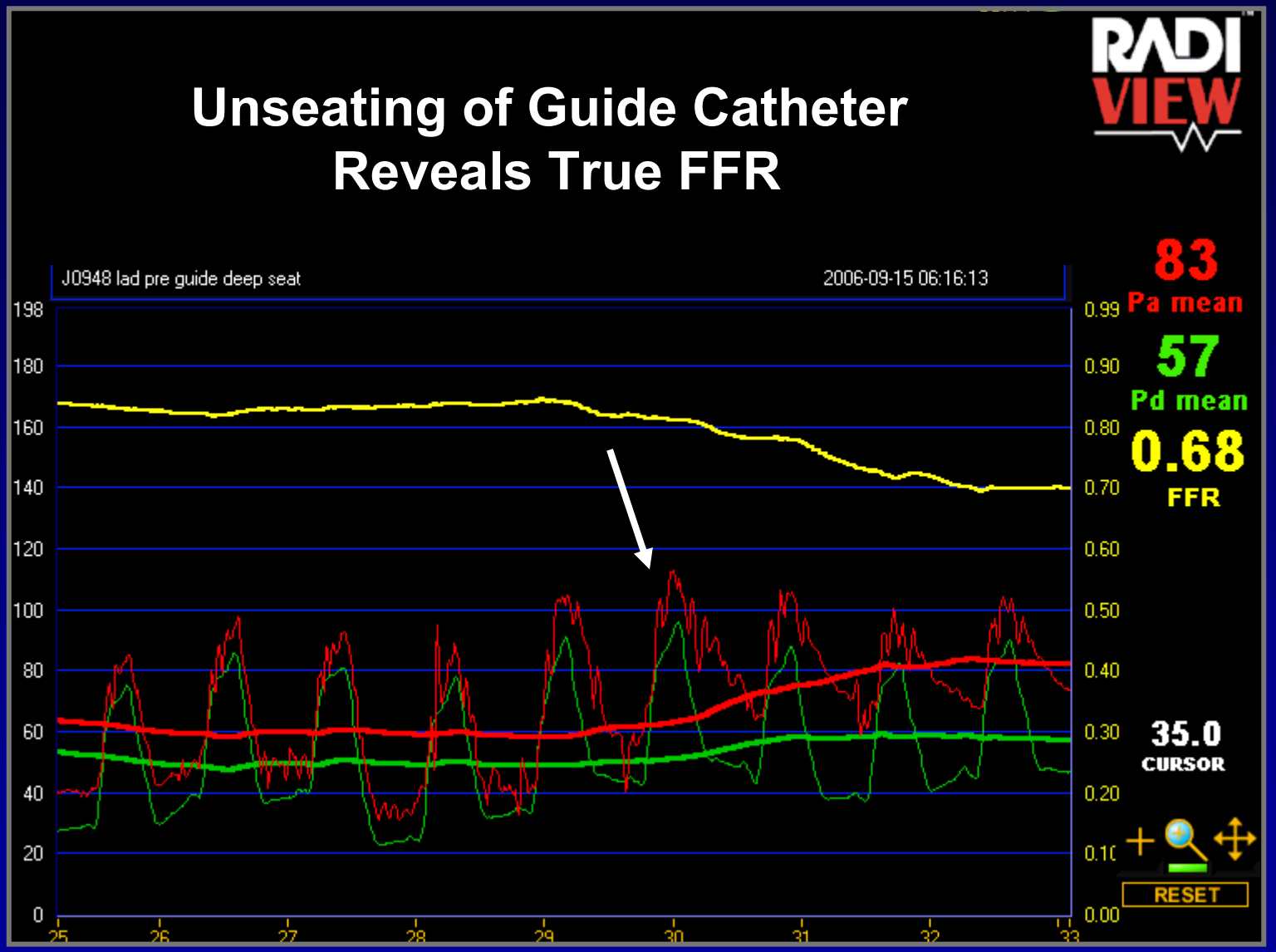
Stanford

Deep-Seated Guide Resulting in Ventricularization

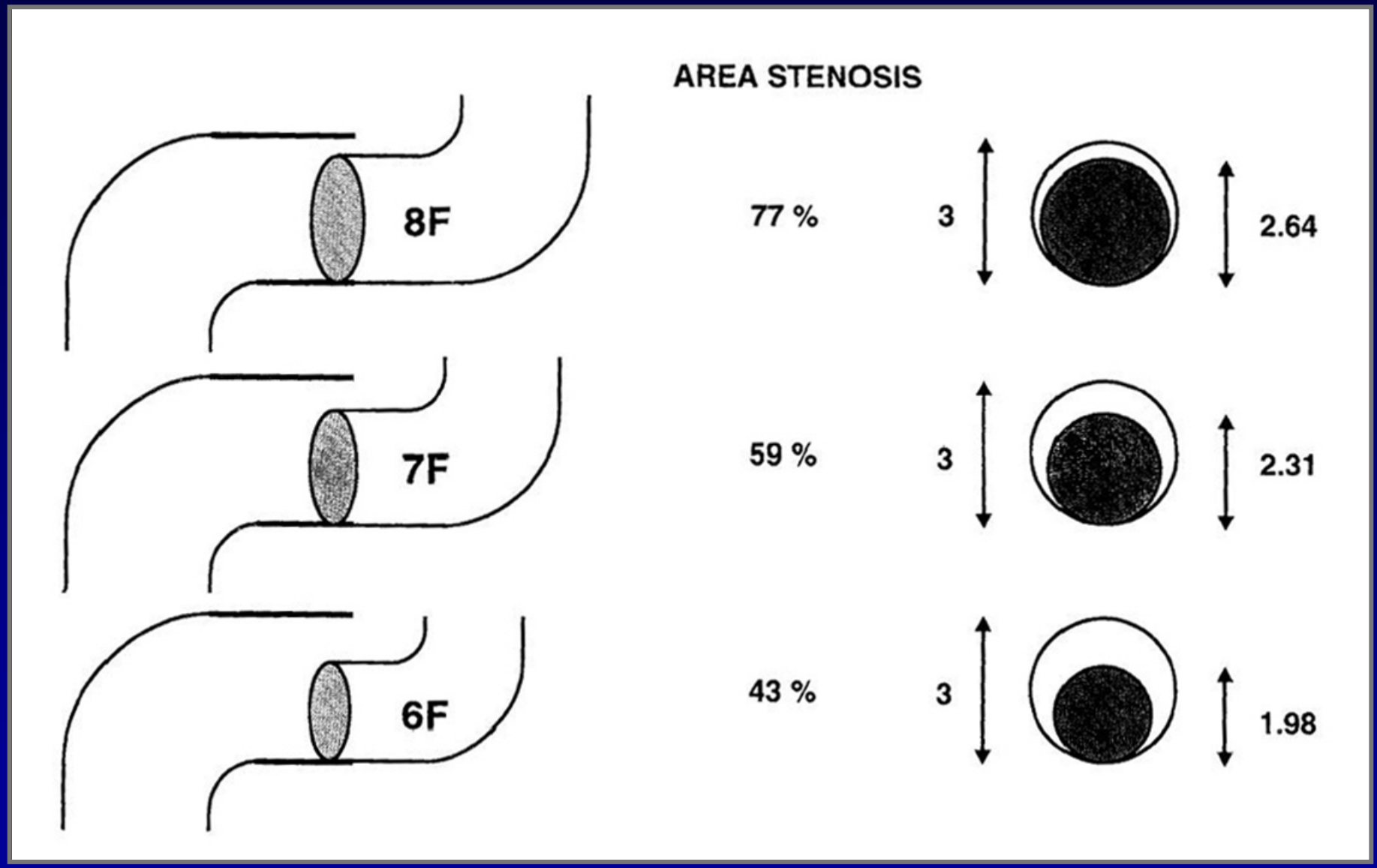


Stanford

Unseating of Guide Catheter Reveals True FFR



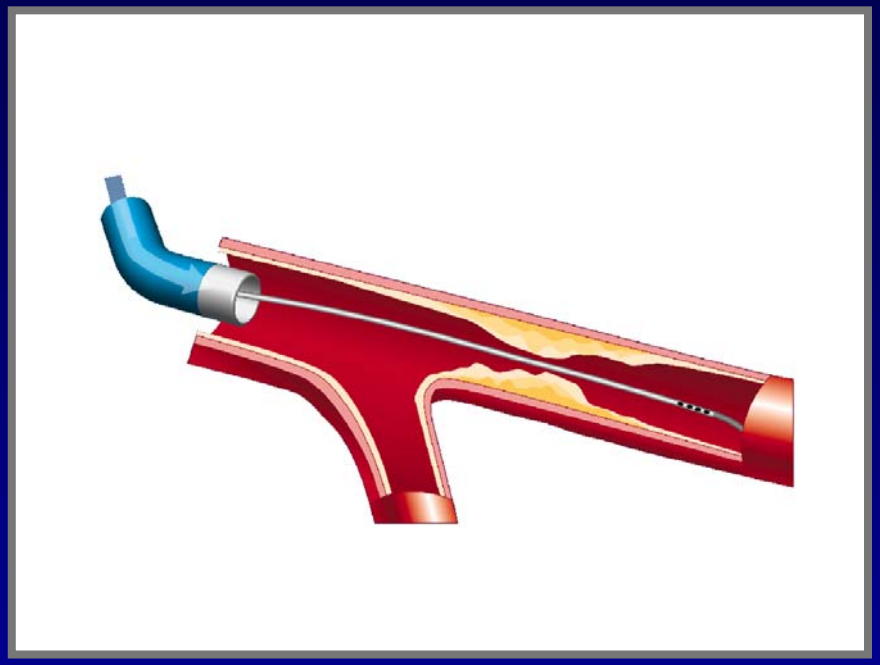
Stanford

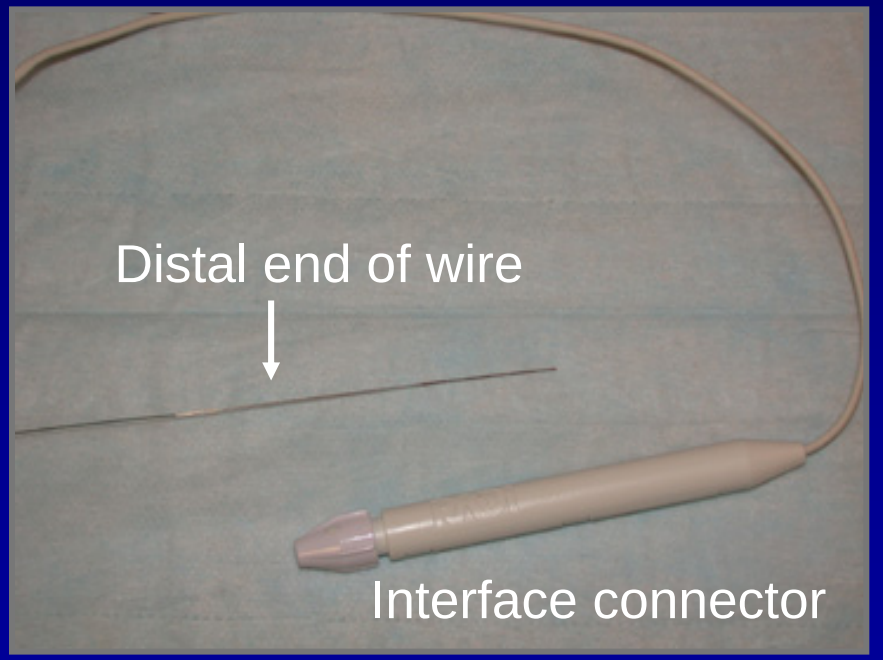


De Bruyne et al. Cathet Cardiovasc Diagn 1994;33:145-152.

Stanford

Wiring Tortuous Vessels





Consider disconnecting the wire from the interface connector

Can use exchange catheter to more safely position the pressure wire

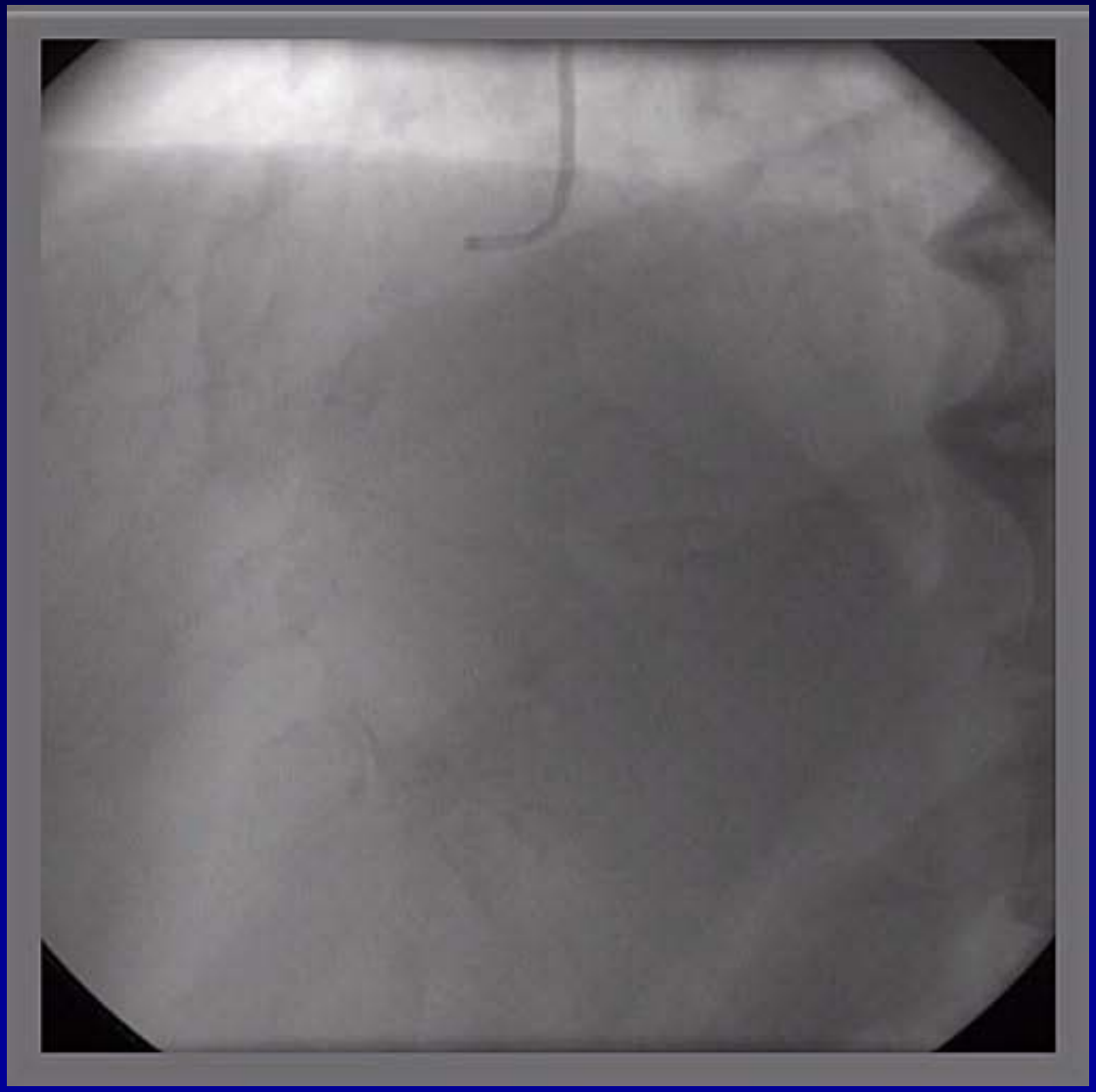
Pitfalls / Tips & Tricks

- Inadequate hyperemia
- Pressure drift
- Guide catheter / wire issues
- Particular patient subsets
- Incorporating physiology into your practice

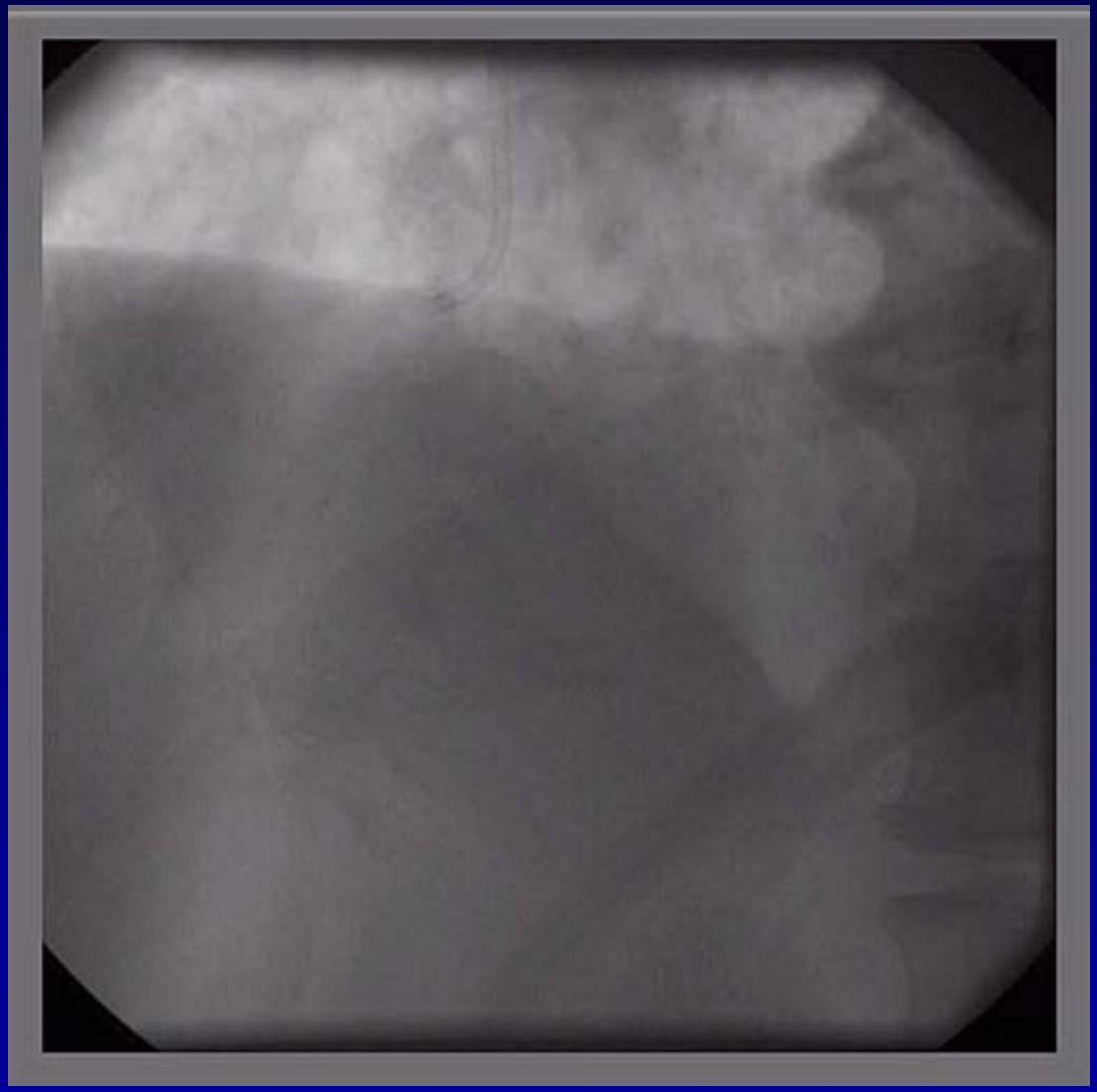
Potential Pitfalls

- Particular patient subsets
  - LVH
    - ↑↑ muscle mass compared to vasculature
    - FFR cuttoff value may be higher than 0.75
  - Exercise-induced vasoconstriction
    - Greater stenosis with exercise compared to adenosine

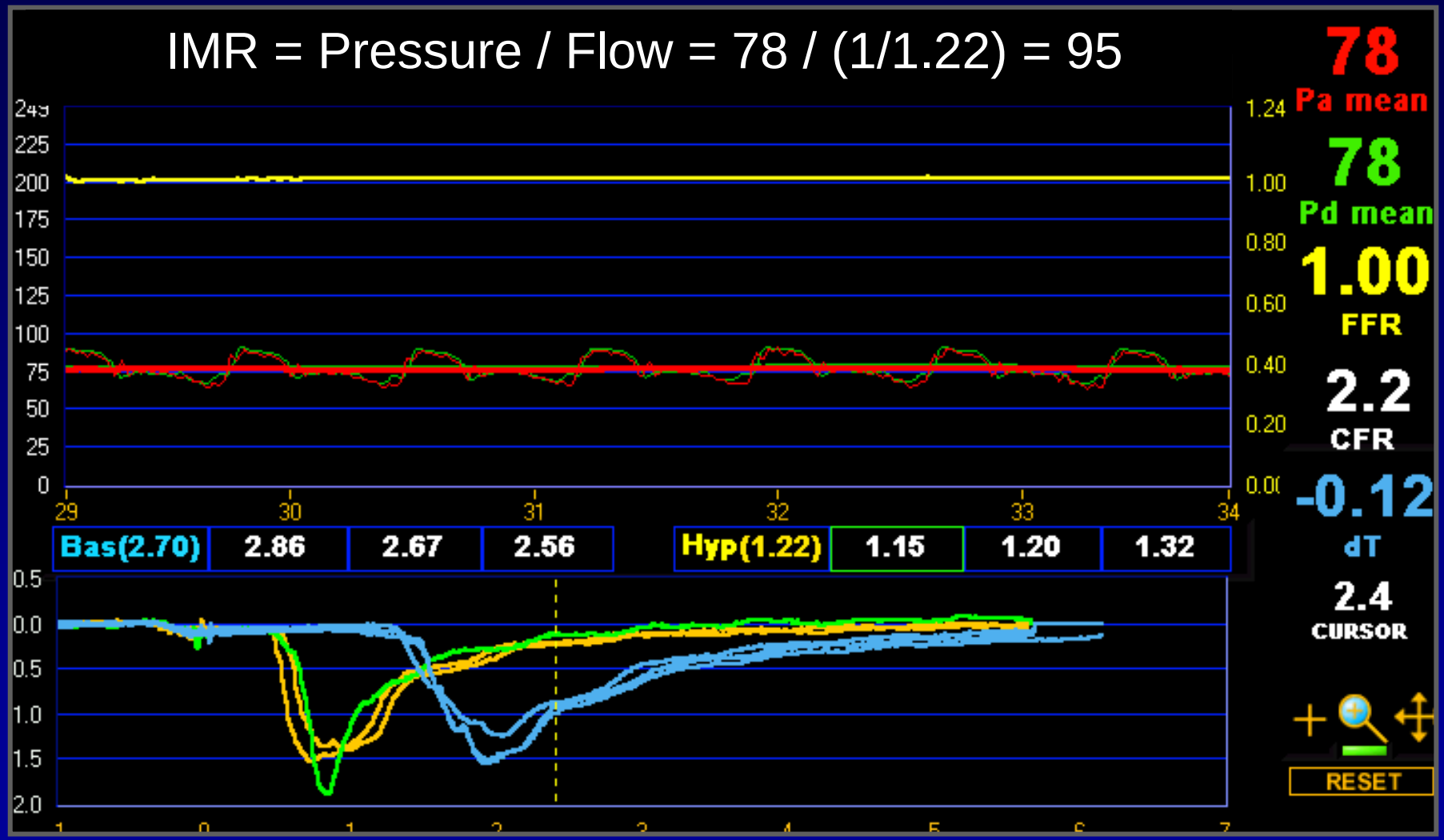
FFR during STEMI



FFR during STEMI



FFR during STEMI



Stanford

Acute Microvascular Damage and FFR

STEMI

Variable Degree of Reversible Microvascular Stunning

Maximum Achievable Flow is Less

Smaller Gradient and Higher FFR across Any Given Stenosis

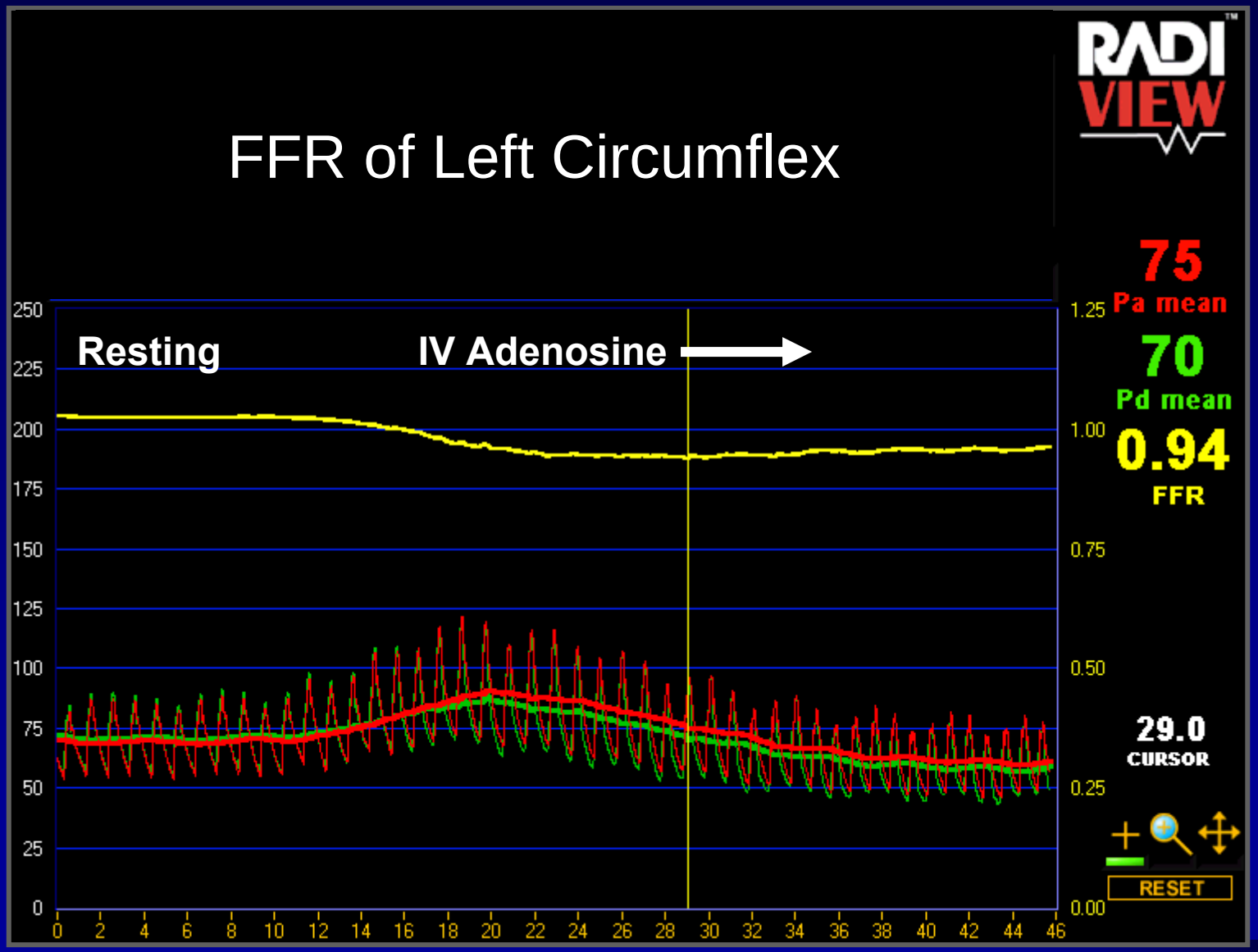
With time, the microvasculature may recover, maximum achievable flow may increase, and a larger gradient with a lower FFR may be measured across a given stenosis

FFR in Chronic MI

67 yo man 9 months after STEMI and PCI of Cx

Stanford

FFR in Chronic MI



Stanford

Chronic Microvascular Damage and FFR

Old Myocardial Infarction

Irreversible Microvascular Damage

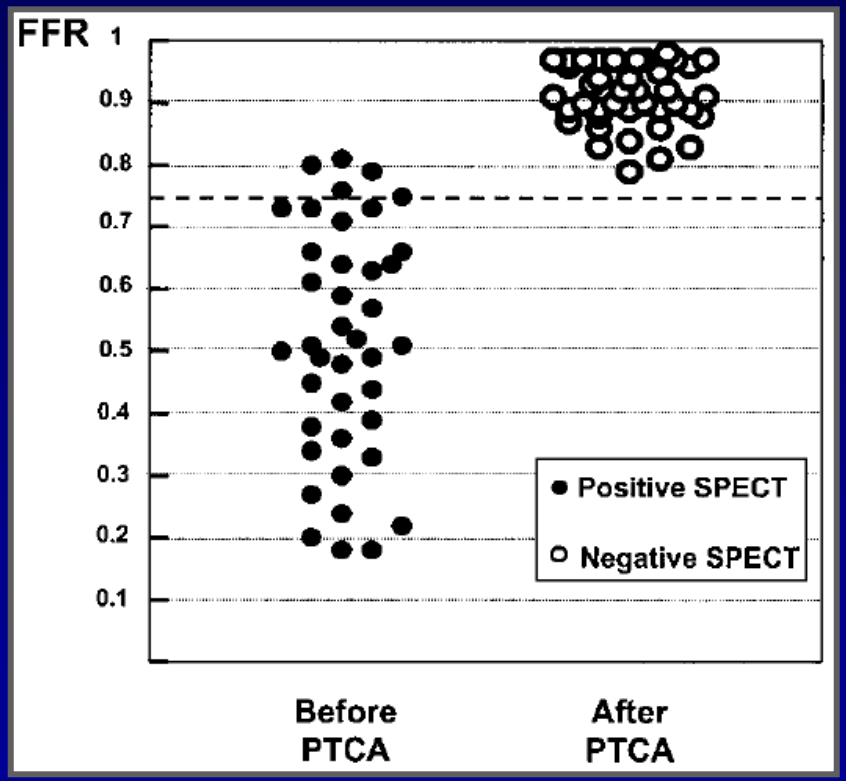
Maximum Achievable Flow is Less

Smaller Gradient and Higher FFR across Any Given Stenosis

In the setting of chronic microvascular dysfunction, the higher FFR is not falsely elevated, but reflects the smaller amount of viable myocardium supplied by the vessel and still provides information about the expected gain in flow after PCI

FFR in Chronic MI

Comparison of FFR in 57 patients with an MI ≥ 6 days old to SPECT imaging before and after PCI



	MIBI + n = 40	MIBI - n = 40
FFR≥0.75 n = 45	5	40
FFR<0.75 n = 35	35	0

Concordance = 94%

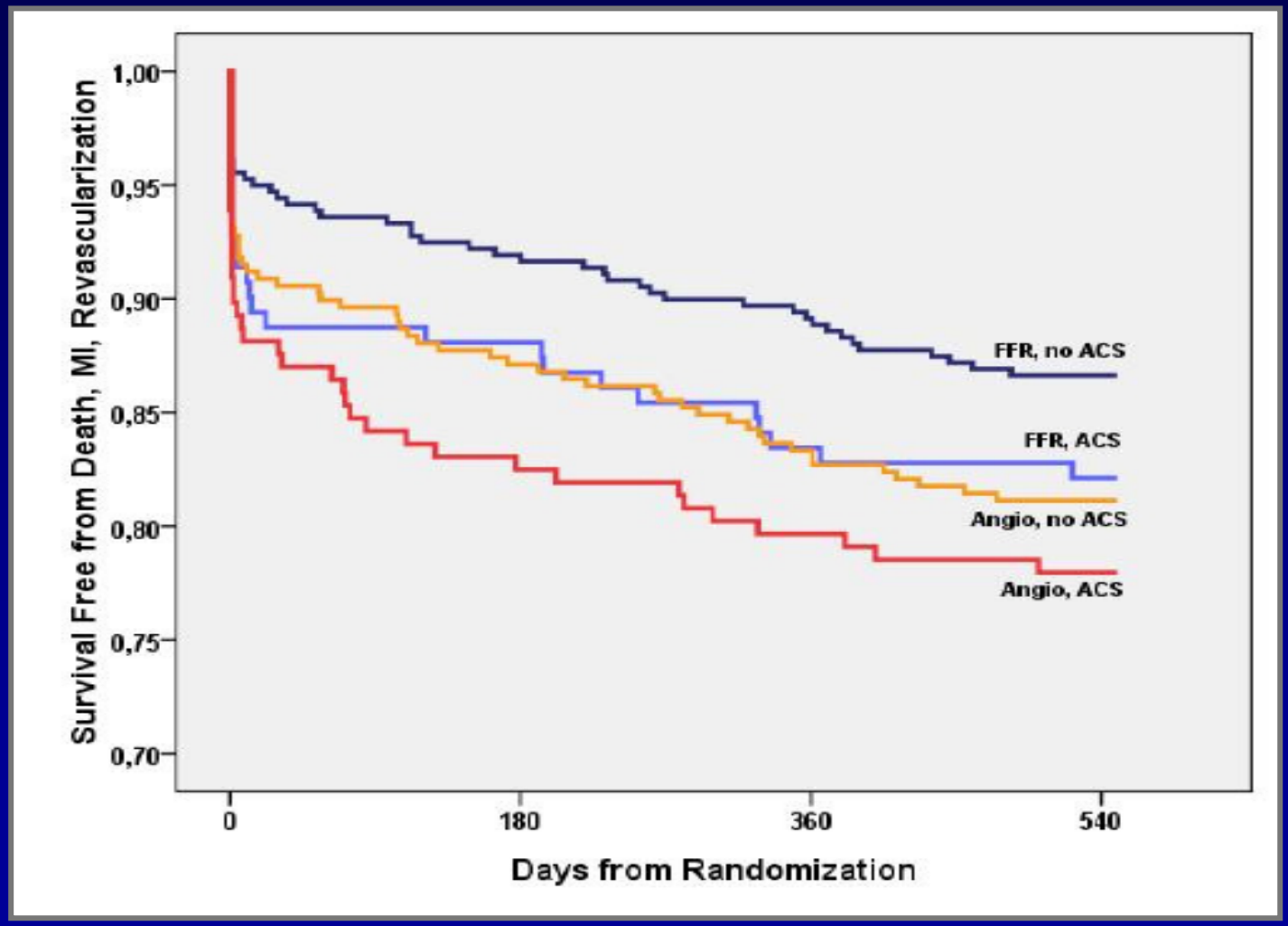
κ = 0.87; P<0.0001

De Bruyne et al. Circulation 2001;104:157-162

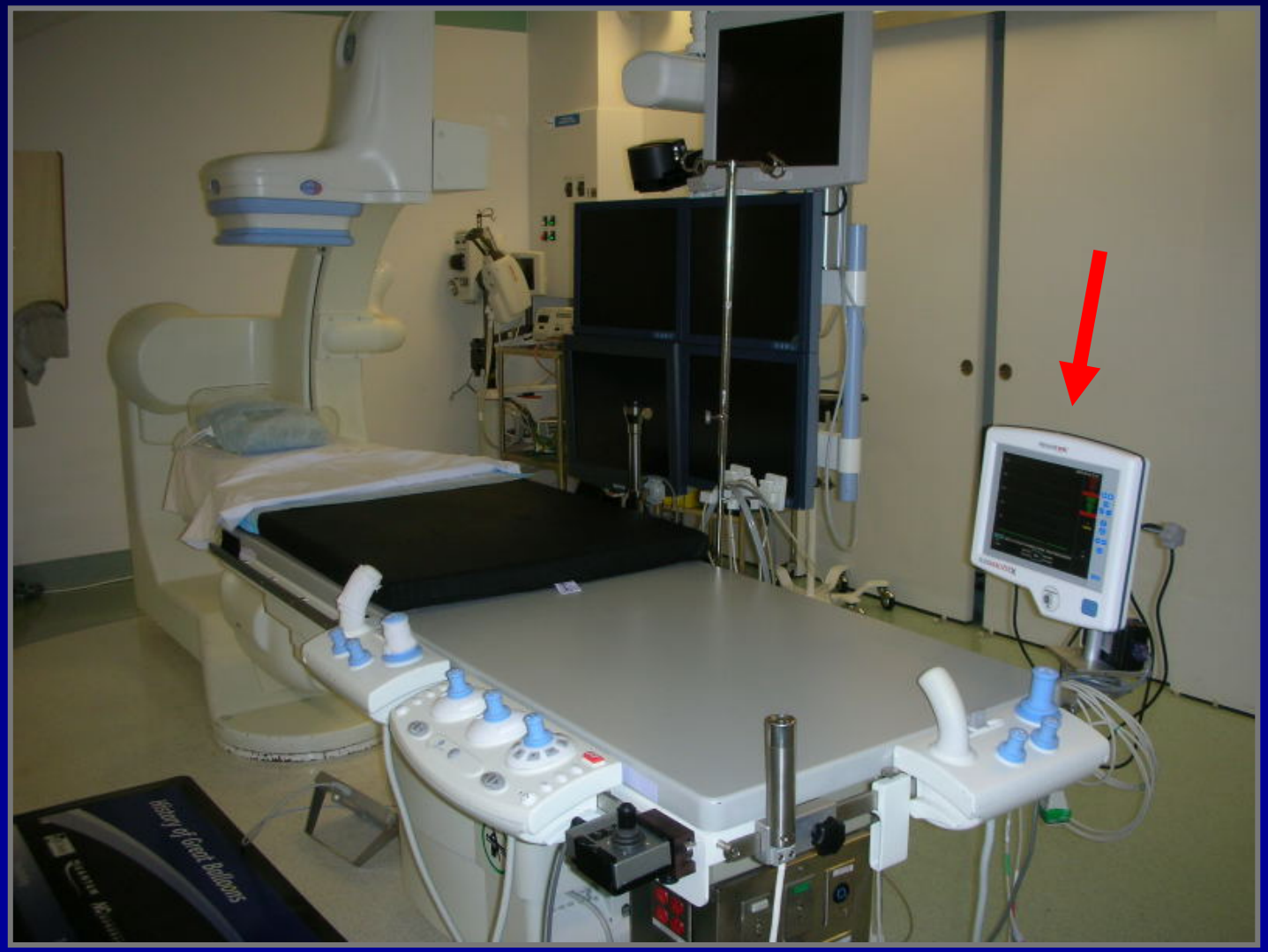
Stanford

FFR in NSTE ACS

Comparison of MACE in FAME patients with and without ACS



Incorporating Physiology



Incorporating Physiology

- Educating your assistants
  - Limitations of angiography
  - Benefits of physiology
  - Measure FFR in 10 consecutive PCI cases
- Streamlining set-up
  - Identify point person
  - Post medication mixing and dosing instructions
  - Keep analyzer connected at all times