# IMR in Stable Patients

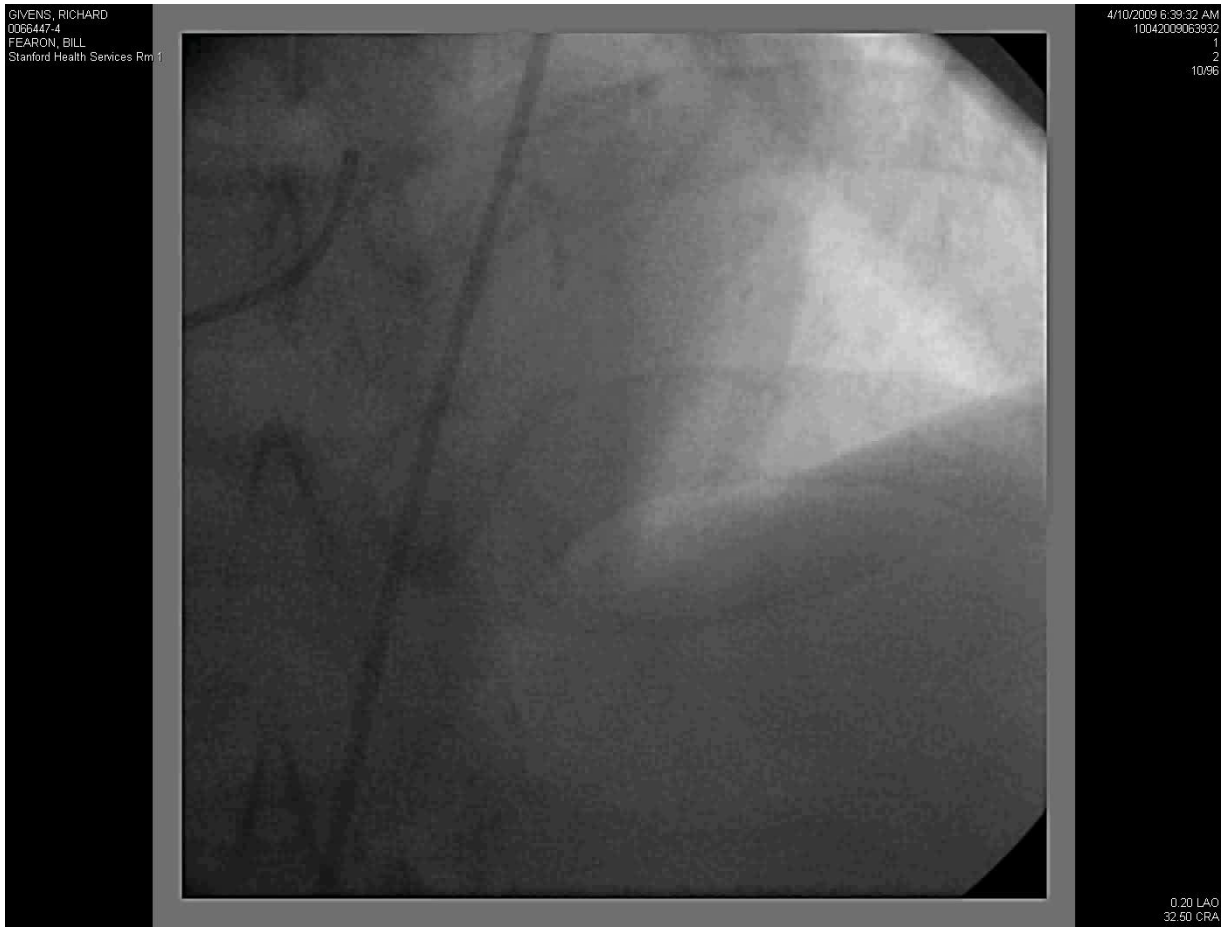
William F. Fearon, MD
Associate Professor of Medicine
Director, Interventional Cardiology
Stanford University Medical Center

# Indications for IMR in Stable Patients

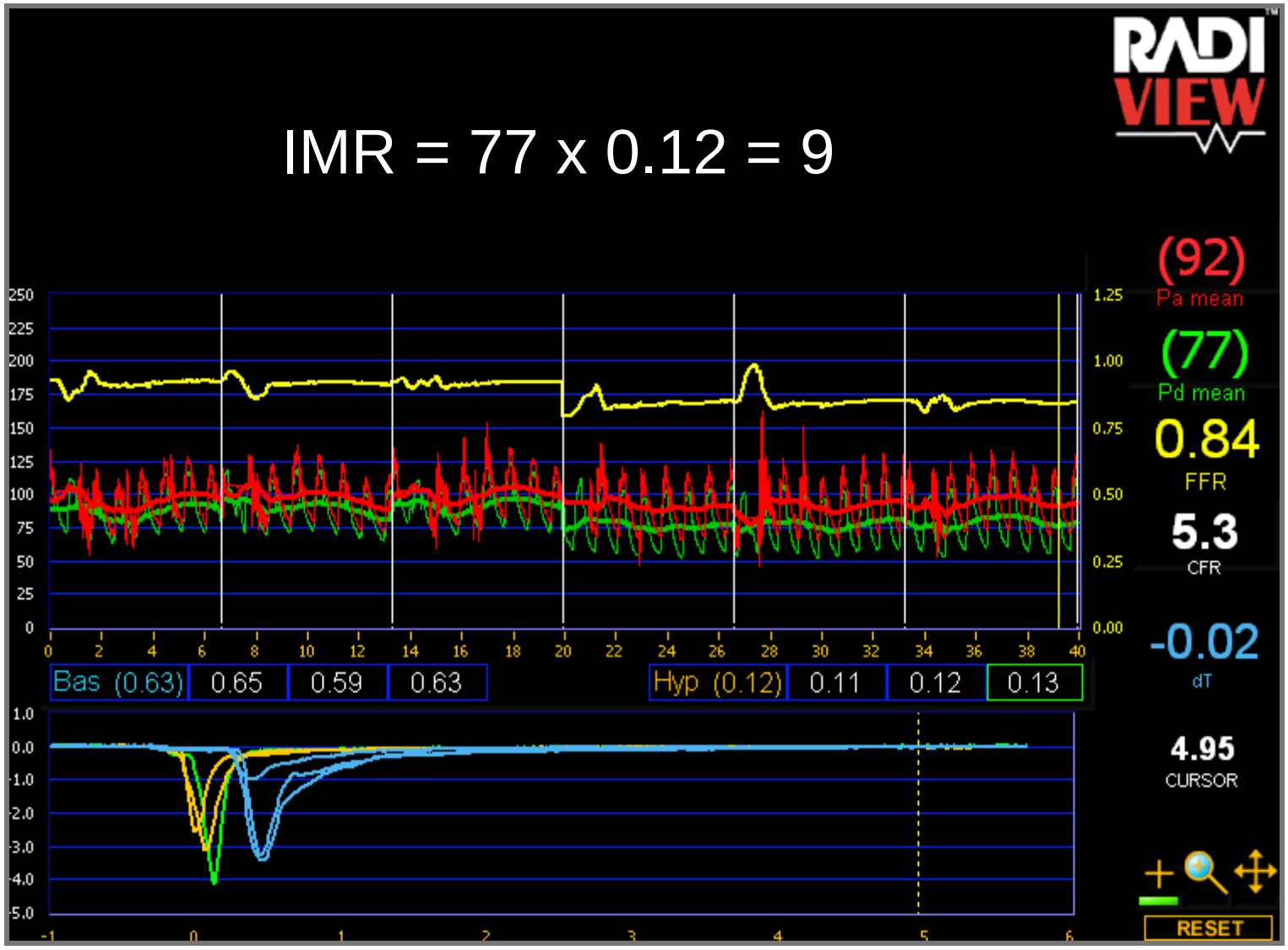
- To evaluate the etiology of chest pain/abnormal stress test in a patient with angiographically appearing normal coronaries
- To assess for the likelihood of peri-PCI myocardial infarction
- Research purposes

# Clinical Application of IMR

***65 year old man with HTN, ↑Chol, and chest pain with anterior ischemia on ETT-Echo***

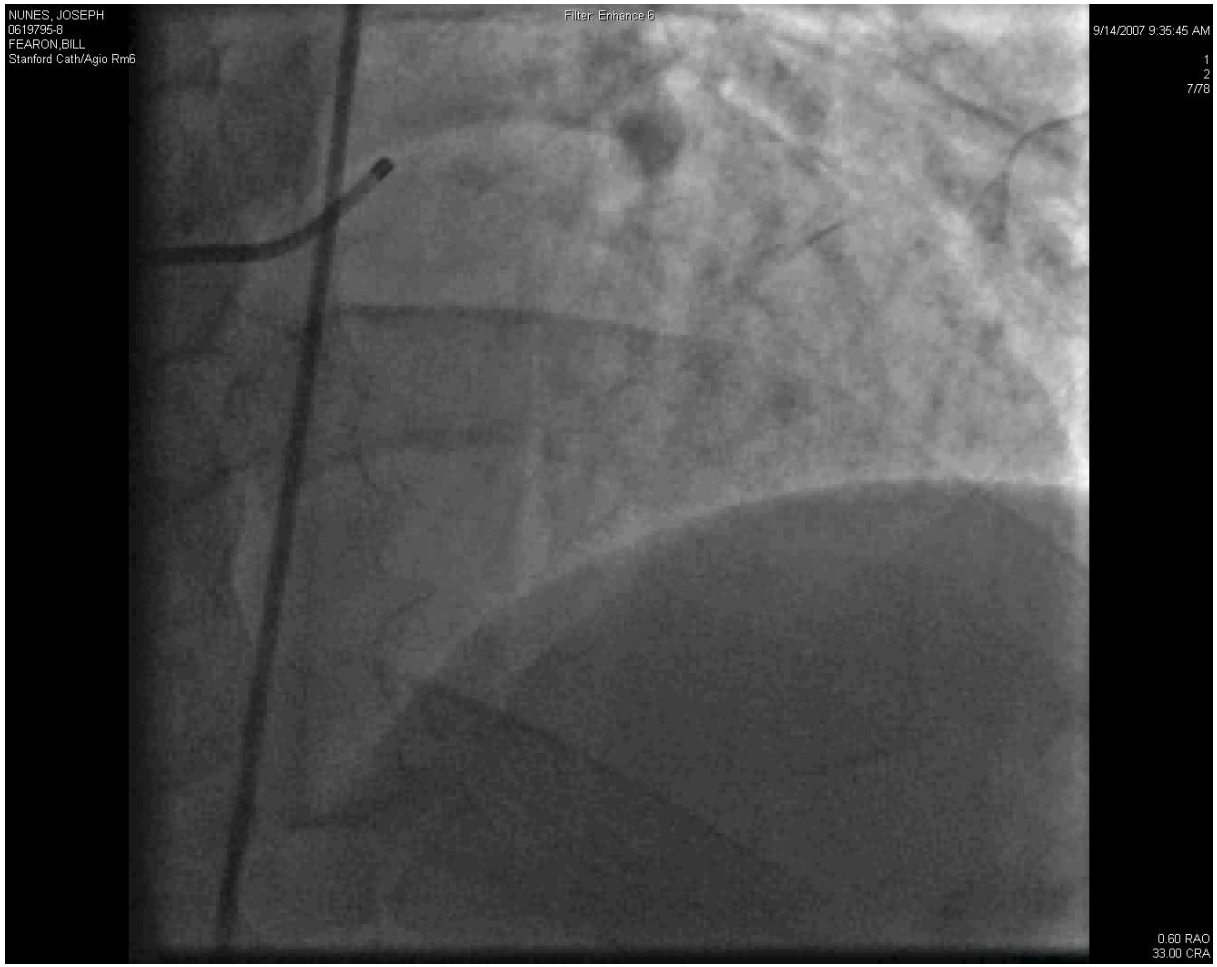


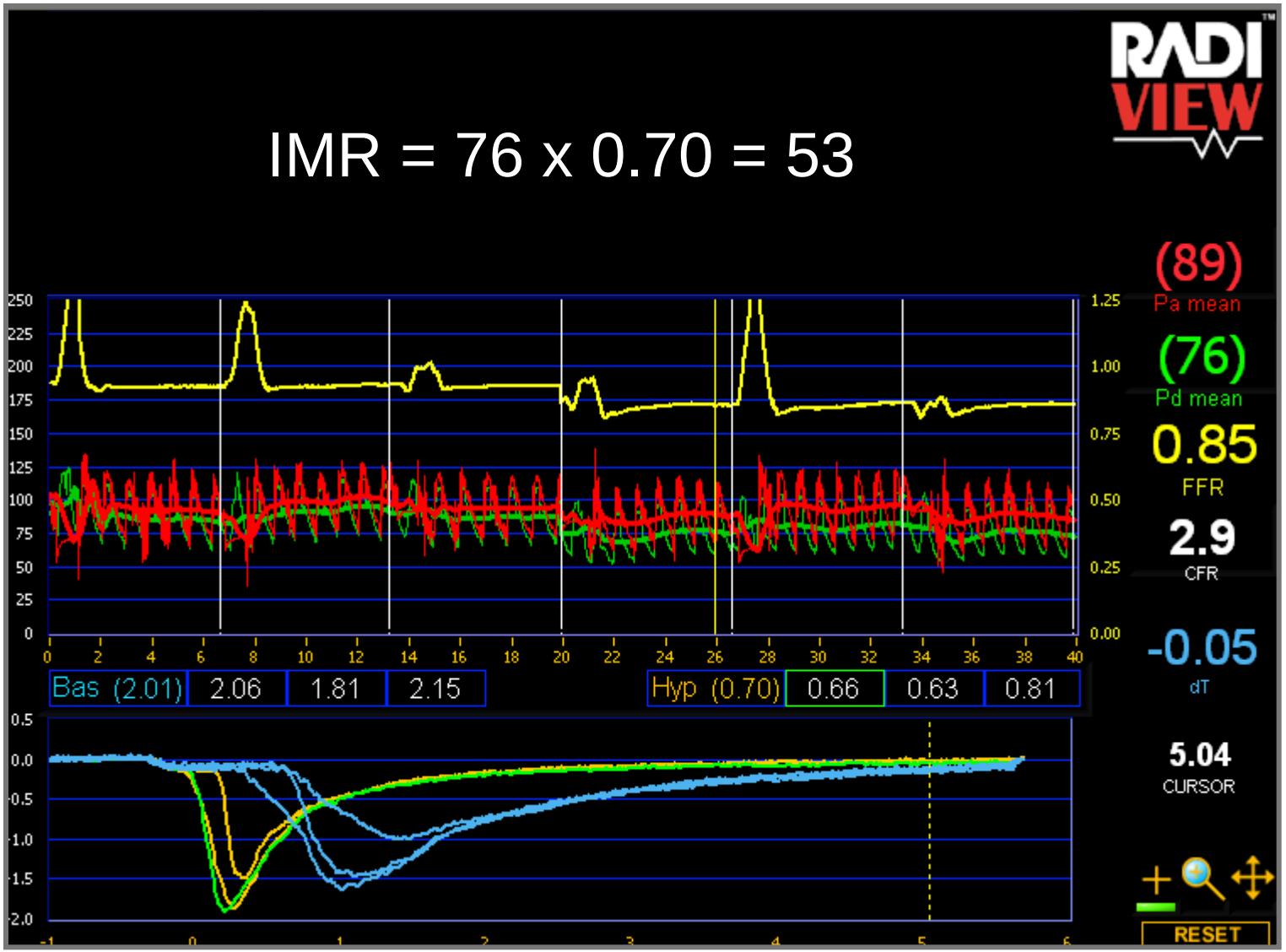
# IMR = 77 x 0.12 = 9


RADI VIEW
(92)
Pa mean
(77)
Pd mean
0.84
FFR
5.3
CFR
-0.02
dT
4.95
CURSOR
RESET
Bas (0.63) 0.65 0.59 0.63
Hyp (0.12) 0.11 0.12 0.13

# Clinical Application of IMR

***59 year old man with HTN, dyslipidemia and chest pain with emotional stress and septal ischemia on Nuclear Scan***

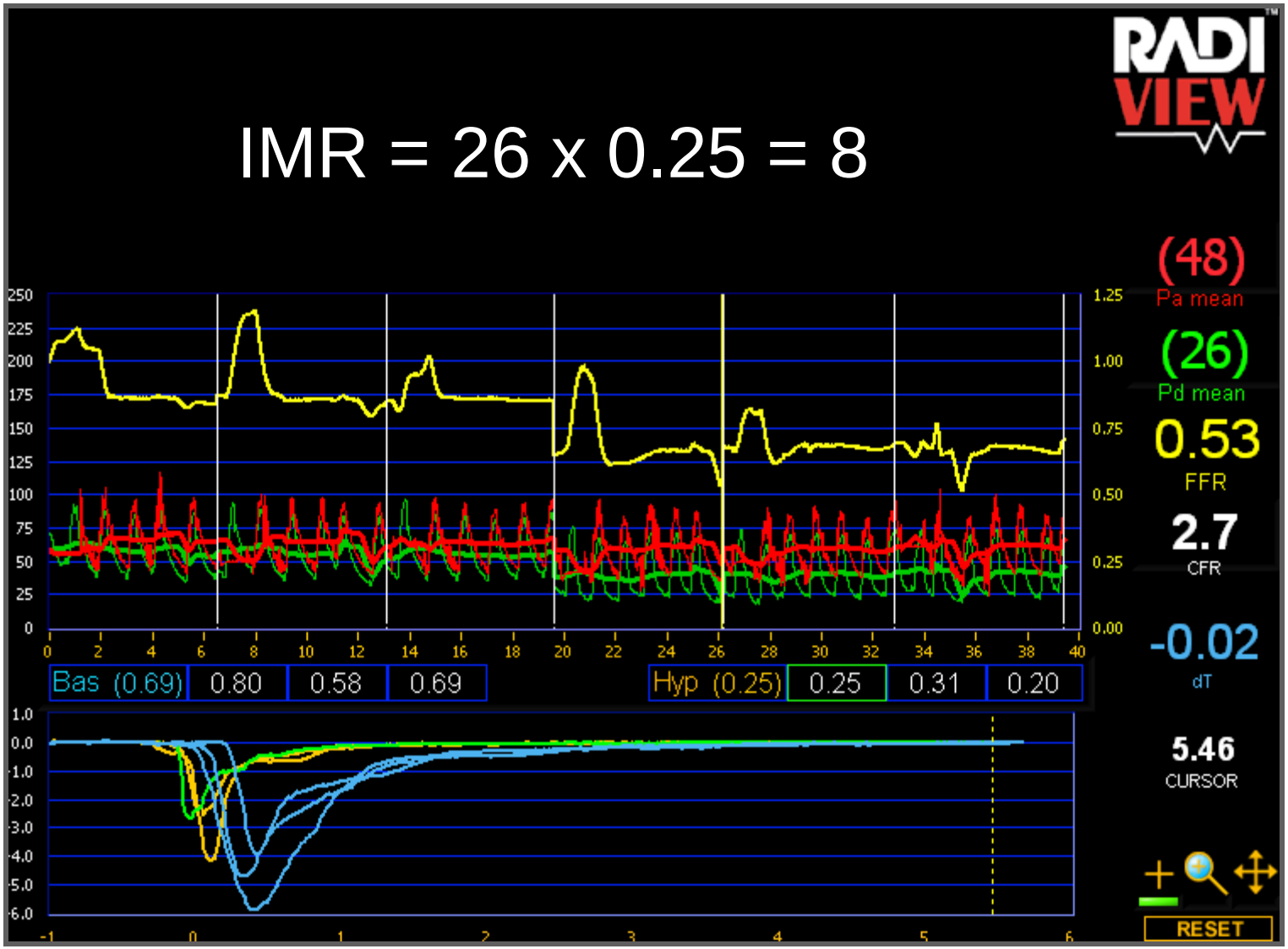



IMR = 76 x 0.70 = 53
RADI VIEW
(89)
Pa mean
(76)
Pd mean
0.85
FFR
2.9
CFR
-0.05
dT
5.04
CURSOR
RESET
Bas (2.01) 2.06 1.81 2.15
Hyp (0.70) 0.66 0.63 0.81

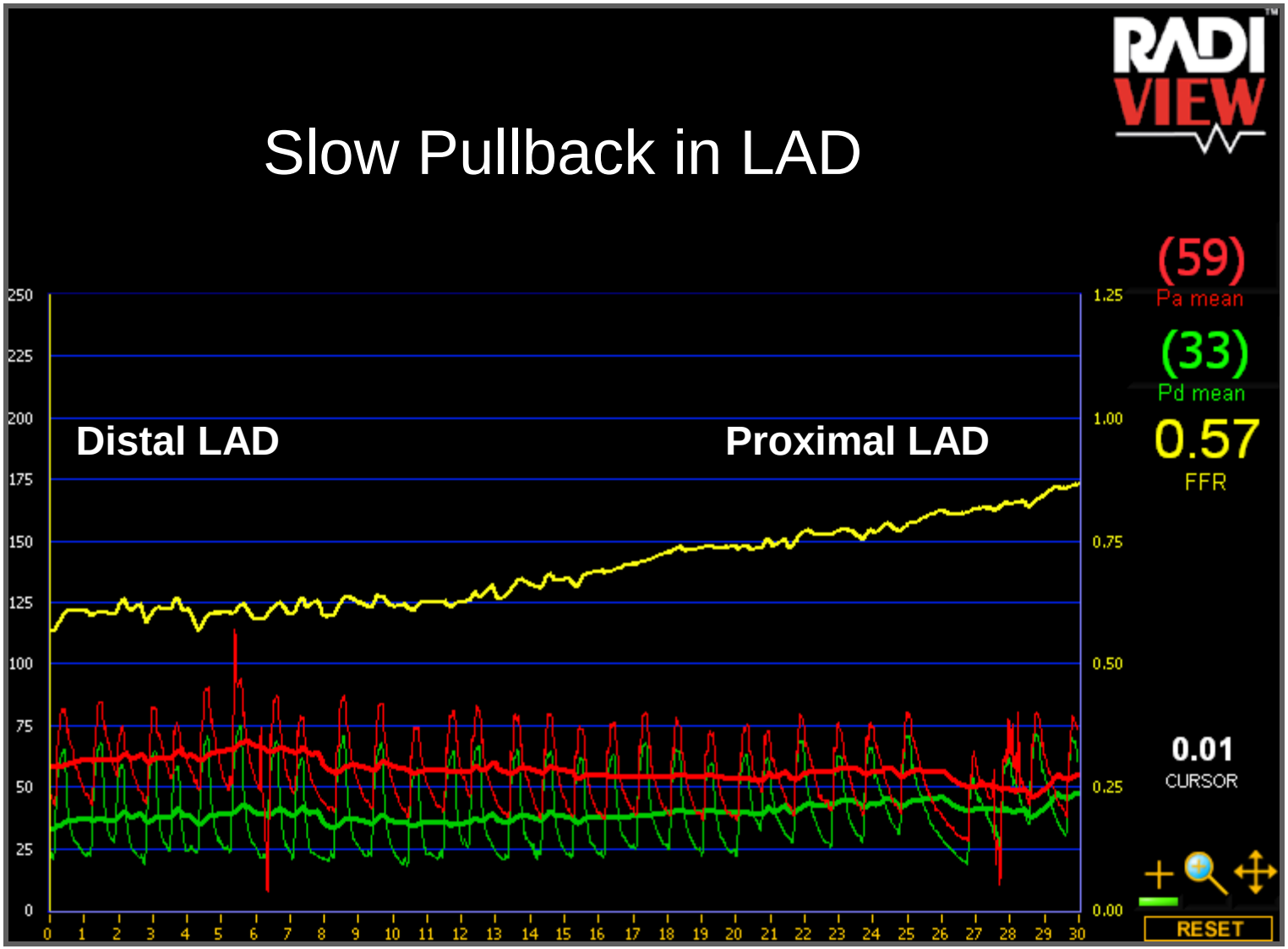
# Clinical Application of IMR

***68 year old man HTN and tobacco use with negative stress echo 4 months ago, but increasingly severe classic exertional angina***

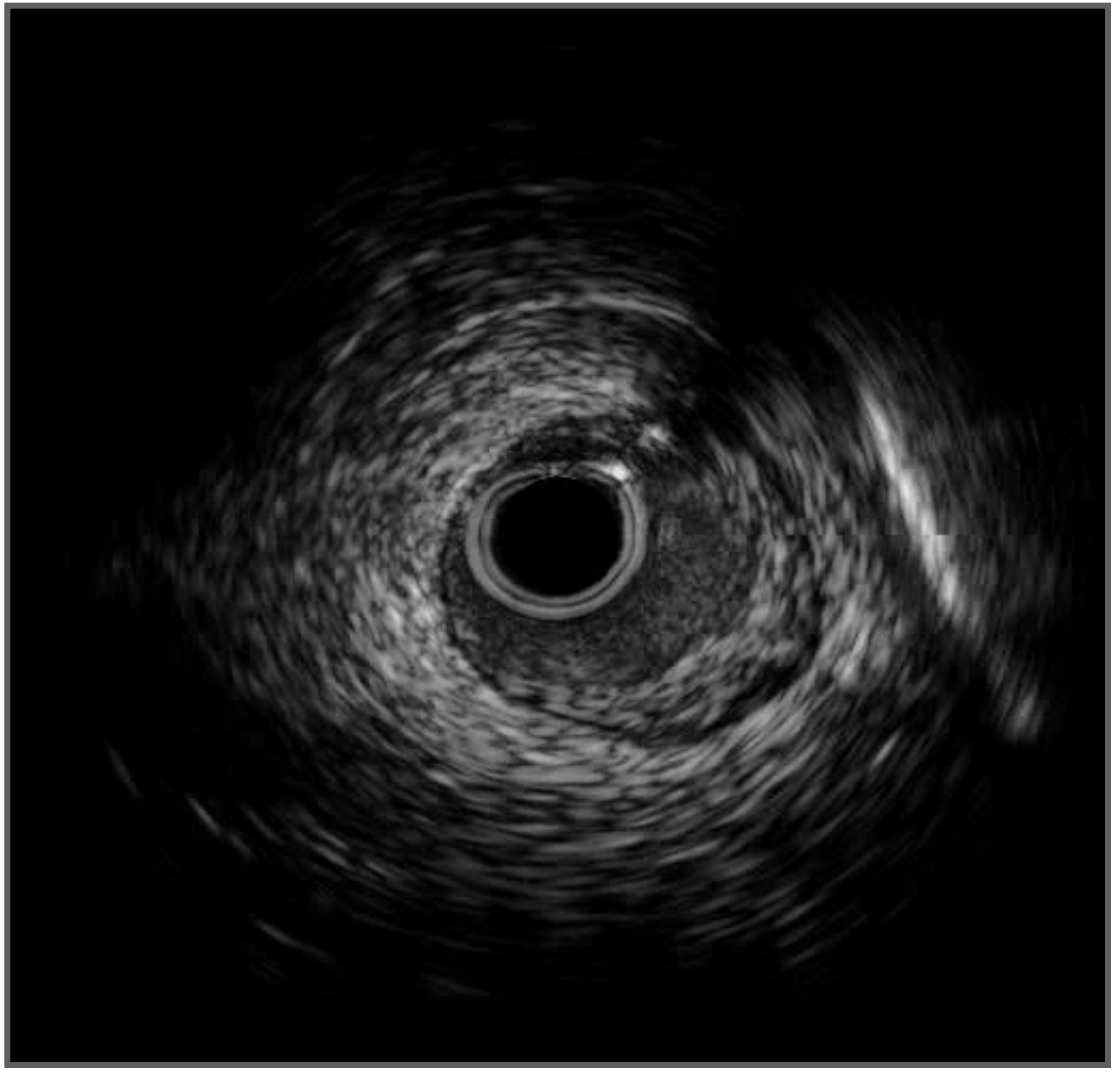
# IMR = 26 x 0.25 = 8


RADI VIEW
(48)
Pa mean
(26)
Pd mean
0.53
FFR
2.7
CFR
-0.02
dT
5.46
CURSOR
RESET
Bas (0.69) 0.80 0.58 0.69
Hyp (0.25) 0.25 0.31 0.20

# Slow Pullback in LAD



# IVUS of LAD



# Chest Pain and "Normal Coronaries"

- 139 patients referred for coronary angiography because of symptoms and/or abnormal stress test and found to have "normal" appearing coronaries

- FFR, IMR, CFR, IVUS and acetylcholine challenge were performed down the LAD

Lee, Tremmel, et al. Unpublished data

# Chest Pain and “Normal Coronaries”

| Patient Characteristic | n=139 |
|---|---|
| Age (years) | 54 ±11 |
| Female | 77% |
| Hypertension | 53% |
| Diabetes | 23% |
| Dyslipidemia | 63% |
| Tobacco Use | 8% |
| Typical Angina | 32% |
| Positive Stress Test | 42% |

Lee, Tremmel, et al. Unpublished data

# Chest Pain and "Normal Coronaries"

- The mean IMR was 19.6 ±9.1
- Microvascular dysfunction was present in 21% (defined as IMR ≥ 25)
  - Typical angina was more frequent (52% vs 26%, p=0.01) in patients with microvascular dysfunction
  - Positive stress tests were more common (65% vs. 41%, p=0.04)
- Predictors of microvascular dysfunction were age, BMI, and typical angina

Lee, Tremmel, et al. Unpublished data

# Chest Pain and "Normal Coronaries"

- 4% of patients had an FFR of the LAD ≤ 0.80
- 44% had epicardial endothelial dysfunction
- 44% had a myocardial bridge

- 42% had nonischemic FFR, normal IMR, no significant endothelial dysfunction
- 34% had nonischemic FFR, normal IMR, no endothelial dysfunction and no "bridge"

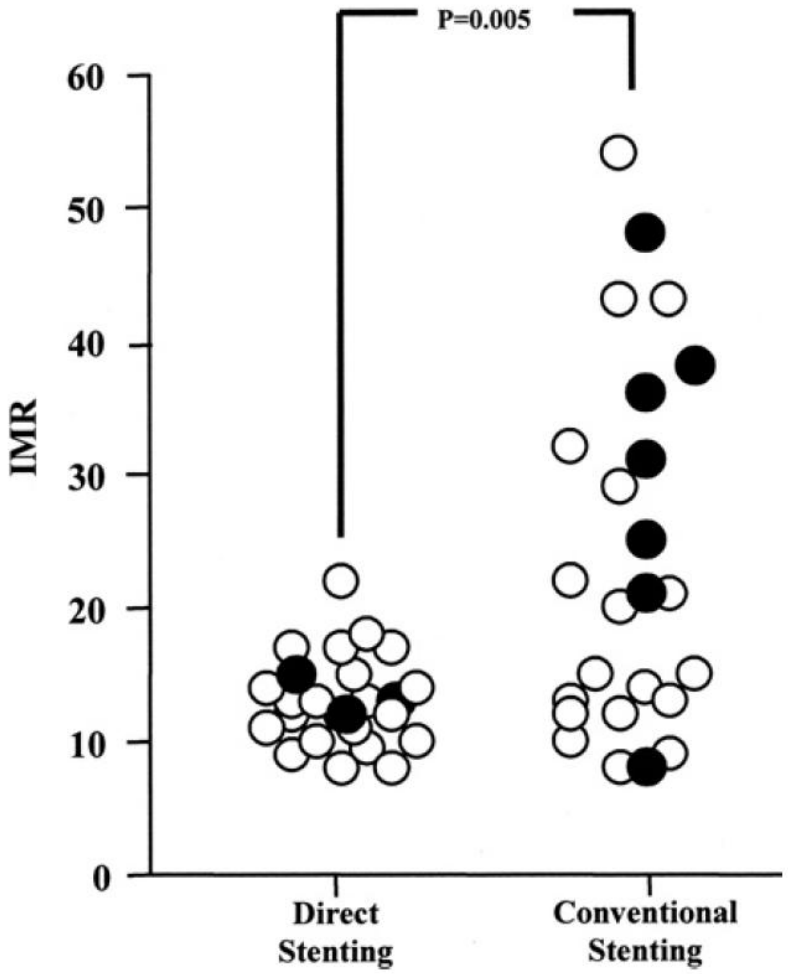
Lee, Tremmel, et al. Unpublished data

# Indications for IMR in Stable Patients

- To evaluate the etiology of chest pain/abnormal stress test in a patient with angiographically appearing normal coronaries
- To assess for the likelihood of peri-PCI myocardial infarction
- Research purposes

# IMR after PCI in Stable Patients

- **50 patients randomized to conventional stenting with predilatation versus direct stenting**
- **IMR measured after PCI and correlated with troponin release**
- **In the 10 patients with elevated Tn post PCI, IMR was 24.7 ±13.3 vs. 16.9 ±10.2, p=0.04.**




Cuisset, et al. J Am Coll Cardiol;2008:51:1060

# Is IMR Independent of Epicardial Stenosis?

**Comparison of IMR and TMR Values Under Various Epicardial and Microcirculatory Conditions**

| | Normal Microcirculation | Abnormal Microcirculation | *P* |
|---|---|---|---|
| IMR, U | | | |
| Total group | 16.9±6.5 | 25.9±14.4 | 0.002 |
| Stenosis absent | 14.7±4.8 | 23.9±3.8 | 0.01 |
| Stenosis present | 19.2±7.3 | 28.6±14.5 | <0.03 |
| TMR, mm Hg · $mL^{-1}$ · $min^{-1}$ | | | |
| Total group | 0.51±0.14 | 0.79±0.32 | 0.0001 |
| Stenosis absent | 0.48±0.14 | 0.71±0.25 | 0.005 |
| Stenosis present | 0.58±0.16 | 0.90±0.39 | <0.001 |

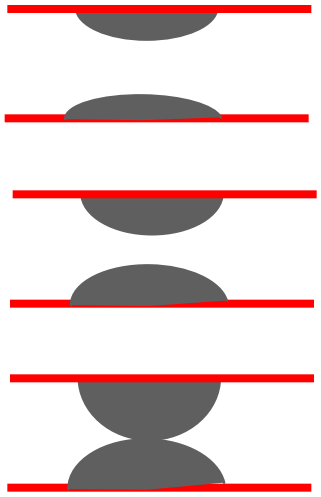
Circulation 2003;107:3129-3132.

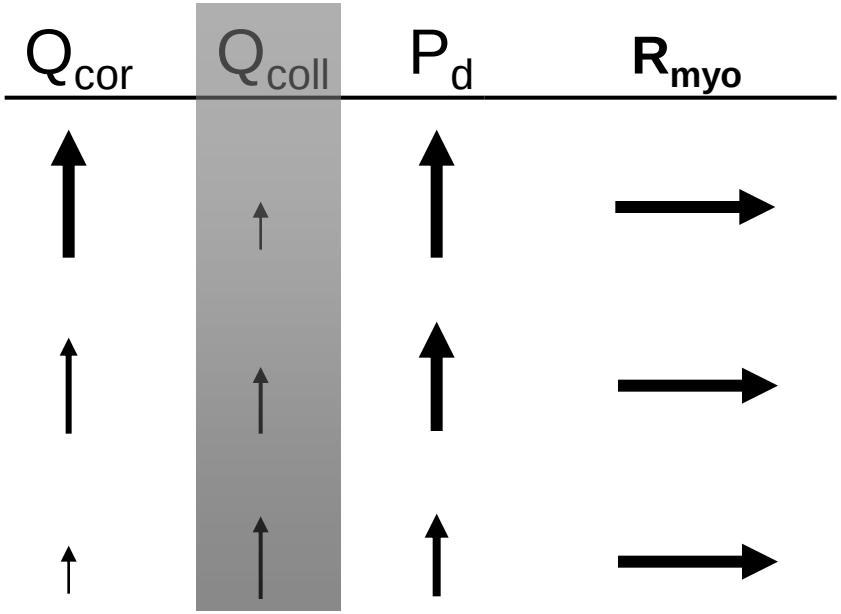
# Importance of Collaterals when Measuring IMR

- Resistance = Pressure / $Q_{myo}$
- $Q_{myo} = Q_{cor} + Q_{coll}$
- Simplified IMR = $P_d$ x $T_{mn}$
- But $T_{mn}$ is inversely proportional to *coronary flow*

Catheter Cardiovasc Interv 2004;62:56-63.

# Importance of Collaterals when Measuring IMR



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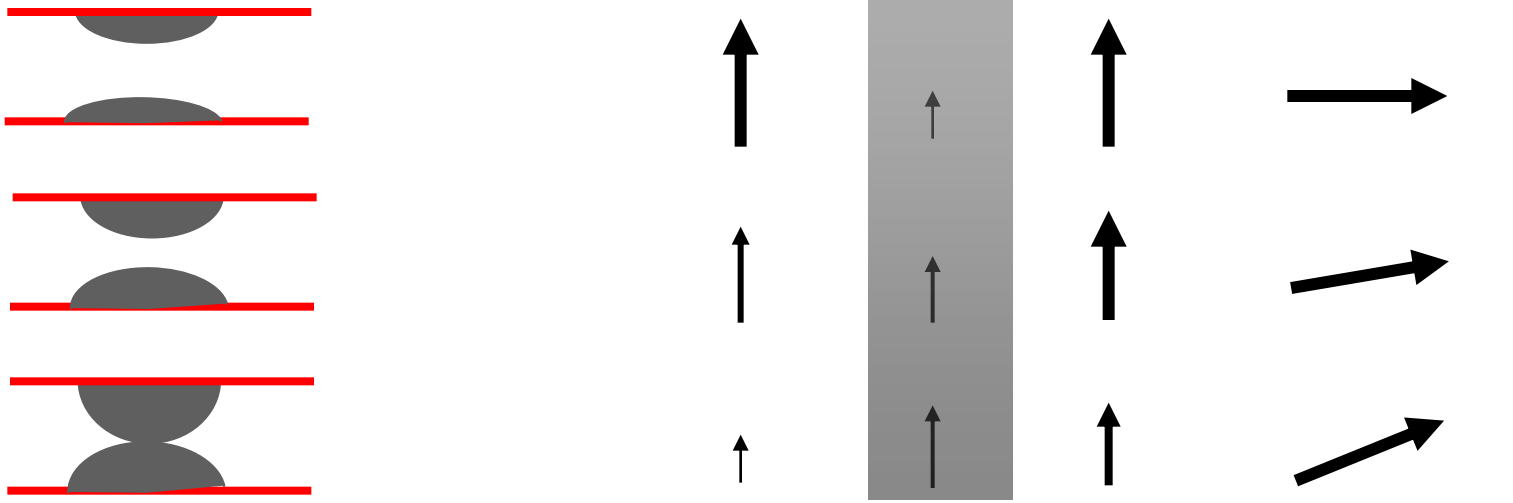



Flow ↓'s more than it should, $T_{mn}$ ↑'s and $IMR_{app} = P_d \times T_{mn}$ ↑'s

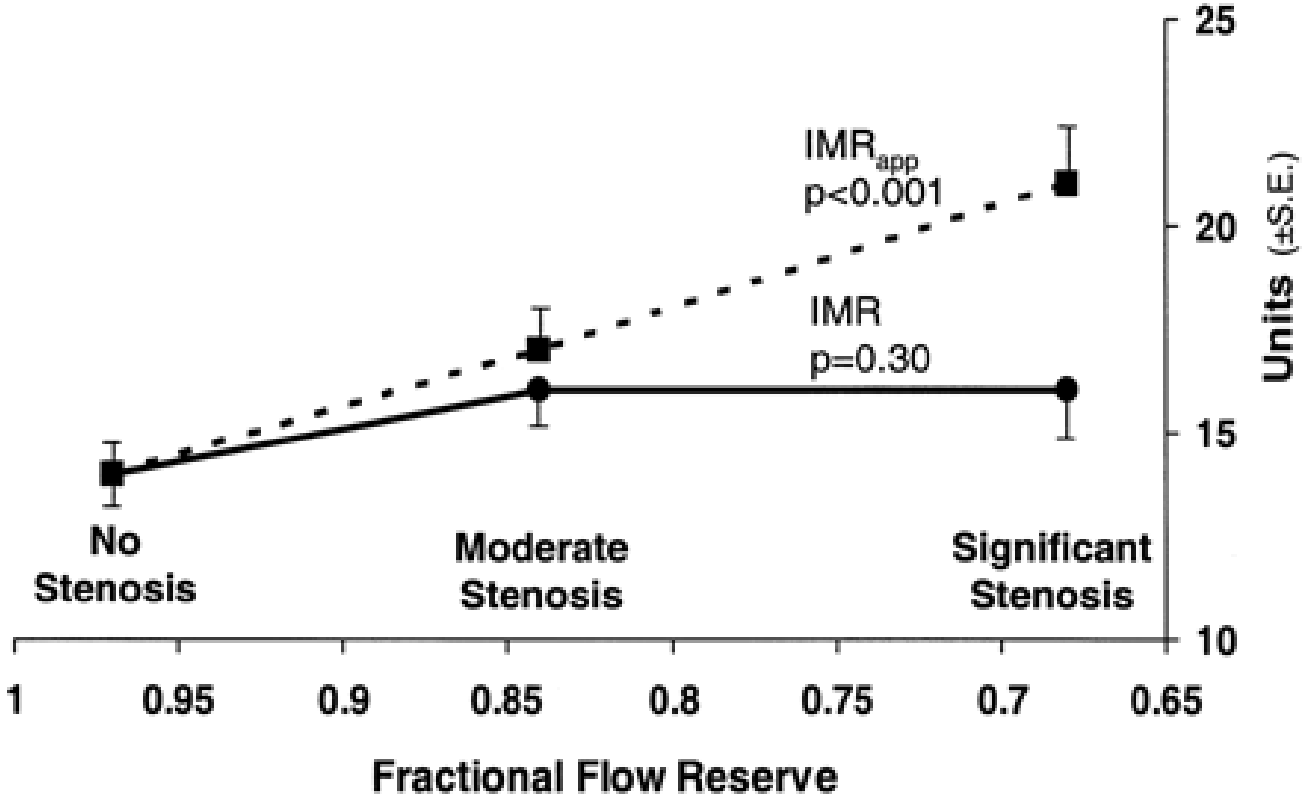
***To measure true IMR, must measure coronary wedge pressure to incorporate collateral flow***

$$\mathbf{IMR = P_d \times T_{mn} \times (FFR_{cor} / FFR_{myo})}$$

Catheter Cardiovasc Interv 2004;62:56-63.

# IMR is not affected by epicardial stenosis severity:

## *Animal Validation*

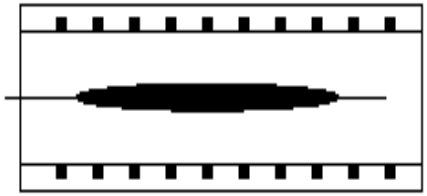



Circulation 2004;109:2269-2272

# IMR is not affected by epicardial stenosis severity:

## *Human Validation*

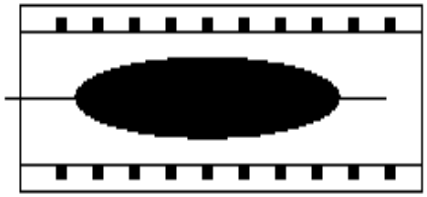
10% AS



FFR = 0.84 ± 0.08

IMR = 22 ± 15

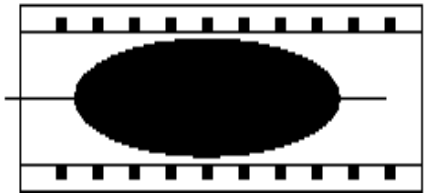
50% AS



FFR = 0.69 ± 0.09

IMR = 23 ± 14

75% AS



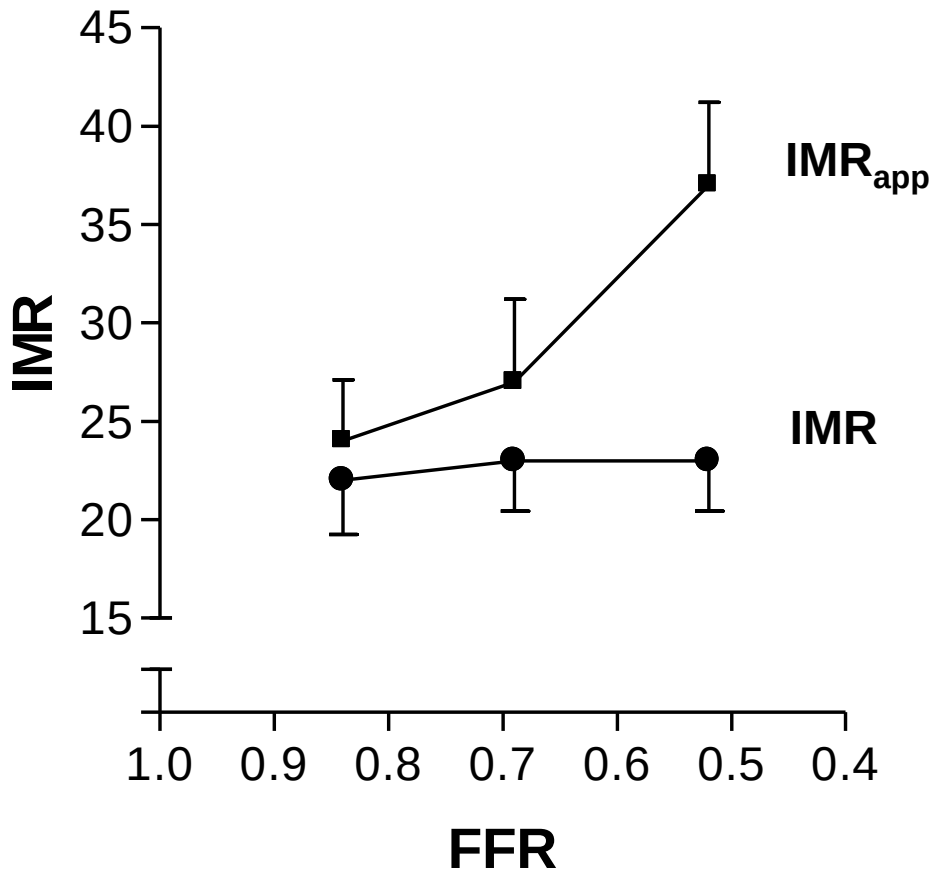
FFR = 0.52 ± 0.11

IMR = 23 ± 14

Aarnoudse, et al. Circulation 2004;110:2137-42

# IMR is not affected by epicardial stenosis severity:

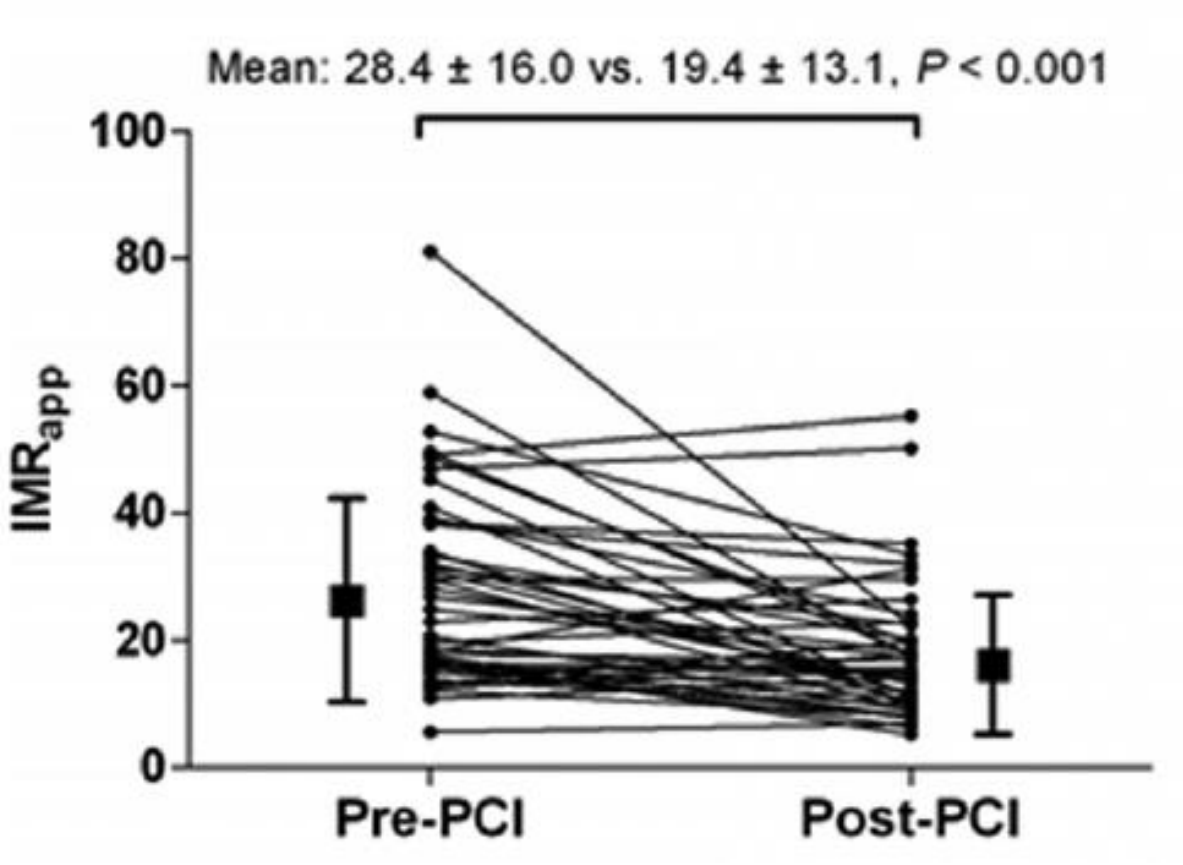
## *Human Validation*




Aarnoudse, et al. Circulation 2004;110:2137-42

# IMR is not affected by epicardial stenosis severity:

***IMR measured pre and post PCI in 43 patients with significant LAD disease***




Yong, et al. Circ Cardiovasc Interv 2012;5:103-8.

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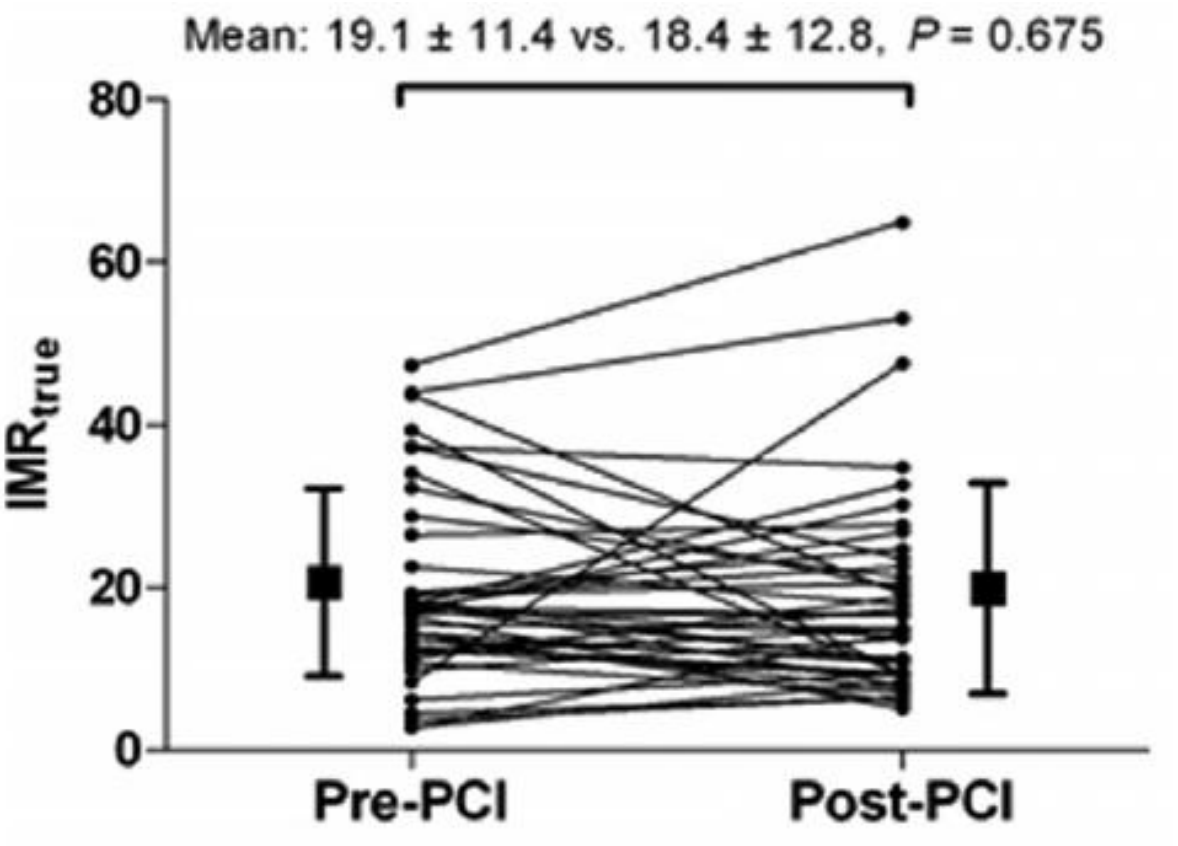


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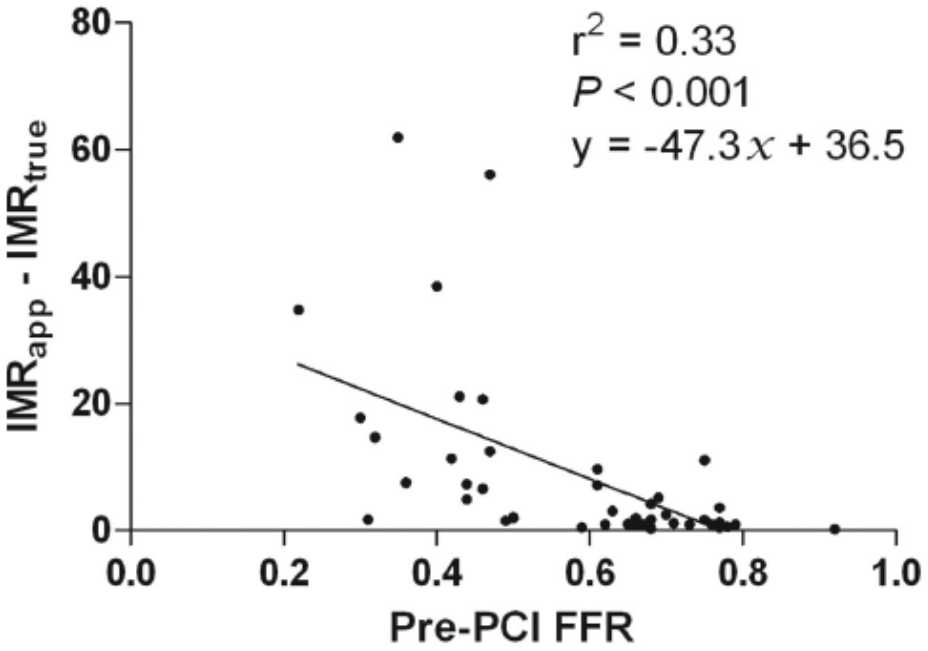
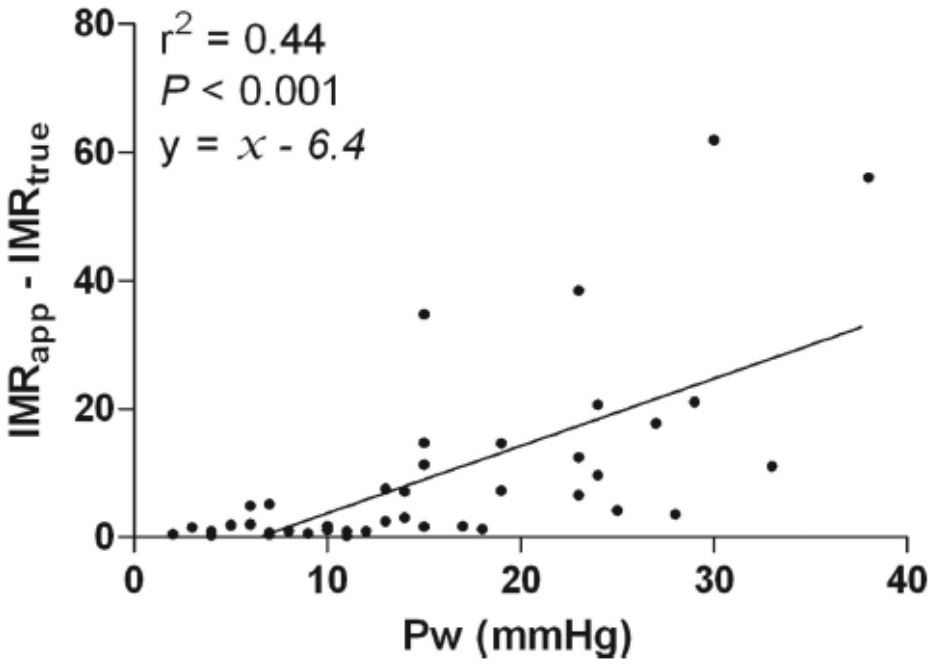
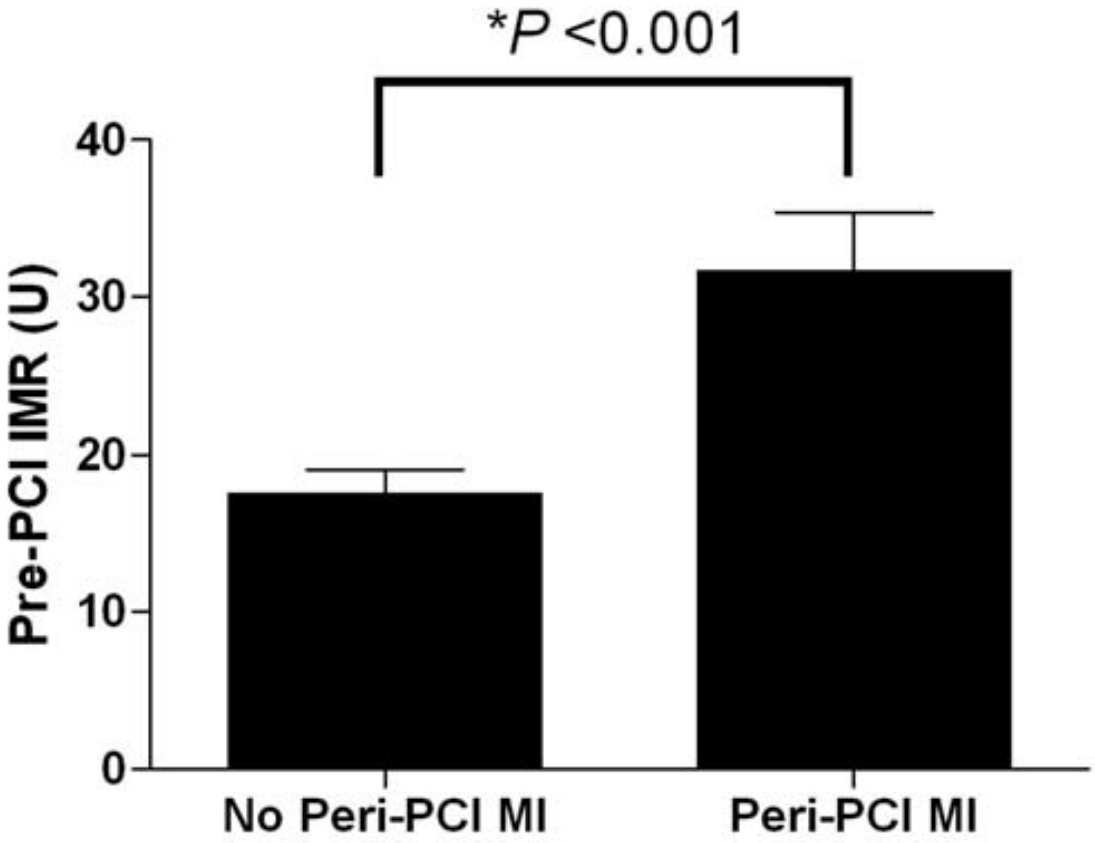



Yong, et al. Circ Cardiovasc Interv 2012;5:103-8.

# IMR *Before* PCI in Stable Patients

***IMR measured before PCI in 50 stable patients undergoing LAD PCI***




Ng, et al. Circ Cardiovasc Interv 2012;5:515-22.

# IMR *Before* PCI in Stable Patients

***IMR measured before LAD PCI in 50 stable patients***

**Multivariable Regression Analysis**

| Variable | *P* | Odds ratio | 95% Confidence interval |
|---|---|---|---|
| IMR | 0.002 | 1.25 | 1.08 – 1.43 |
| Beta-blocker | 0.064 | 13.97 | 0.97 – 200.56 |
| Post-dilation | 0.072 | 0.09 | 0.01 – 1.24 |
| Total inflation time | 0.115 | 1.01 | 0.99 – 1.03 |
| Stent length | 0.35 | 1.08 | 0.92 – 1.27 |

Ng, et al. Circ Cardiovasc Interv 2012;5:515-22.

# IMR *Before* PCI in Stable Patients

***IMR measured before PCI in 54 stable patients***

**Multivariable Regression Analysis**

| Variable | OR (95% CI) | p Value |
|---|---|---|
| IMR culprit | 10.9 (1.3 to 90.5) | 0.02 |
| IMR post | 18.3 (0.9 to 354) | 0.054 |
| rPIMR | 1.09 (1.0 to 1.19) | 0.02 |
| Inflation (n) | 1.4 (1.0 to 1.9) | 0.05 |

Layland, et al. Heart 2012;98:1492-7.

# Estimating True IMR without Wedge

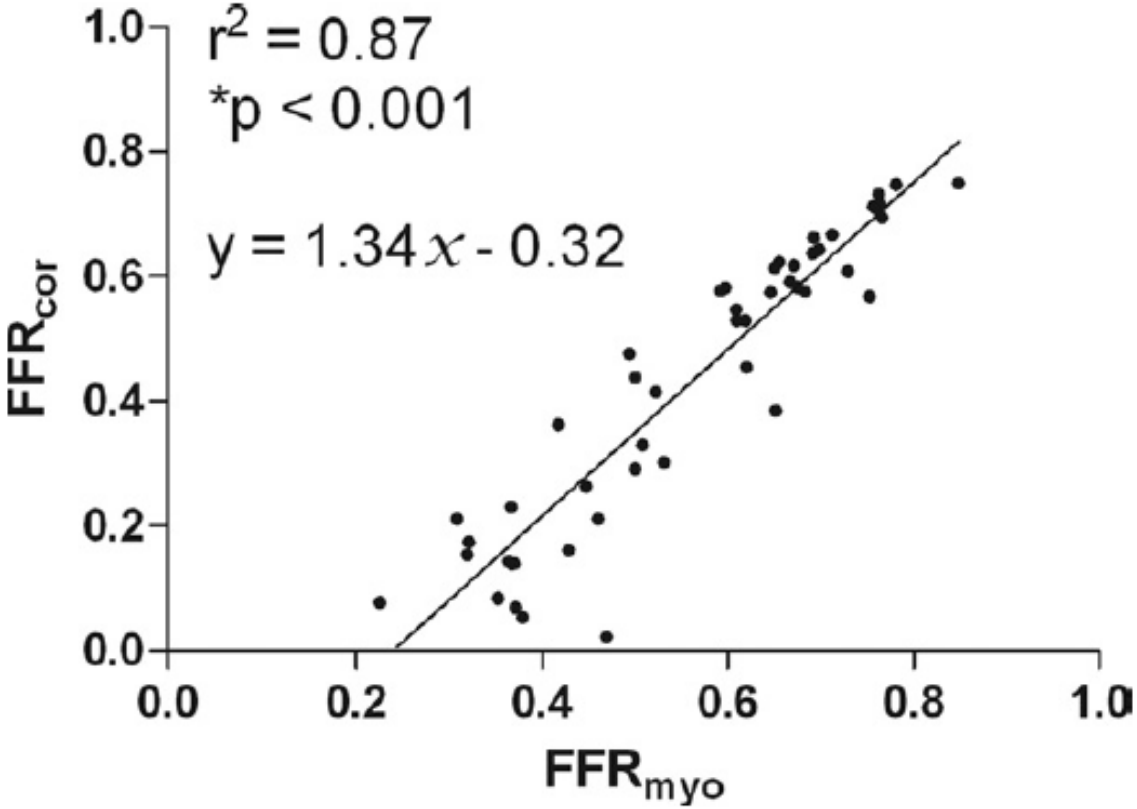
- $IMR = P_d \times T_{mn} \times (FFR_{cor} / FFR_{myo})$
- $IMR = P_d \times T_{mn} \times ((P_d-P_w)/(P_a-P_w) / (P_d/P_a))$

- **If there is a relationship between $FFR_{cor}$ and $FFR_{myo}$, perhaps we can estimate $FFR_{cor}$ without having to measure the coronary wedge pressure.**

Yong, et al. J Am Coll Cardiol Intv 2013;6:53-8.

# Estimating True IMR without Wedge

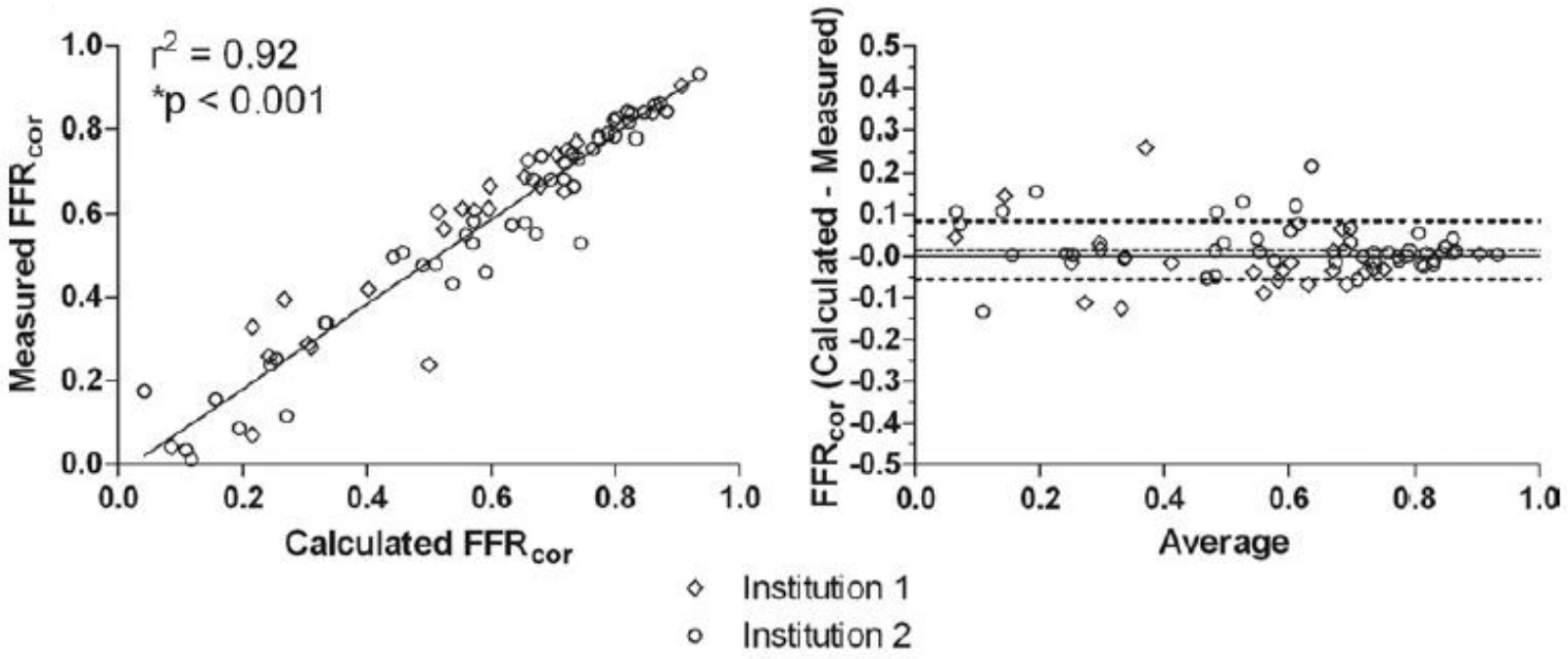
***In a derivation cohort of 50 patients, a strong linear relationship was found between $FFR_{cor}$ and $FFR_{myo}$.***




Yong, et al. J Am Coll Cardiol Intv 2013;6:53-8.

# Estimating True IMR without Wedge

***In a validation cohort of 72 patients, there was no significant difference in IMR with estimate $FFR_{cor}$ or measured $FFR_{cor.}$***

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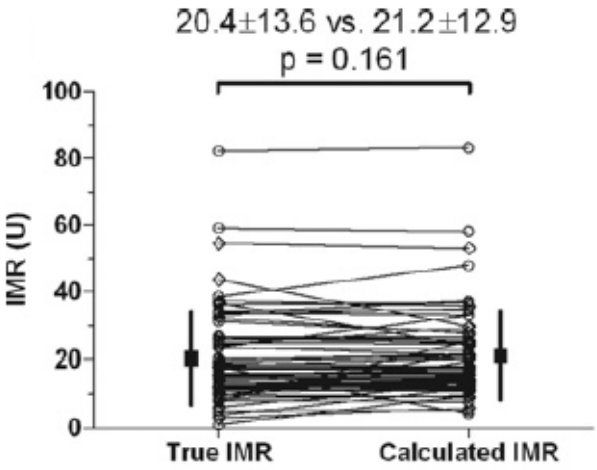


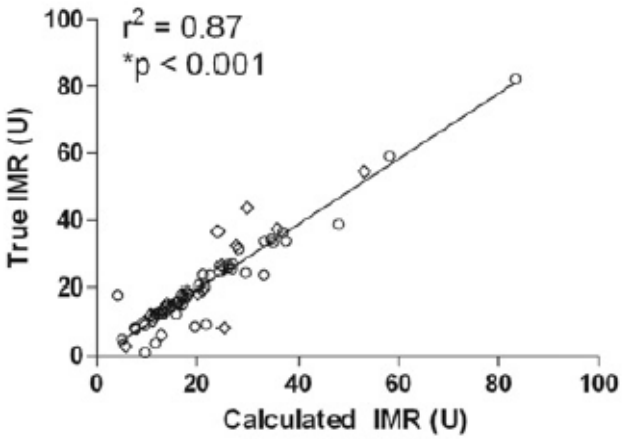


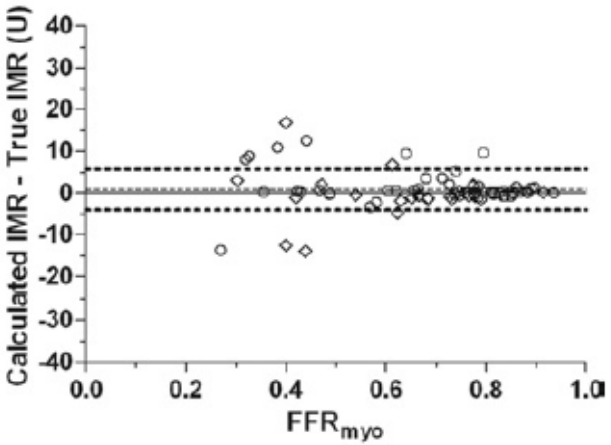


Yong, et al. J Am Coll Cardiol Intv 2013;6:53-8.

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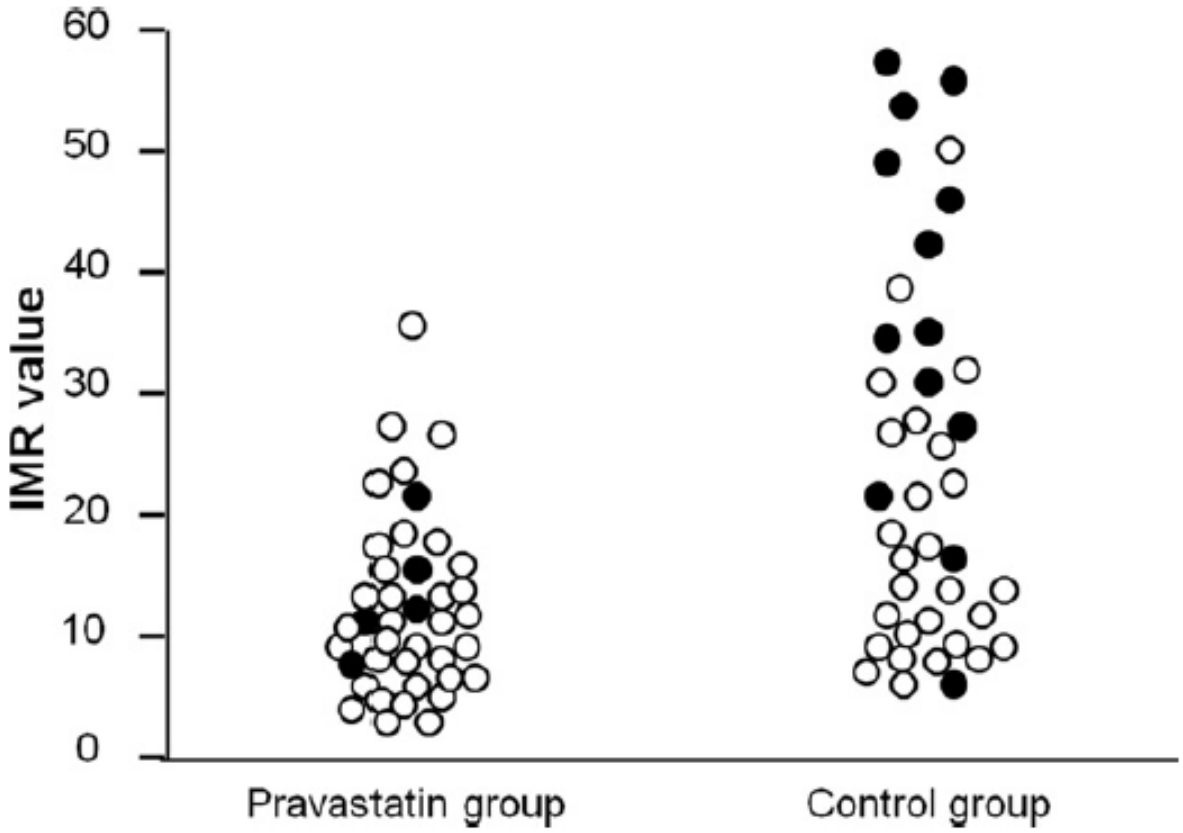
- To evaluate the etiology of chest pain/abnormal stress test in a patient with angiographically appearing normal coronaries
- To assess for the likelihood of peri-PCI myocardial infarction
- Research purposes

# IMR post Statin Therapy

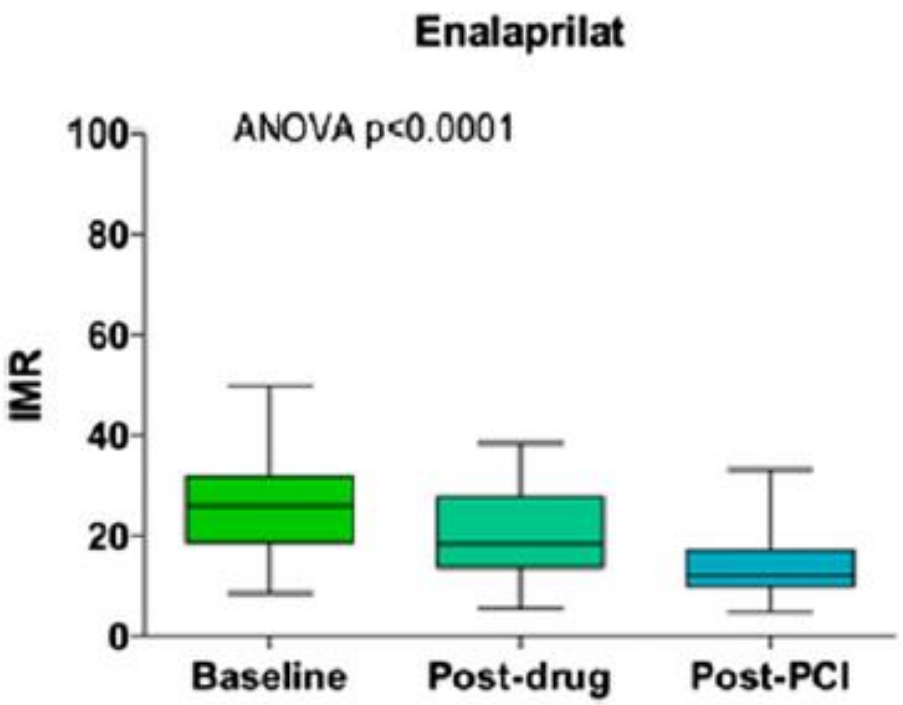
***IMR measured after PCI in 80 patients randomized to either 1 month pretreatment with pravastatin or placebo***

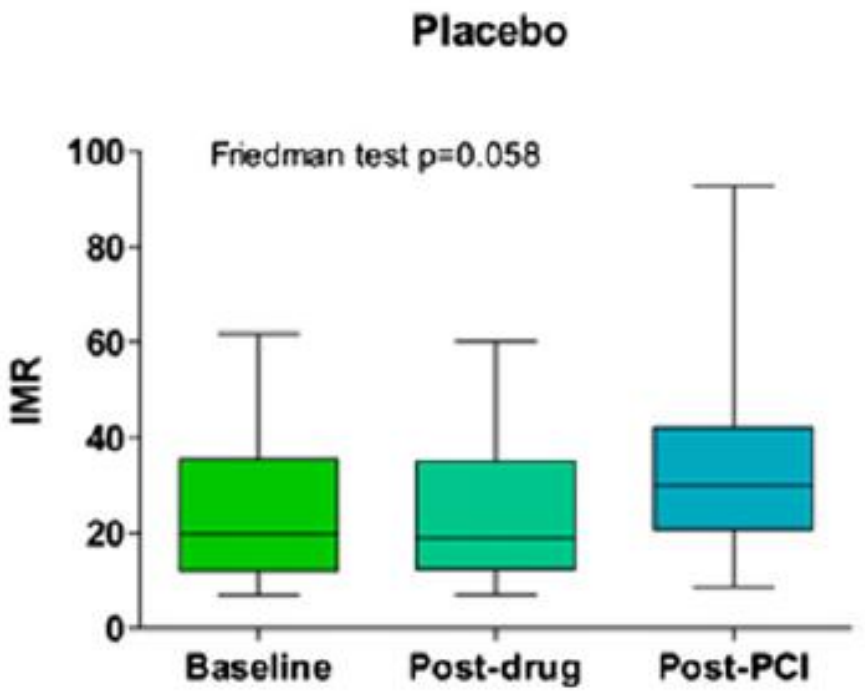



Fujii, et al. J Am Coll Cardiol Intv 2011; 4:513-20.

# IMR post ACE Inhibitor Therapy

***40 patients randomized to IC enalaprilat or placebo prior to PCI***




Mangiacapra, et al. J Am Coll Cardiol 2013; 61:615-21.

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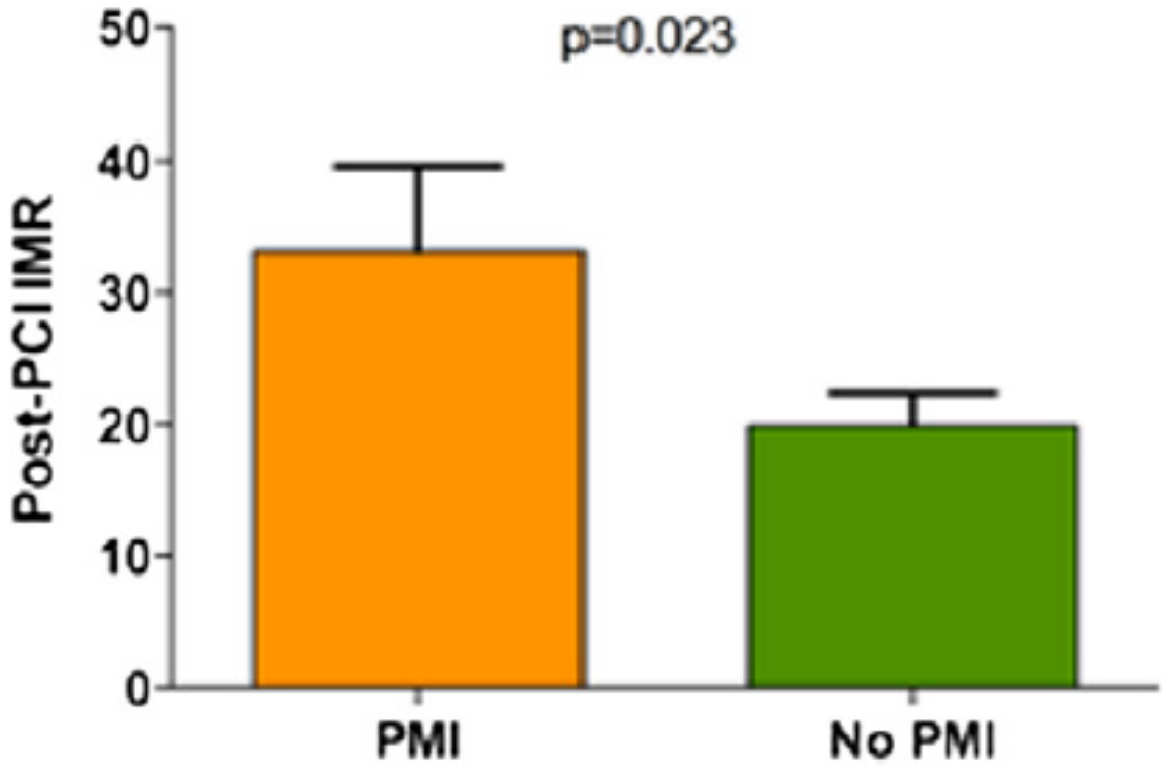
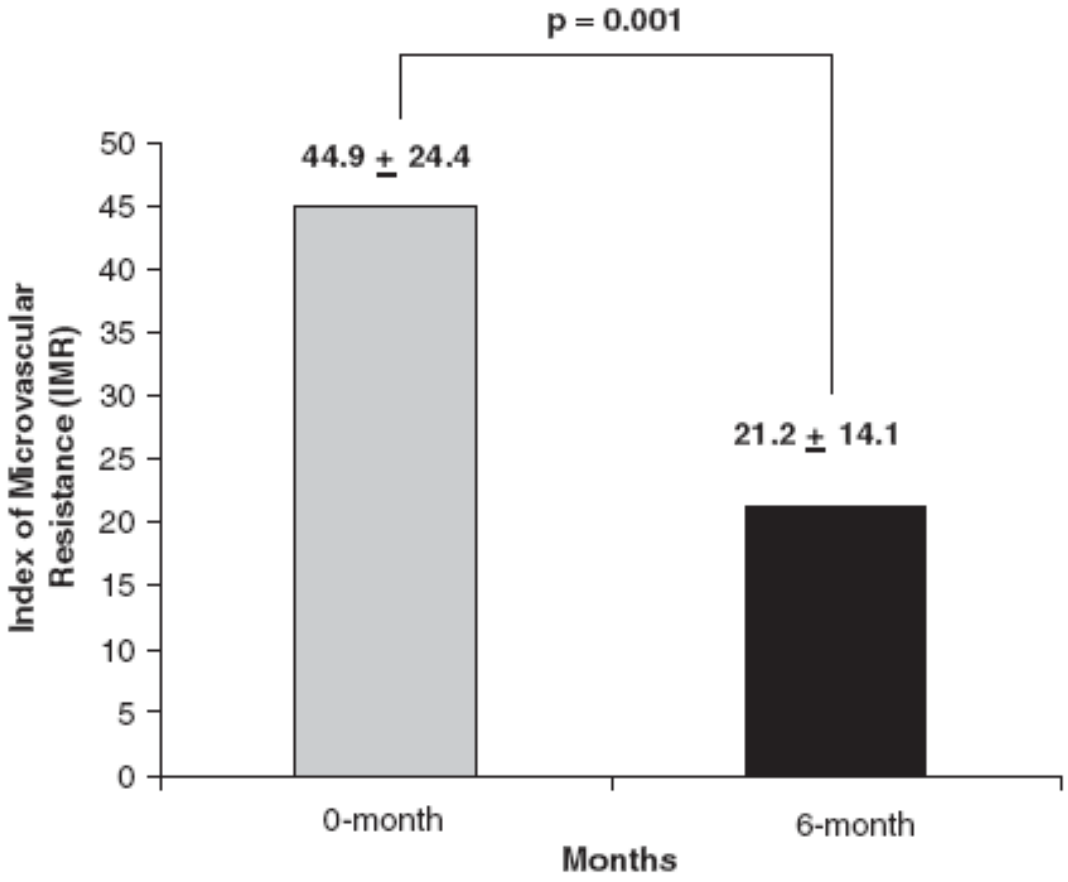



Mangiacapra, et al. J Am Coll Cardiol 2013; 61:615-21.

# IMR post Stem Cell Therapy

***IMR measured in 15 patients with ischemic cardiomyopathy before and 6 months after intracoronary stem cell delivery***




Tayyareci, et al. Angiology 2008;59:145

# Conclusions:

- Measurement of FFR and IMR can help to diagnose the etiology of chest pain/abnormal stress test in patient with angiographically normal appearing coronaries.
- IMR measured at the time of PCI can predict peri-procedural myocardial infarction.
- IMR is a useful research tool for evaluating the efficacy of various therapies.