
How and Why to Invasively Assess the Coronary Microcirculation

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Disclosure Statement of Financial Interest

Within the past 12 months, I or my spouse/partner have had a financial interest /arrangement or affiliation with the organization(s) listed below

Affiliation/Financial Relationship

Company

Grant/ Research Support:

St. Jude Medical

Consulting Fees/Honoraria:

Tryton Medical

Major Stock Shareholder/Equity Interest:

Royalty Income:

Ownership/Founder:

Salary:

Intellectual Property Rights:

Other Financial Benefit (minor stock options):

HeartFlow



Assessing the Microvasculature

Techniques

Noninvasive:

e.g., MR, PET, Contrast Echo

Angiographic:

e.g., Blush score

Invasive:

e.g., Doppler CFR

Limitations

Not readily available in the cath lab; Require expertise

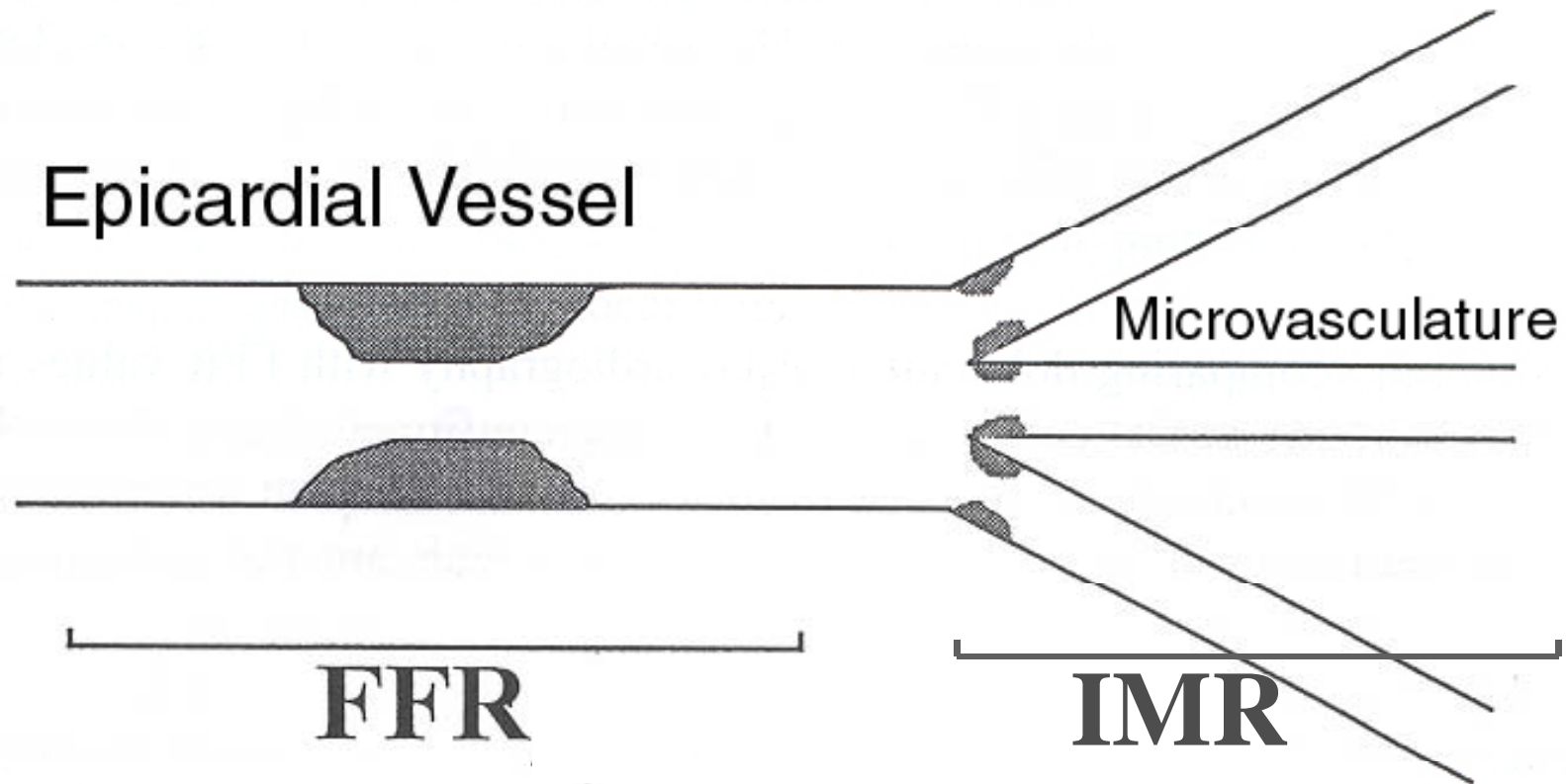
Qualitative;

Useful in large populations

Interrogates both epicardial vessel and microvasculature;
Affected by resting hemodynamics



Index of Microcirculatory Resistance



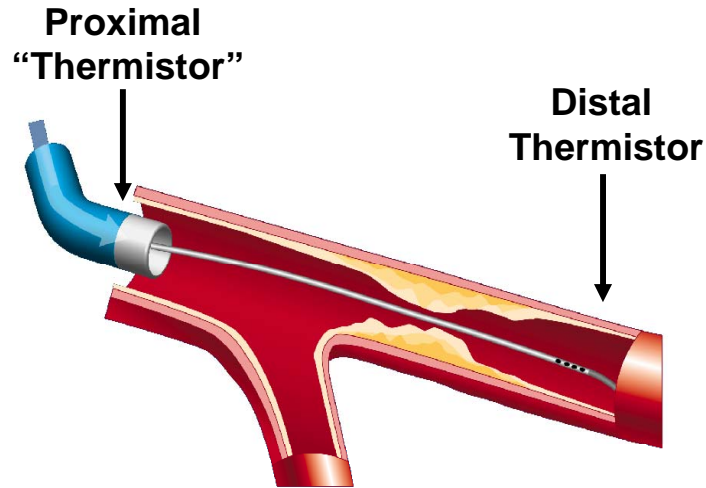
Index of Microcirculatory Resistance

Potential Advantages:

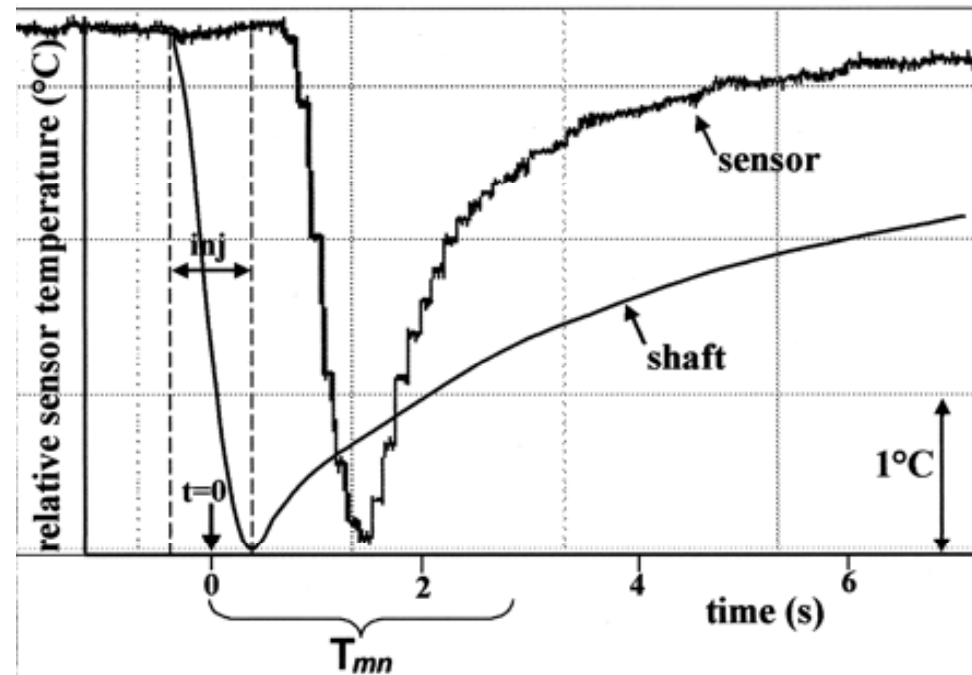
- ❑ Readily available in the cath lab
- ❑ Specific for the microvasculature
- ❑ Quantitative and reproducible
- ❑ Predictive of outcomes



Estimation of Coronary Flow



Calculation of mean transit time



Derivation of IMR:

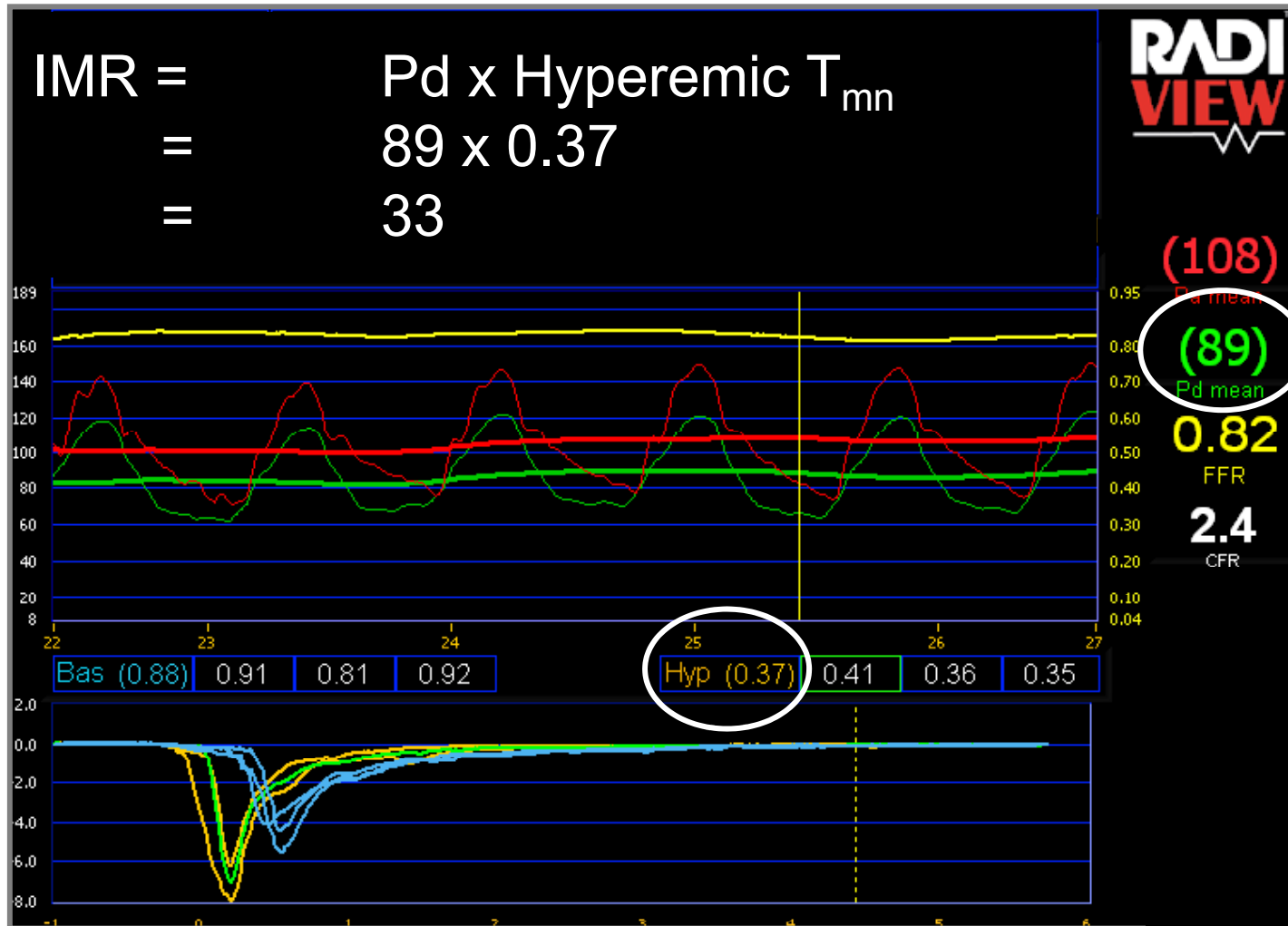
- Resistance = Δ Pressure / Flow
- $1 / T_{mn} \cong$ Flow
- IMR = Distal Pressure / $(1 / T_{mn})$
- IMR = Distal Pressure x T_{mn}

*at maximal
hyperemia...*



Practical Measurement of IMR

$$\begin{aligned} \text{IMR} &= \text{Pd} \times \text{Hyperemic } T_{mn} \\ &= 89 \times 0.37 \\ &= 33 \end{aligned}$$



Why should we assess the coronary microvasculature?

- In stable patients with “normal” coronary arteries, abnormal microvascular function predicts adverse outcome.
- In stable patients undergoing PCI, abnormal microvascular resistance may predict adverse outcome.
- Immediately after STEMI, impaired microvascular function predicts adverse outcome.
- For research purposes.



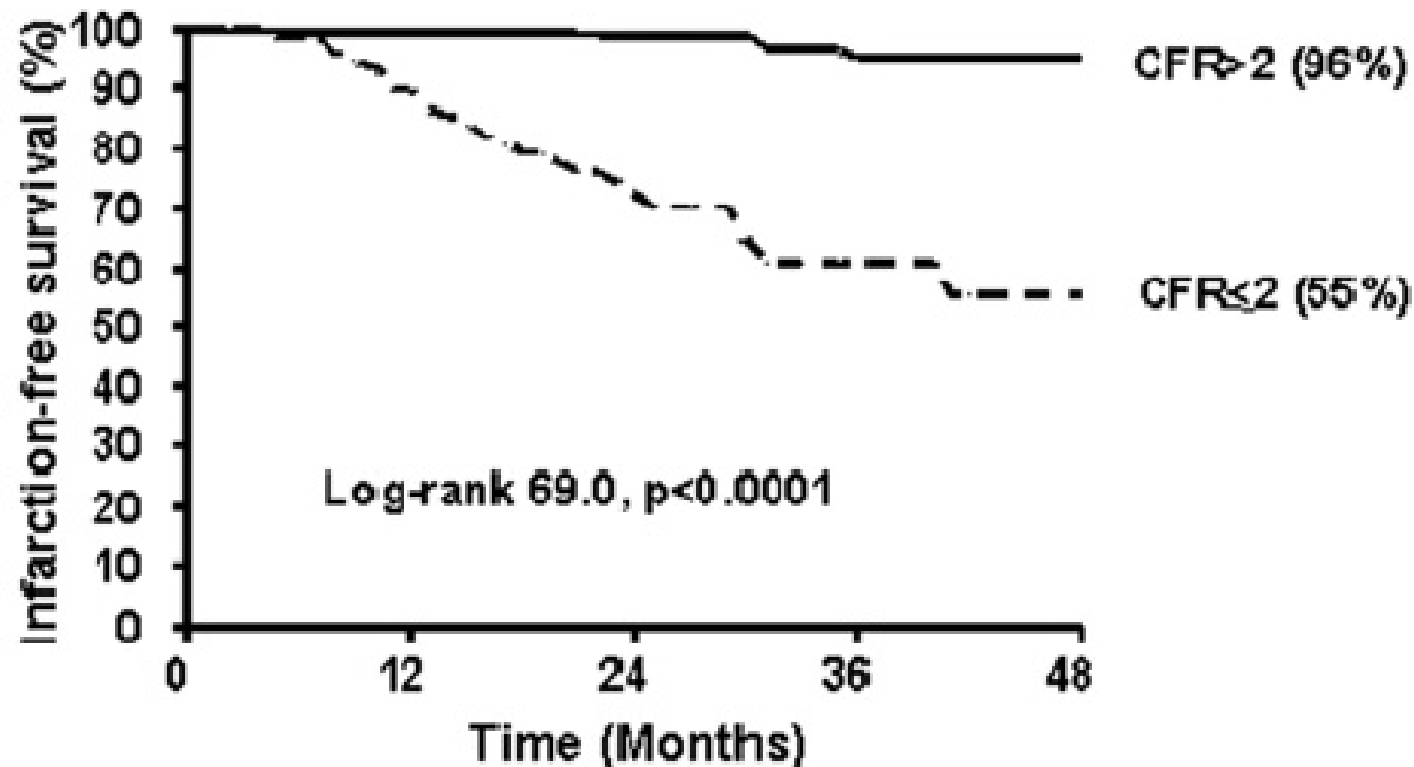
Why should we assess the coronary microvasculature?

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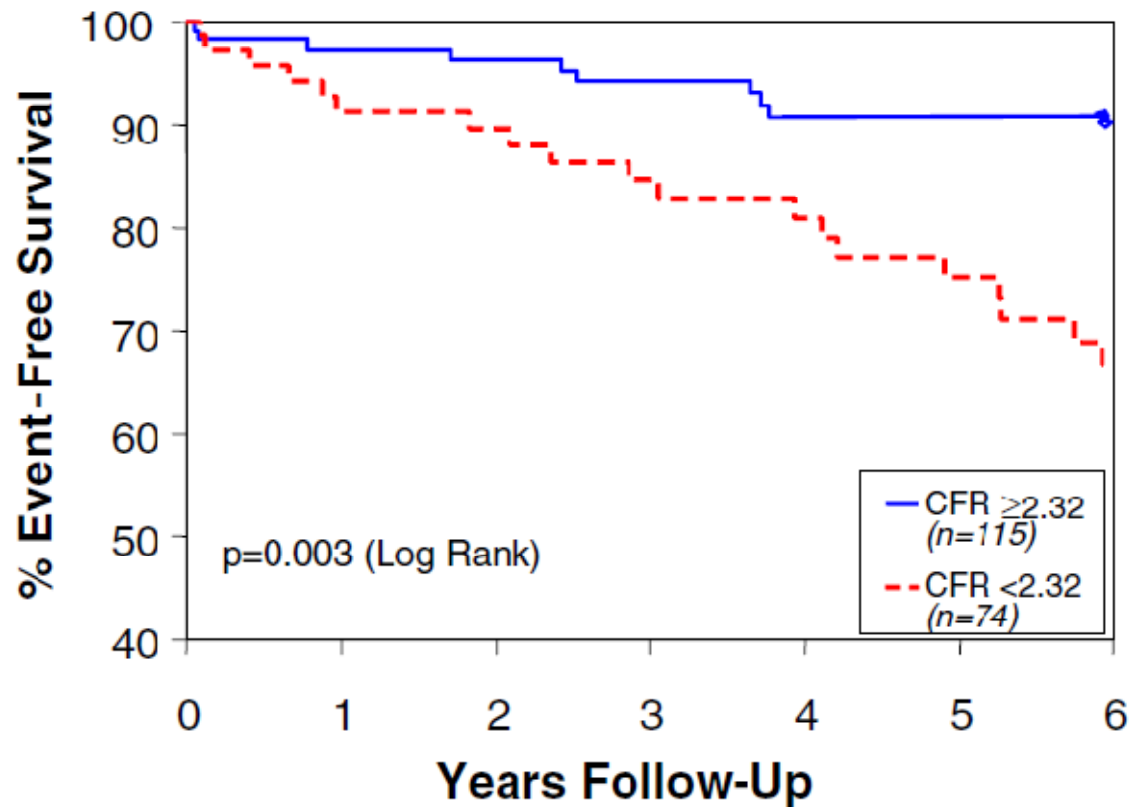
Importance of the Microcirculation

Infarct-Free Survival based on Echo-Derived CFR in 394 Patients with Chest Pain and Normal Coronaries



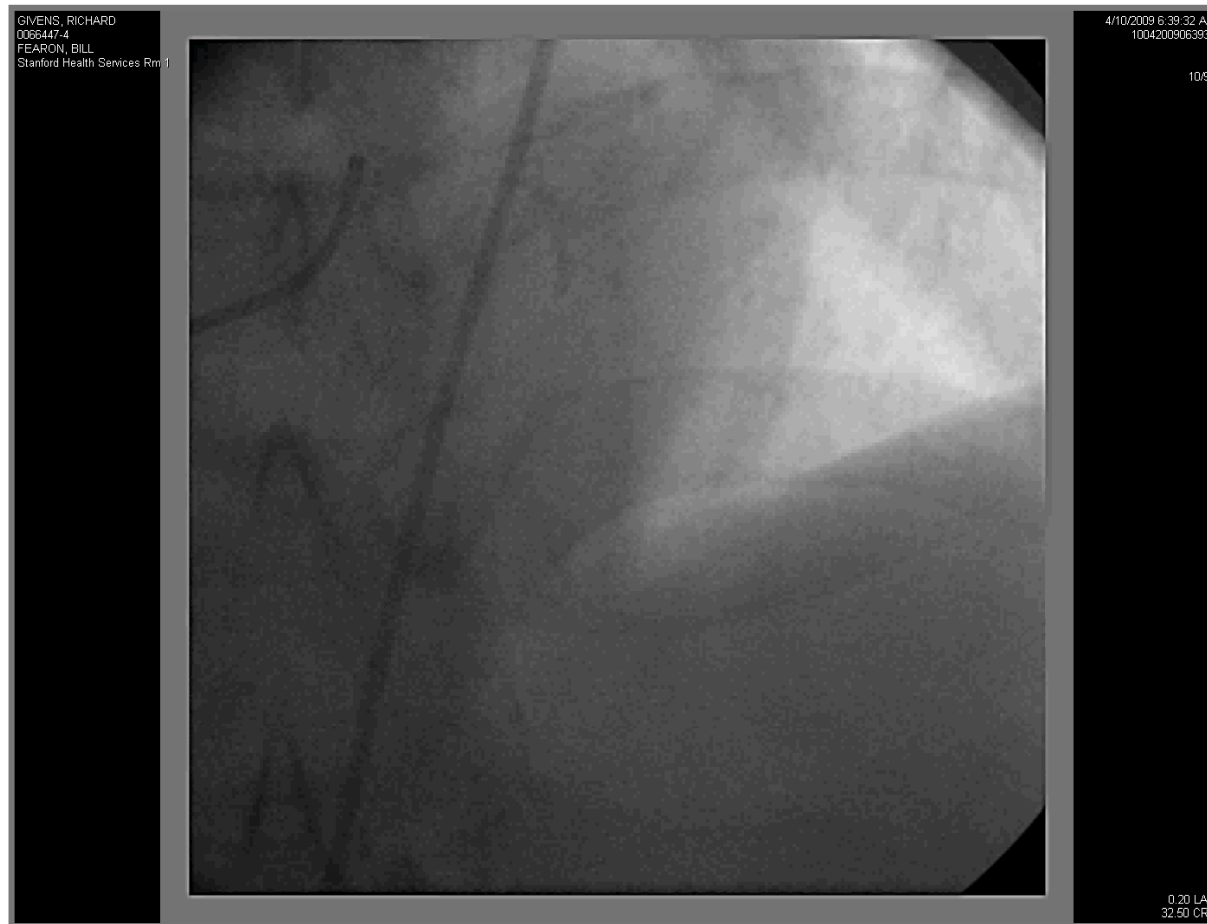
Importance of the Microcirculation

*189 women with chest pain and “normal” coronary arteries:
% free of Death, MI, CVA, or CHF*

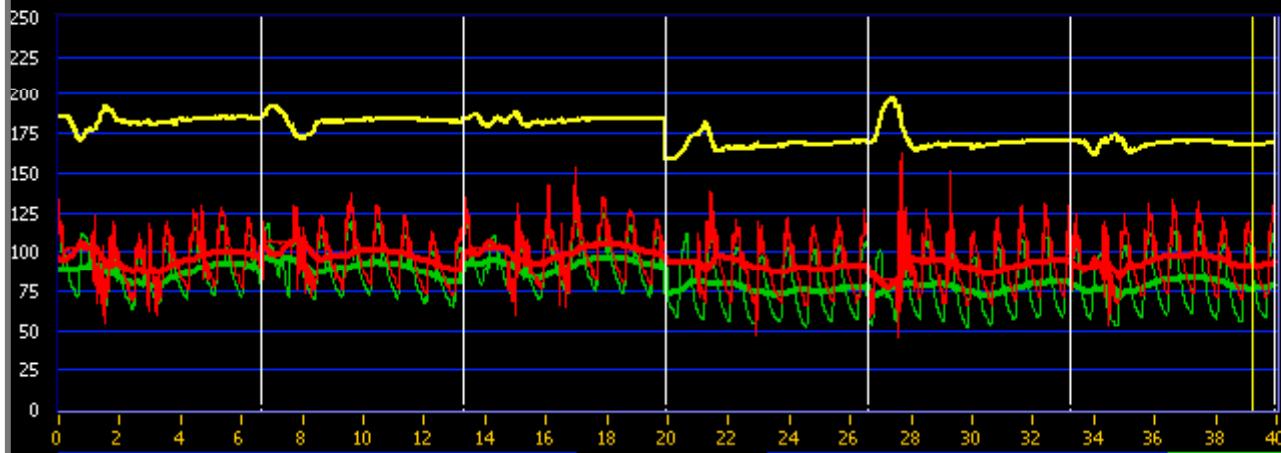


Clinical Application of IMR

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



$$\text{IMR} = 77 \times 0.12 = 9$$



(92)
Pa mean

(77)
Pd mean

0.84
FFR

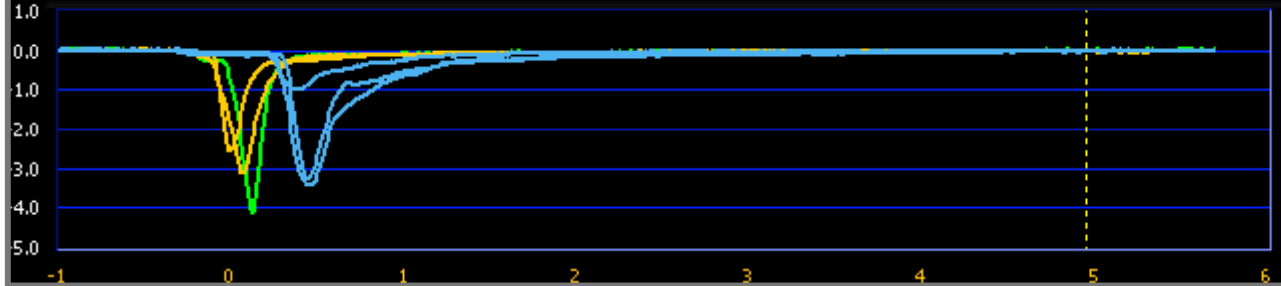
5.3
CFR

-0.02
dT

4.95
CURSOR

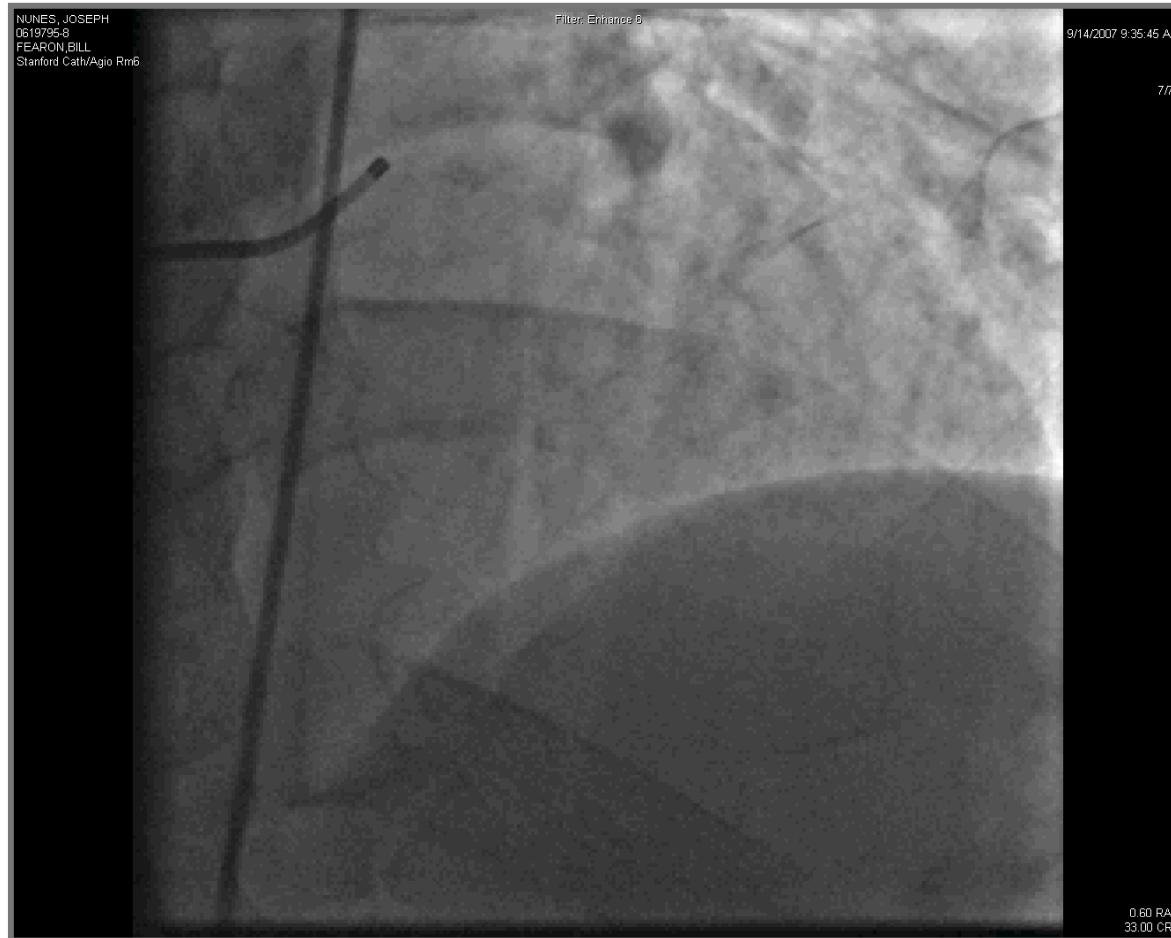
+ [magnifying glass] [crosshair]
RESET

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



$$\text{IMR} = 76 \times 0.70 = 53$$



(89)
Pa mean
(76)
Pd mean
0.85
FFR
2.9
CFR
-0.05
dT
5.04
CURSOR
+ [magnifying glass] [crosshair]
RESET



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

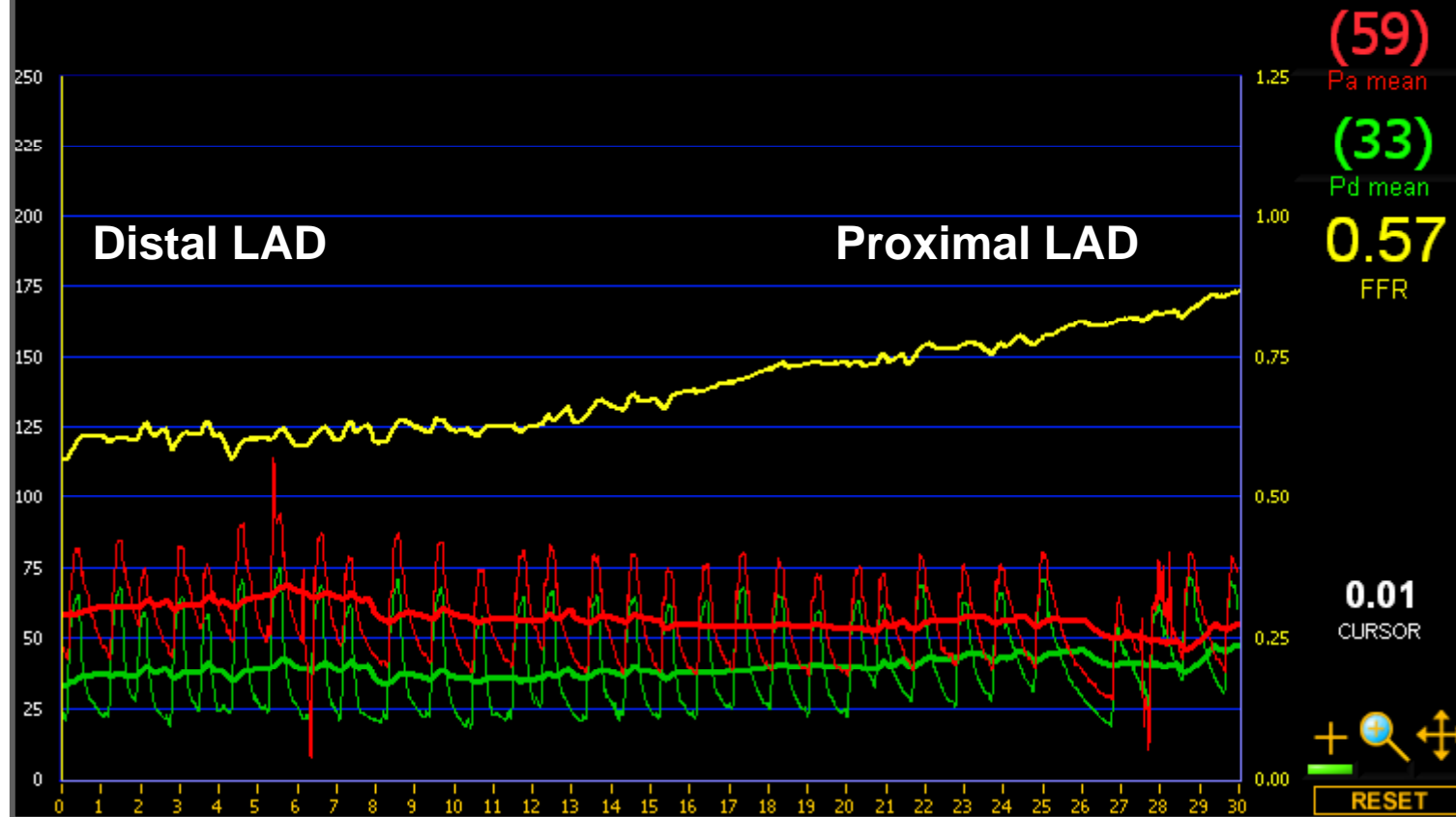


$$\text{IMR} = 26 \times 0.25 = 8$$

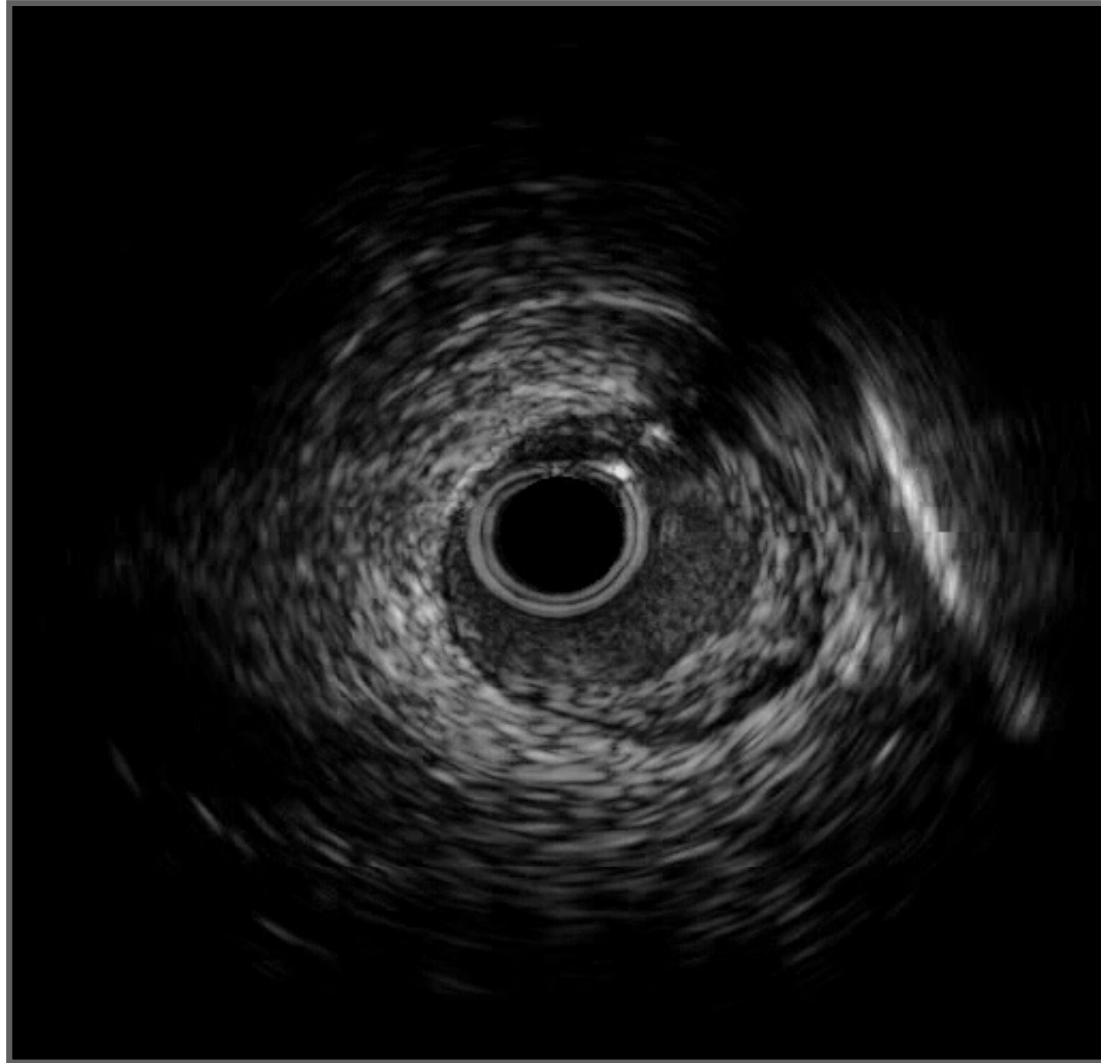
**RADI
VIEW**



Slow Pullback in LAD



IVUS of LAD



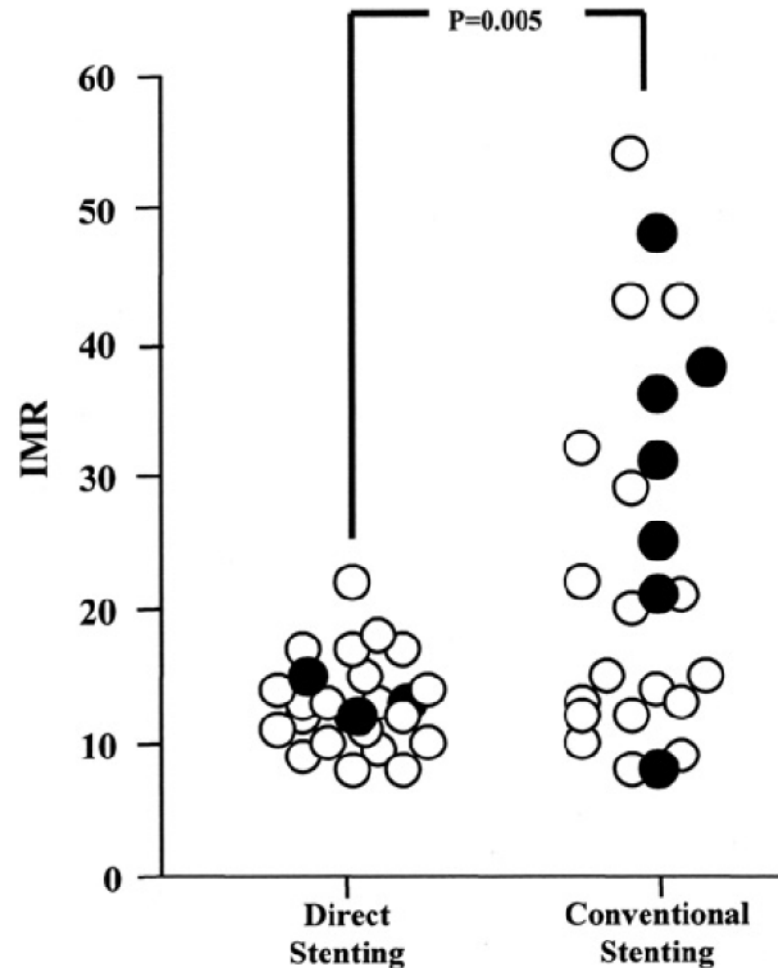
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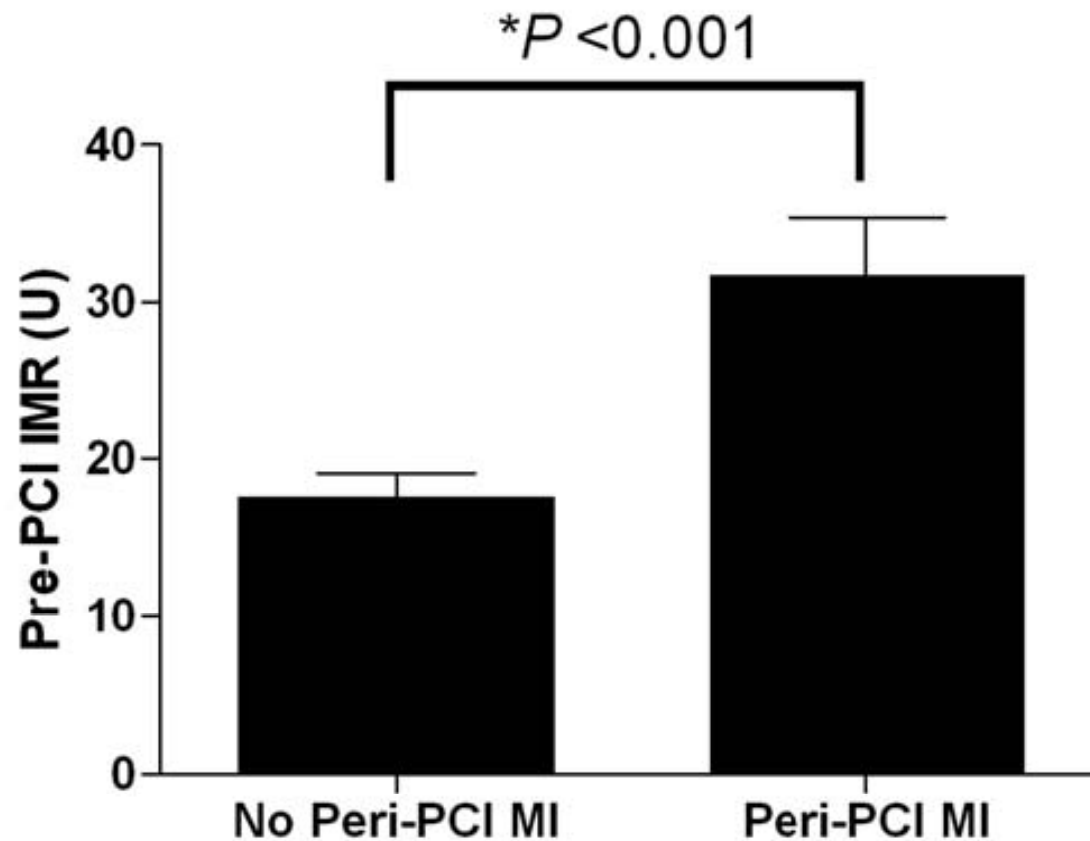
IMR after PCI in Stable Patients

- 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 , $p=0.04$.



IMR Before PCI in Stable Patients

IMR measured before PCI in 50 stable patients undergoing LAD PCI



IMR *Before* PCI in Stable Patients

IMR measured before PCI in 50 stable patients undergoing LAD PCI

Multivariable Regression Analysis

Variable	<i>P</i>	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



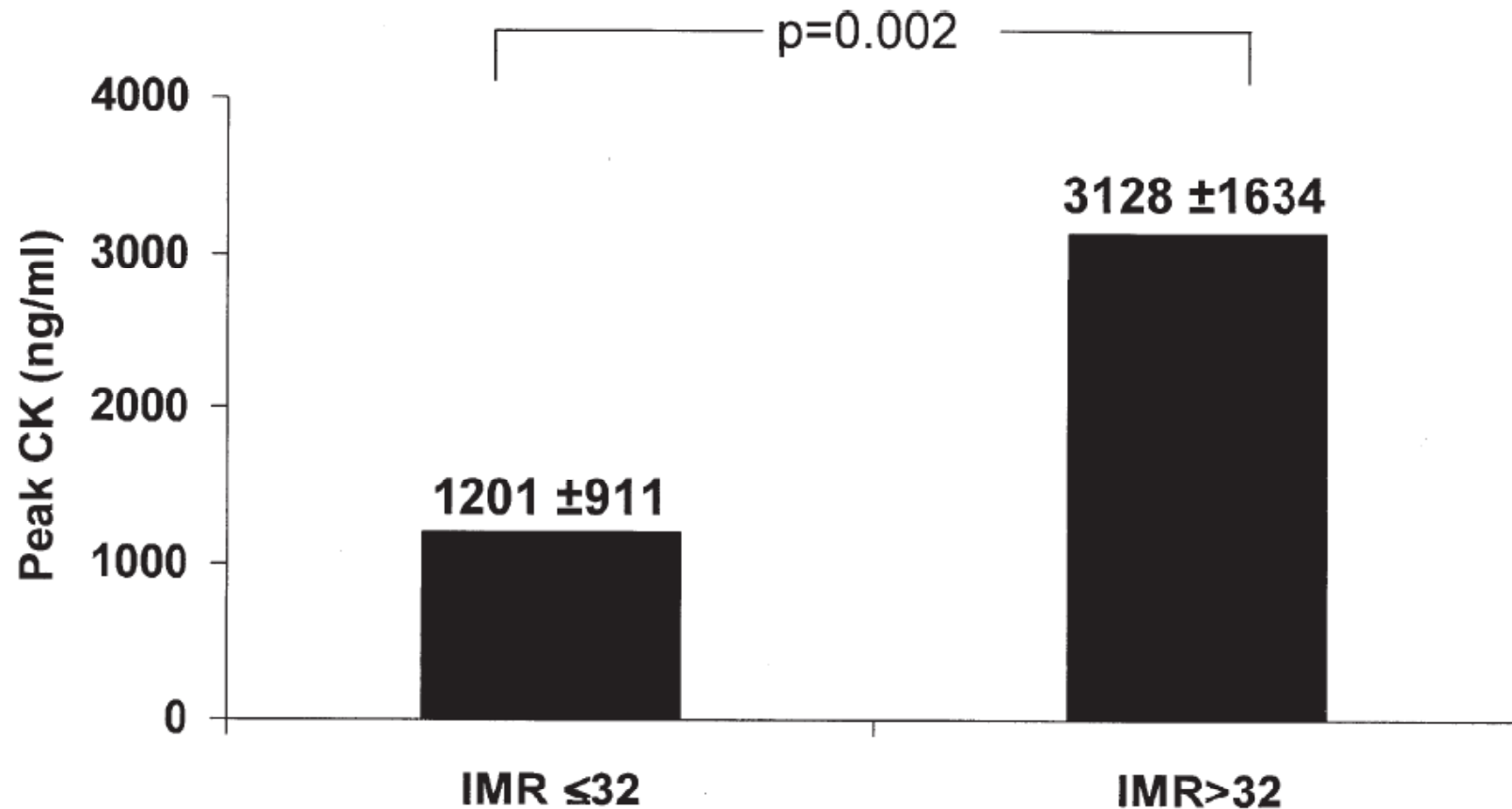
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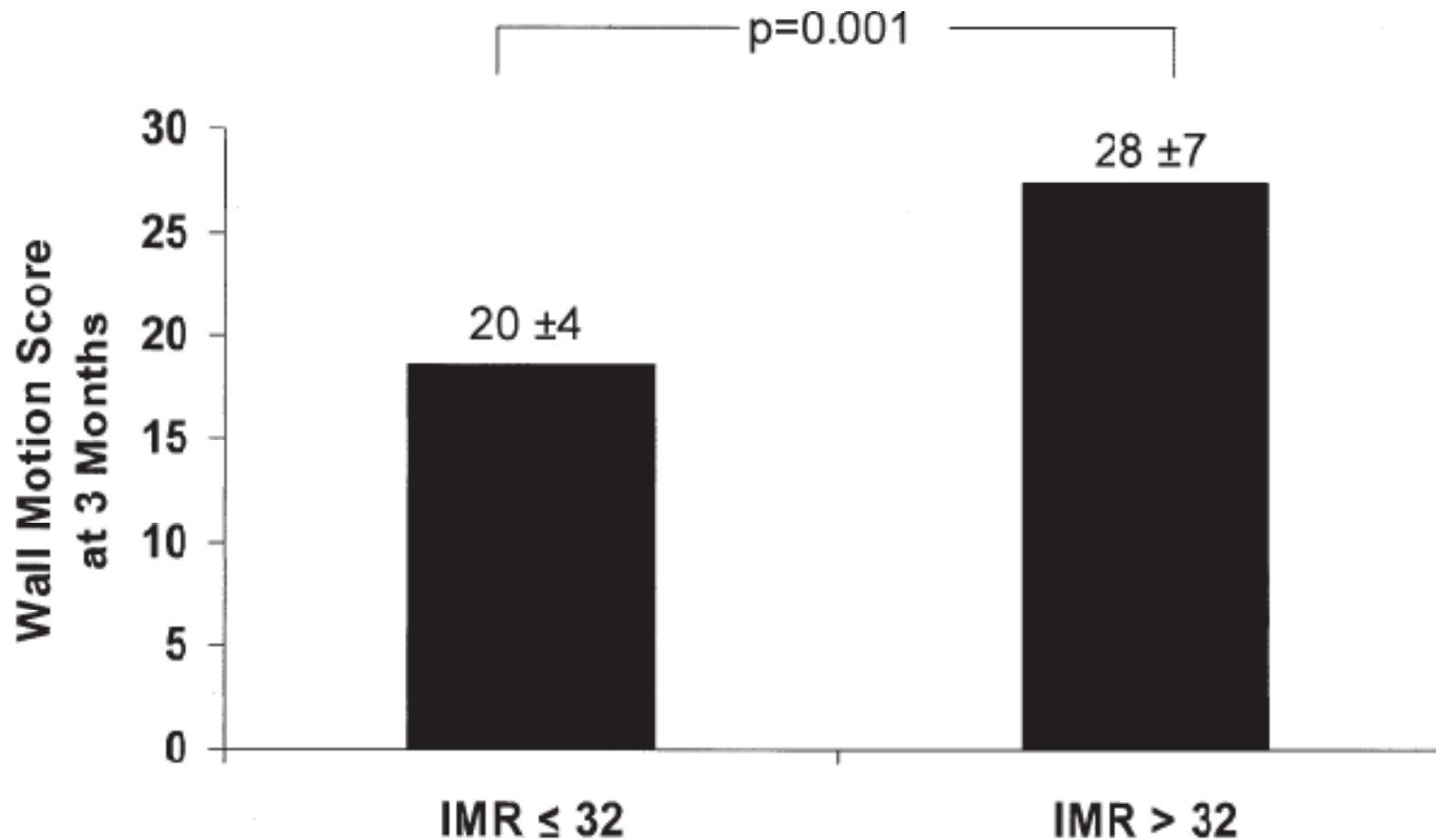
Predictive Value of IMR after PCI for STEMI

IMR predicts peak CK in patients with STEMI



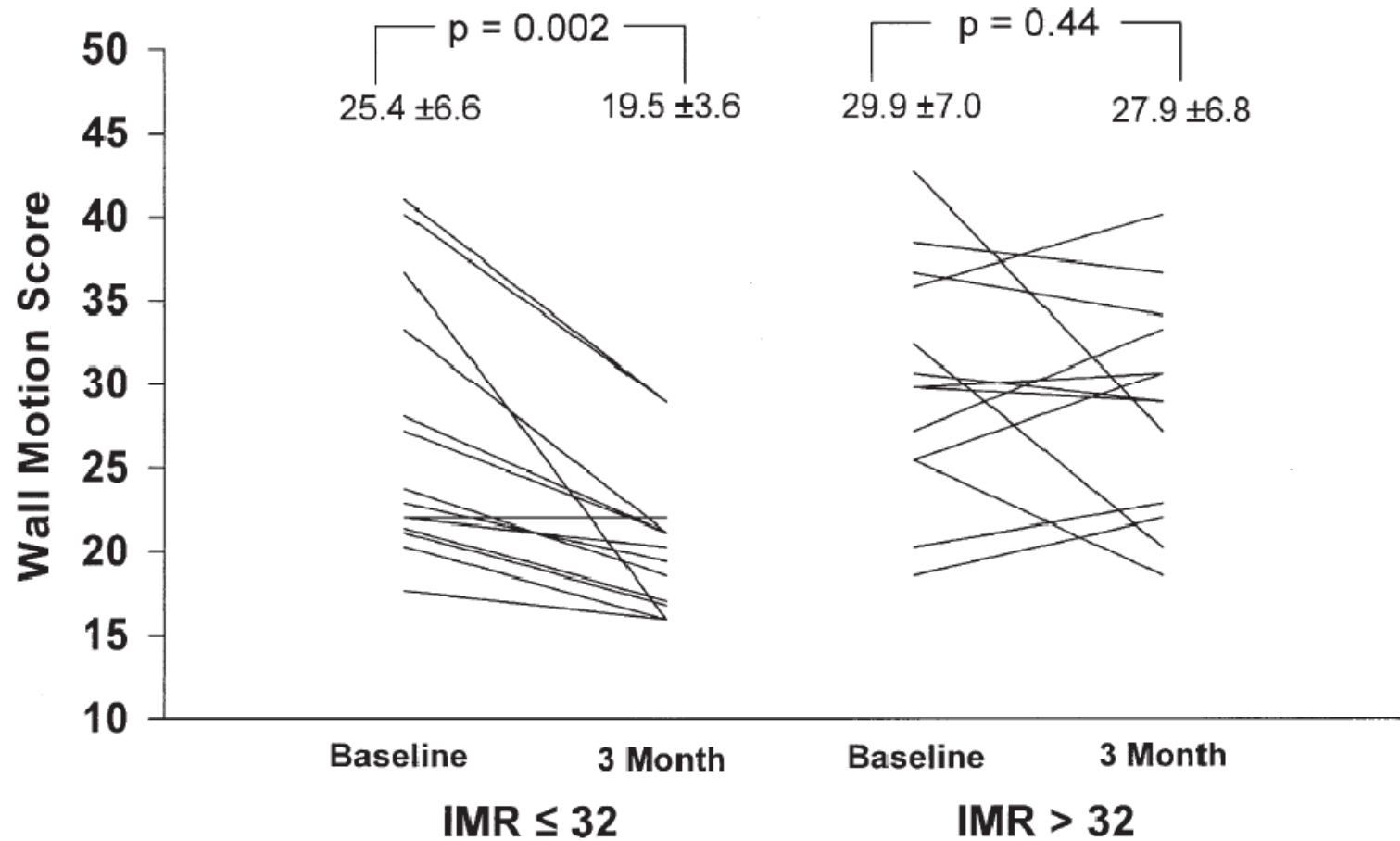
Predictive Value of IMR after PCI for STEMI

IMR predicts LV function 3 months after STEMI



Predictive Value of IMR after PCI for STEMI

IMR predicts which patients will have improved LV function after STEMI



Predictive Value of IMR after PCI for STEMI

Correlation between measures of microvascular function and peak CK and 3-month wall motion score

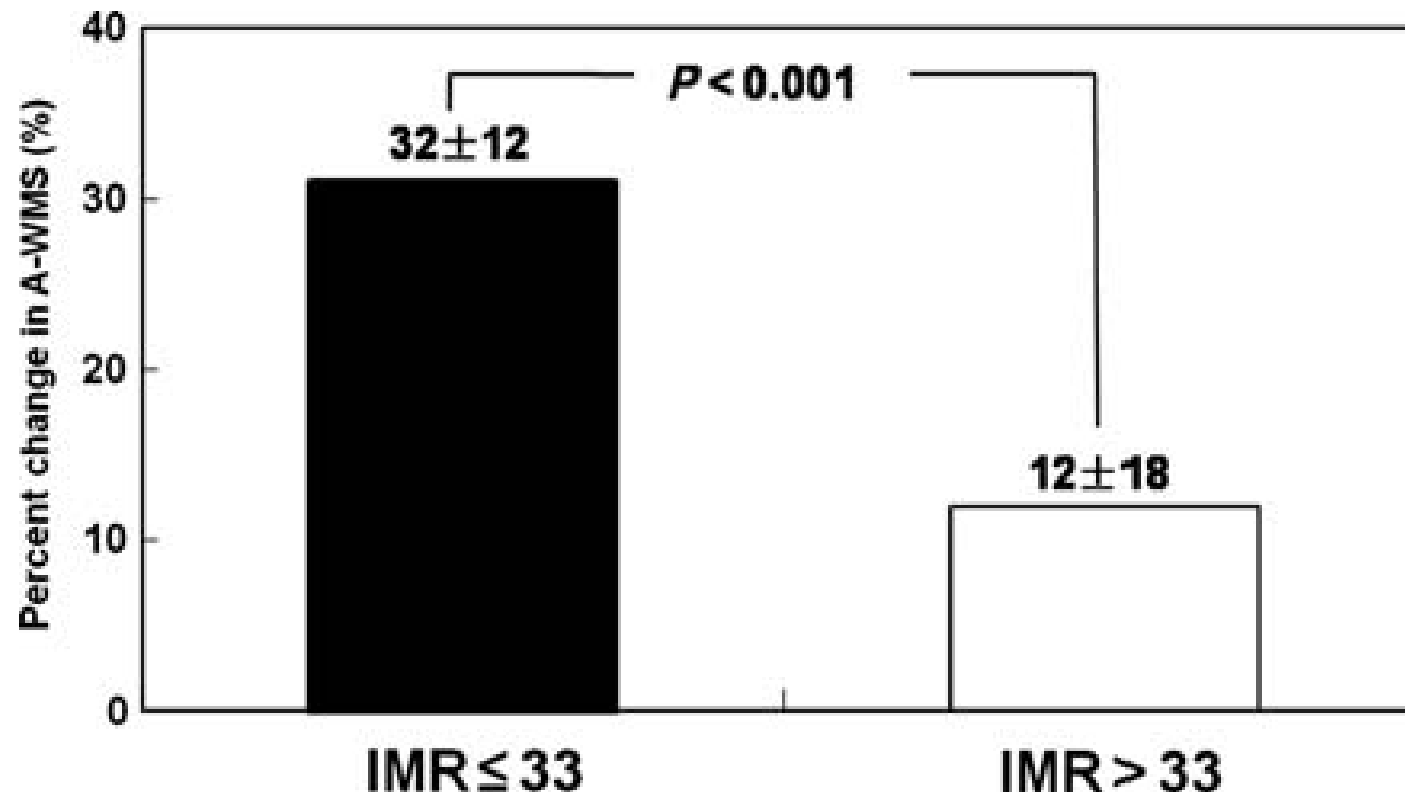
Variable	Peak CK	3-Month WMS
IMR	0.61*	0.59†
TMPG	0.05	0.12
CFR	-0.32	-0.35
ST-segment resolution	-0.35	-0.34
cTFC	-0.02	0.06

*p = 0.0005, †p = 0.002, p = NS for all others.



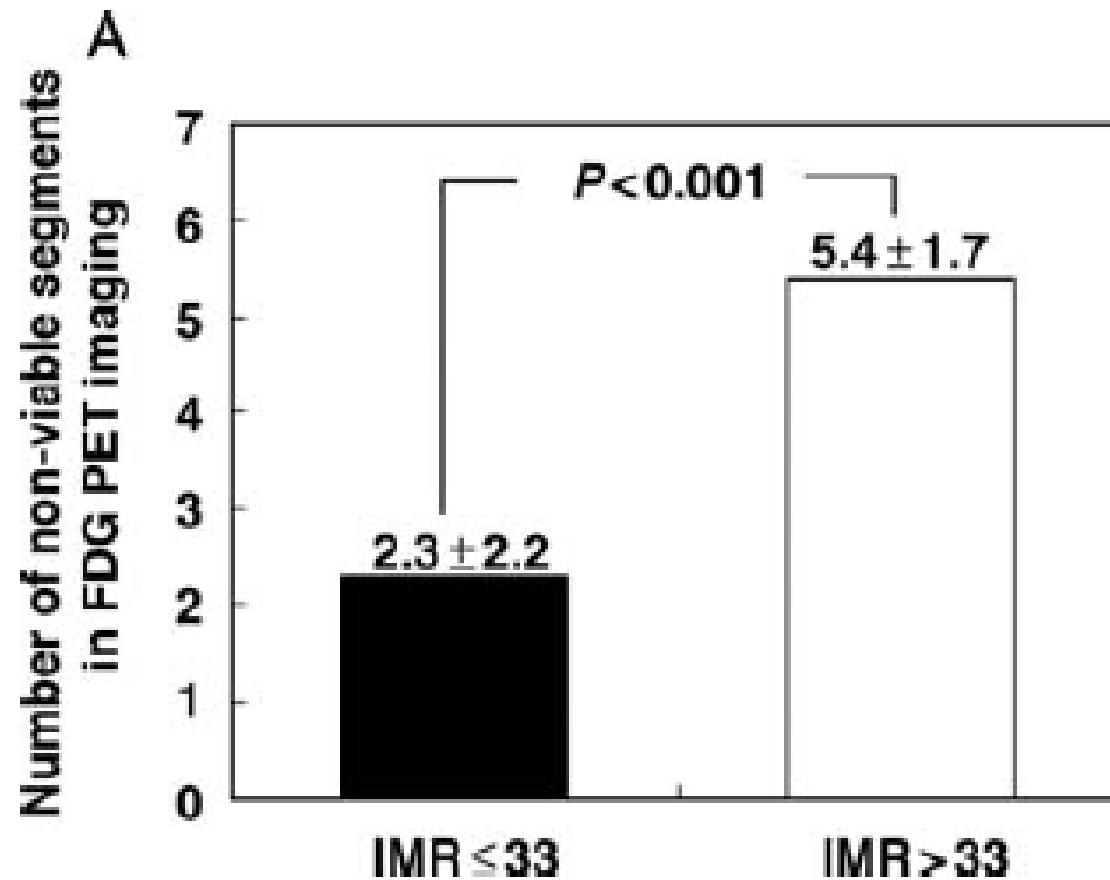
Predictive Value of IMR after PCI for STEMI

Relation between IMR and recovery of LV function in 40 STEMI patients



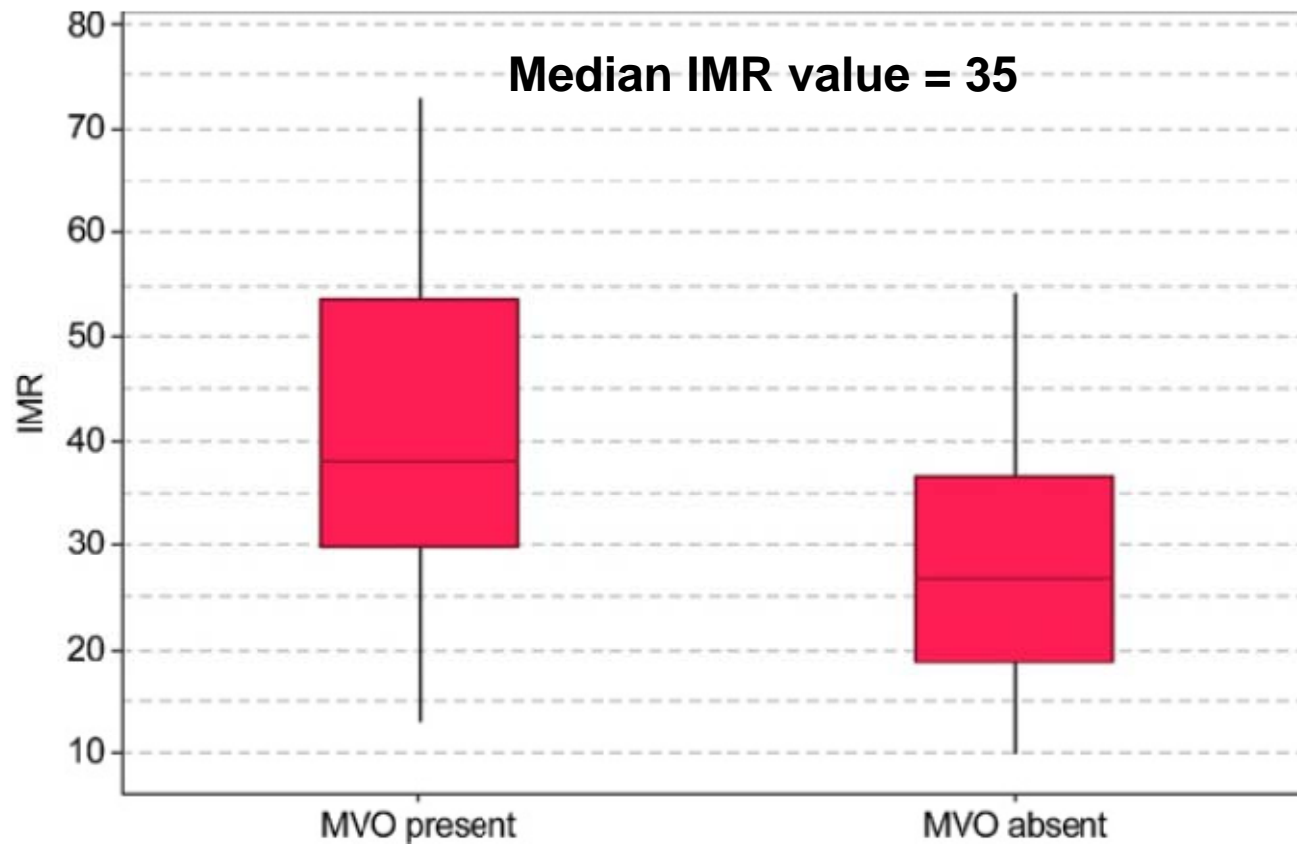
Predictive Value of IMR after PCI for STEMI

Relation between IMR and PET viability in 40 STEMI patients



Predictive Value of IMR after PCI for STEMI

Correlation between IMR and cardiac MR assessment of microvascular obstruction in 57 patients after STEMI



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Research Applications of IMR

The NEW ENGLAND JOURNAL of MEDICINE

ORIGINAL ARTICLE

Intracoronary Streptokinase after Primary Percutaneous Coronary Intervention

Murat Sezer, M.D., Hüseyin Oflaz, M.D., Taner Gören, M.D., İrem Okçular, M.D.,
Berrin Umman, M.D., Yılmaz Nişancı, M.D., Ahmet Kaya Bilge, M.D.,
Yasemin Şanlı, M.D., Mehmet Meriç, M.D., and Sabahattin Umman, M.D.

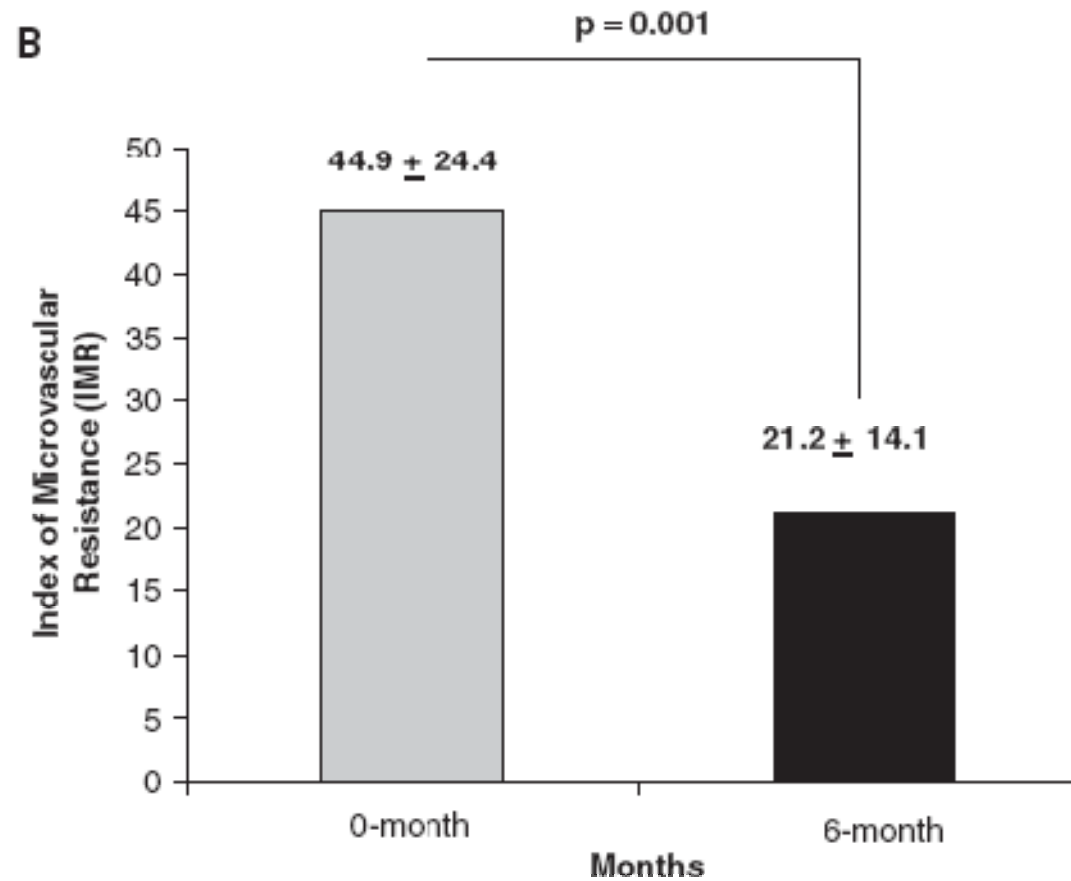
41 patients randomized to IC SK or placebo after primary PCI for STEMI

IMR was significantly lower (16 vs. 32, $p < 0.001$) in the SK group



IMR post Stem Cell Therapy

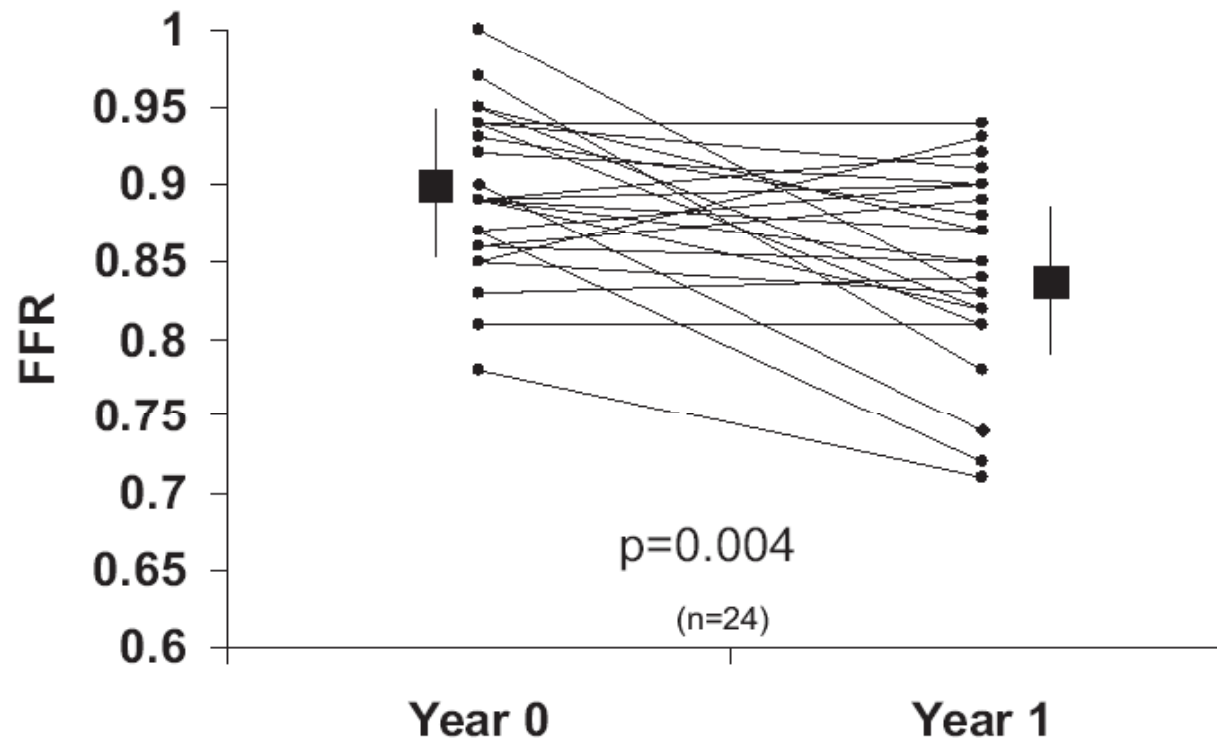
IMR measured in 15 patients with ischemic cardiomyopathy before and 6 months after intracoronary stem cell delivery



Research Applications of IMR:

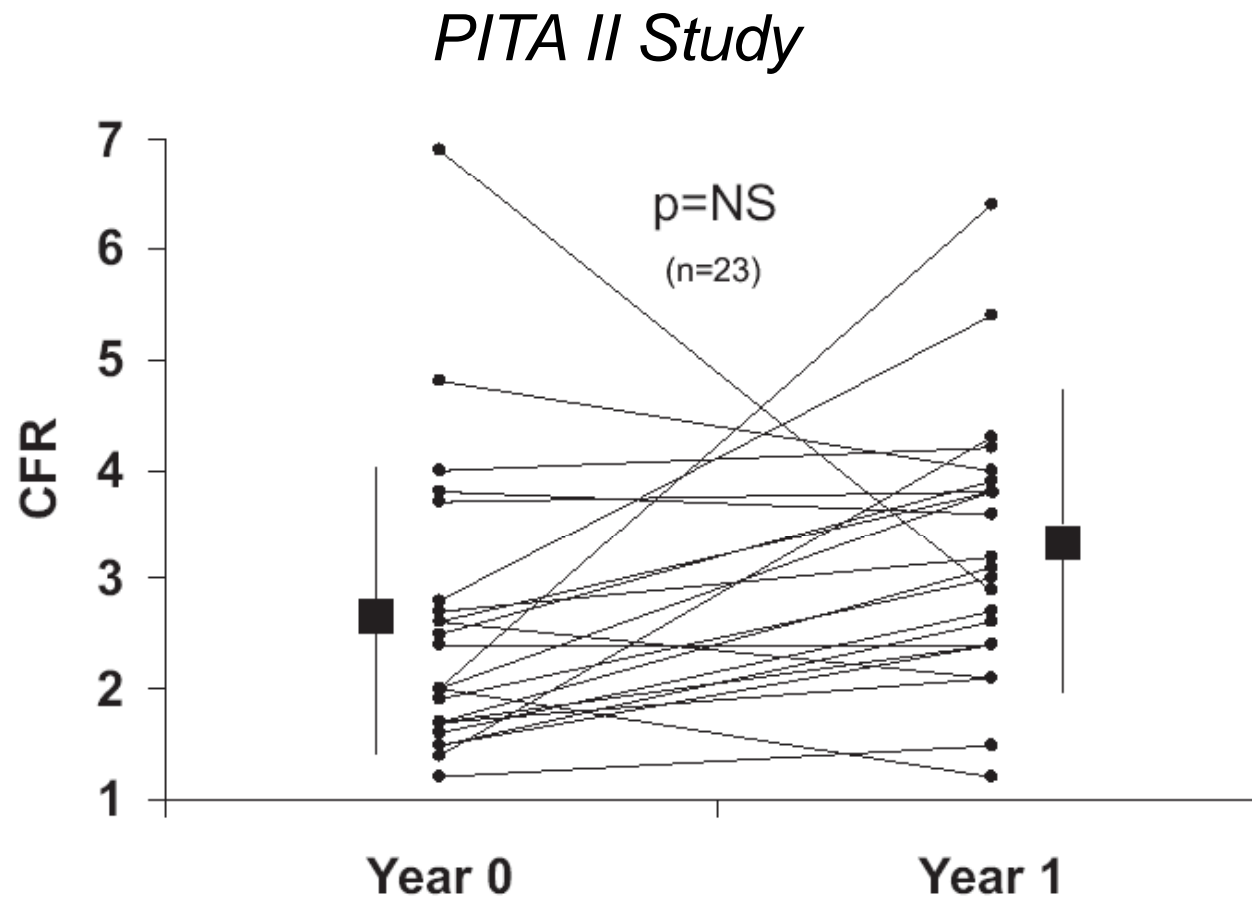
Post Heart Transplantation

PITA II Study



Research Applications of IMR:

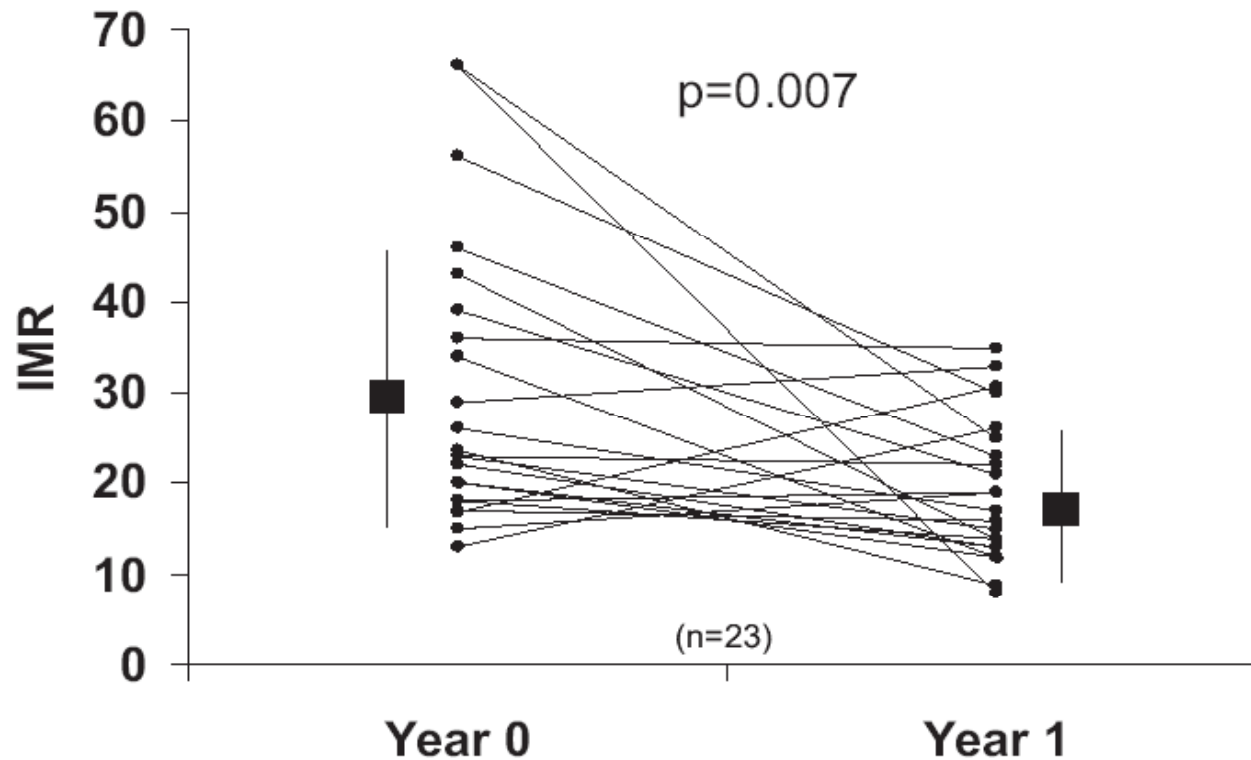
Post Heart Transplantation



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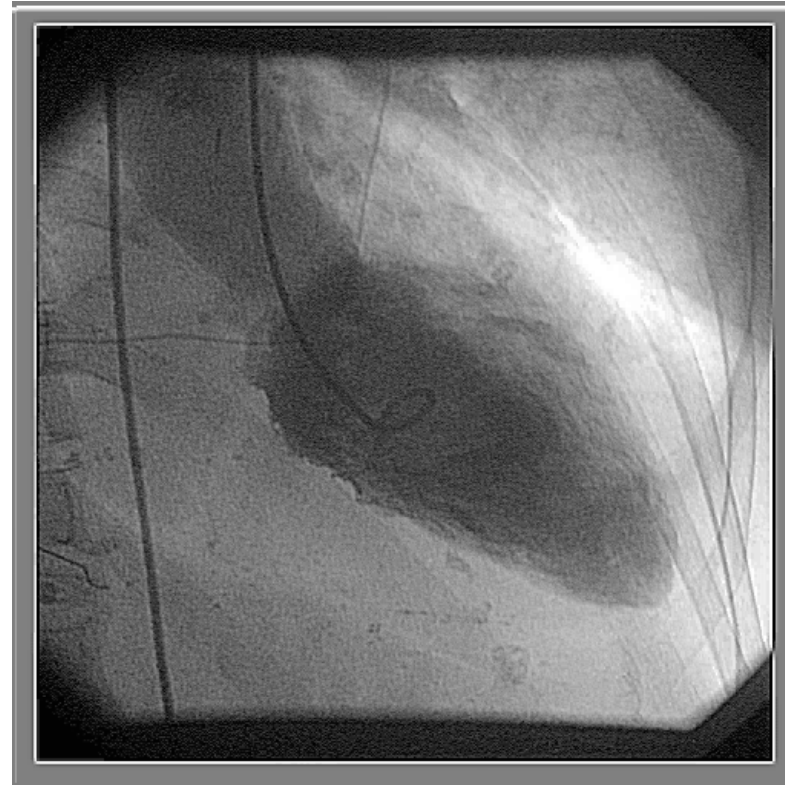
Post Heart Transplantation

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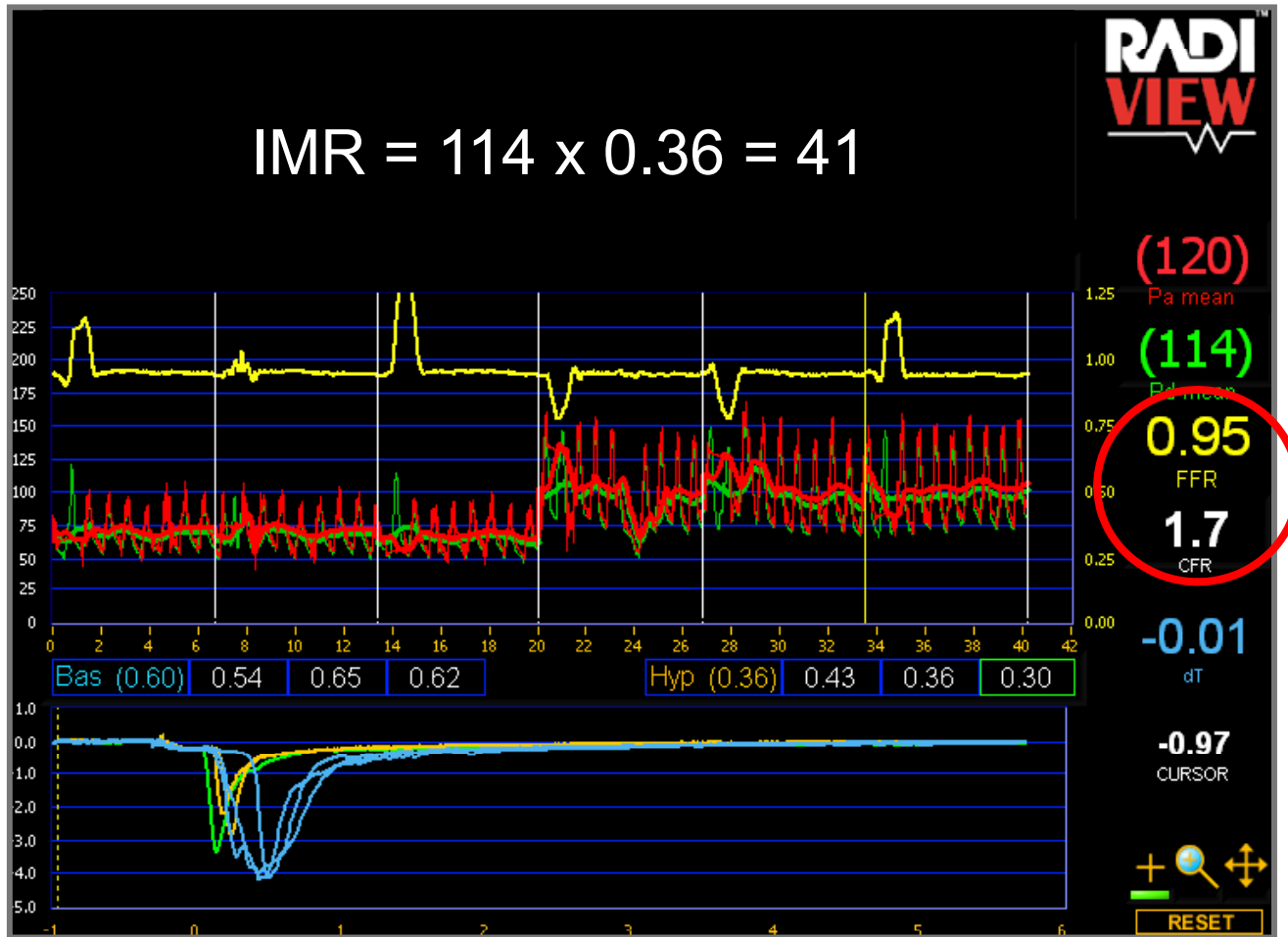
Research Applications of IMR:

Tako-Tsubo (Stress Cardiomyopathy)



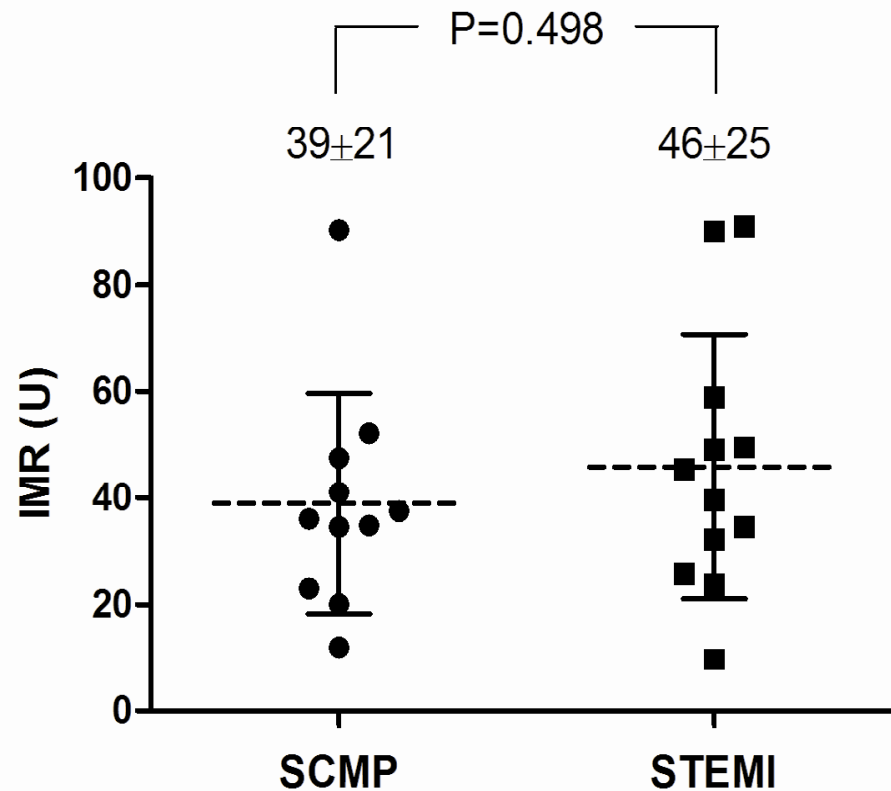
Research Applications of IMR:

Tako-Tsubo (Stress Cardiomyopathy)



Research Applications of IMR:

Tako-Tsubo (Stress Cardiomyopathy)



Why/How to Assess the Microcirculation

Take Home Messages:

- The microvasculature can be assessed easily and reliably by measuring IMR.
- In stable patients with “normal” coronary arteries, simultaneous assessment of FFR and IMR can guide therapy.
- IMR predicts outcomes in acute MI; emerging data suggest its utility in stable PCI patients, as well.

