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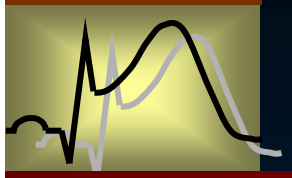

Invasive Assessment of Microvascular Circulation Indexes in AMI

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Suwon, Korea

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Invasive Assessment of Microvascular Integrity in AMI

- **TIMI Myocardial Perfusion Grade (TMPG)**
- Coronary Flow Reserve
  : $CFR_{doppler}$, CFR_{thermo}
- Coronary Flow Velocity Patterns
  : DDT, SAPV, Systolic flow reversal
- Microvascular Resistance Index
  : IMR, MVRI
- Coronary Capillary Wedge Pressure
  : Pcw, Pcw/Pa, CFIp

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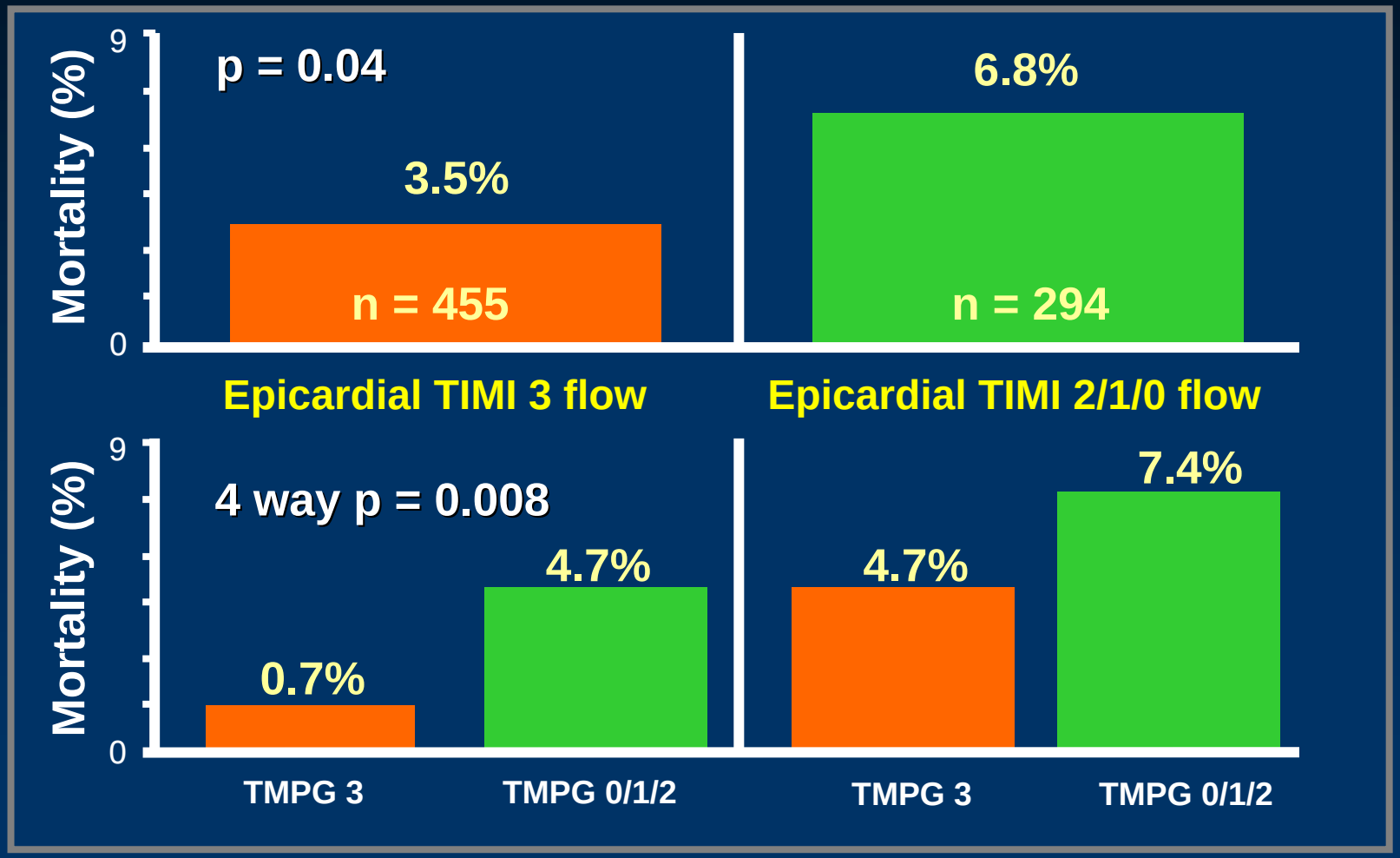
Myocardial Blush Scores

- Relationship of both TIMI grade and TMP grade to 30-day mortality



Gibson et al. *Circulation* 2000;101;125-130

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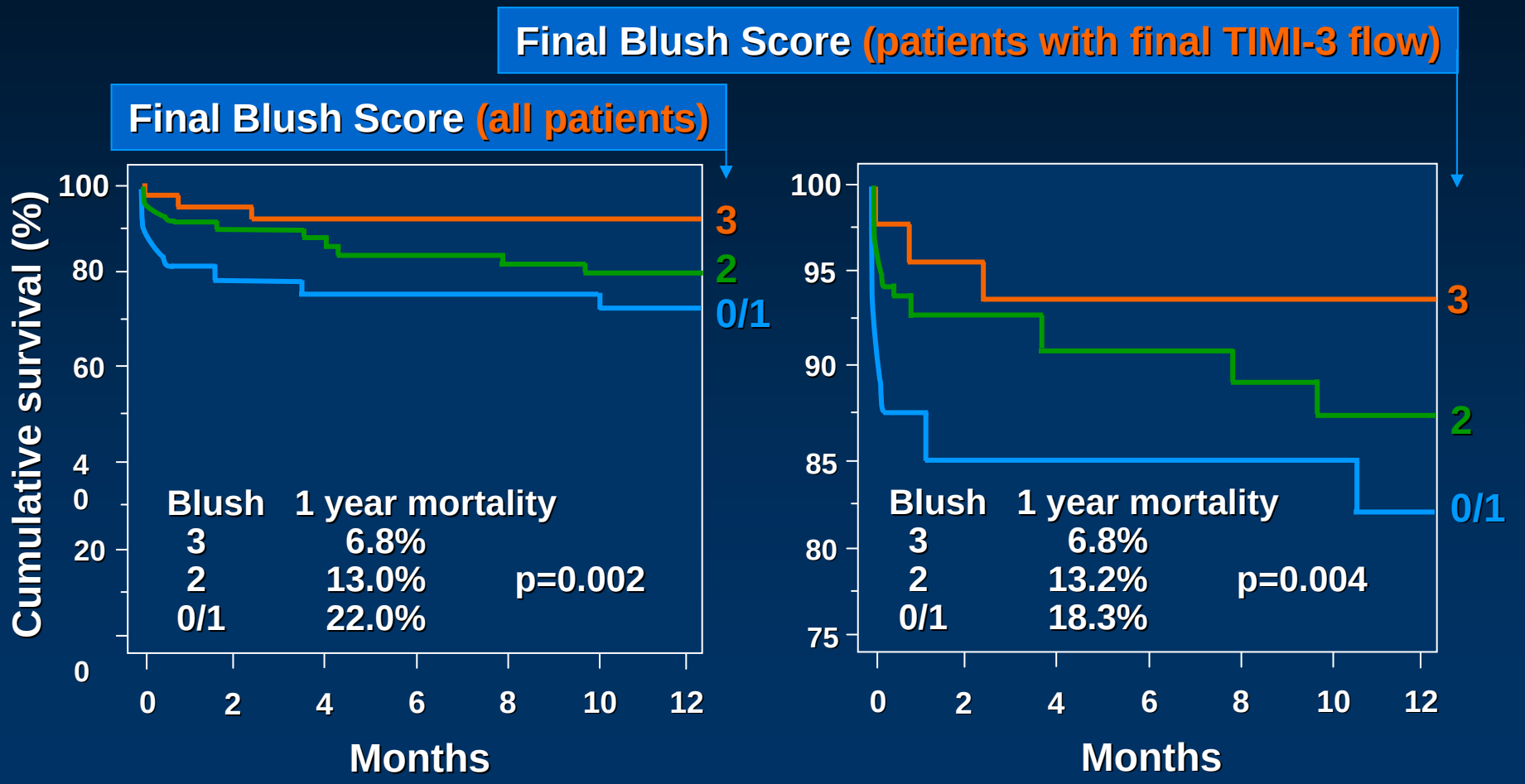
Myocardial Blush Scores

- Cumulative survival (1 yr) after PCI in 173 pts with AMI and in 163 patients in whom TIMI-3 flow was achieved.



Stone GW, et.al. *J Am Coll Cardiol* 2002;39:591

Myocardial Blush Scores

- Inter- and intraobserver variability of myocardial blush grades

		Differences		
	N	Agreement	1 Grade	2 Grades	3 Grades
Intraobserver variability	40	92.5%	7.5%	0%	0%
Interobserver variability	40	85.0%	12.5%	2.5%	0%

Stone GW, et.al. *J Am Coll Cardiol* 2002;39:591

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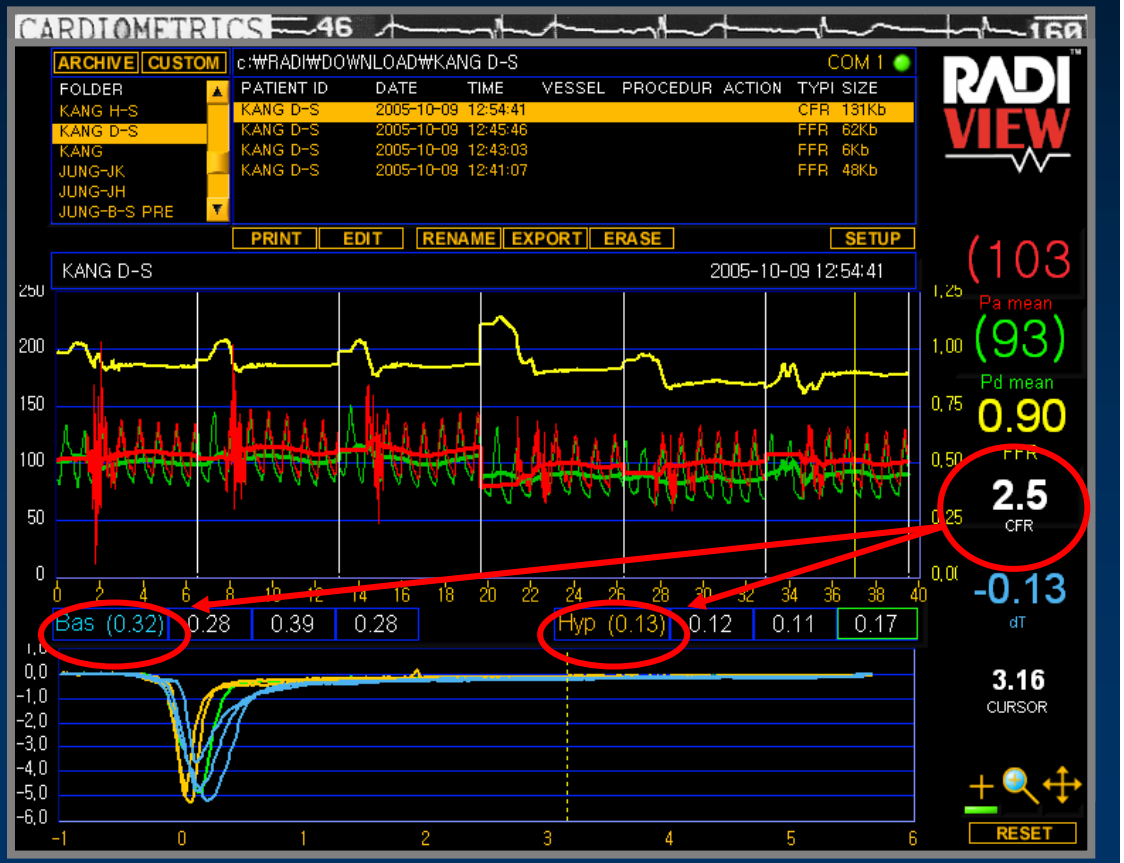
Coronary Flow Reserve(CFR)

- **CFR is defined as the ratio of maximal coronary blood flow at hyperemia and coronary blood flow at resting which means the reservoir capacity of microvascular circulation according to demand.**

- **CFR doppler**
  = hAPV X CSA / bAPV x CSA
  = hAPV / bAPV

- **CFR thermo**
  = mean bTMN / mean hTMN



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Invasive Measurement of CFR Following PCI in MI

	Pts no.	PCI time	Measuring CFR	Infarct location	Comparison	F/U
Lepper W. (Circulation 2000;101:2368)	25	Within 6 hours	Just after PCI and after 24 hours	LAD : 11 RCA : 14	MCE	1 month echo
Mazur W. (Am H J 1998;136:335)	29	6.9±3.4 D	Just after PCI	LAD : 15 LCX : 4 RCA : 10	Ventriculograms (LV RWMAs)	6-8 weeks echo
Teiger E. (Eur H J 1999;20:285)	22	16 ±4 D	Just after PCI	LAD : 10 RCA : 12	Thallium 201 SPECT	4 months ventriculogram
Beygui F. (J Am Coll Cardiol 2002;40:877)	41	Within 6 hours	Pre-discharge	LAD : 16 RCA : 25	Thallium 201 SPECT	6 months Thallium 201 SPECT
Feldman LJ (Circulation 2003;107:2684)	50	Within 12 hours	Just after PCI	LAD : 32	ST resolution Thallium 201 SPECT	
Shimada Y. (Circ J 2004;68:208)	37	Within 12 hours	3 weeks after PCI (pre-discharge)	LAD : 37	Ventriculograms (LVEDV)	3 wks, 6 months ventriculogram
Sezer M (Heart 2006;29)	41	Primary	Within 48 hours after PCI	LAD : 41	Hematologic indexes	.

CFR and LV Function Changes

	Reperfusion Group(n=13)	Nonreperfusion Group(n=12)	p
CFR after PCI	1.67±0.47	1.48±0.31	0.289
CFR at 24 hr follow-up	2.15±0.53	1.58±0.30	0.003

	Recovery Group(n=17)	Nonrecovery Group(n=8)	p
CFR after PCI	1.64±0.42	1.51±0.40	0.451
CFR at 24 hr follow-up	2.15±0.47	1.37±0.11	<0.001

Lepper W, et al. *Circulation* 2000;101:2368

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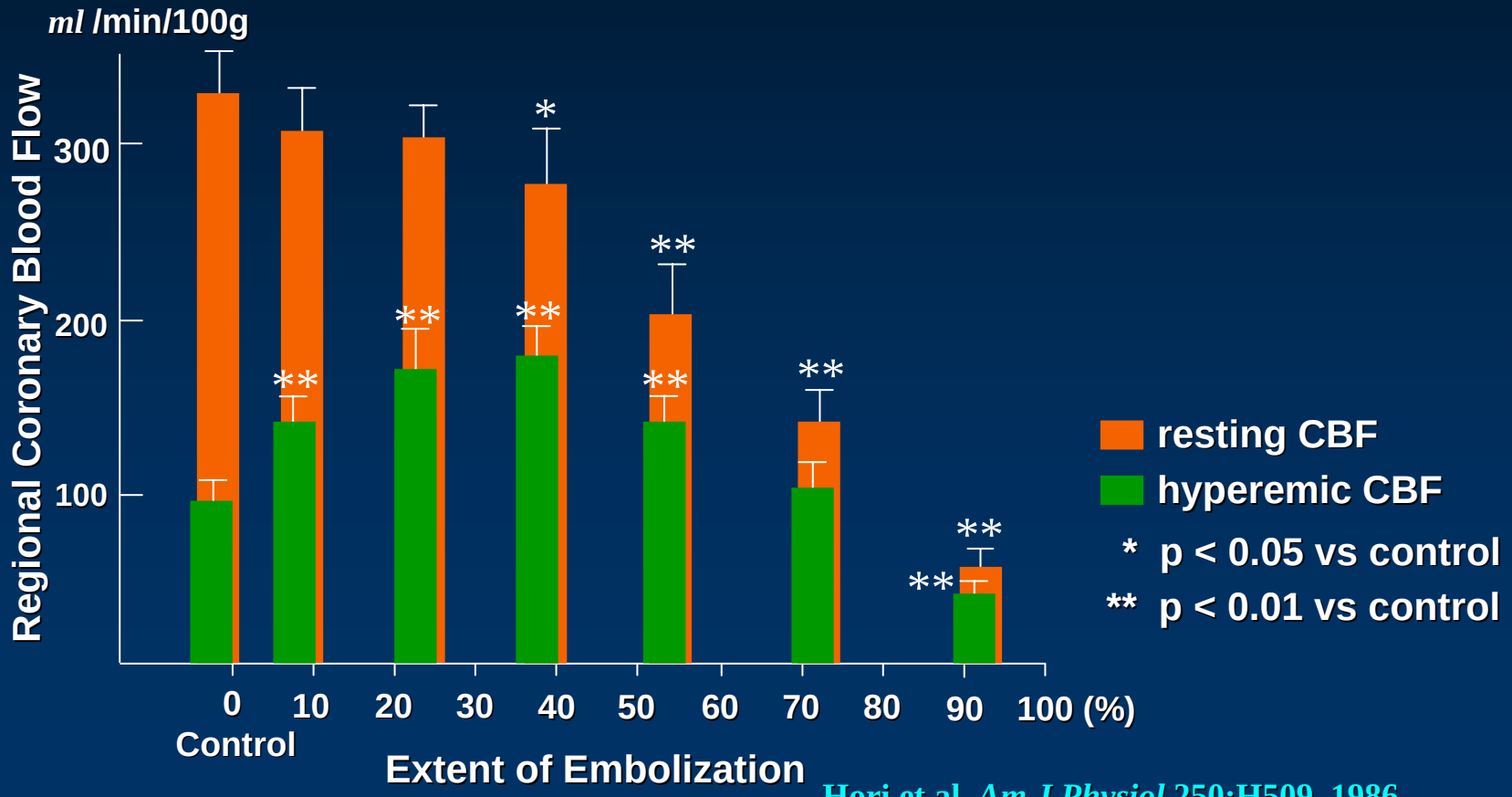
Physiologic Impact of Distal Embolization

- Open chest dogs embolized with microspheres 15, 100, 300 micron, up to 10^5/g of myocardium.
- Initial increase in resting flow (adenosine) but with blunting of hyperemia, and then reduction in resting flow as particulate burden increased.



Hori et al. *Am J Physiol* 250:H509, 1986

CFR and LV Function Changes

	CFR		p
	Recovery Group	Nonrecovery Group	
Lepper W.	2.15±0.53	1.58±0.30	0.003
Mazur W	1.74 ±0.15	1.42 ±0.15	0.07
Teiger E	2.3	1.7	<0.05

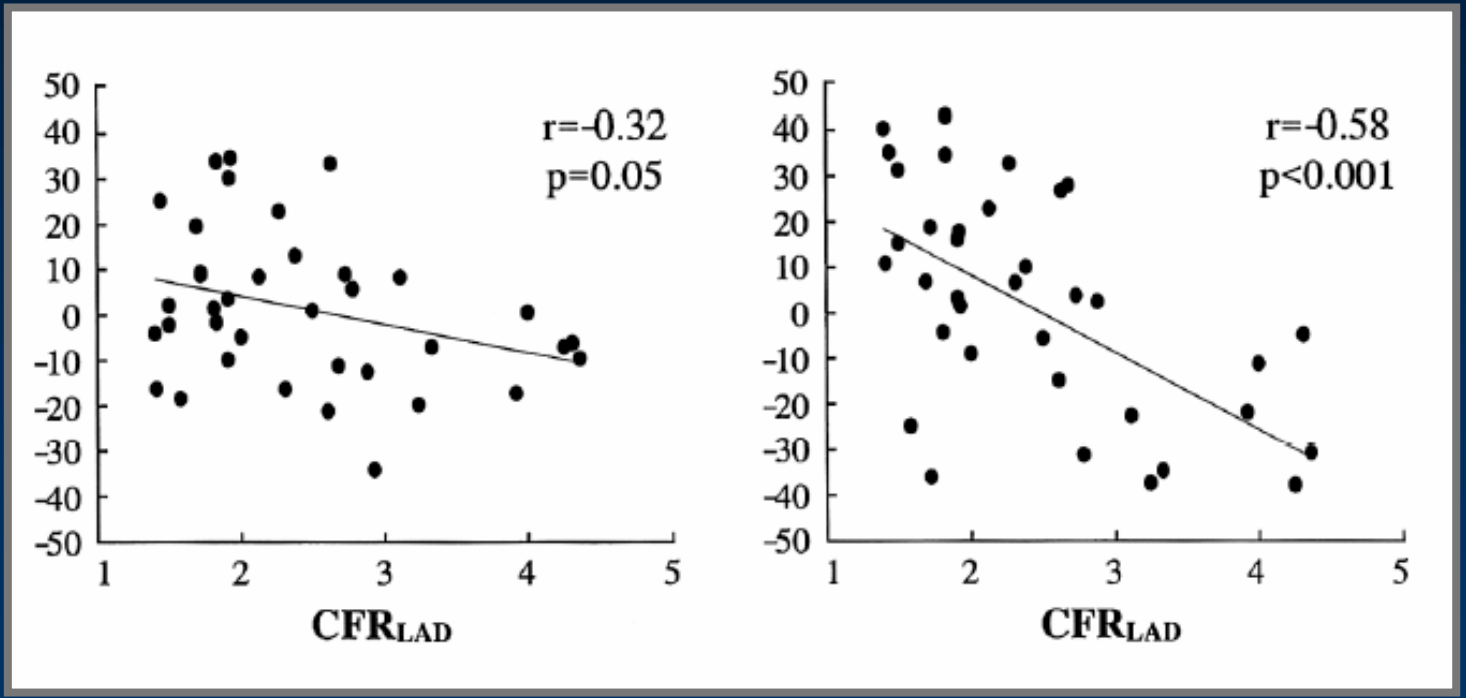
- **CFR at 24 hours after angioplasty** defines recovery and non recovery group on the cut-off value of 1.6.

Lepper W, et al. *Circulation* 2000;101:2368

CFR and LV Function Changes

- **Convalescent stage CFR and late myocardial morphologic outcomes**

Δ EDV% **Δ ESV%**



Shimada Y, et al. *Circ J* 2004;68:208-213

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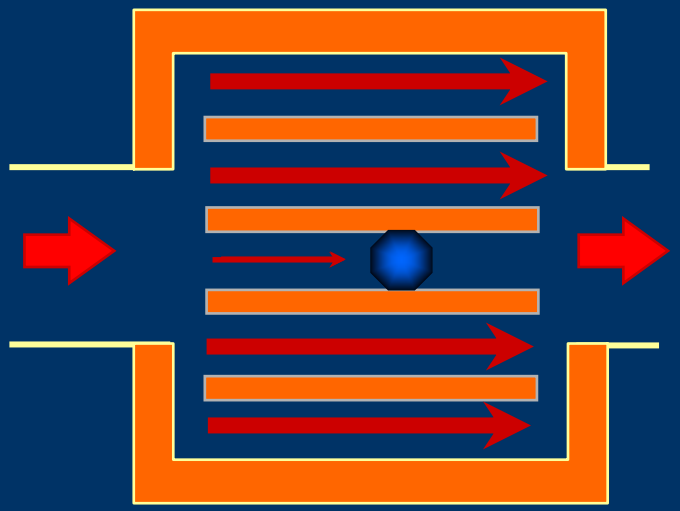
Microvascular Integrity and Coronary Blood Flow

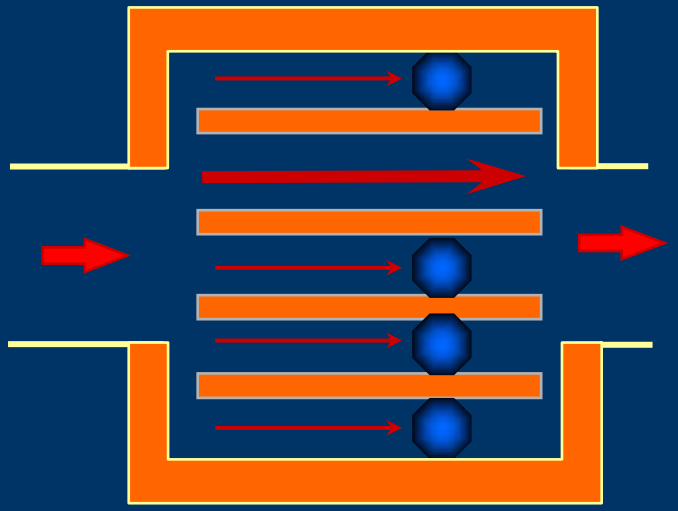
Mild myocardial damage

Diastole



Severe myocardial damage

Diastole



Iwakura. et al. *Circulation* 1996;94:1269-75

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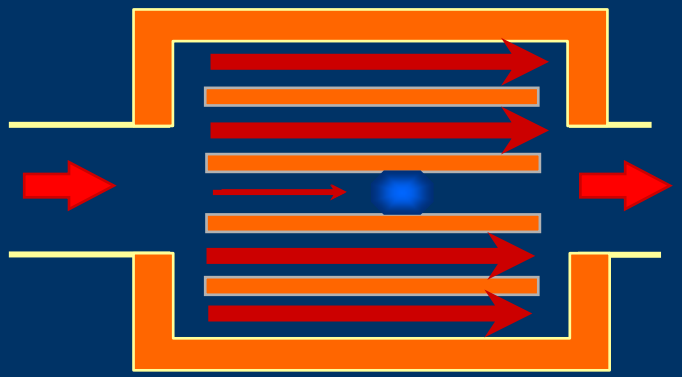
Microvascular Integrity and Coronary Blood Flow

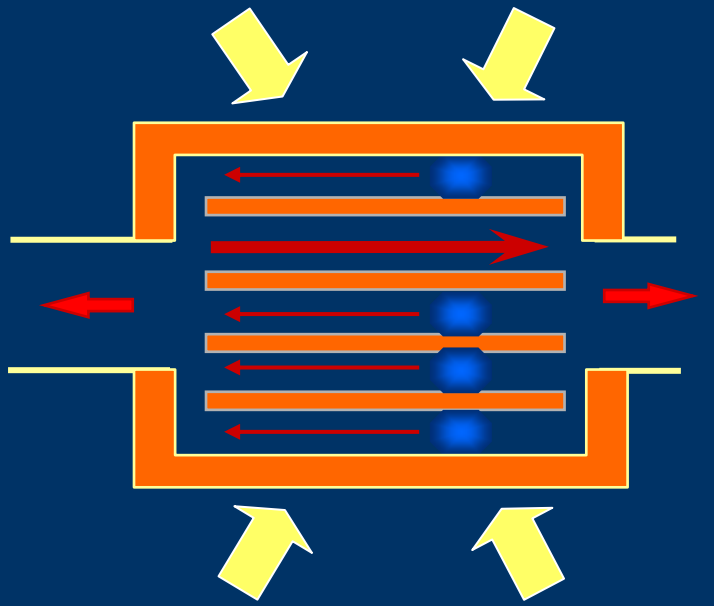
Mild myocardial damage

Systole



Severe myocardial damage

Systole



Iwakura. et al. *Circulation* 1996;94:1269-75

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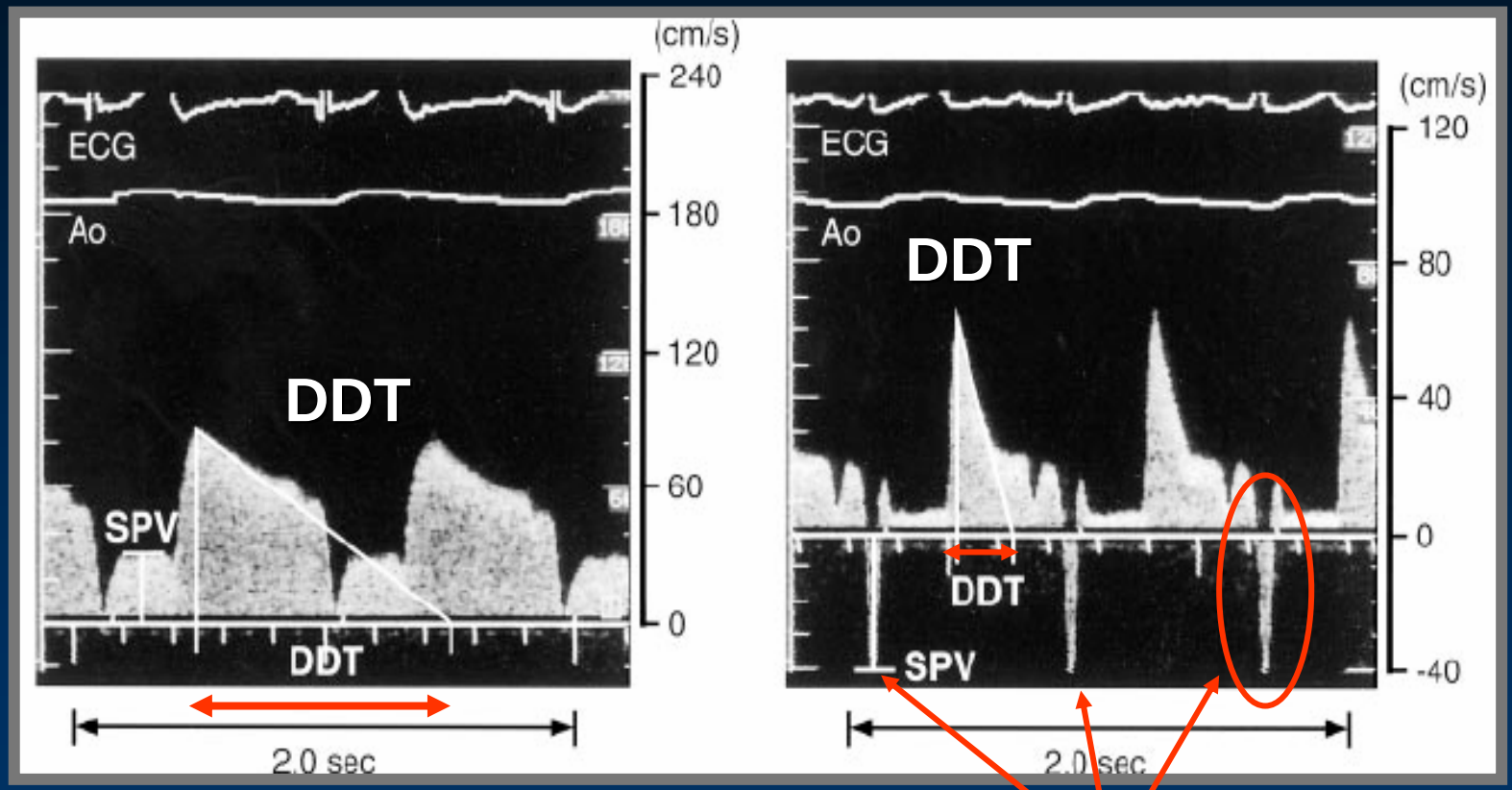
Coronary flow velocity patterns



Systolic reversal flow

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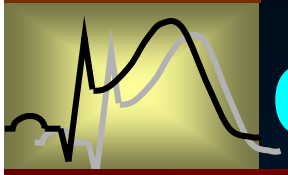

Coronary Flow Velocity Patterns

	Pts no.	Reperfusion time	Measuring flow patterns	Infarct location	Comparison	F/U
Yamamoto K. (J Am Coll Cardiol 2002;40:877)	105	About 9 hours	Just after PCI	LAD : 57 LCX : 9 RCA : 39	MCE TIMI grade	.
Iwakura K. (*Circulation.* 1996;94:1269)	42	?	Just after PCI	LAD : 28 LCX : 4 RCA : 10	MCE	.
Akasaka T (Circulation 1999;100:339)	23	Within 12 hours	Just after PCI	LAD : 23	RWMAs by Echo	1 month Echo
Lepper W (J Am Coll Cardiol	25	Within 6 hours	Just after PCI		MCE	1 month MCE
Okamura A (Am J Cardiol 2005;96:927)	72	Within 24 hours	Just after PCI	LAD : 72	Cardiac enzyme TIMI flow	.
Hoffmann R (Heart 2003;89:1147)	35	Within 6 hours	Just after PCI	LAD: 15 RCA: 20	TMPG	.
Furber AP (Circulation 2004;110:3527)	68	7.6 ± 7.0 h	Just after PCI	LAD : 36 LCX : 6 RCA : 30		MACE 3.8 yrs

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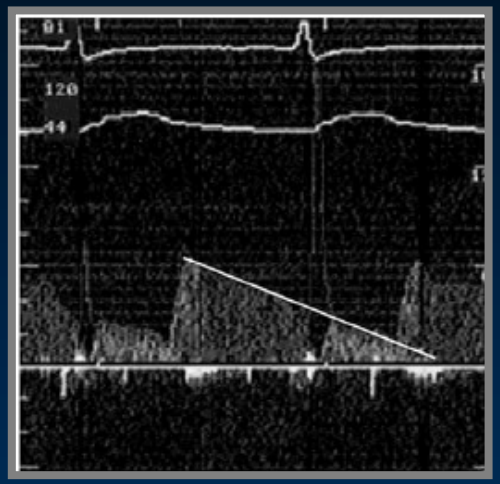
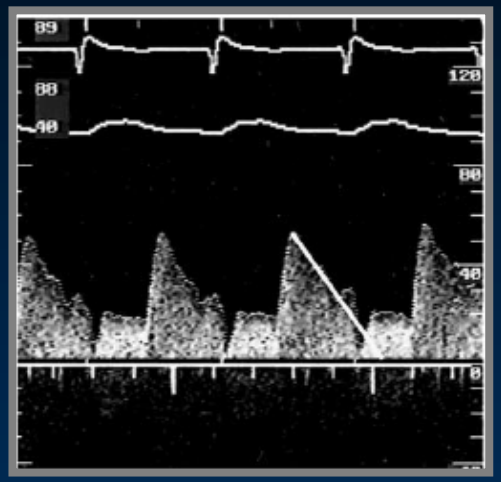
Coronary Flow Velocity Patterns

I DDT≥600msec, SFR(-), SAF(+)

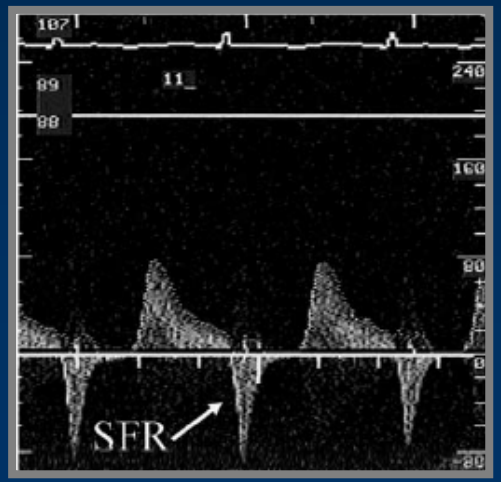


II DDT<600msec, SFR(-), SAF(+)

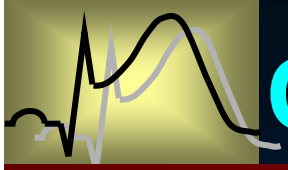


III DDT<600msec, SFR(+), SAF(+)

IV DDT<600msec, SFR(+), SAF(-)



Okamura A, et al. *Am J Cardiol* 2005;96:927



Coronary Flow Velocity Patterns

	Group			
	I (n=31)	II (n=17)	III (n=17)	IV (n=14)
Mean BP(mmHg)	92 ±11	107 ±25	94 ±14	91 ±17
Heart rate(b/min)	81 ±15	81 ±11	85 ±12	89 ±12
PCWP(mmHg)	10 ±8	13 ±8	16 ±7	17 ±7
Sx onset to reperfusion (h)	9 ±9	11 ±9	7 ±6	9 ±7
Peak CK(IU/L)	1385 ± 1339	3269 ± 2676	4053 ± 1385	6092 ± 4166
Good collaterals	65%	70%	59%	57%
TIMI after PCI	0/0/31	0/0/10	0/8/9	4/10/0
APV (cm/s)	28±15	23 ± 6	26 ±13	21 ±14
SAPV (cm/s)	21 ±12	17 ± 6	14 ±7	-
DDT (ms)	987 ±187	455 ±128	355 ±115	241 ±104

Okamura A, et al. *Am J Cardiol* 2005;96:927

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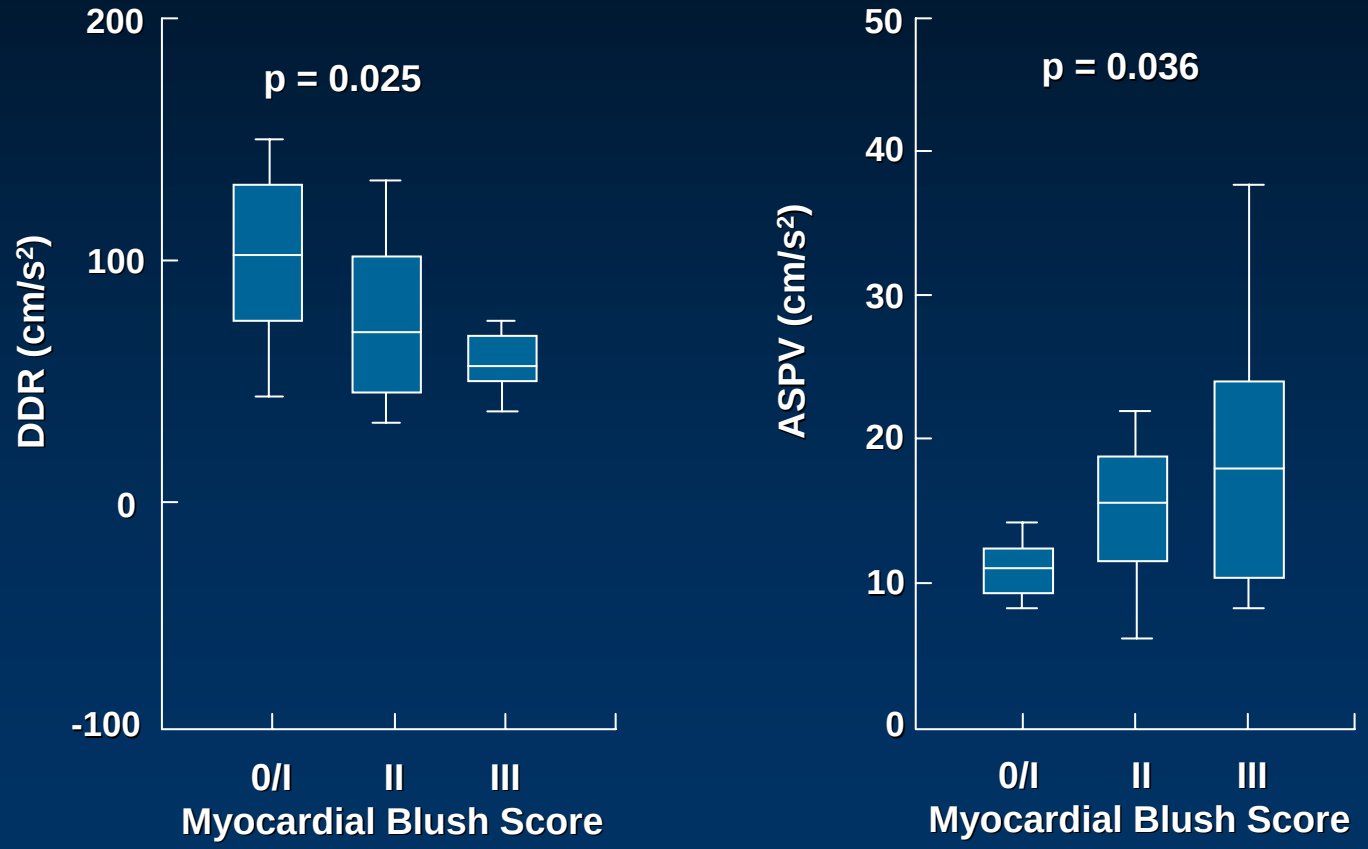
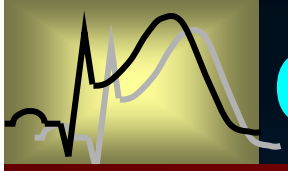
Coronary Flow Velocity Patterns

- Coronary flow velocity patterns between three perfusion levels defined by the myocardial blush grade



DDR: Diastolic deceleration ratio
ASPV: Average systolic peak velocity

Hoffmann R, et al. *Heart* 2003;89:1147



Coronary Flow Velocity Patterns

- Cardiac events in patients with and without no reflow defined by early retrograde systolic flow or a rapid diastolic deceleration time

Qualitative Aspect of Coronary Flow	ERSF, n (%) ERSF (n=20)	No ERSF (n=48)	P	Rapid DTT, n (%) Rapid DDT (n=31)	No Rapid DDT (n=37)	P
In-hospital events						
Cardiac death	3 (15.0)	0	0.02	3 (9.7)	0	NS (0.09)
Reinfarction	1 (5.0)	0	NS	1 (3.2)	0	NS
CHF	4 (20.0)	5 (10.4)	NS	7 (22.6)	2 (5.4)	0.04
Cardiac death± reinfarction± CHF	4 (20.0)	5 (10.4)	NS	7 (22.6)	2 (5.4)	0.04
Postdischarge events						
Cardiac death or transplantation	2 (11.8)	2 (4.2)	NS	1 (3.6)	3 (8.1)	NS
Reinfarction	0	0	. . .	0	0	. . .
CHF	6 (35.3)	7 (14.6)	NS (0.06)	10 (35.7)	3 (8.1)	0.01
Cardiac death± reinfarction± CHF	6 (35.3)	8 (16.7)	NS	10 (35.7)	4 (10.8)	0.02
All events during follow-up						
Cardiac death or transplantation	5 (25.0)	2 (4.2)	0.02	4 (12.9)	3 (8.1)	NS
Reinfarction	1 (5.0)	0	NS	1 (3.2)	0	NS
CHF	9 (45.0)	9 (18.8)	0.03	13 (41.9)	5 (13.5)	0.01
Cardiac death± reinfarction± CHF	9 (45.0)	10 (20.8)	0.04	13 (41.9)	6 (16.2)	0.02

ERSF indicates early retrograde systolic flow; DDT, diastolic deceleration time.

ESRF: Early reversal systolic flow
DTT: Diastolic deceleration time

Furber AP, et al. *Circulation* 2004;110:3527

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  : $CFR_{doppler}$, CFR_{thermo}
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  : IMR, MVRI
- Coronary Capillary Wedge Pressure
  : Pcw, Pcw/Pa, CFIp

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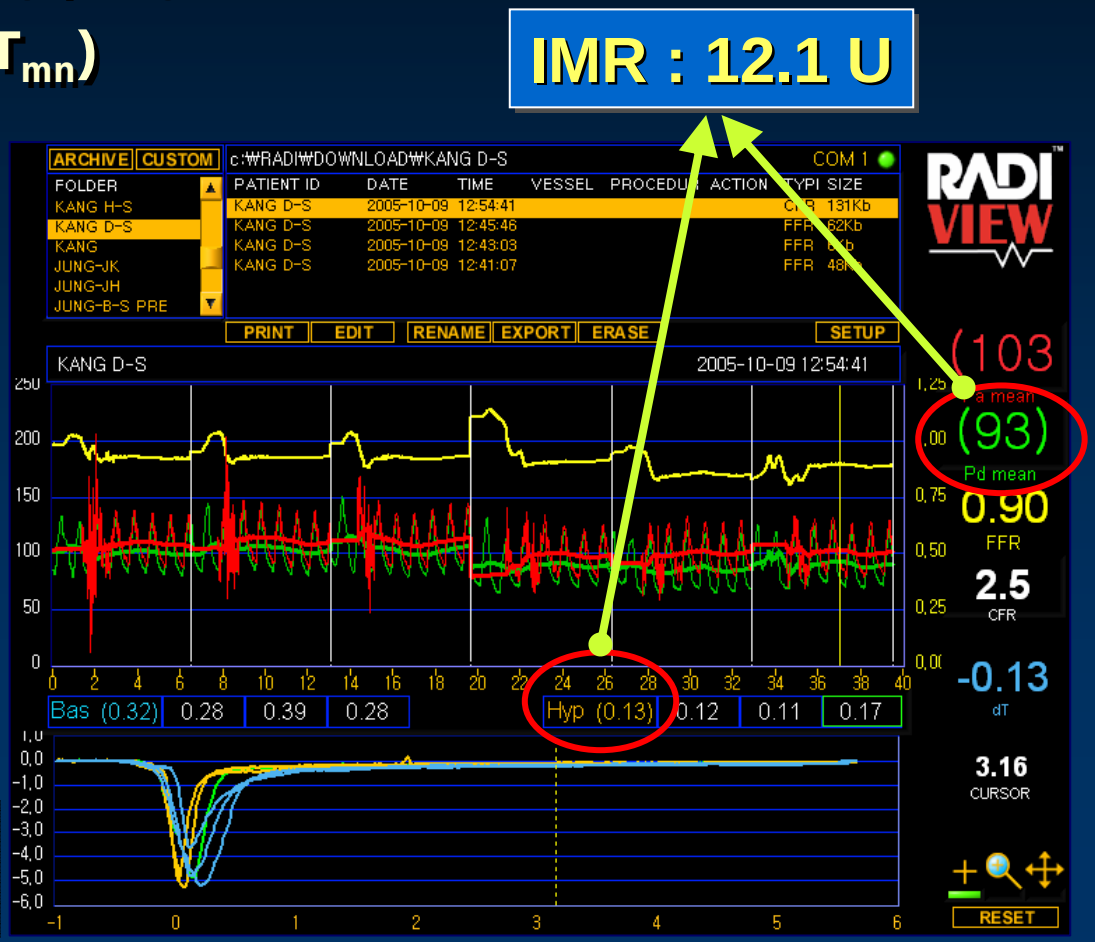
Index of Microvascular Resistance (IMR)

- **Derivation of Index of Microcirculatory Resistance (IMR)**
  - Resistance = Δ Pressure / Flow
  - IMR = $(P_d - P_v) / (1 / T_{mn})$
  - IMR = $P_d \times T_{mn}$
    at maximal hyperemia



Pd: coronary distal Pressure

Tmn: mean transit time

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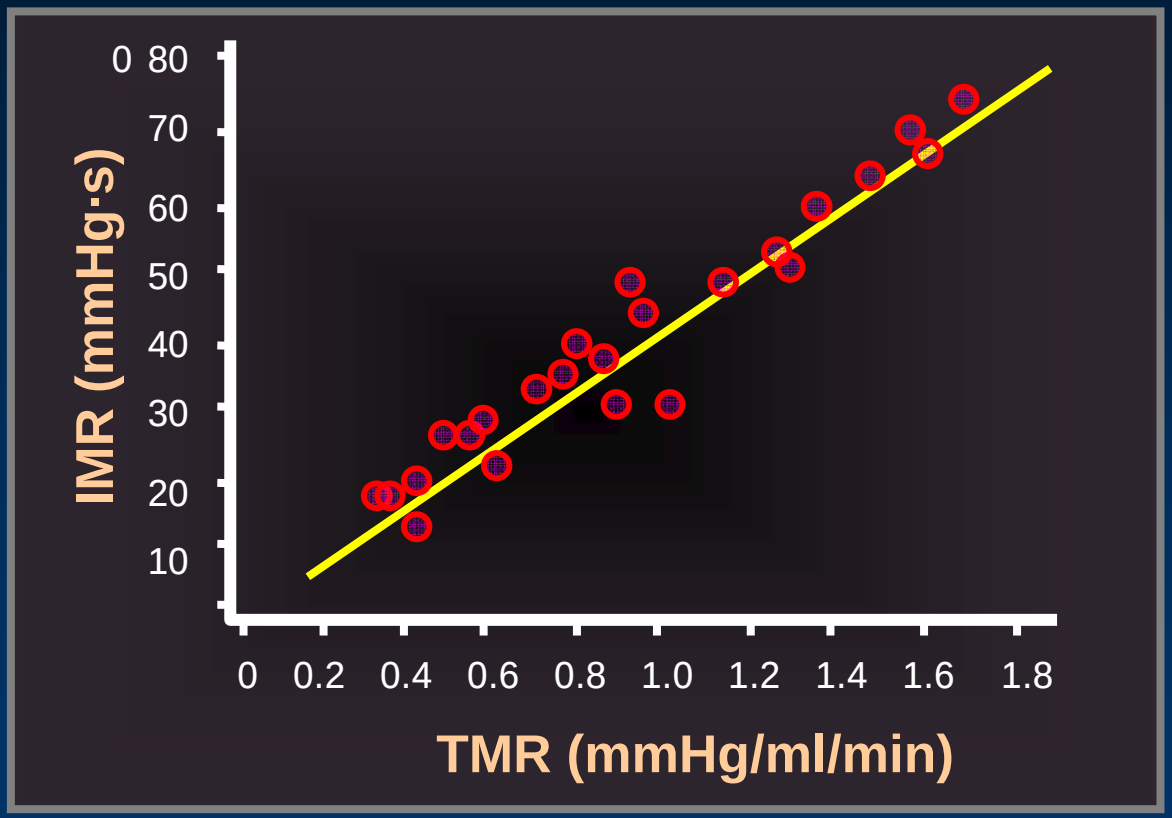
Index of Microvascular Resistance (IMR)

- Correlation between IMR and TMR
- IMR provides a more reproducible assessment of the microcirculation, which is independent of hemodynamic perturbations



Fearon W et al. *Catheter Cardiovasc Interv.* 2004;62:56
Fearon W et al. *Circulation.* 2003;107:3129

IMR and Microvascular Damages

- Twenty-seven patients with STEMI treated with primary stenting.

	IMR	
	r	p
Peak CK	0.54	0.004
Neutrophil %	0.52	0.01
TMPG	-0.42	0.03
TFG	-0.44	0.03
CFR	-0.43	0.03
cTFC	0.54	0.004

- IMR above the median level of 35 had greater peak CK (3387±1531 vs. 1209±966 IU, p=0.03)

Fearon W et al. Abstracts, *Circulation* 2006;II-586

IMR and LV Functional Changes

- Forty-one patients with AMI treated with primary angioplasty.
- LV systolic(ESV) and diastolic volume(EDV) of 32 patients were measured at six months.

	IMR	
	r	p
ESV	0.66	<0.001
EDV	0.69	<0.001

- BCV of IMR for predicting LV EF was 24.5 U (sensitivity 78%, specificity 88%)

Sezer M, et al. Abstracts, *Circulation* 2006;II-587

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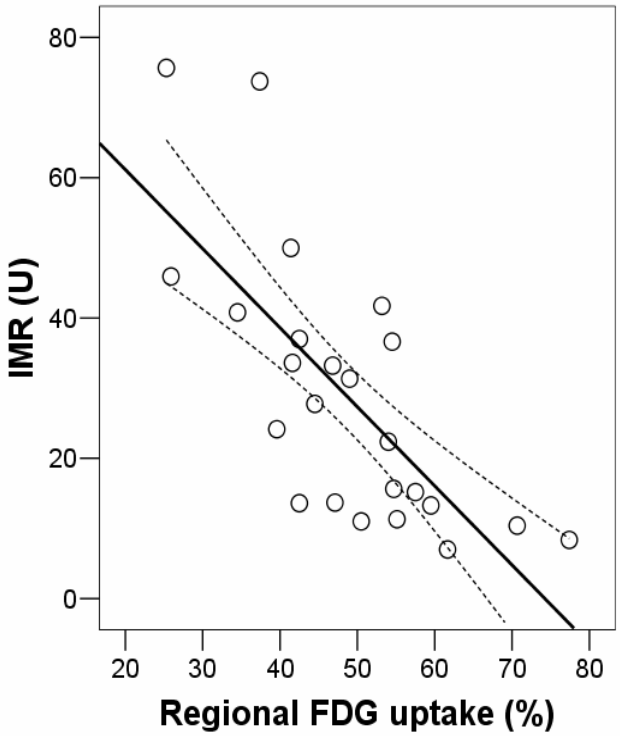
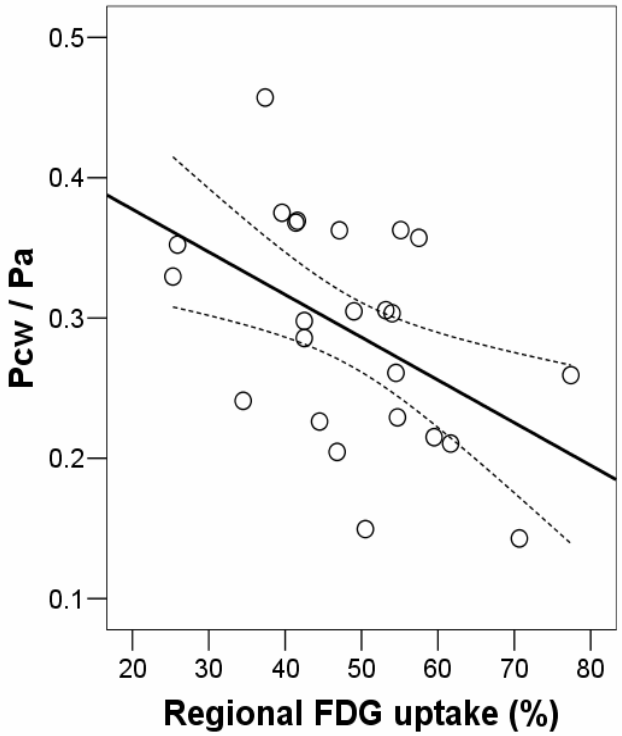
IMR and Cardiac PET

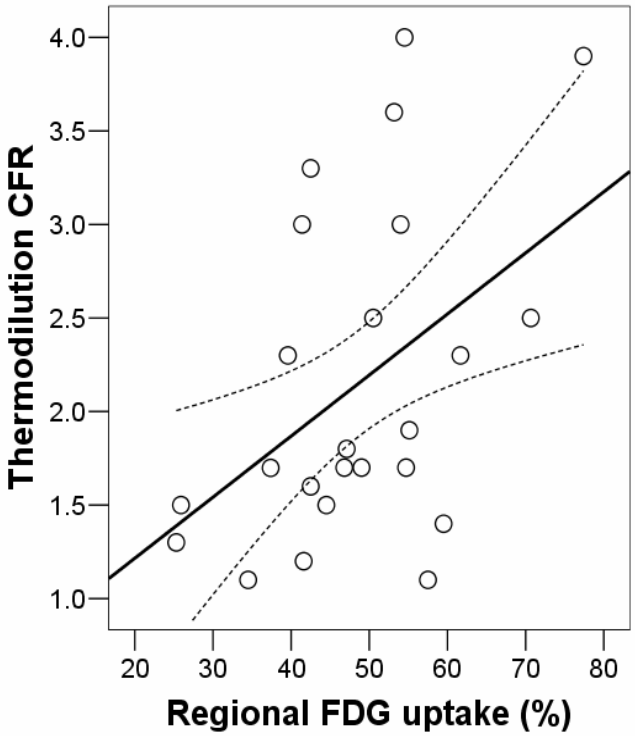
- Correlation between IMR and FDG uptake rate by Cardiac PET
- Twenty-four patients with STEMI treated with primary PCI was studied.



r = -0.696
p < 0.001



r = -0.480
p = 0.018



r = 0.454
p = 0.026

Tahk SJ, et al. *Korean Circulation* 2006;36(suppl II)

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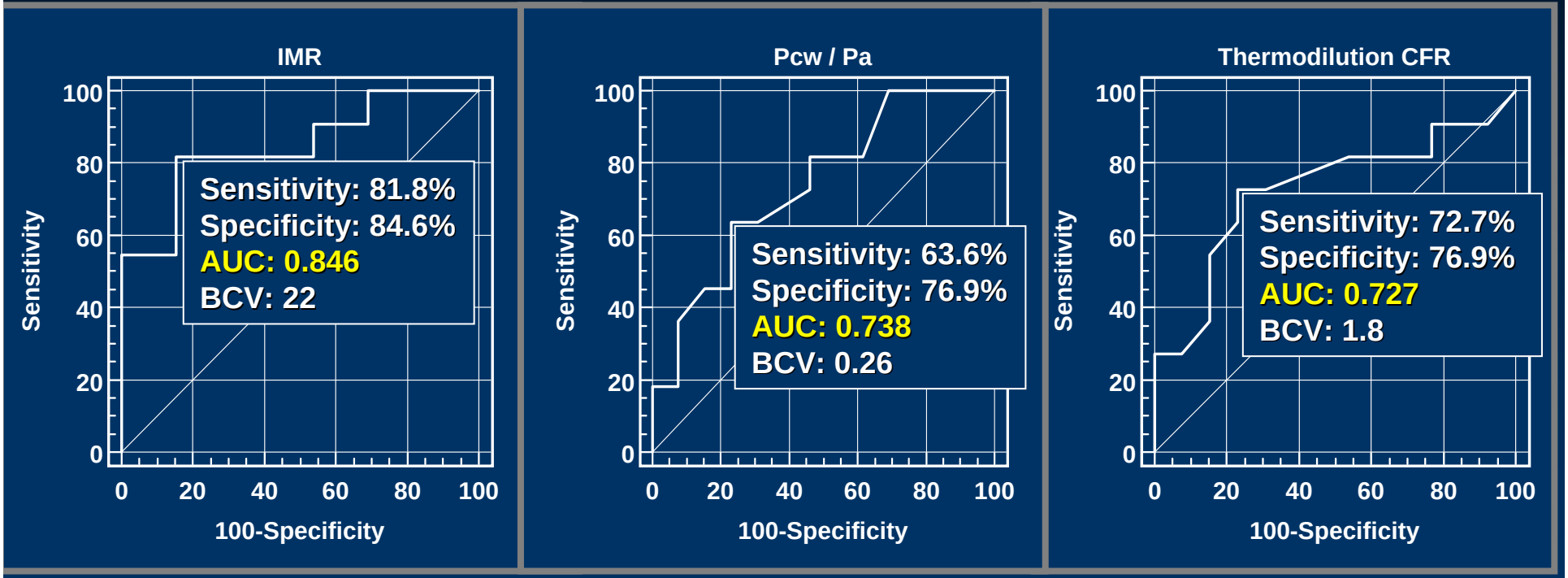
IMR and Cardiac PET

- Accuracy of IMR for predicting viability (50%>FDG uptake rate)



AUC: Area under the Curve
BCV: Best Cutoff Value

Tahk SJ, et al. *Korean Circulation* 2006;36(suppl II)

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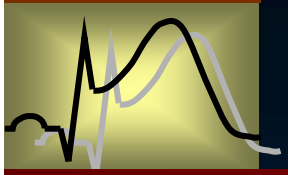

Coronary Wedge Pressure

	Pts no.	Reperfusion time	Measuring flow patterns	Infarct location	Comparison	F/U
Yamamoto K. (J Am Coll Cardiol 2001;38:1383)	48	Within 24 hours	Just after PCI	LAD : 31 Others : 17	MCE	28 D LV Ventriculogram
Shimada et al. (Heart 2003;38:71)	27	Within 12 hours	Just after PCI	LAD :27	PET	1, 6 M Echo.
Ito et al. (Am J Cardiol 2004;94:209)	48	Within 24 hours	Just after PCI	LAD :48	RWMAs by Echo	3 month Echo
Lee CH (J Am Coll Cardiol 2000;35:949)	70	Within 12 hours	Just after PCI	LAD: 43 LCX: 4 RCA: 23	RWMAs by Echo	1 month Echo
Sezer M. (Heart 2004;90:146)	33	Within 6 hours	Just after PCI	LAD: 22 LCX: 7 RCA: 4	ECG resolution	.

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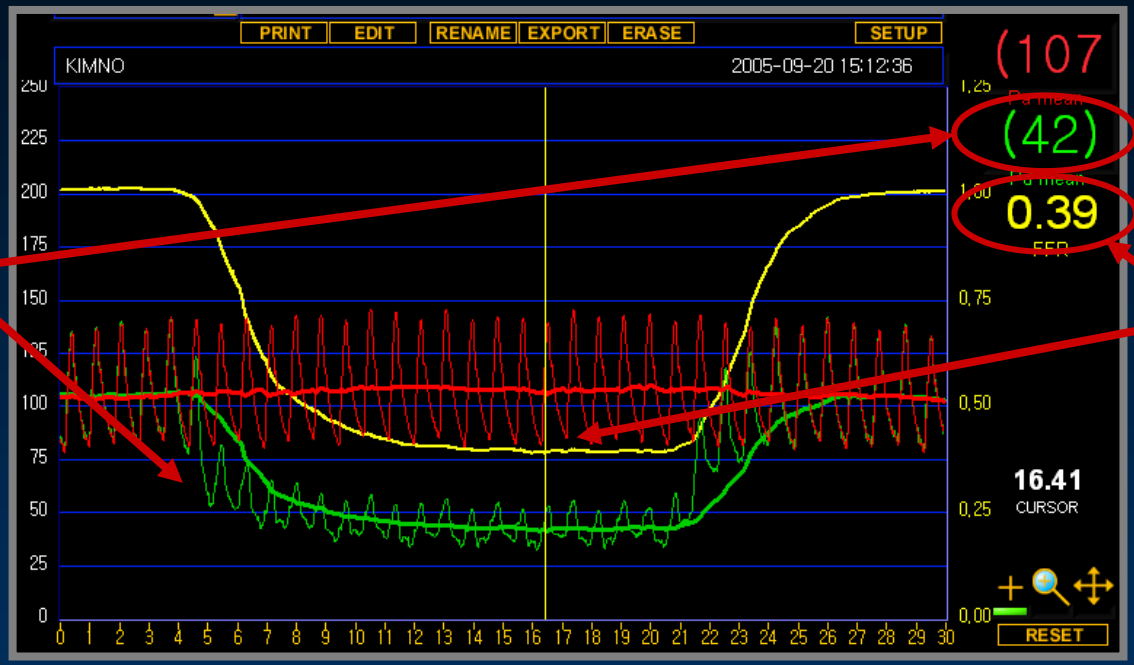
Coronary Wedge Pressure



- **Coronary Wedge Pressure (Pcw)**
  - The distal coronary artery wedge pressure during balloon occlusion
- **Pressure derived Collateral Flow Index (CFIp)**
  - (Pcw – Pv) / (Pa – Pv)
  - simplified by Pcw / Pa

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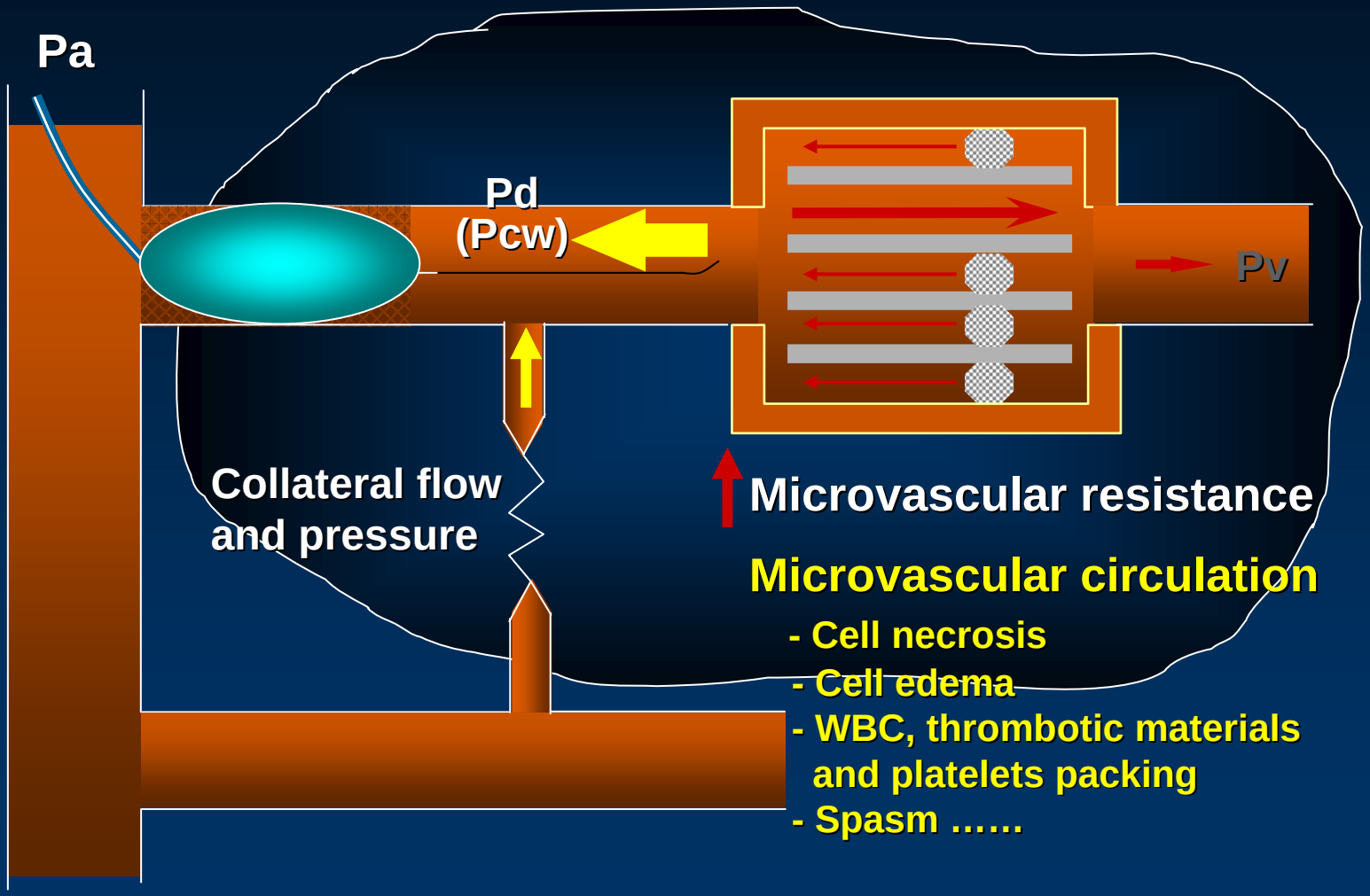
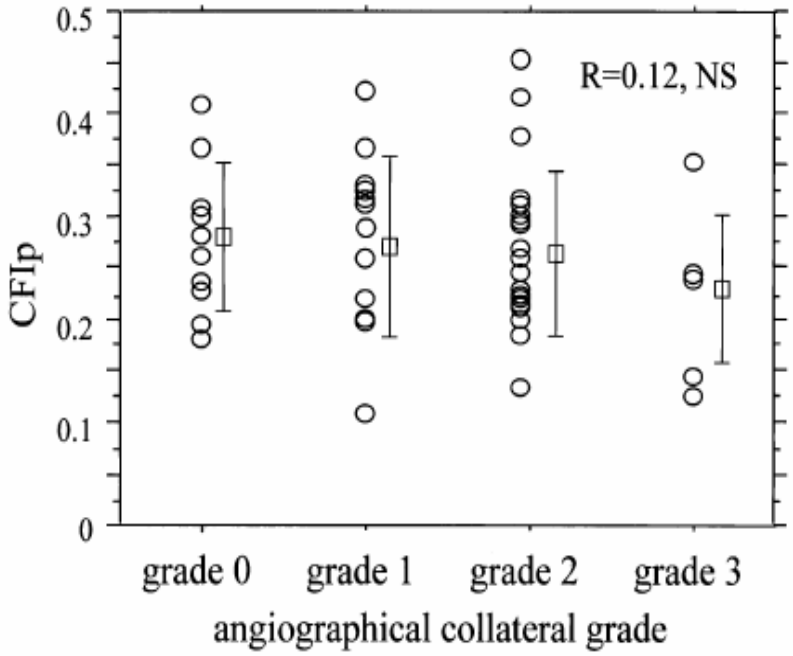
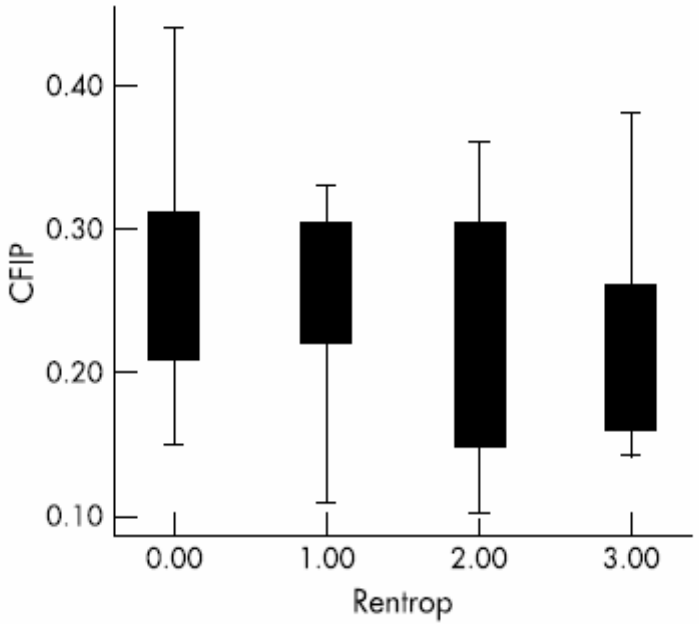
Coronary Wedge Pressure Collateral Flow in AMI



Coronary Wedge Pressure

- Comparison of pressure-derived collateral flow index(CFIp) among angiographically collateral grades in AMI with PCI within 12 hours.

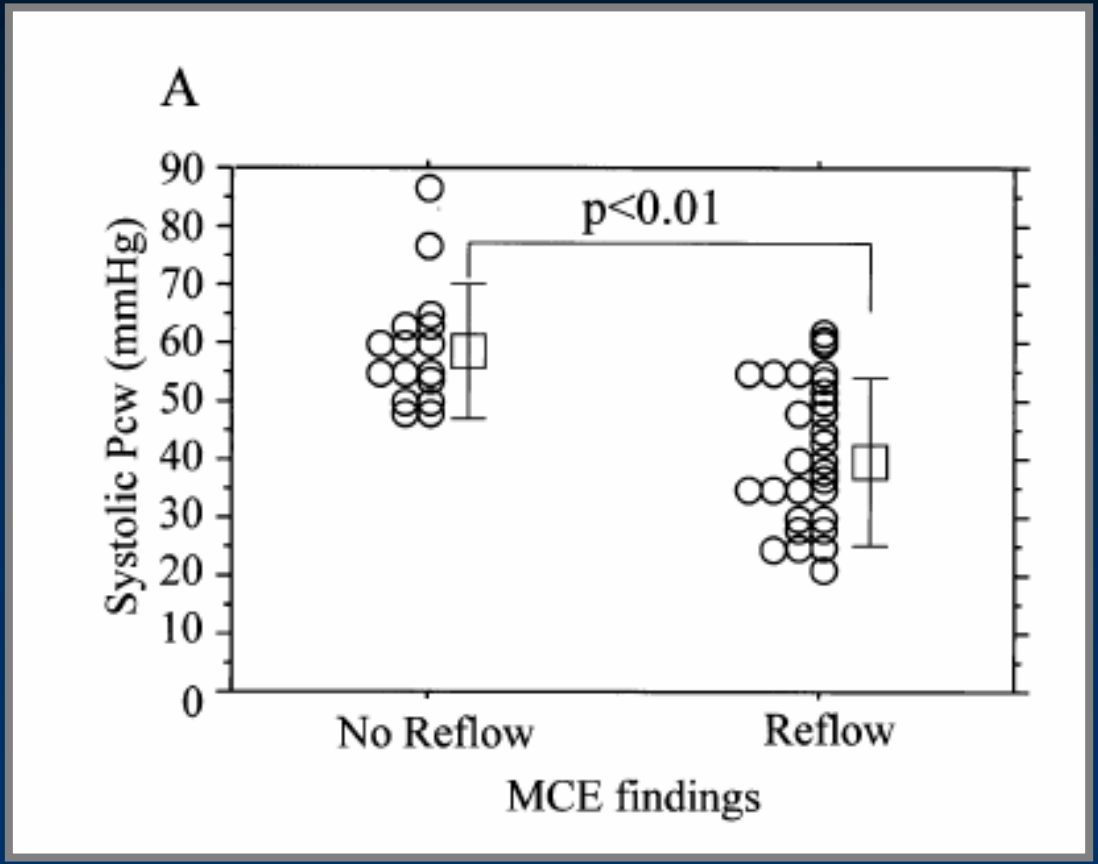




Yamamoto, et al. *J Am Coll Cardiol* 2001;38:1383
Sezer M, et al. *Heart* 2004;90:146

Coronary Wedge Pressure

- Comparison of peak systolic Pcw and end diastolic Pcw in AMI with PCI within 12 hours



Yamamoto, et al. *J Am Coll Cardiol* 2001;38:1383

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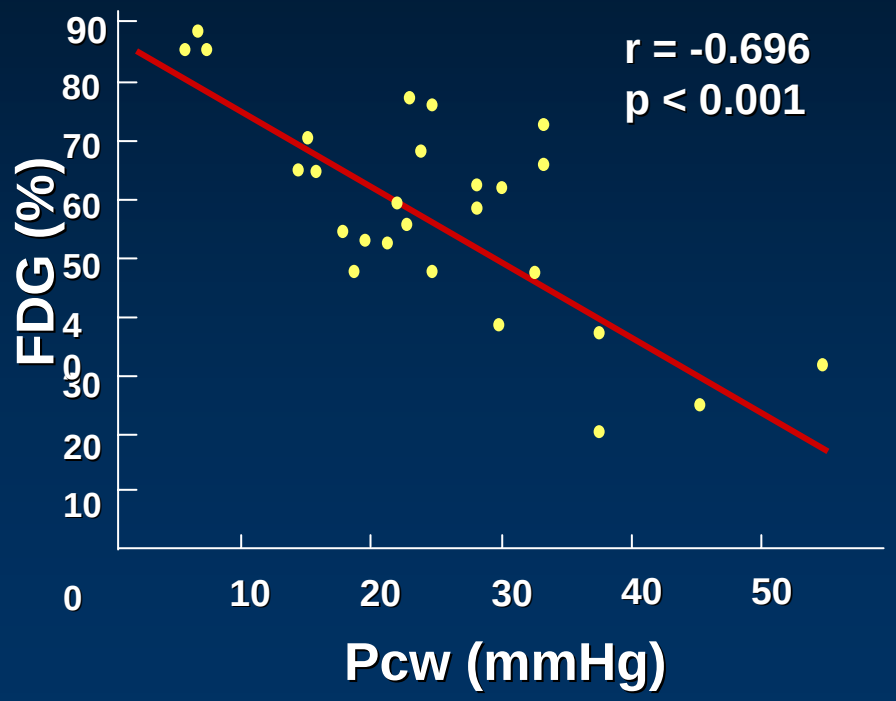
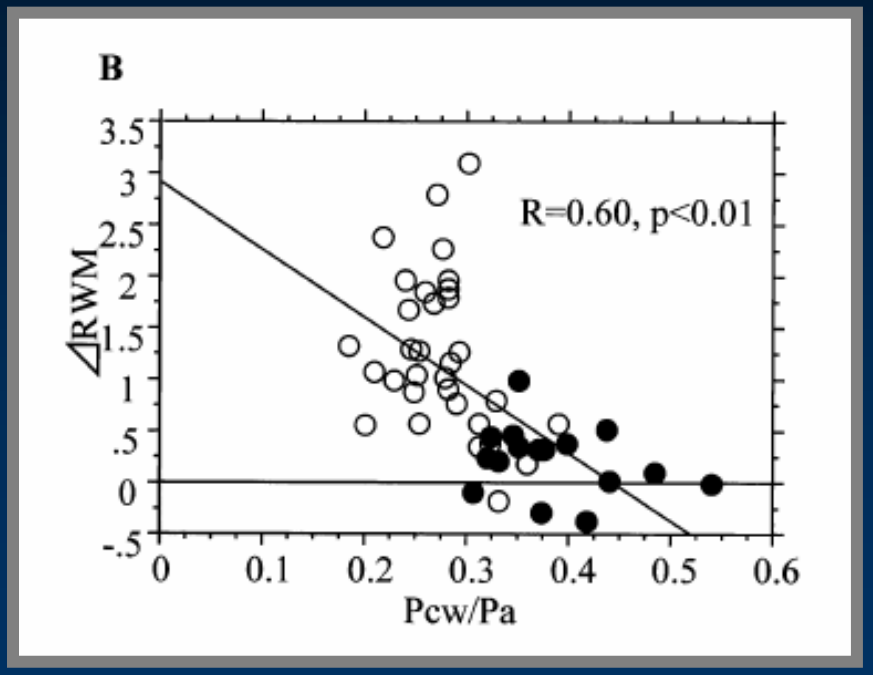
Coronary Wedge Pressure

- Relationship between Pcw and % FDG uptake, wall moton chandes



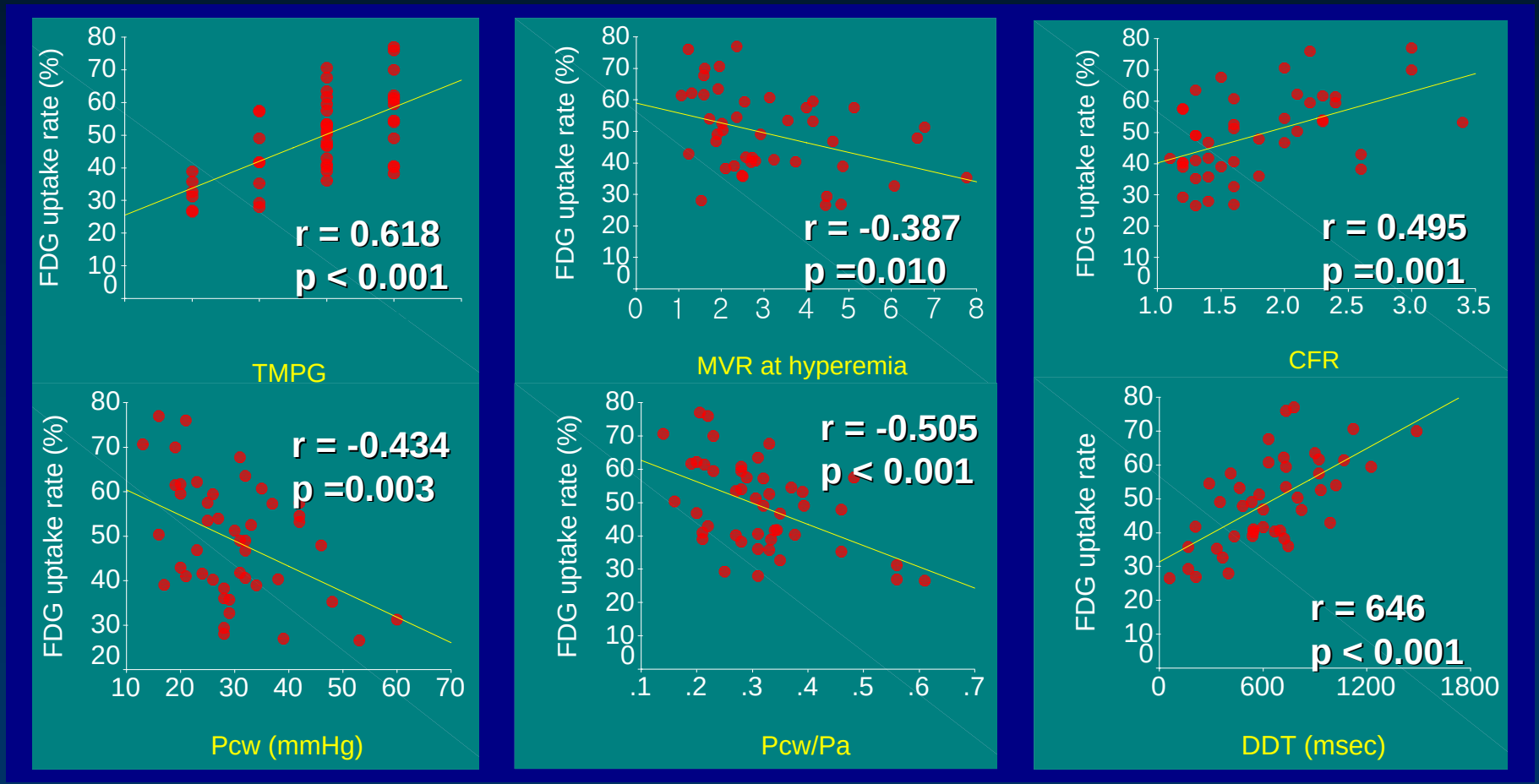


Yamamoto, et al. *J Am Coll Cardiol* 2001;38:1383
Shimada, et al. *Heart* 2003;38:71-6

CPIS 2007

Correlation of Microvascular Integrity Indexes with FDG PET

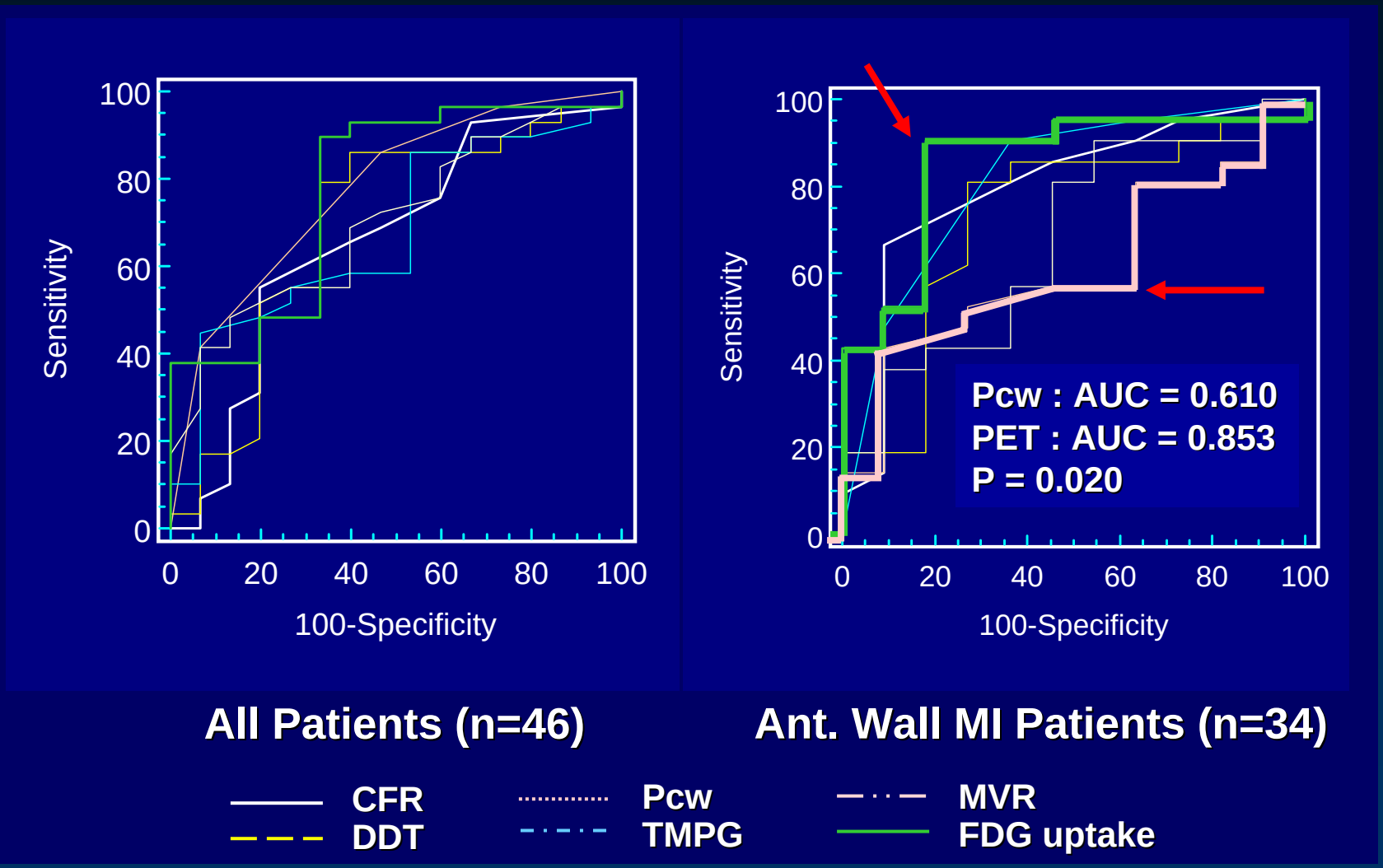
- **Forty-six patients with STEMI treated with primary PCI and follow up echocardiography at 6 months was studied.**



Yoon MH, et al. *Korean Circulation* 2006;36:701

CPIS 2007

Comparison of the Accuracy for Predicting LV Wall Motion by ROC Curve



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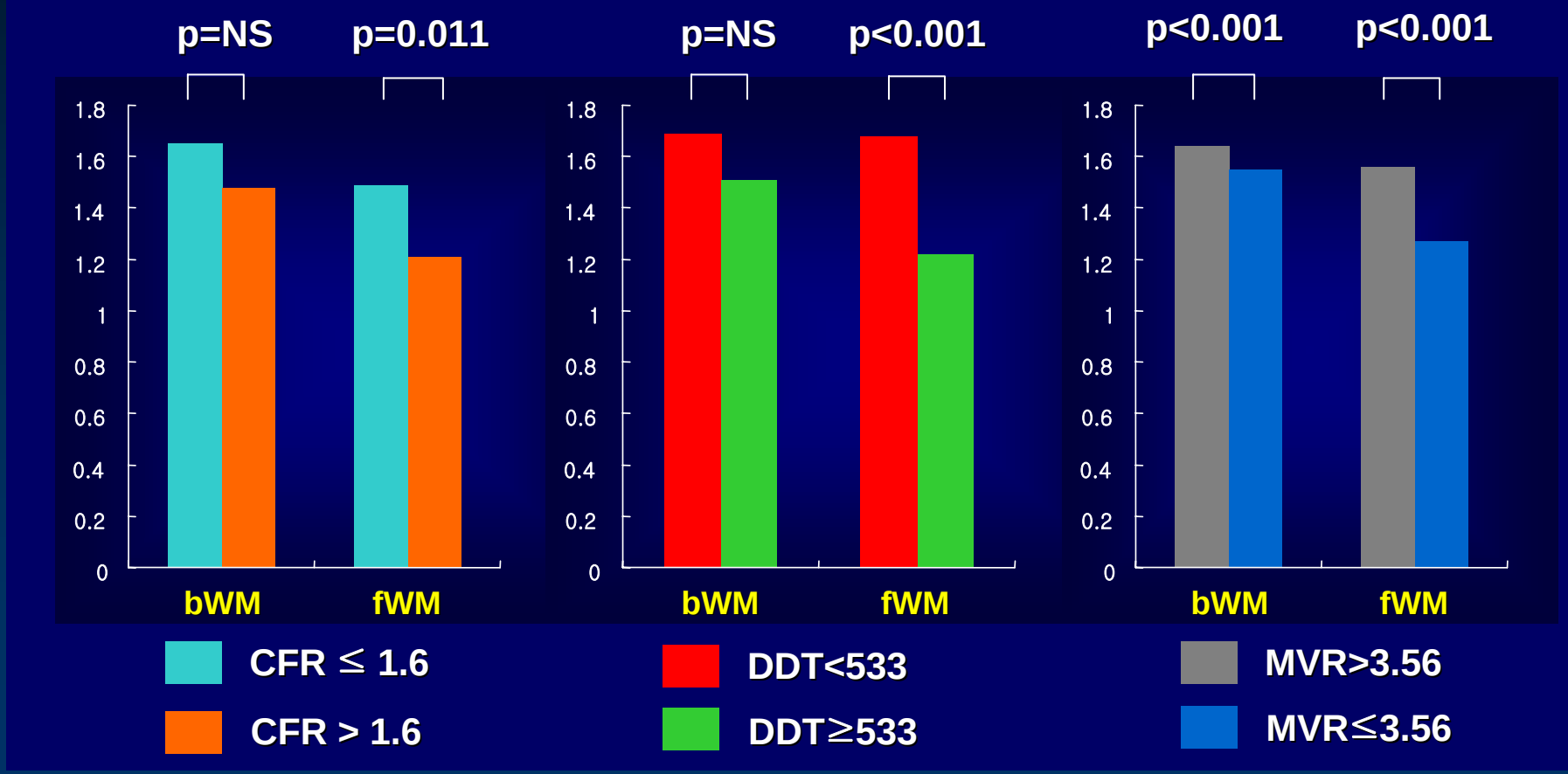
Comparison of the Wall Motion Improvement

- Comparison the LV wall motion recovery in patients divided into two groups by BCV



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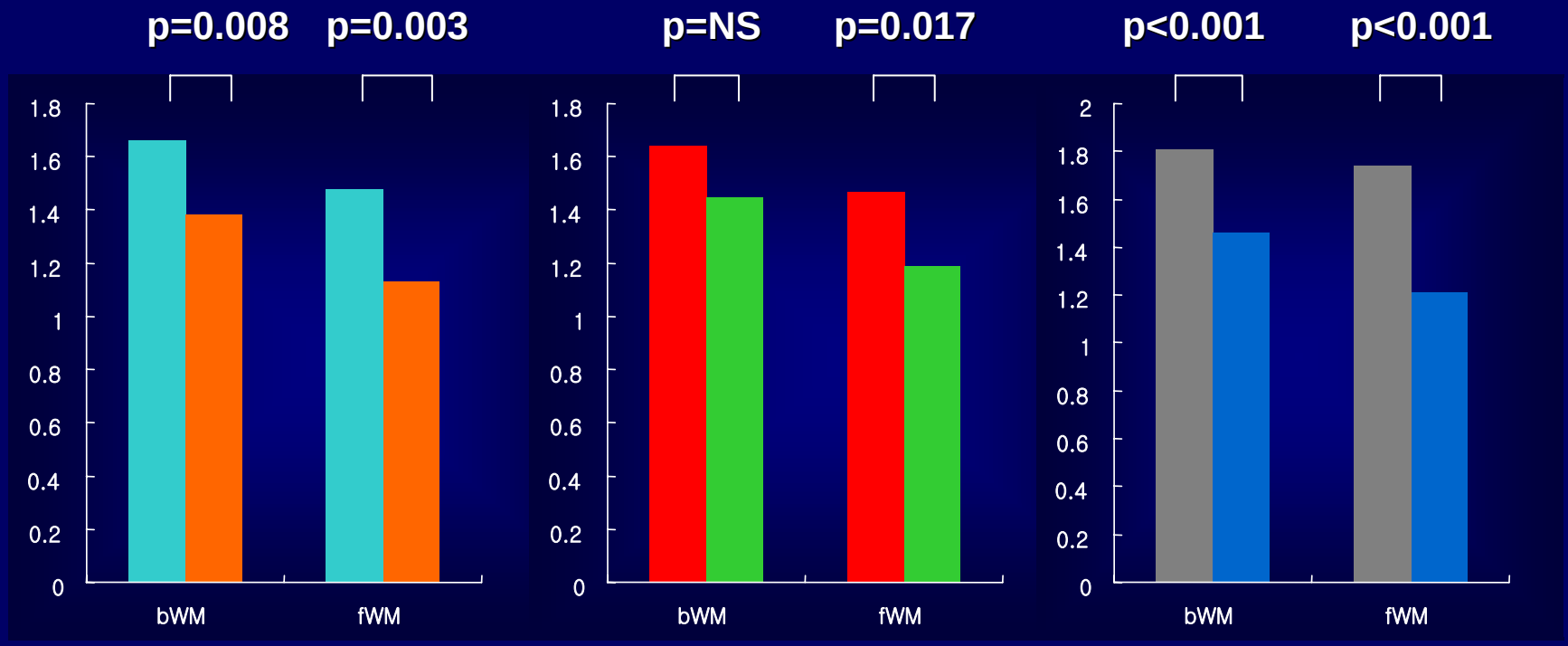
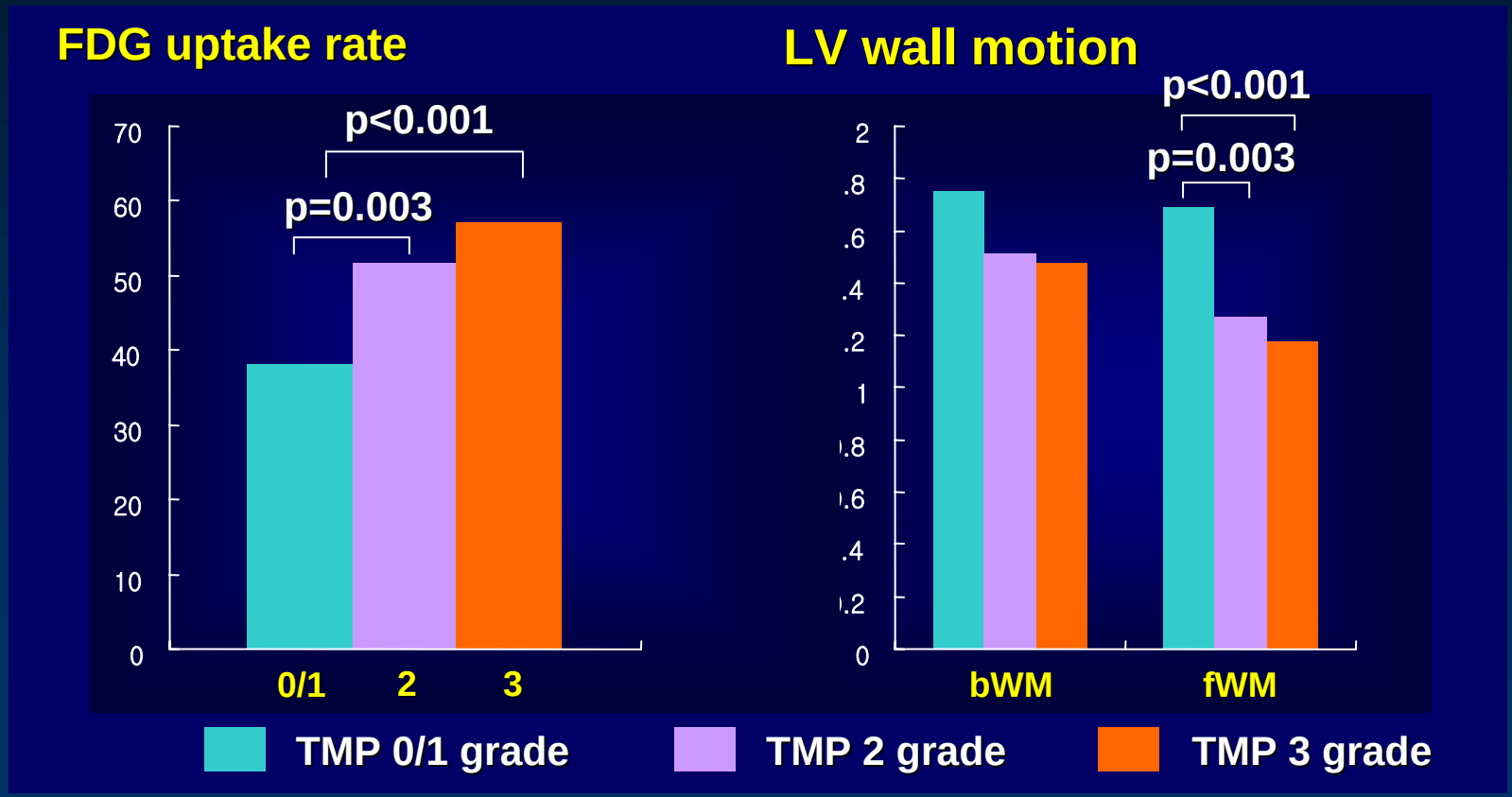
Comparison of the Wall Motion Improvement

- Comparison the LV wall motion recovery in patients divided into two groups by BCV

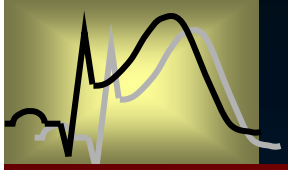


Comparison of the FDG Uptake and LV Wall Motion According to TMPG

- Correlation TMPG and FDG uptake rate and wall motion improvement



Tahk SJ, et al. *Circulation* 2006;114:II:II-784
Tahk SJ, et al. *Korean Circulation* 2006;36(suppl II)



Limitations

- Although, there are little studies about the **IMR**, it might be an excellent index for predicting microvascular integrity in AMI regardless of the patient's hemodynamic status.
- The **CFR** might be a good index for predicting microvascular integrity, however, it was affected by patient's hemodynamics and baseline flows after primary PCI in acute stage of AMI.
- Further study will be required about the effect of collateral flows on the **Pcw** in acute stage of AMI.
- Although, the **TMPG** is a subjective index, it might be a simple and useful index for predicting microvascular integrity.

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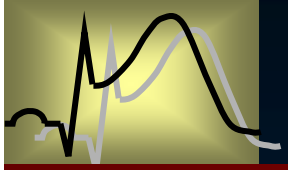

Conclusion

- **Indexes of microvascular integrity**, such as CFR, Coronary flow patterns(DDT), MVR index, Pcw/Pa, and TMPG, which are measured during primary PCI in AMI, **are comparable with FDG PET for predicting the LV functional changes.**