What would be the Optimal IVUS Criteria to Predict Functional Significance?

Akiko Maehara, MD

Cardiovascular Research Foundation/Columbia University Medical Center, New York

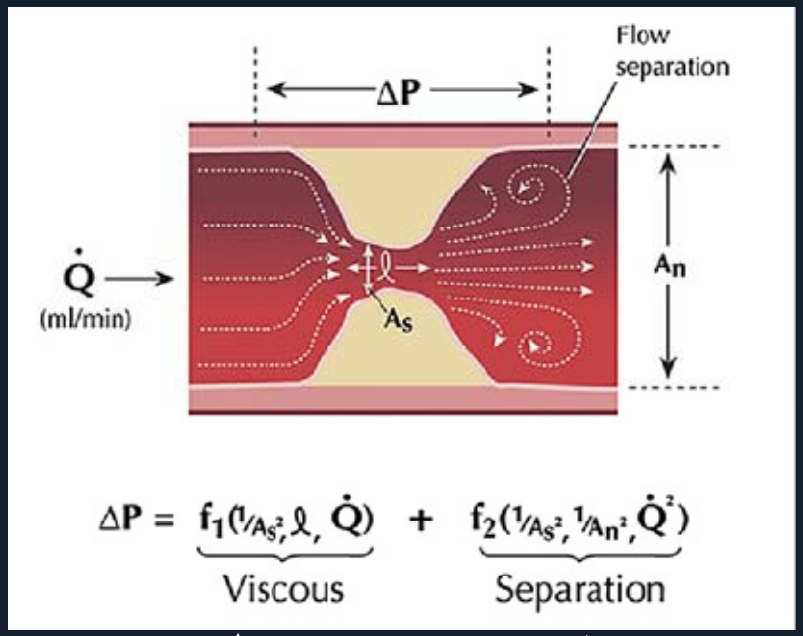
CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell

How much blood does the ROI (region of interest) need to supply distal to the ROI?

1. Distal RCA 80% stenosis→ FFR>0.8
2. Mid LAD 80% stenosis with good flow via bypass to distal LAD → FFR>0.8
3. RCA mid 40% stenosis which gives collateral flow for LAD CTO → FFR<0.8
4. Proximal LAD 60% stenosis → FFR<0.8

Main Determinants for Pressure Drop



Law of Poiseuille ***Law of Bernoulli***

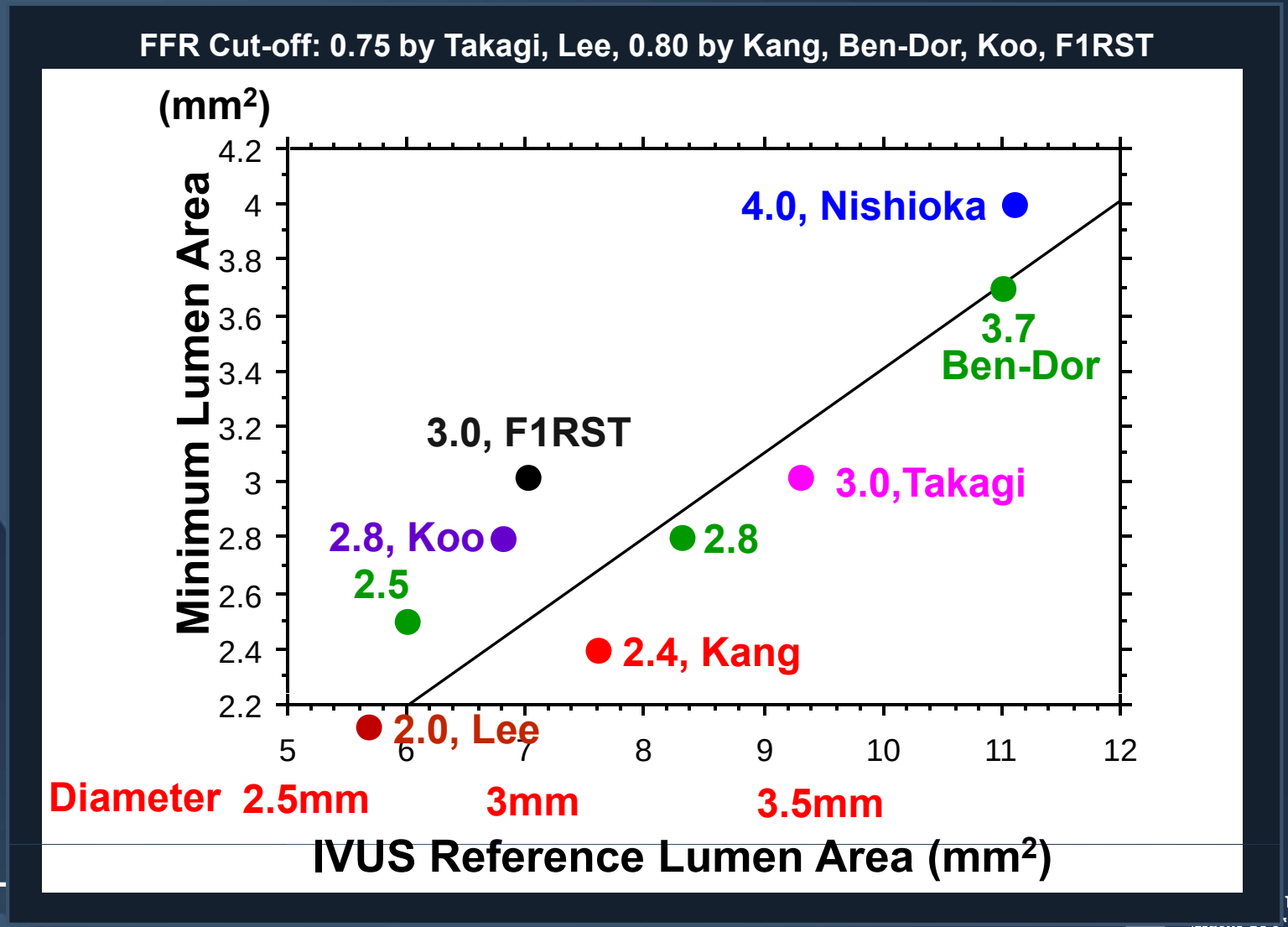
$$\text{Pressure Drop} \propto \frac{\text{Length}}{(\text{Stenotic Area})^2}$$

Kern and Samady, J Am Coll Cardiol, 55:173-85.

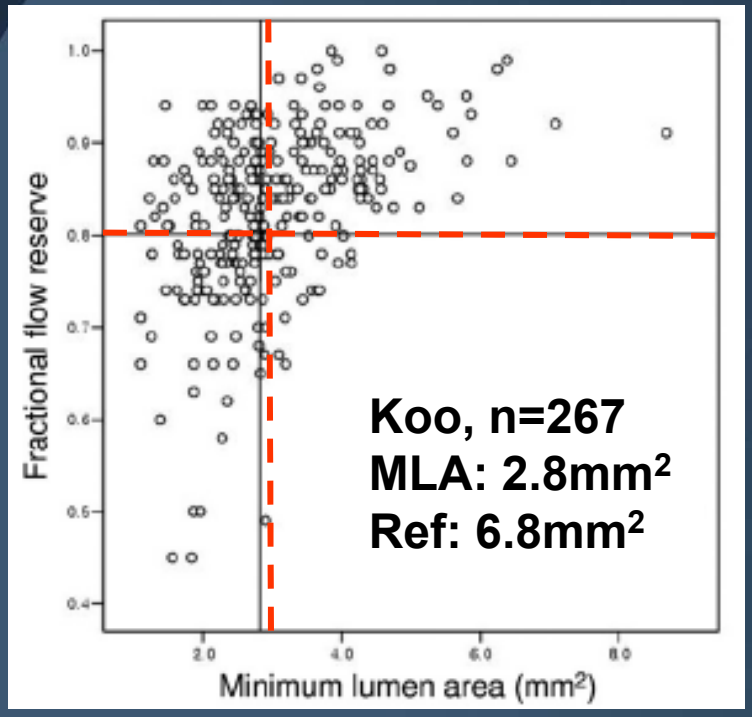
Correlation between IVUS and FFR

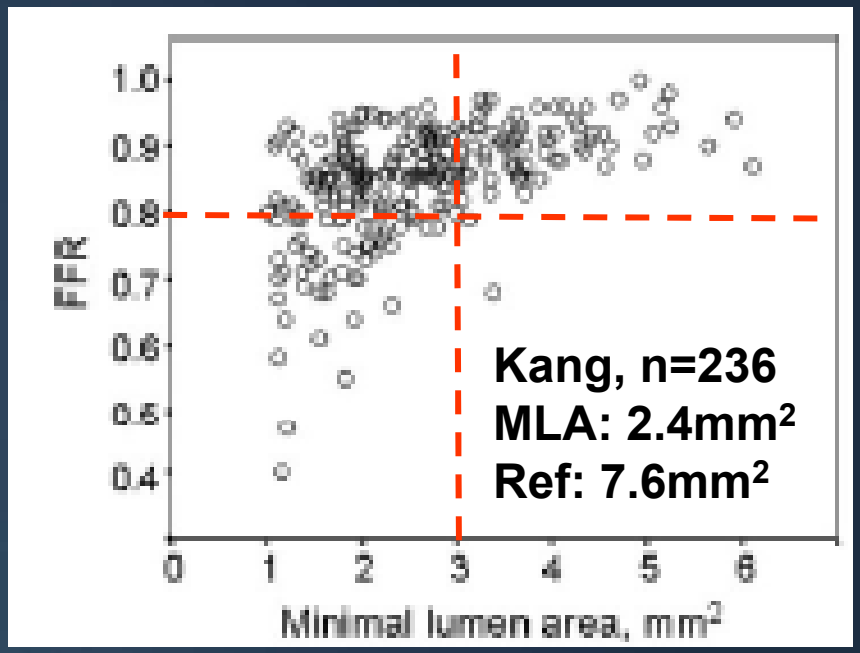
Author	year	Against	n	Cut-Off MLA (mm^2)	Ref Area (mm^2)
Nishioka	1999	SPECT	70	4.0	11.4±3.9
Takagi		FFR 0.75	51	3.0	9.3±2.7
Lee	2010	FFR 0.75	94	2.0	5.7±2.0
Kang	2011	FFR 0.8	236	2.4	7.6±2.5
Ben-Dor			92	3.2	RVD>2.5mm
Koo			267	2.8	6.8±2.5
F1RST			320	3.0	RVD 2.9mm

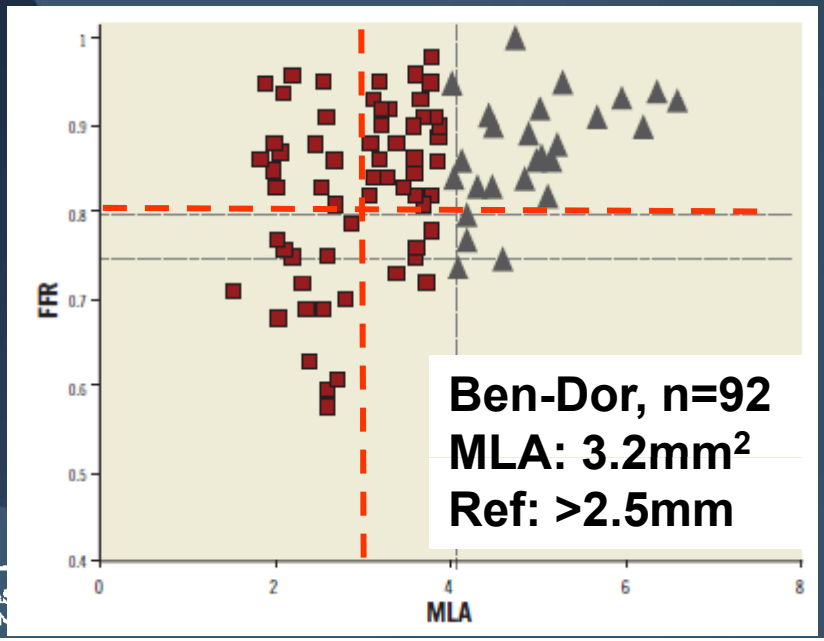
Cut-off MLA and Reference Area

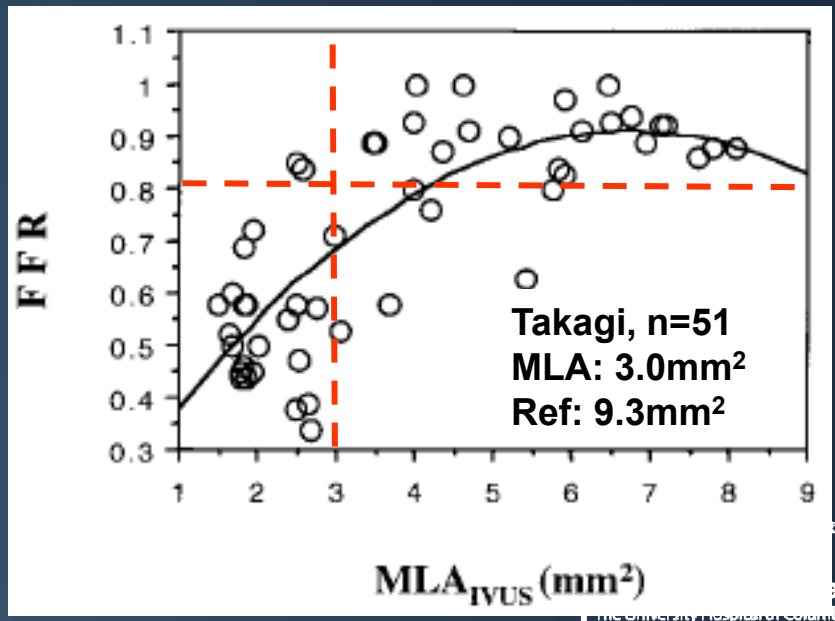


Similar Scatter Plot



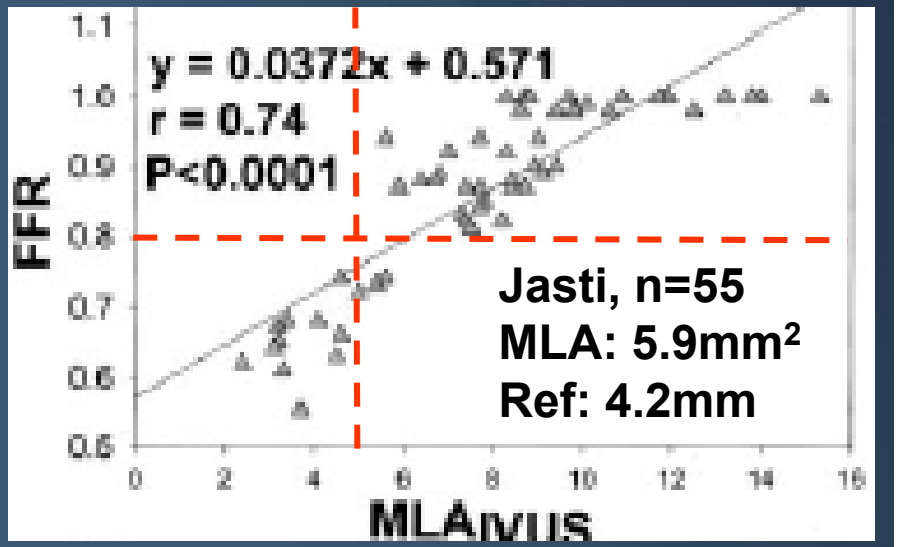


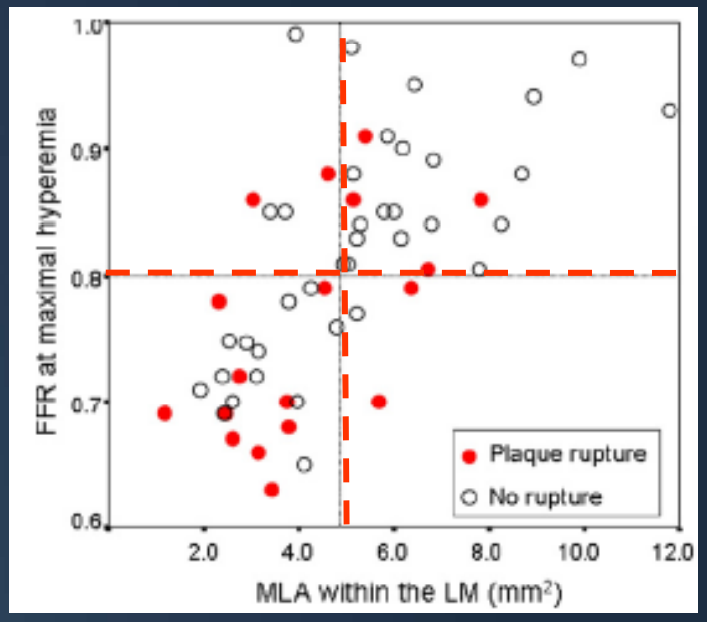




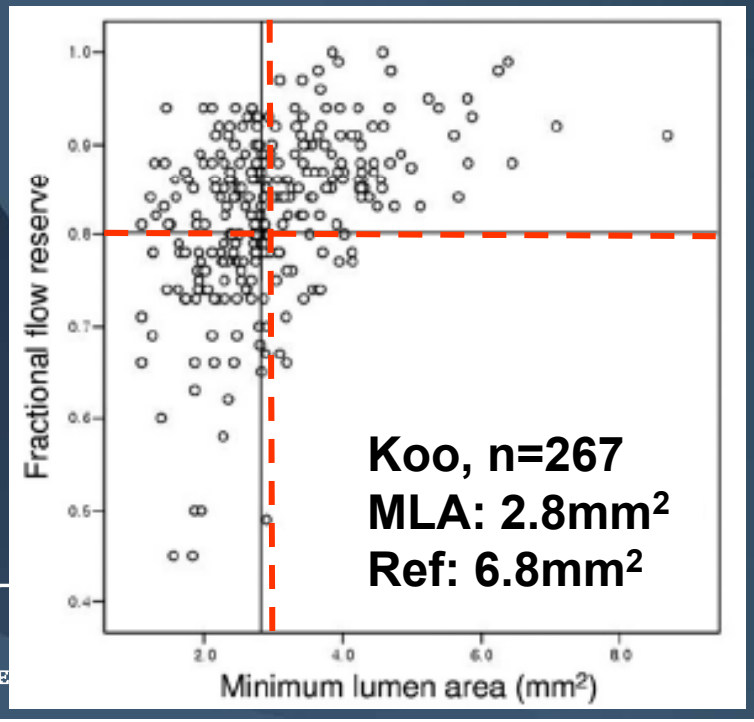
LMCA vs non-LMCA

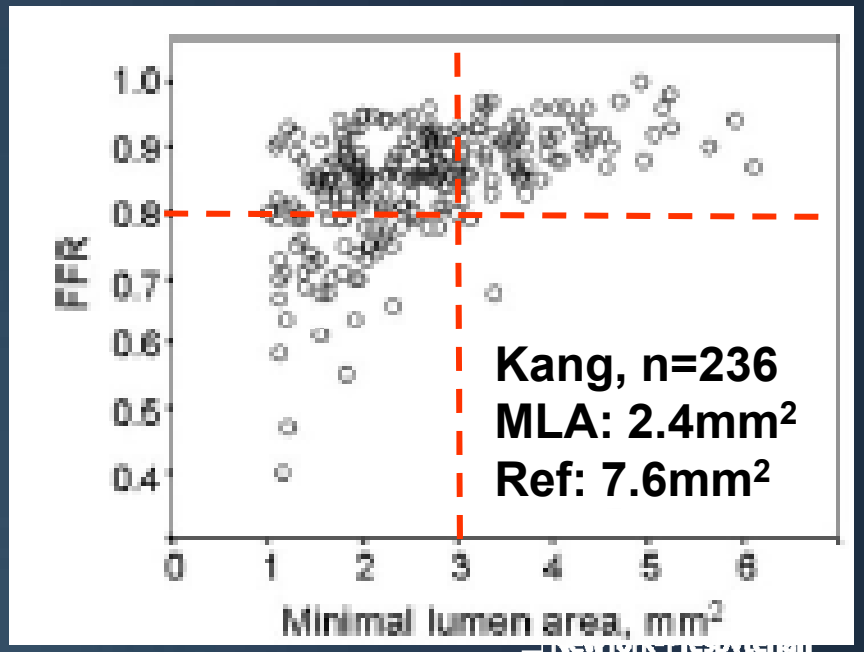
LMCA





Non-LMCA



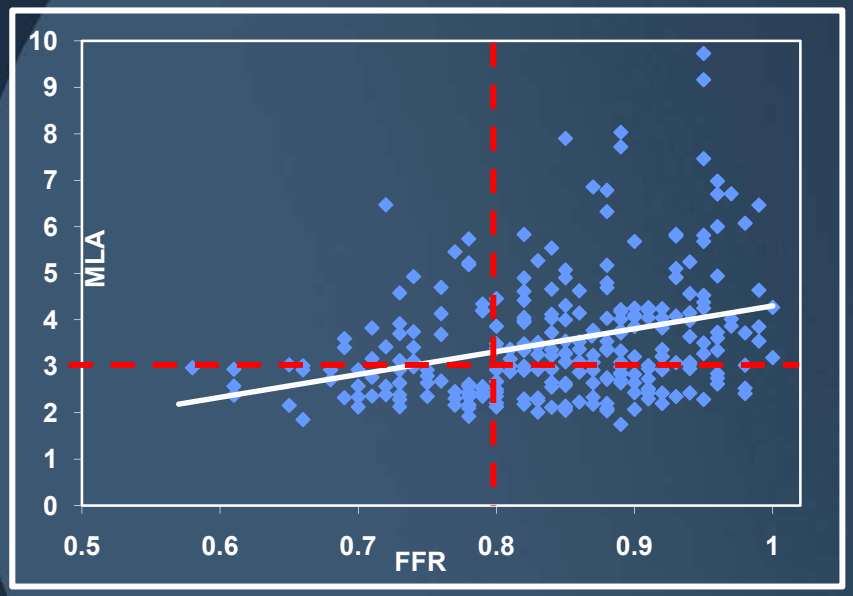


Fractional Flow Reserve and Intravascular Ultrasound RelationShip (F1RST Trial)

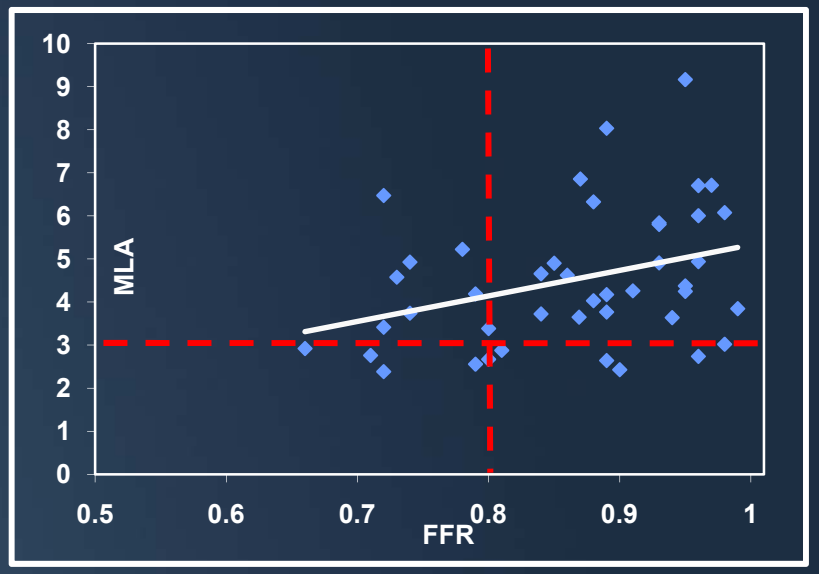
1. Prospective Multi-center Registry in US and Europe
2. Primary Endpoint: Correlation between FFR and IVUS MLA
3. Secondary Endpoint: Correlation between FFR and plaque burden, TCFA
4. Vessel Size>2.5mm
5. Intermediate lesion: Angio DS=40-80%
6. 320 lesions in 304 patients
7. 30% of patient had prior MI
8. Include 2 LM lesion, 4 STEMI patients

FIRST

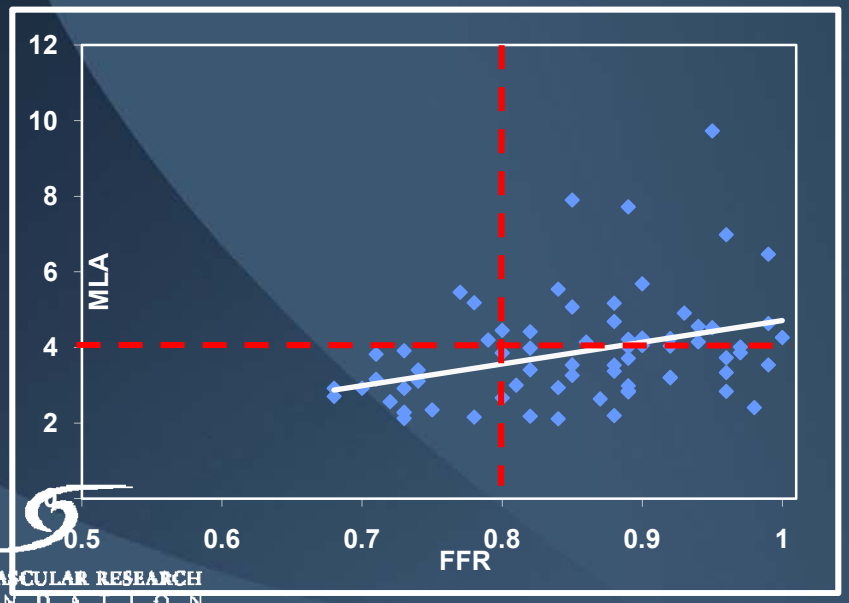
ALL



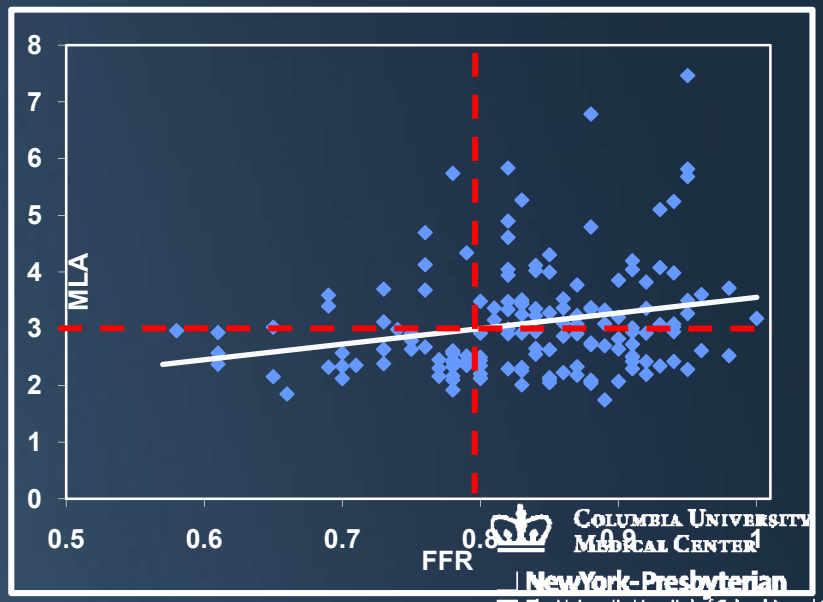
RVD > 3.5 mm



RVD 3.0 to 3.5 mm



RVD < 3.0 mm



CARDIOVASCULAR RESEARCH FOUNDATION

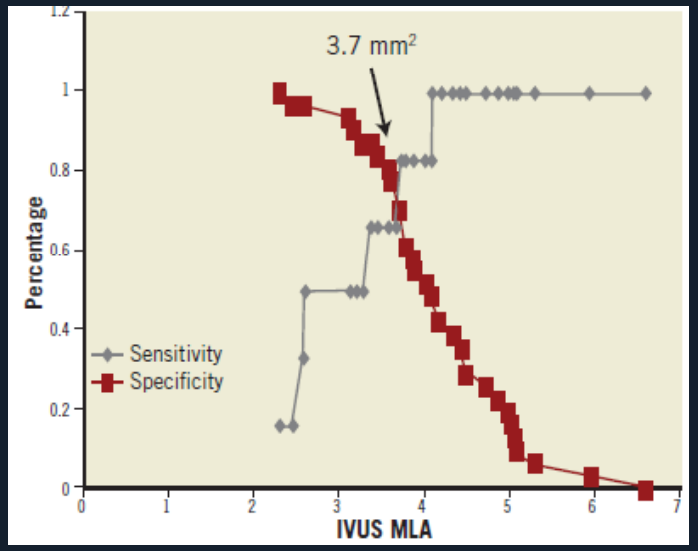
COLUMBIA UNIVERSITY MEDICAL CENTER

NewYork-Presbyterian

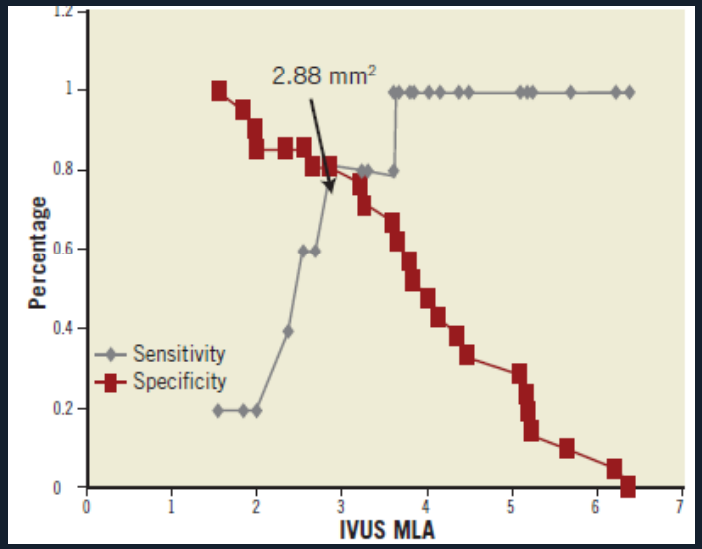
The University Hospital of Columbia and Cornell

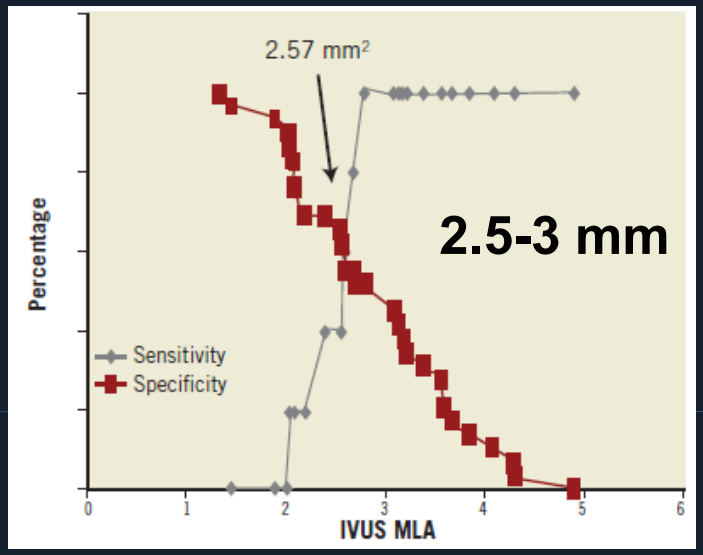
Cut-off in relation to vessel size

>3.5mm



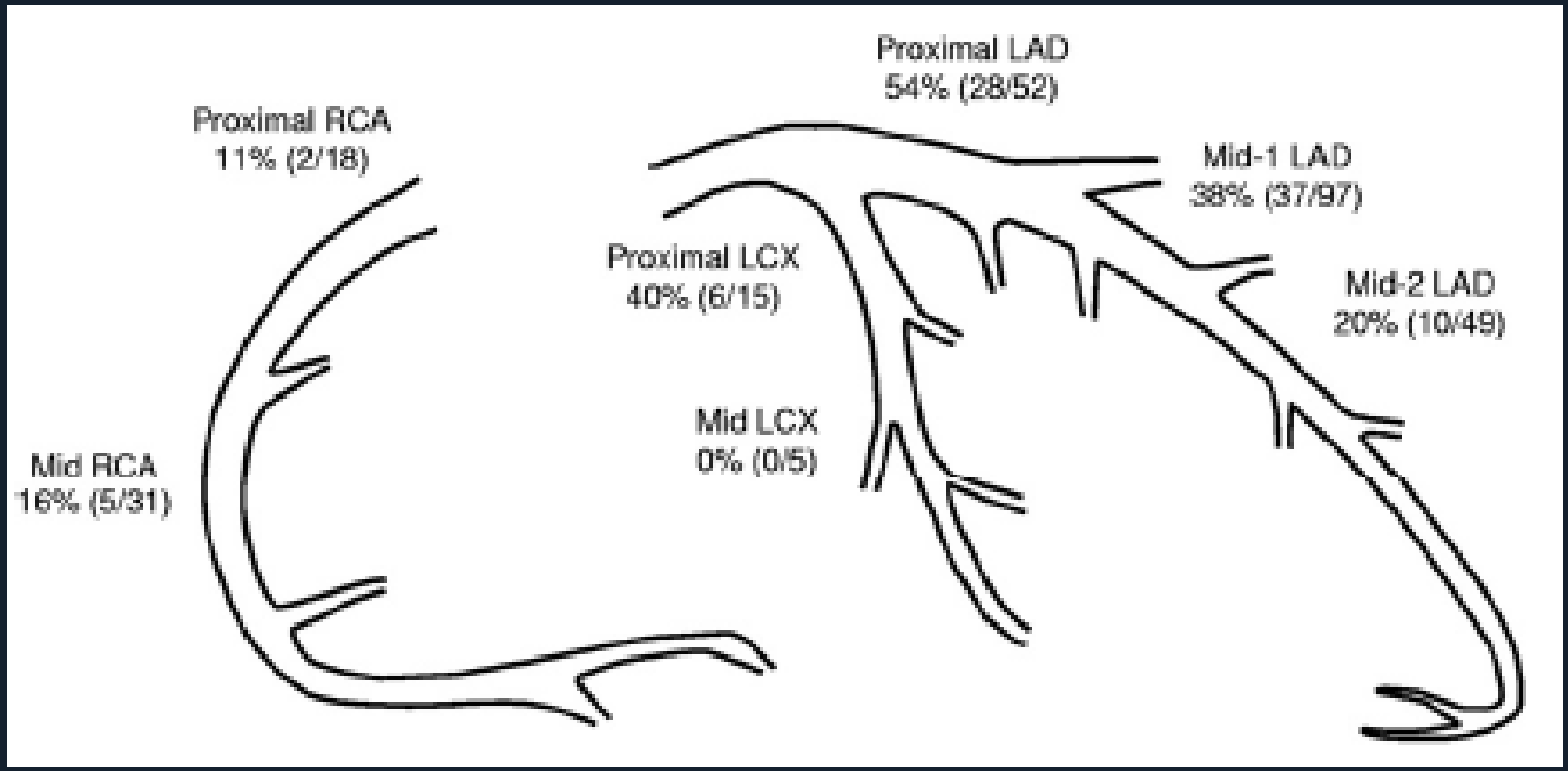
3~3.5mm





Ben-Dor I et al. Eurointerv

Cut-off in relation to location

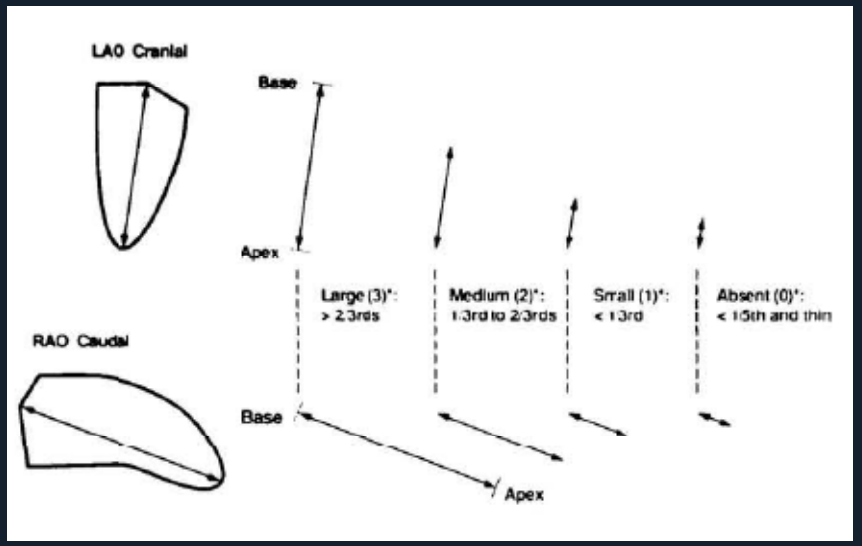


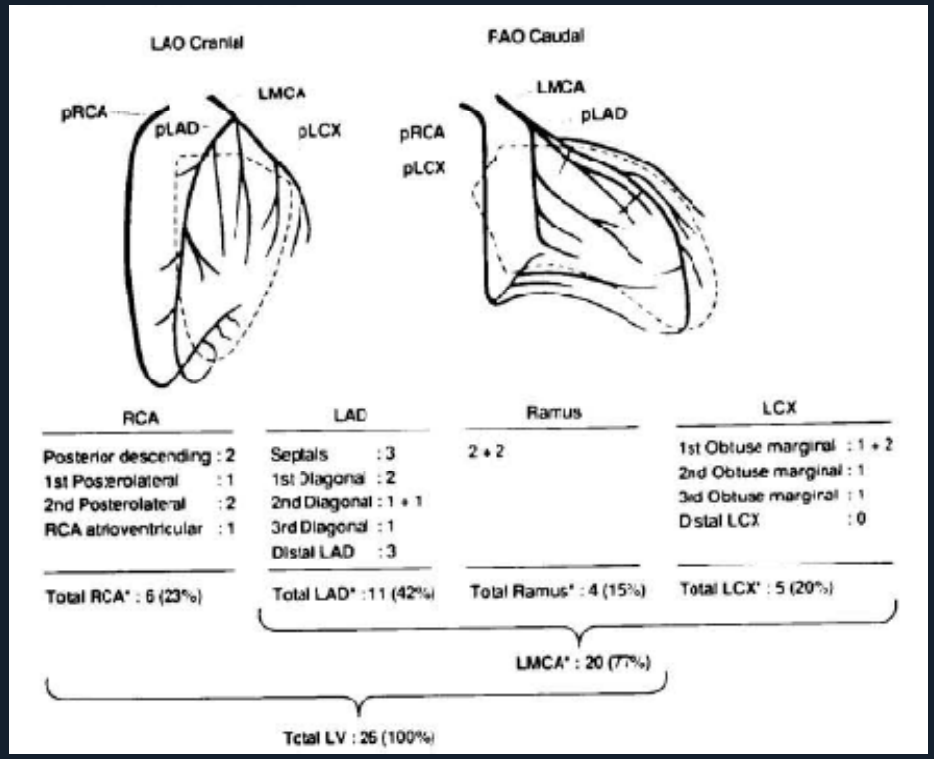
Cut-off in relation to Location

Lesion Location	Cut-Off MLA	AUC	95% CI
Proximal LAD (n=52)	3.0	0.81	0.68-0.91
Mid LAD (n=146)	2.5	0.64	0.56-0.72
Mid1-LAD (n=97)	2.75	0.76	0.66-0.84
Mid2-LAD (n=49)	NA		
RCA	3.0	0.68	0.66-0.84
LCX	NA		
Vessel Size			
≥3.0mm	3.0	0.70	0.61-0.76
<3.0mm	2.5	0.61	0.52-0.71

BARI Score to define Territory

Vessel	LAD	LCX	RCA
Range	43±7 (32-55)%	26±8 (14-44)%	31±7 (15-41)%





Edwin L et al, Coronary Artery Disease 1992;3: 1189-1207

VH Findings by FFR

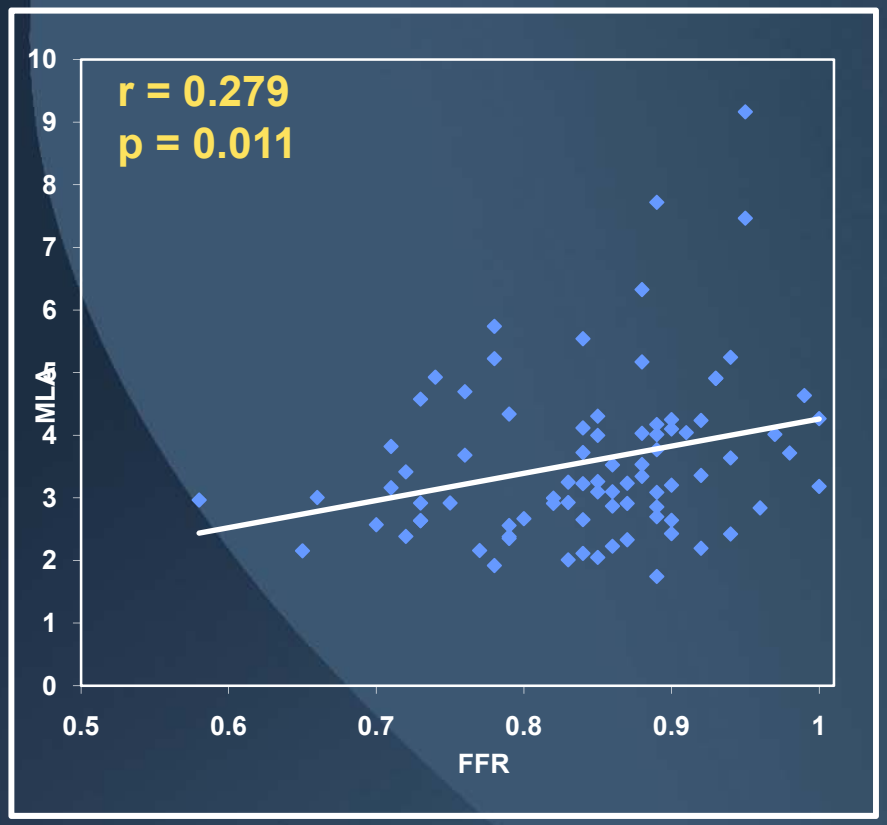
VH Variable	FFR < 0.8	FFR ≥ 0.8	P value
Plaque Burden, %	72.1 ± 8.7	67.2 ± 11.9	0.001
Plaque Area, mm	8.7 ± 3.8	8.5 ± 3.6	0.676
Necrotic Core Tissue, %	21.8 ± 7.8	22.1 ± 9.6	0.872
Necrotic Core Tissue, mm^2	1.4 ± 0.9	1.4 ± 0.9	0.859
Fibrofatty Tissue, %	13.7 ± 8.9	11.9 ± 8.1	0.154
Fibrofatty Tissue, mm^2	0.9 ± 0.9	0.8 ± 0.7	0.216
Fibrous Tissue, %	54.5 ± 12.3	51.8 ± 16.9	0.207
Fibrous Tissue, mm^2	3.3 ± 1.9	3.1 ± 1.9	0.550
Dense Calcium, %	10.0 ± 7.8	11.5 ± 11.8	0.271
Dense Calcium, mm^2	0.6 ± 0.5	0.7 ± 0.7	0.657

FFR Correlation with VH

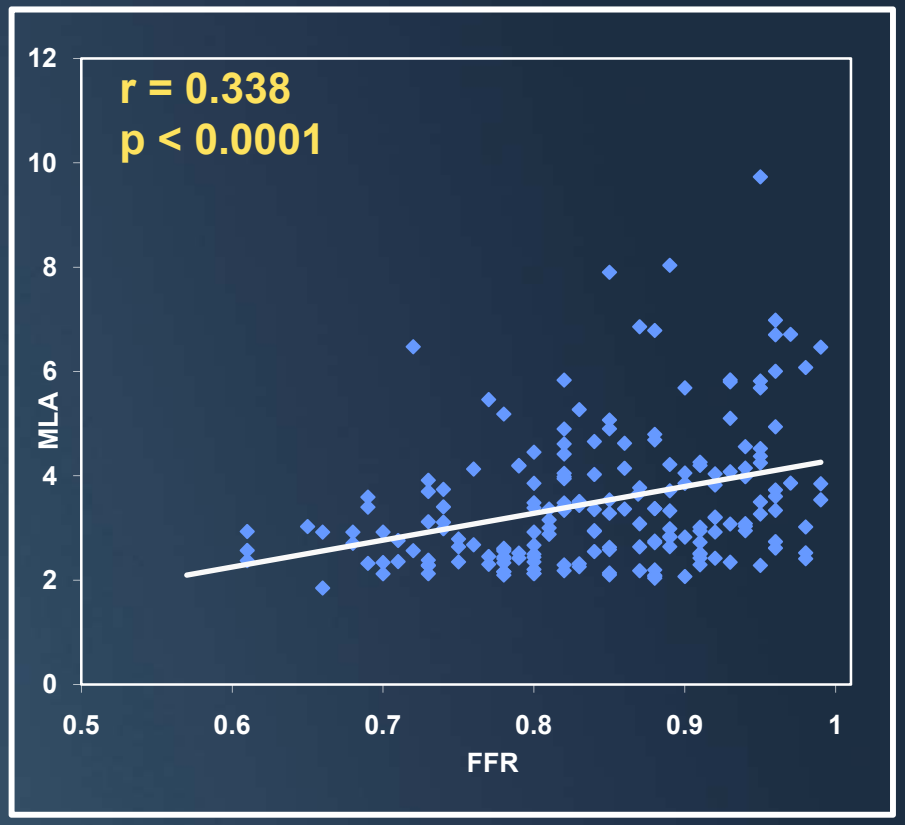
VH Variable	Mean ± SD	r value	p value
Plaque Burden, %	68.7 ± 11.2	-0.184	0.0082
Plaque Area, mm	8.5 ± 3.6	0.044	0.5319
Necrotic Core Tissue, %	22.0 ± 9.1	-0.011	0.8758
Necrotic Core Tissue, mm^2	1.3 ± 0.9	0.033	0.6337
Fibrofatty Tissue, %	12.4 ± 8.4	-0.019	0.786
Fibrofatty Tissue, mm^2	0.8 ± 0.8	-0.032	0.6458
Fibrous Tissue, %	52.6 ± 15.7	-0.059	0.4009
Fibrous Tissue, mm^2	3.1 ± 1.9	0.011	0.8809
Dense Calcium, %	11.1 ± 10.8	0.024	0.7371
Dense Calcium, mm^2	0.6 ± 0.7	0.065	0.3581

Correlations of FFR to MLA by TCFA

Lesions with CaTCFA or TCFA



Lesions without CaTCFA or TCFA



CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell

Independent Predictor for FFR

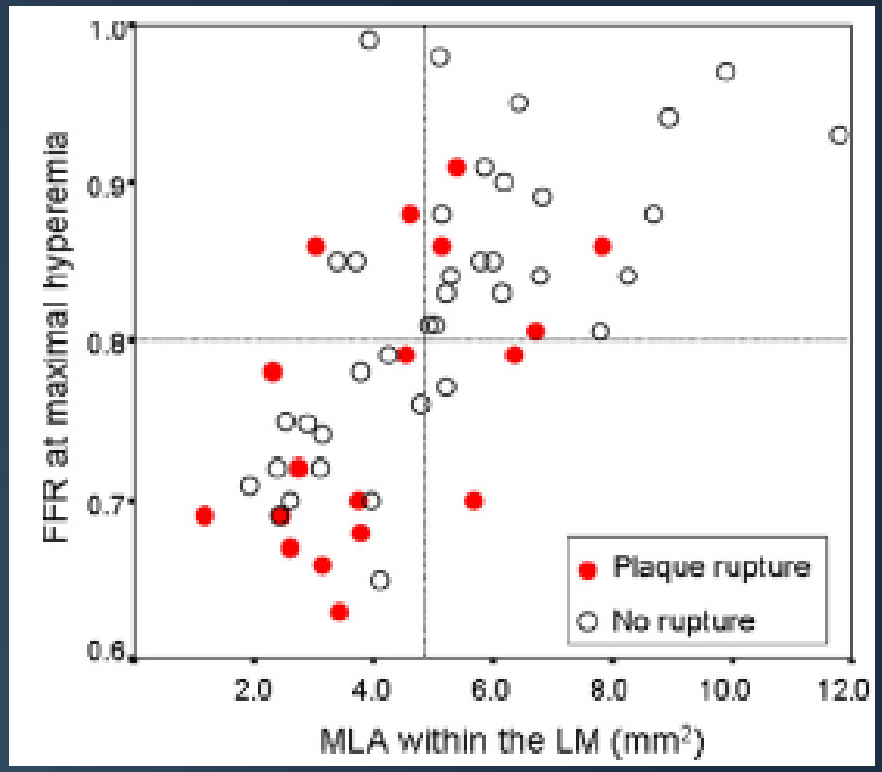
Koo, n=267, RVD=3.1mm

Parameter	OR	95%CI	p-value
MLA (mm^2)	0.35	0.19-0.66	0.0001
Proximal location	2.97	1.20-7.32	0.02
LAD lesions	3.4	1.24-9.3	0.02

Lee, n=94, RVD=2.7mm

Parameter	OR	95%CI	p-value
MLA (mm^2)	0.08	0.01-0.52	0.009
Lesion length (mm)	1.14	1.02-1.28	0.021
Plaque burden (%)	1.22	1.06-1.39	0.004

LMCA, Kang, n=55, RVD=3.7mm



- MLA(β= 0.598)
- Plaque Rupture (β= -0.255)

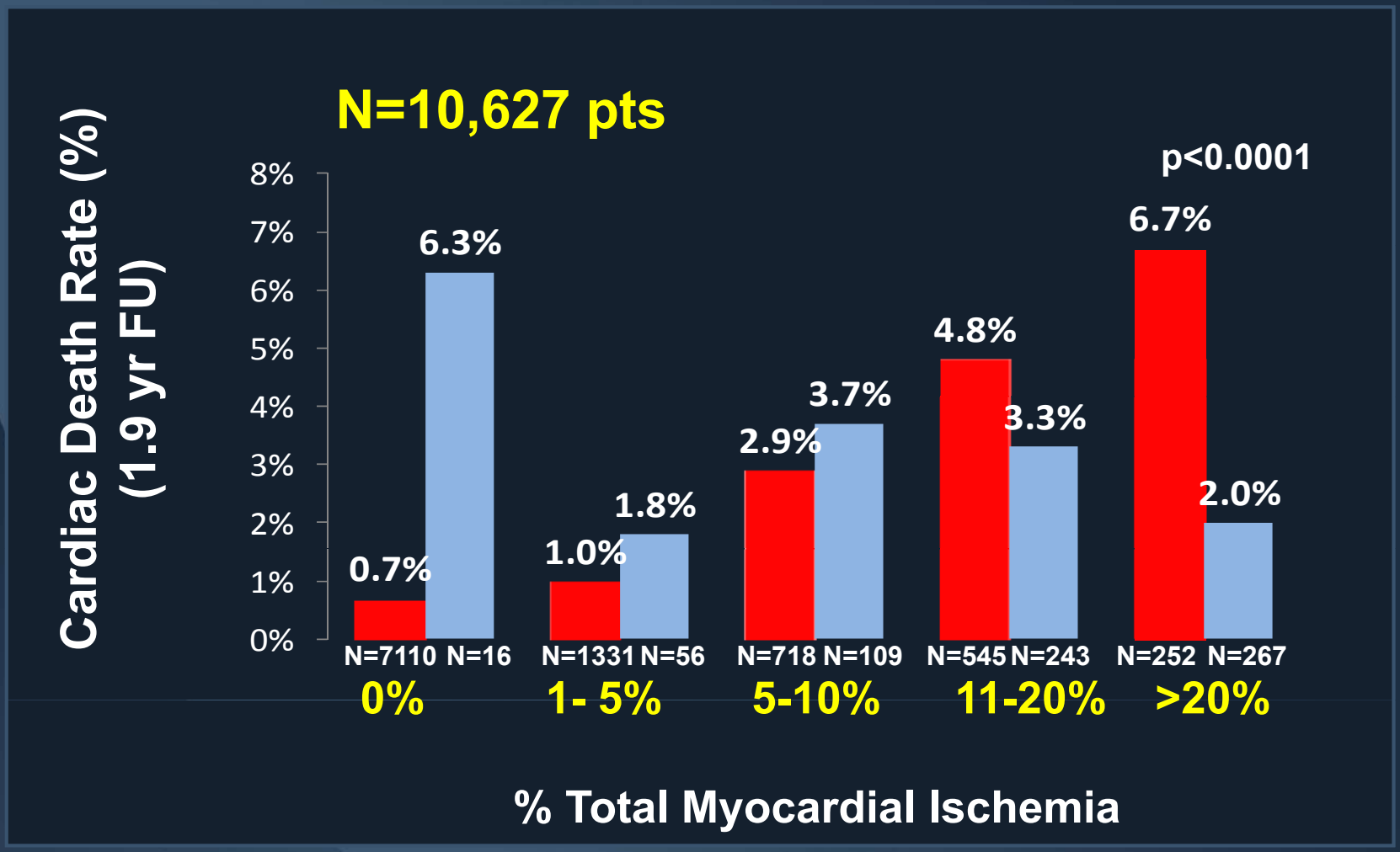
CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell

Cut-off in relation to Location

Lesion Location	Cut-Off MLA	AUC	95% CI
Proximal LAD (n=52)	3.0	0.81	0.68-0.91
Mid LAD (n=146)	2.5	0.64	0.56-0.72
Mid1-LAD (n=97)	2.75	0.76	0.66-0.84
Mid2-LAD (n=49)	NA		
RCA	3.0	0.68	0.66-0.84
LCX	NA		
Vessel Size			
≥3.0mm	3.0	0.70	0.61-0.76
<3.0mm	2.5	0.61	0.52-0.71

Cardiac Mortality in Medically Treated or Revascularized Patients According to Ischemic Risk – CSMC Database

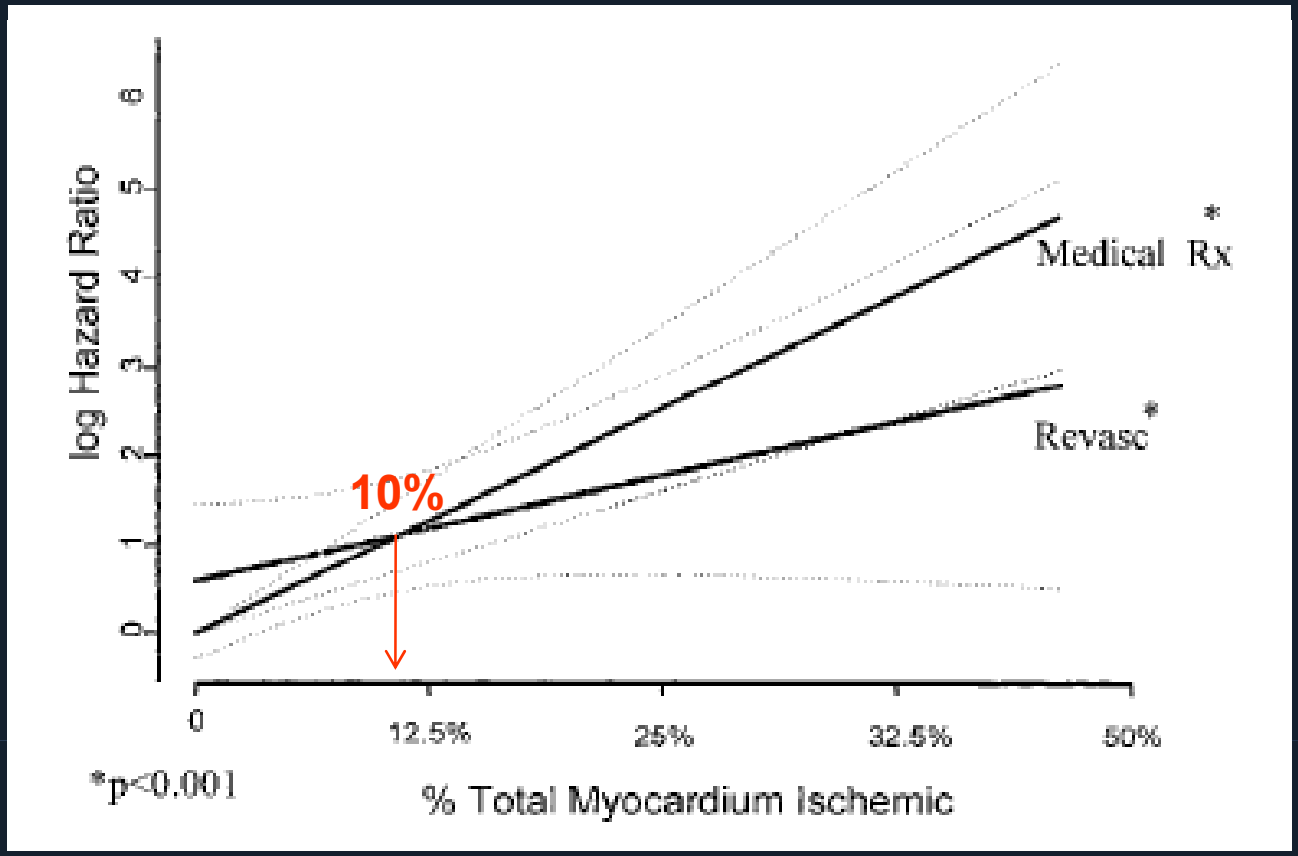


Hachamovitch et al *Circulation*. 2003;107:2900-07

CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell

Log Hazard ratio for Revasc vs Medical Therapy as a function of % myocardium ischemia

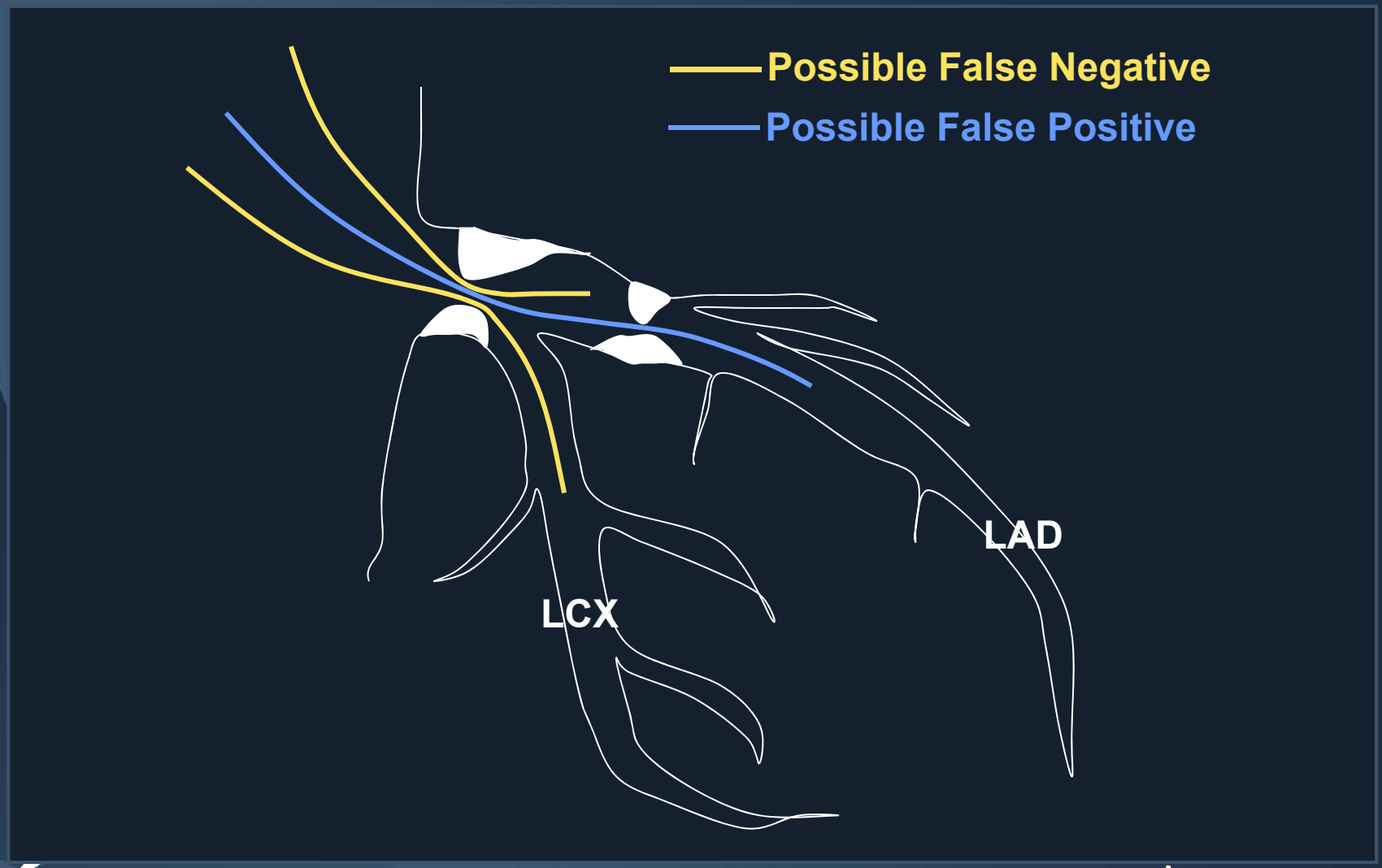


Hachamovitch et al *Circulation*. 2003;107:2900-07

CARDIOVASCULAR RESEARCH FOUNDATION

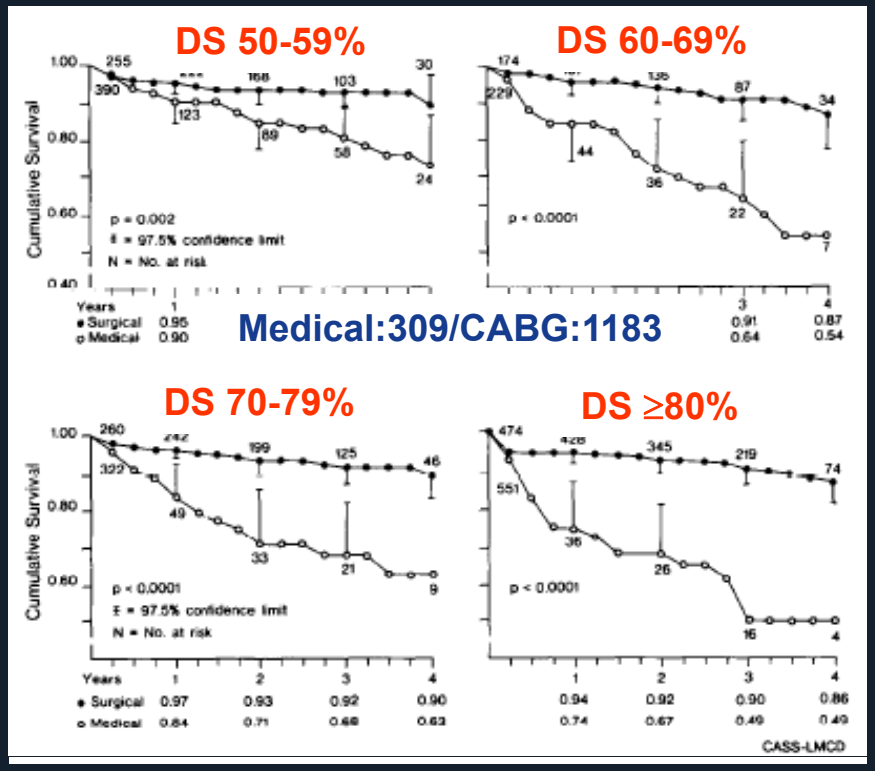
COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell

Problem of FFR for LMCA Lesions



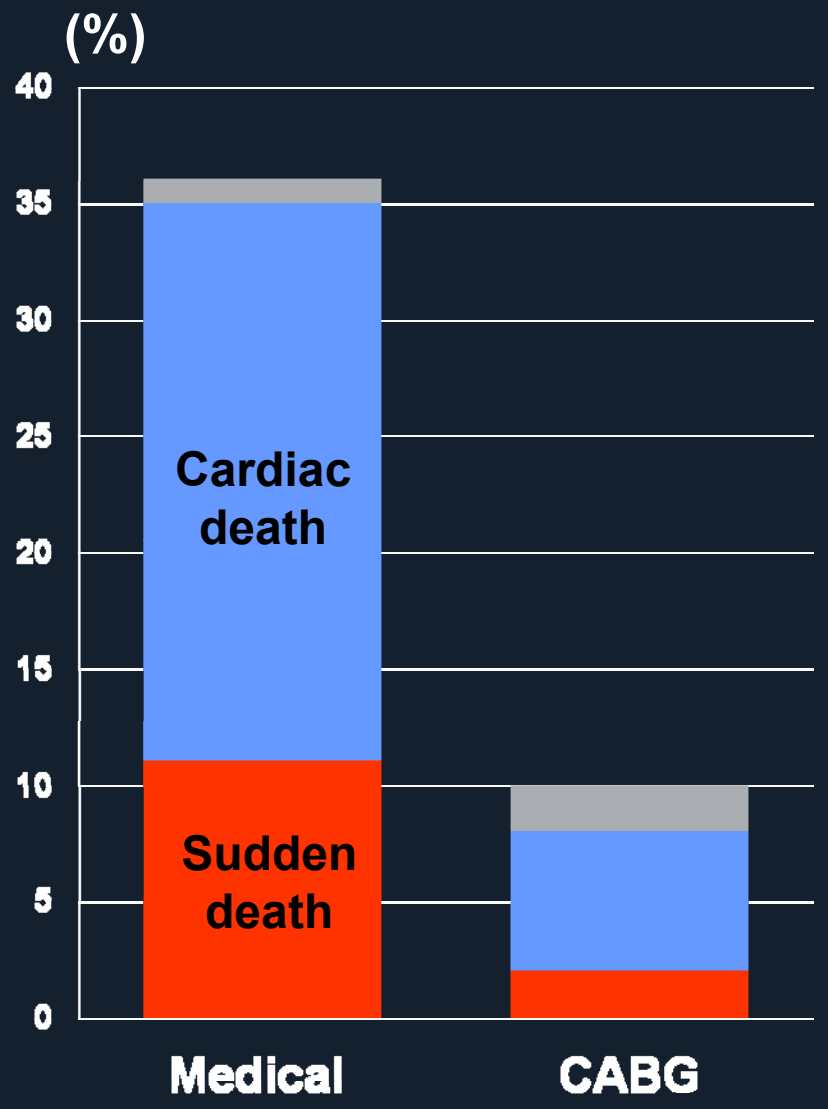
CARDIOVASCULAR RESEARCH FOUNDATION

COLUMBIA UNIVERSITY MEDICAL CENTER
NewYork-Presbyterian
The University Hospital of Columbia and Cornell



Medical:309/CABG:1183

Chaitman et al, *AJC* 1981;48: 765-777



ACC/AHA 2004 Guideline Update for Coronary Artery Bypass Graft Surgery

3.2.2. Location and Severity of Stenoses

3.2.2.1. Left Main Disease

The benefit of surgery over medical treatment for patients with significant left main stenosis is little argued. All of the trials define significant left main stenosis as being greater than 50% diameter stenosis as judged by contrast angiography. The median survival for surgically treated patients is 13.3 years versus 6.6 years in medically treated patients (92,93).

Left main equivalent disease, defined as severe (greater than or equal to 70%) diameter stenosis of the proximal LAD and proximal left circumflex disease, appears to behave similarly to true left main disease. Median survival for surgical patients is 13.1 years versus 6.2 years for med-

For the decision making in LMCA, not only function, the prognosis (acute progression→ sudden death) should be considered.

Take Home Message

1. In general, MLA=3.0mm^2 as a cut off for physiologicaly significant lesion.
2. MLA>4mm^2 can highly predict “non physiological significant.
3. In addition to MLA, longer lesion length, larger plaque burden, LAD location can predict physiological significant.
4. The effect of TCFA, amount of NC, rupture etc needs further evaluation in relation to the clinical implication (ie. vulneralble plaque).
5. If there is an isolated LMCA lesion, MLA should be more accurate than other epicardial lesions because of homogeneity of myocardial burden distal to LMCA.