DIU imagerie cardiaque et vasculaire

La viabilité myocardique en SPECT et en TEP

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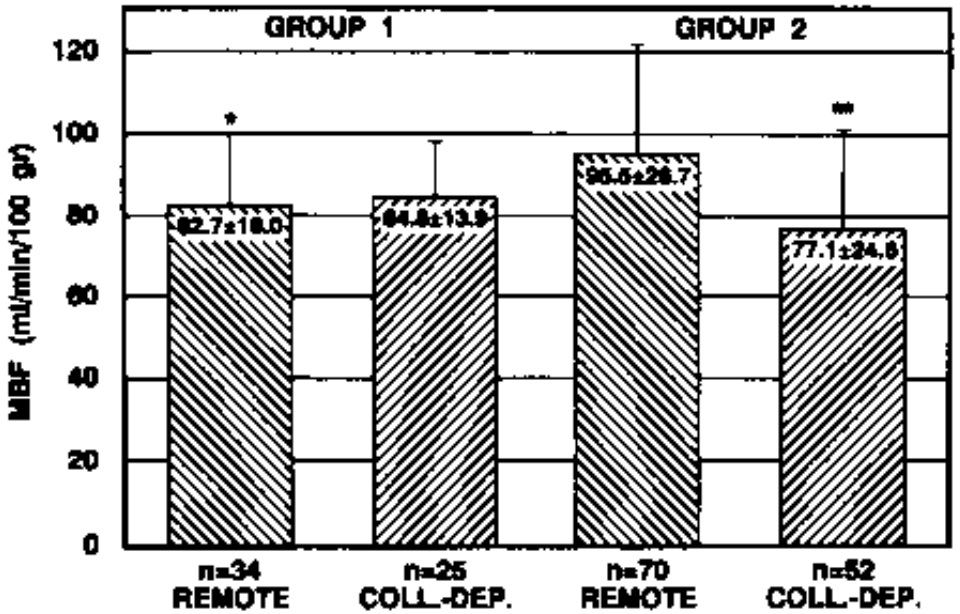
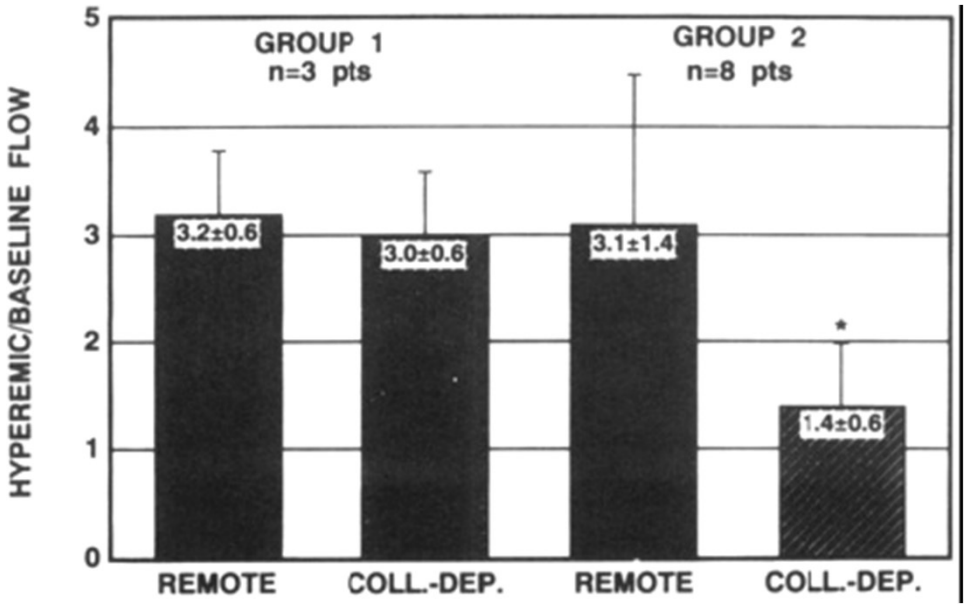
Ischemia *vs.* viability

Myocardial blood flow evaluated by $^{13}NH_3$ PET

Baseline myocardial blood flow



Coronary flow reserve

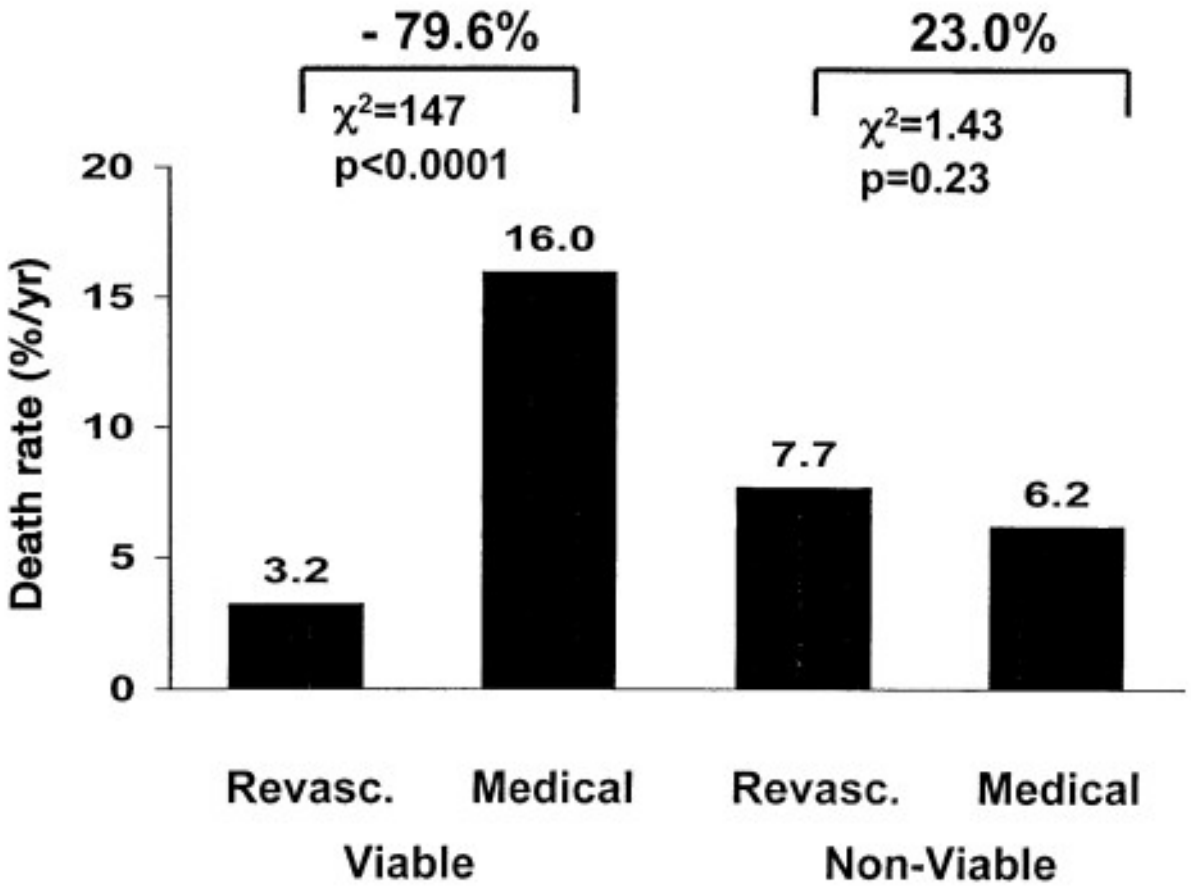


Group 1: normal motion of the collateral-dependent segments
Group 2: dysfunction of the collateral-dependent segments

Vanoverschelde JL et al., Circ 1993

Prognostic value

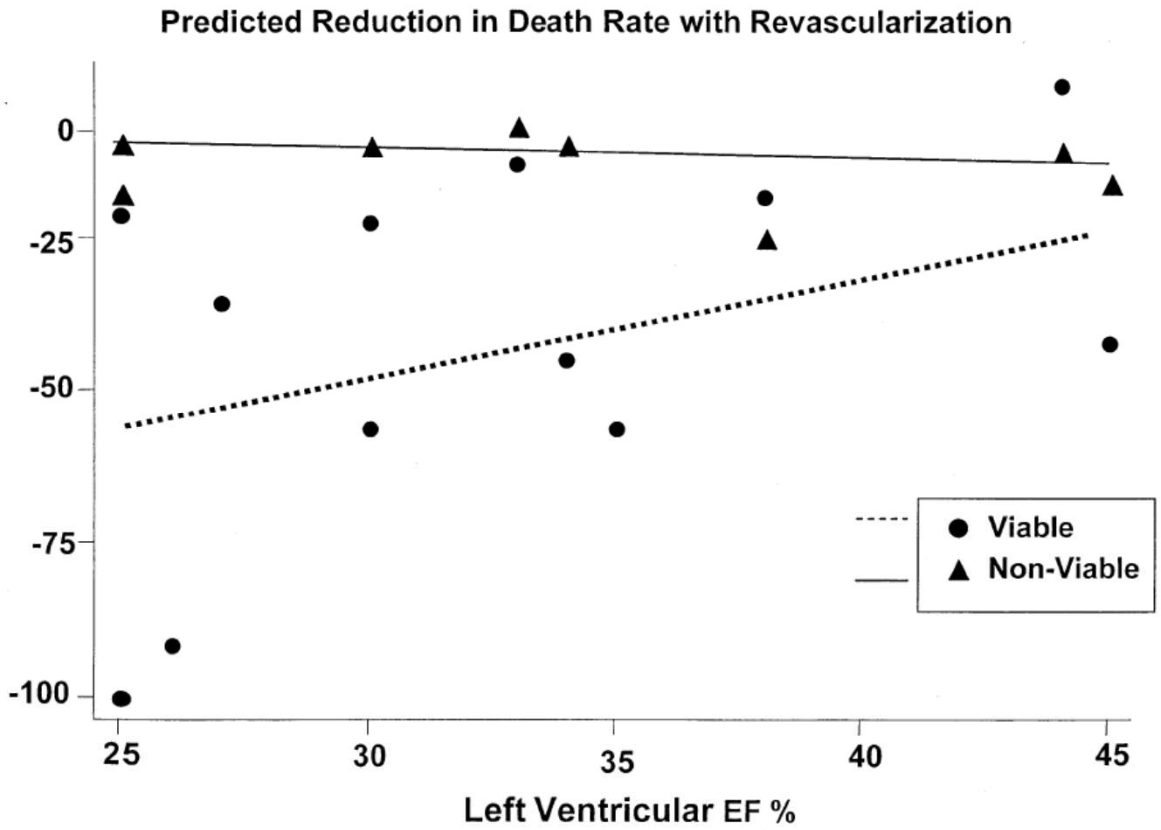
According to therapy



Allman et al., J Am Coll Cardiol 2002

Prognostic value

According to LVEF



Allman et al., J Am Coll Cardiol 2002

Viabilité myocardique

Principe : Quantifier l'activité métabolique du myocarde

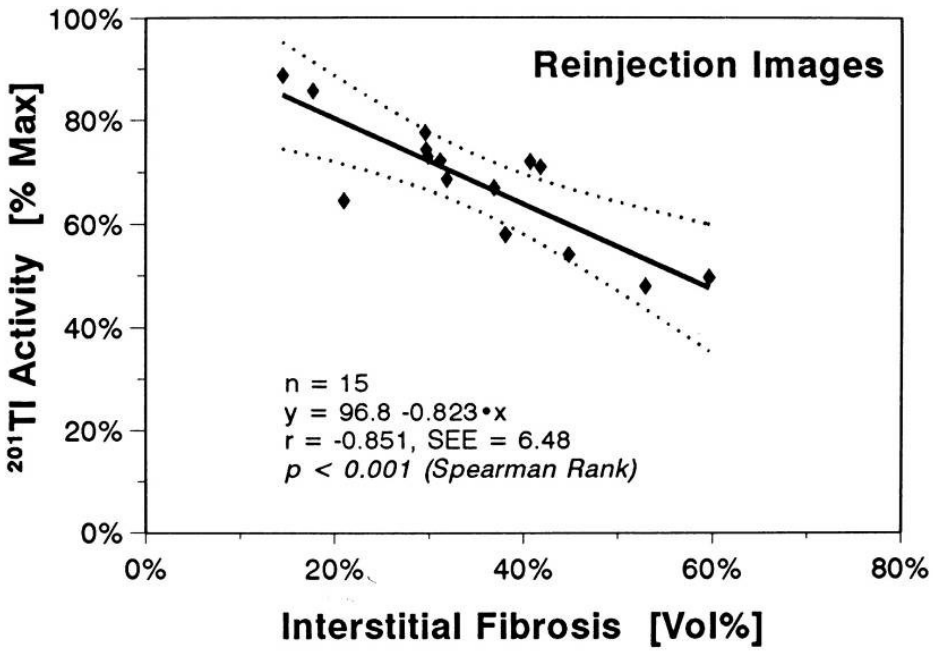
Deux approches :

- Traceur de perfusion (SPECT ou TEP) : leur captation témoigne de la viabilité des myocyctes
- Mesure de l'activité glycolytique : FDG en TEP

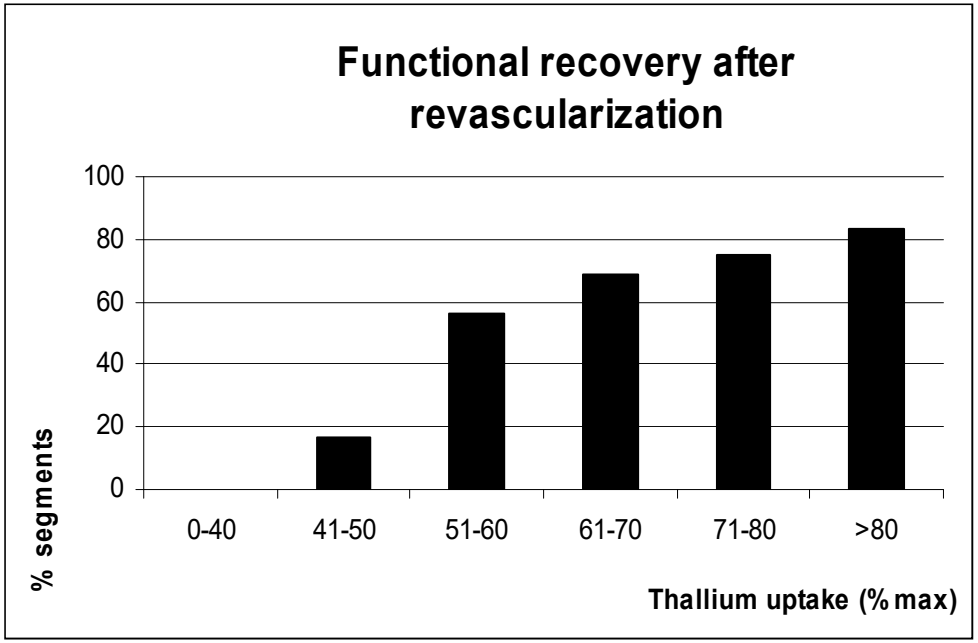
Perfusion tracers: SPECT or PET

Uptake is dependant on blood flow and membrane integrity

Thallium SPECT



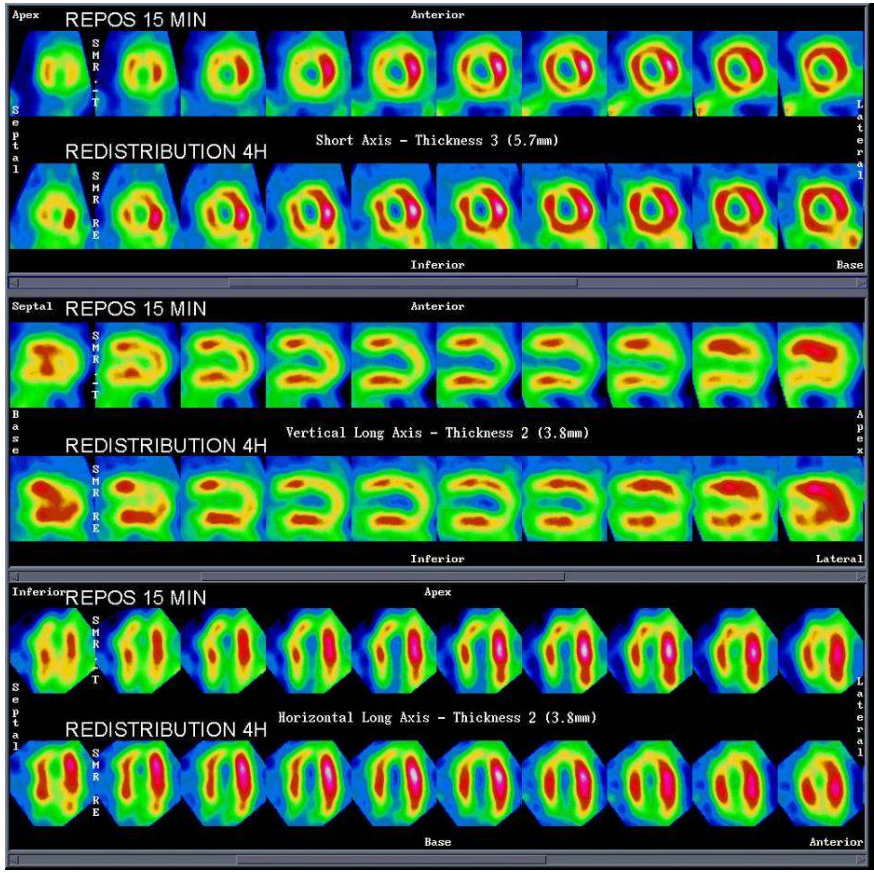
Zimmermann, Circulation 1999

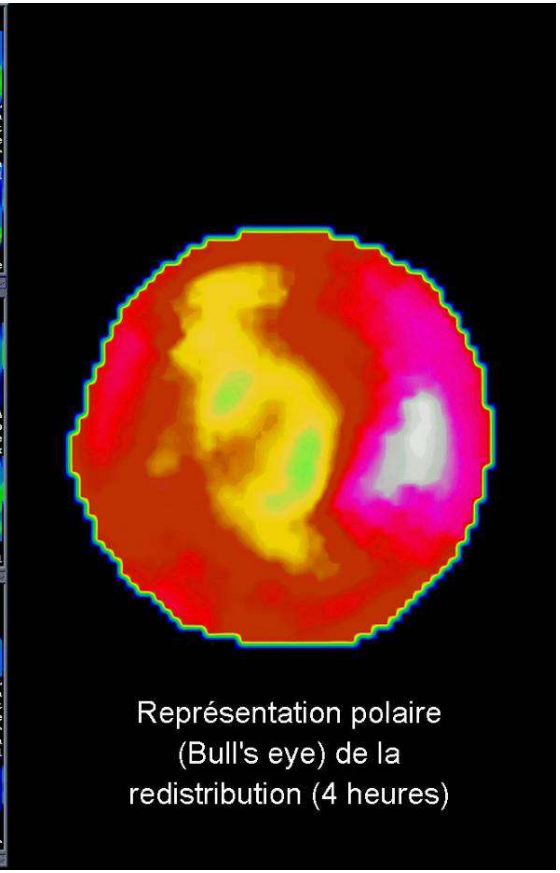


Perrone-Filardi, Circulation 1996

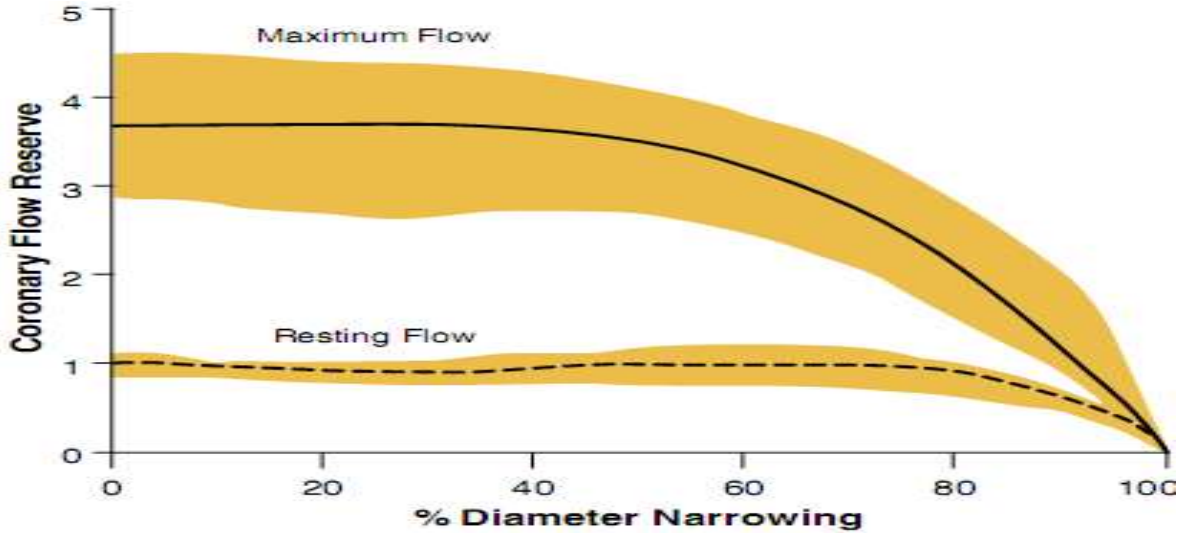
Viabilité myocardique

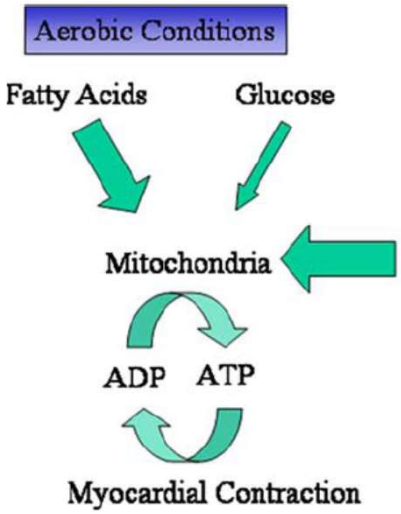
Infarctus antéro-septo-apical

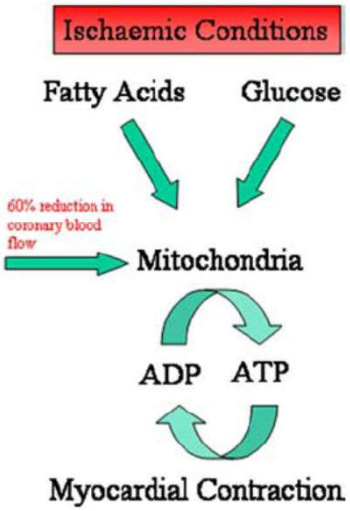




Représentation polaire (Bull's eye) de la redistribution (4 heures)


Maximum Flow
Resting Flow
Coronary Flow Reserve
% Diameter Narrowing
0
1
2
3
4
5
0
20
40
60
80
100


Aerobic Conditions
Fatty Acids
Glucose
Mitochondria
ADP
ATP
Myocardial Contraction

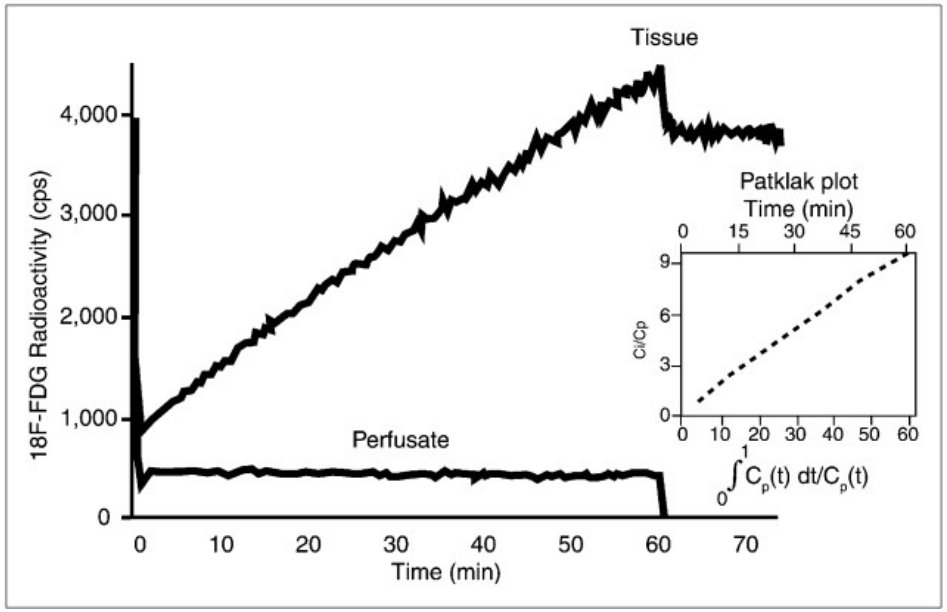

Ischaemic Conditions
Fatty Acids
Glucose
60% reduction in coronary blood flow
Mitochondria
ADP
ATP
Myocardial Contraction

Vibilité en TEP

^{18}F-deoxyglucose (FDG)

Glucose → (*Hexokinase*) **Glucose-6-P** → (*Phosphoglucose isomerase*) **Fructose-6-P**

^{18}FDG → (*Hexokinase*) **^{18}FDG-6-P** → (*Phosphoglucose isomerase*) X

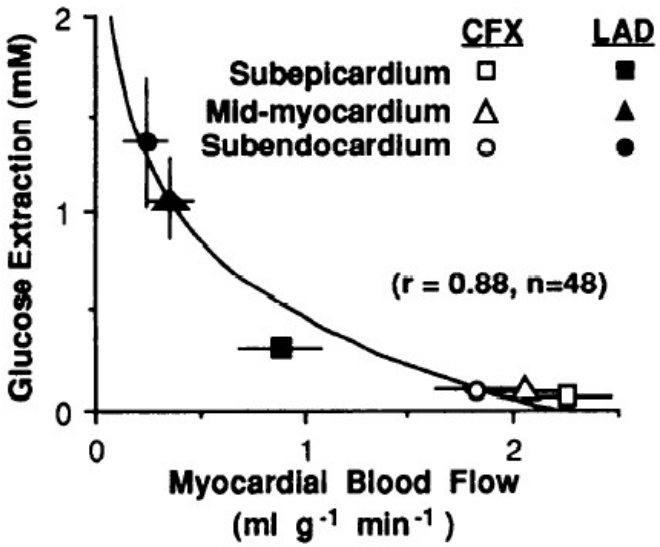


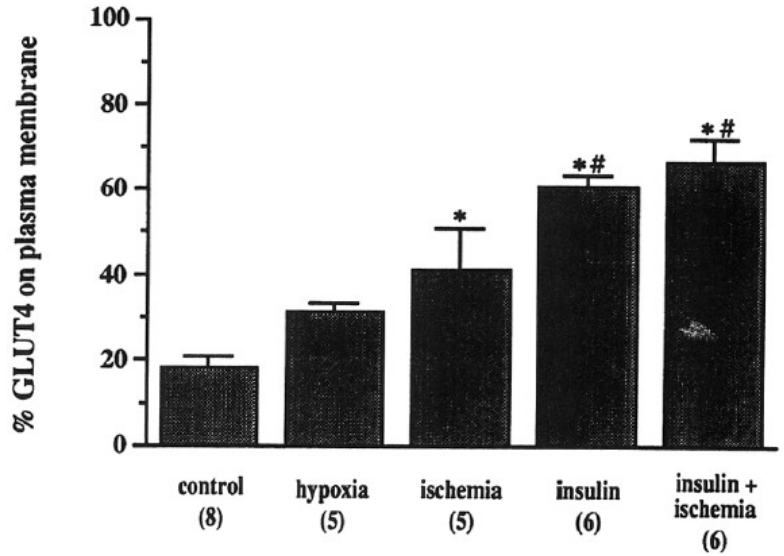
L'accumulation de ^{18}FDG est proportionnelle à la consommation énergétique (glycolyse) du myocarde.

Nguyen et al., Am J Physiol 1990

Glucose utilization (^{18}FDG PET)

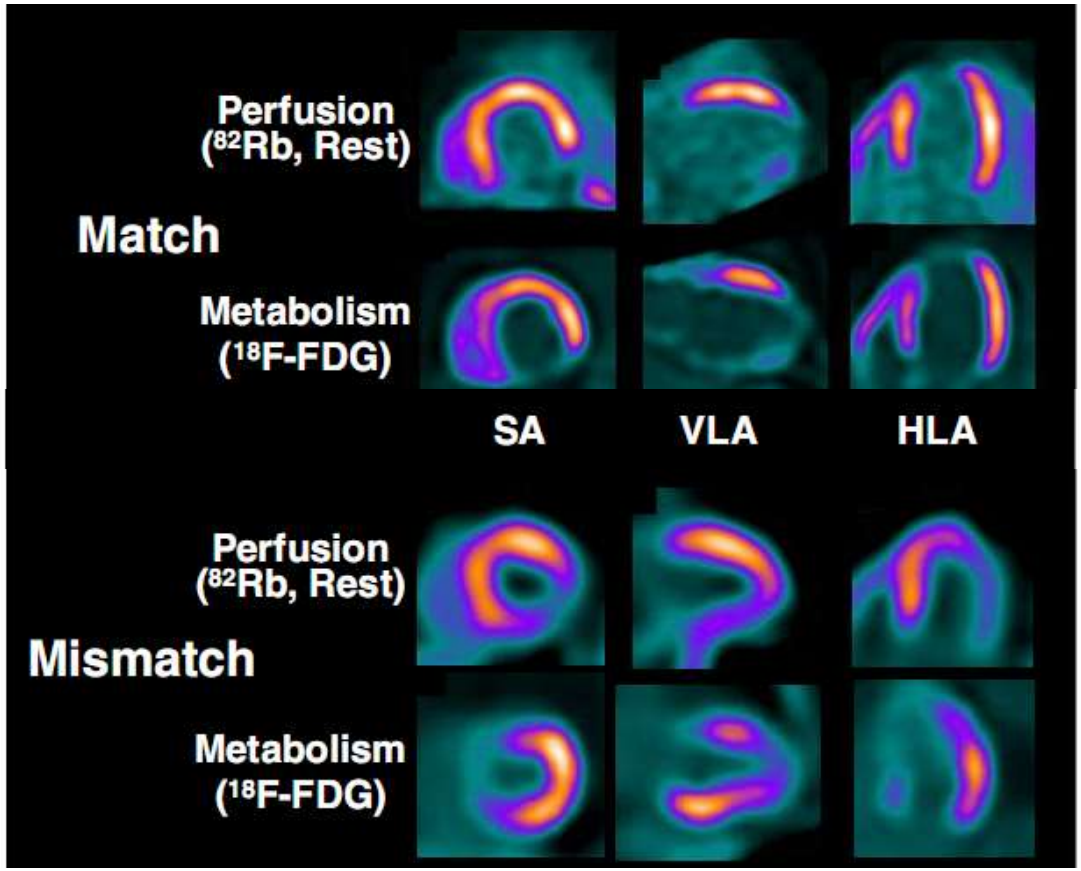
- In severe ischemia, myocardial glucose extraction is inversely related to coronary flow.
- Lack of oxygen induces a shift to anaerobic metabolism = stimulation of glucose uptake (GLUT4), glycogenolysis and glycolytic flux.





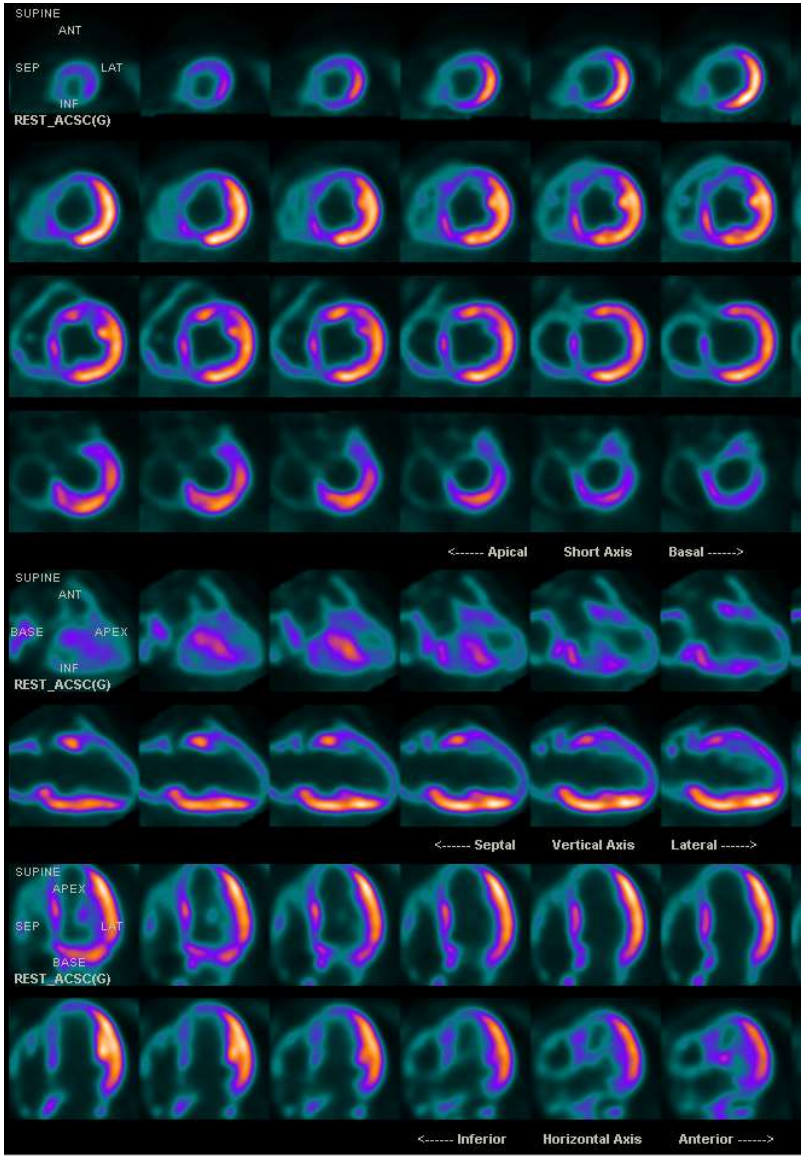
Stanley et al., Am J Physiol 1992; Sun et al., Circulation 1994

Combined perfusion & metabolism

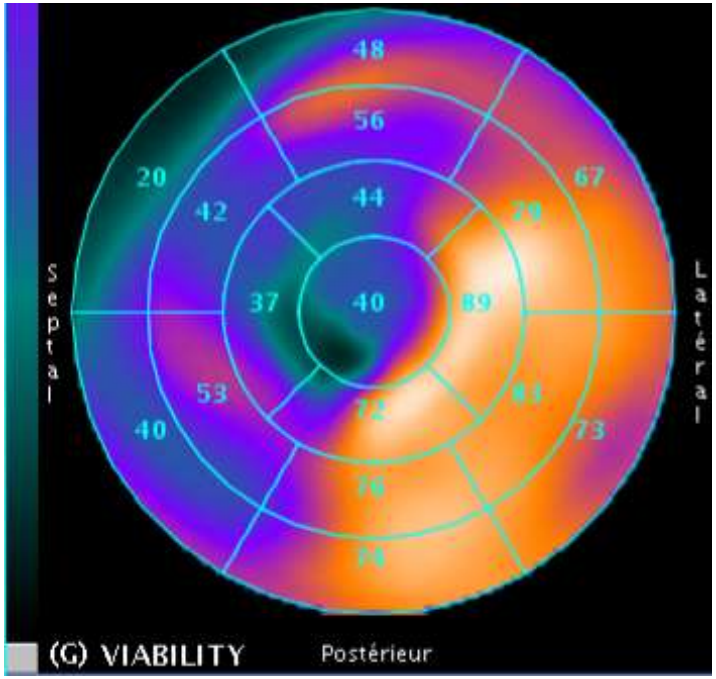


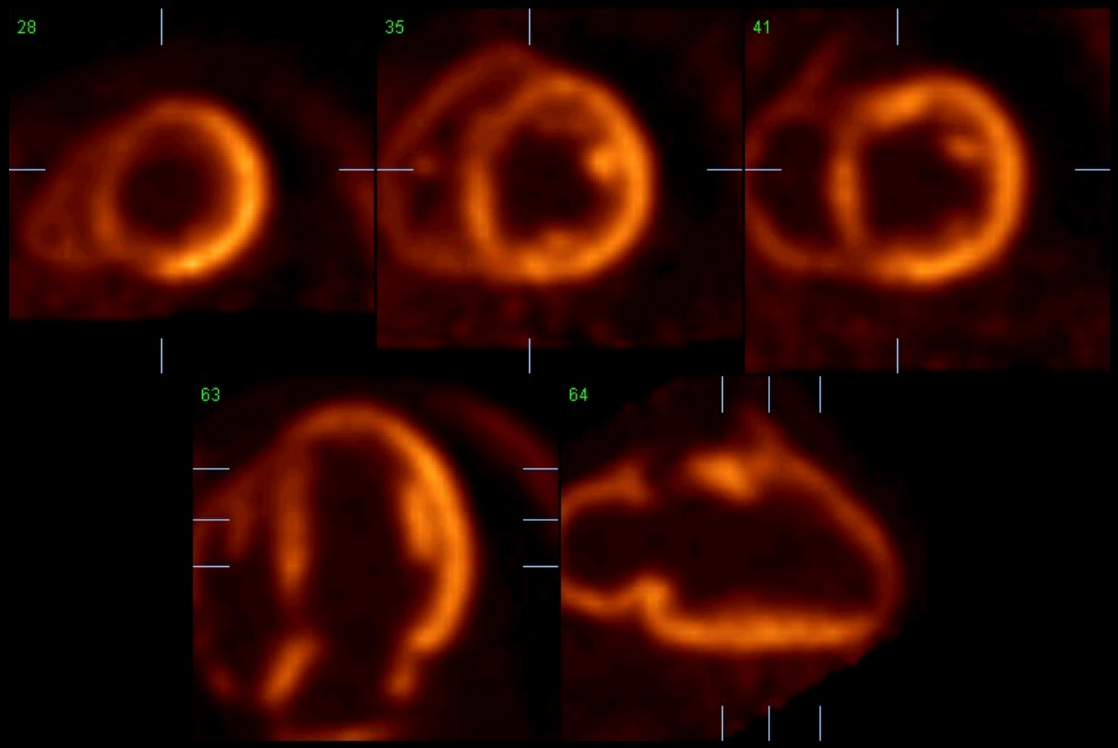
scar

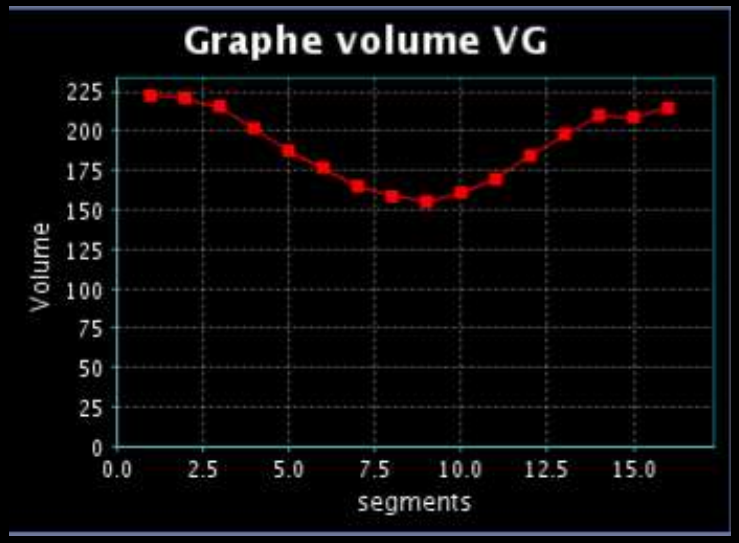
viable myocardium



Quantification of ^{18}FDG uptake on a polar map

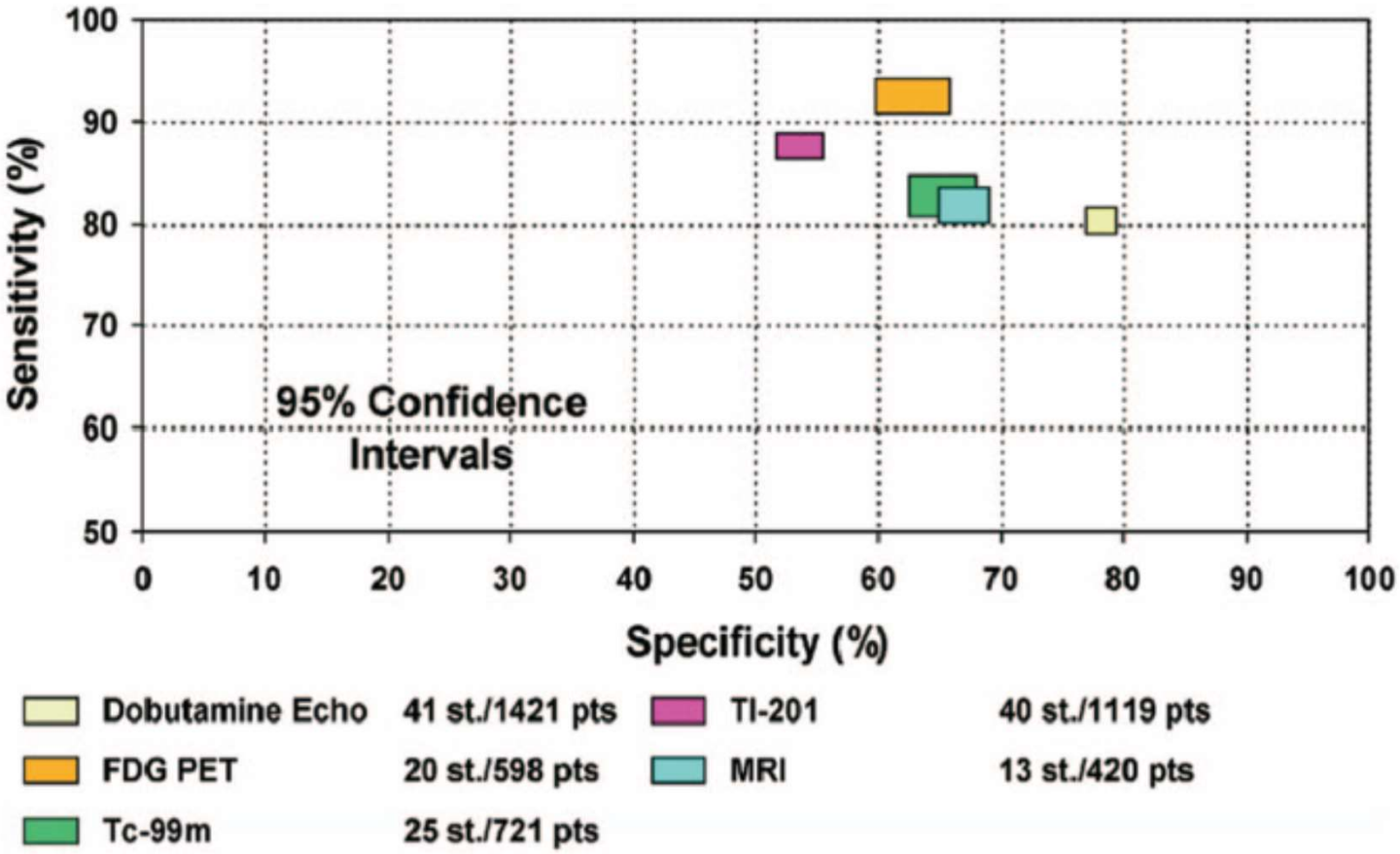






VIABILITY(G)	
ESV	155 ml
EDV	223 ml
EF	30 %
SV	67 ml
Mass	183 g

Viabilité

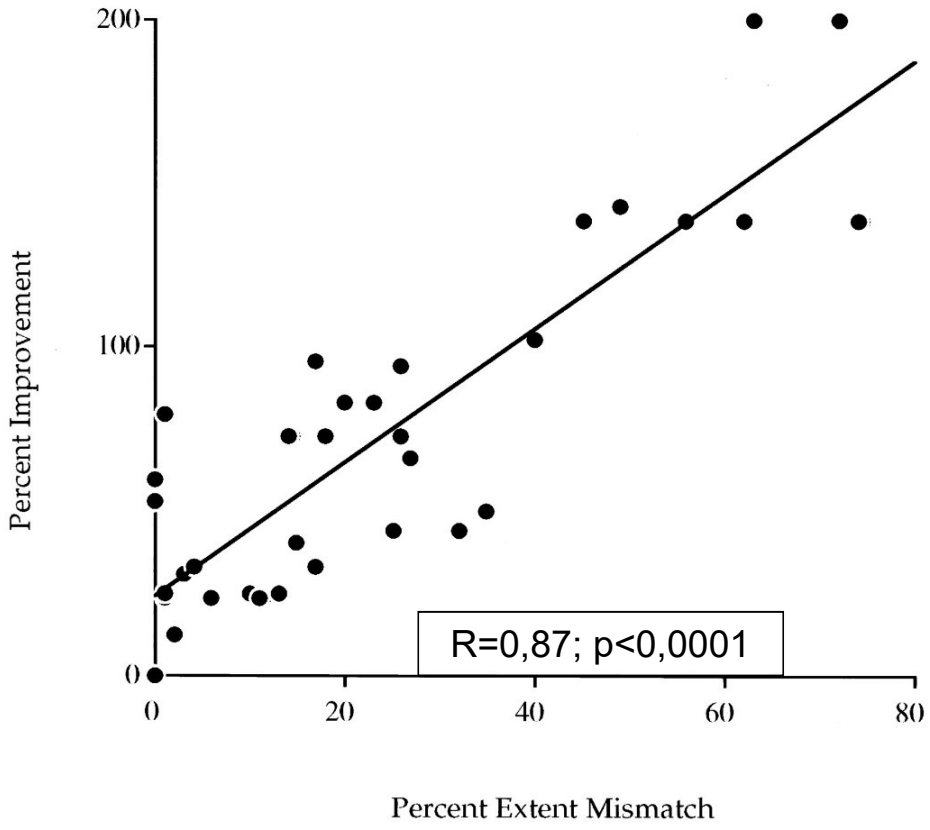


Buckley et al, Circulation 2011

Mismatch : amélioration fonctionnelle

36 patients, FEVG : 28±6%, revascularisation chirurgicale

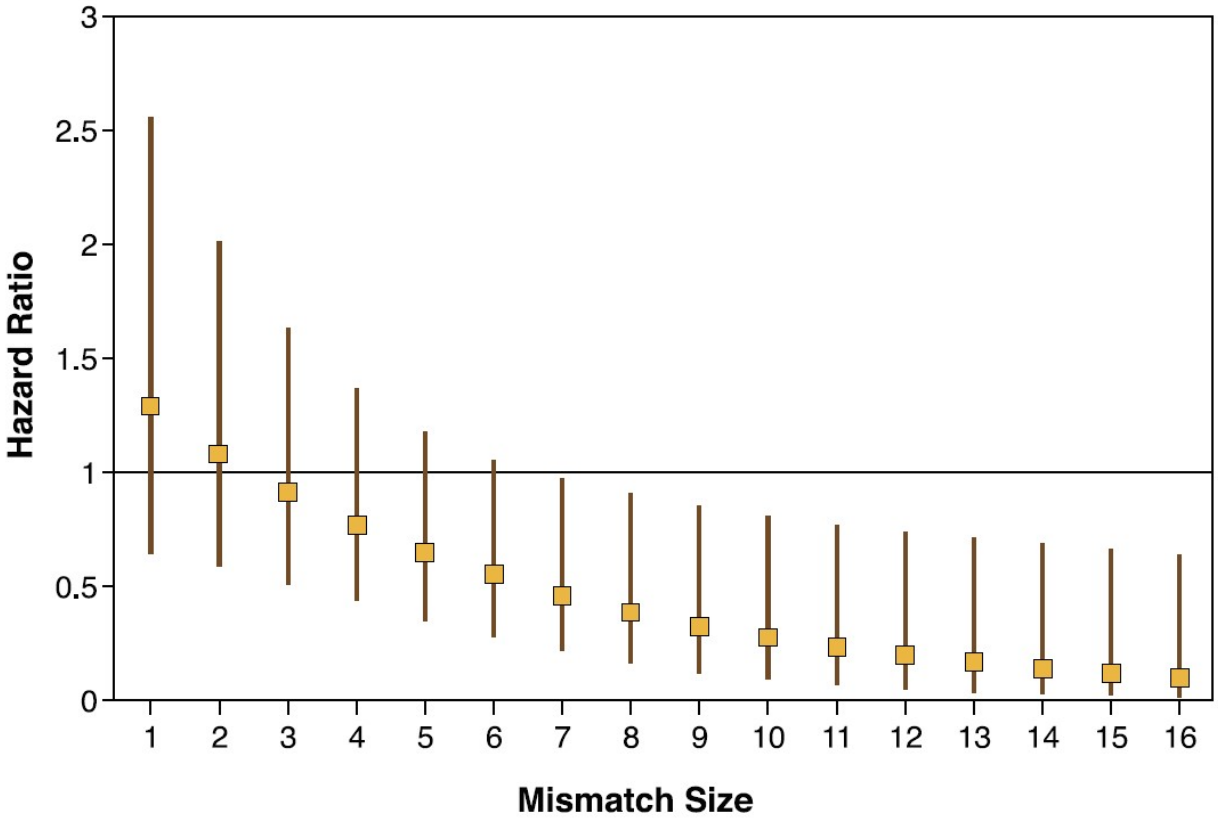
score fonctionnel : Specific Activity Score



MF Di Carli, Circulation 1995

Mismatch: PARR-2 study

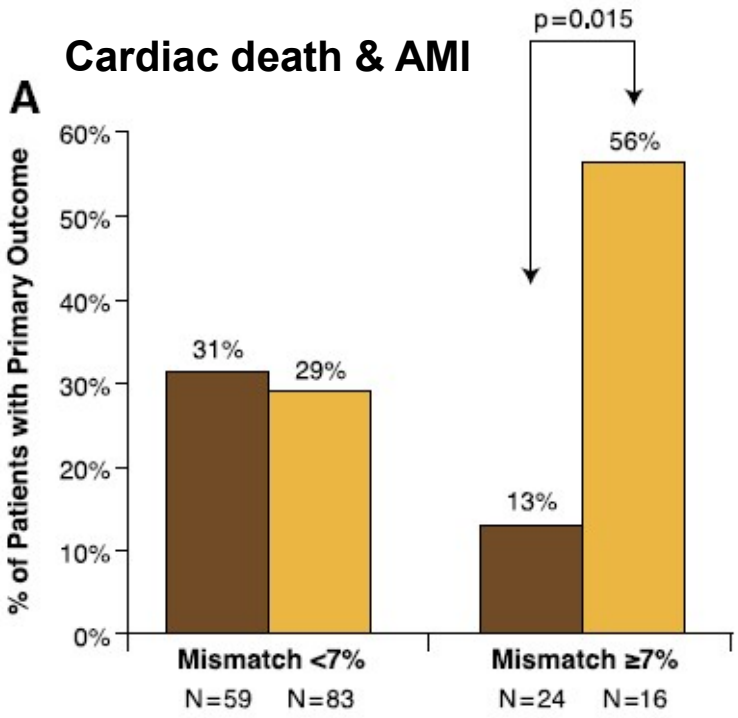
Mismatch Measured as a Continuous Variable

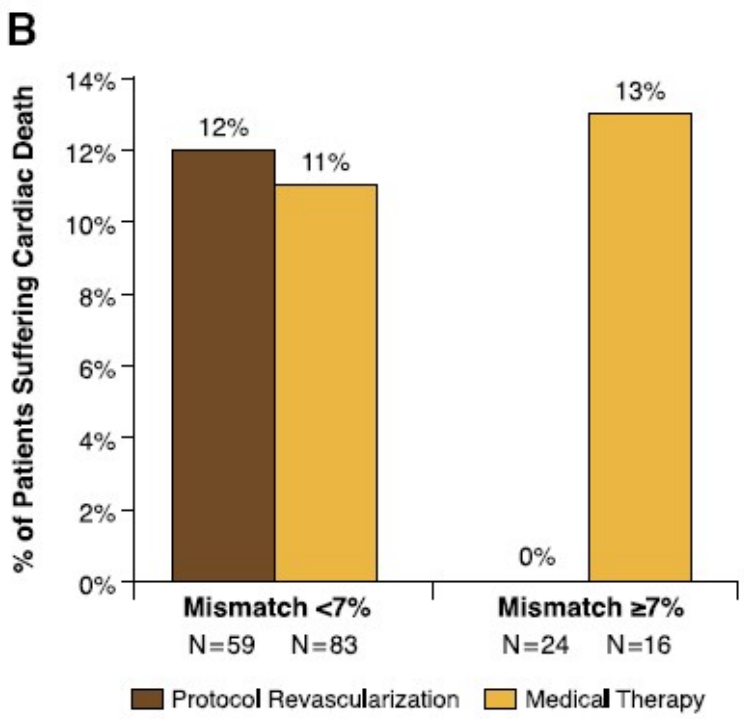


D'Egidio G et al, JACC 2009

Mismatch: PARR-2 study

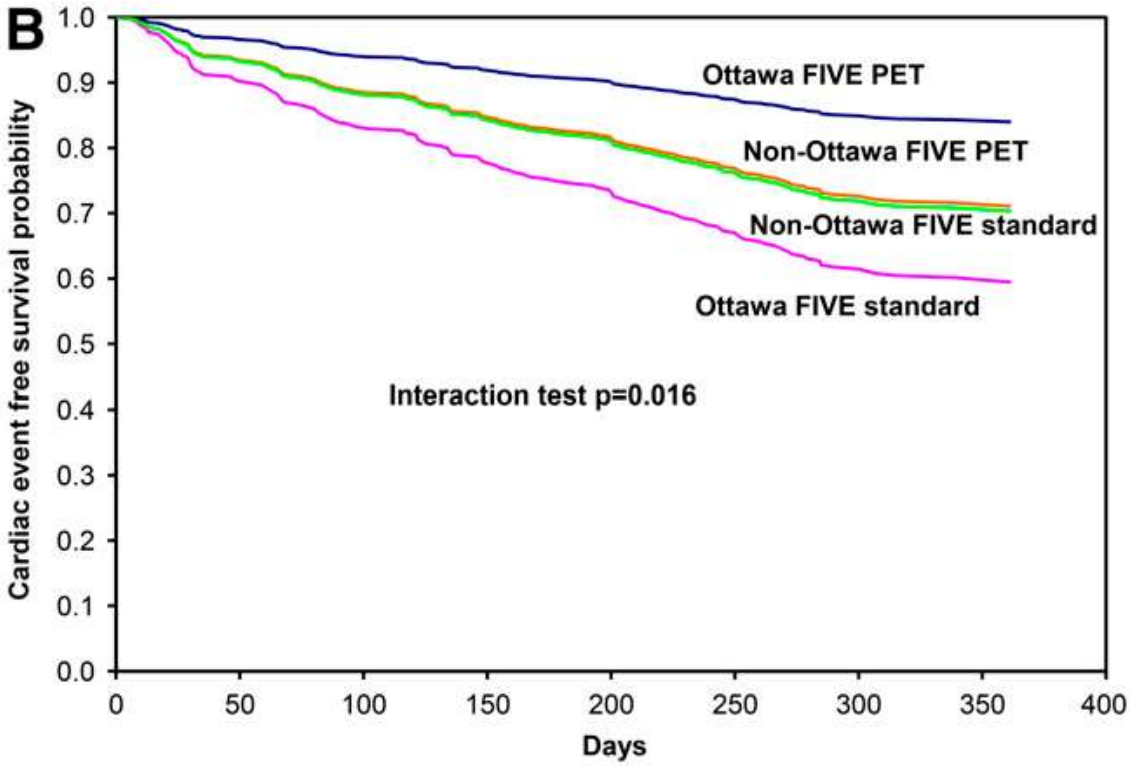
Effect of Revascularization or Medical Therapy





D'Egidio G et al, JACC 2009

Ottawa FIVE substudy: heart team



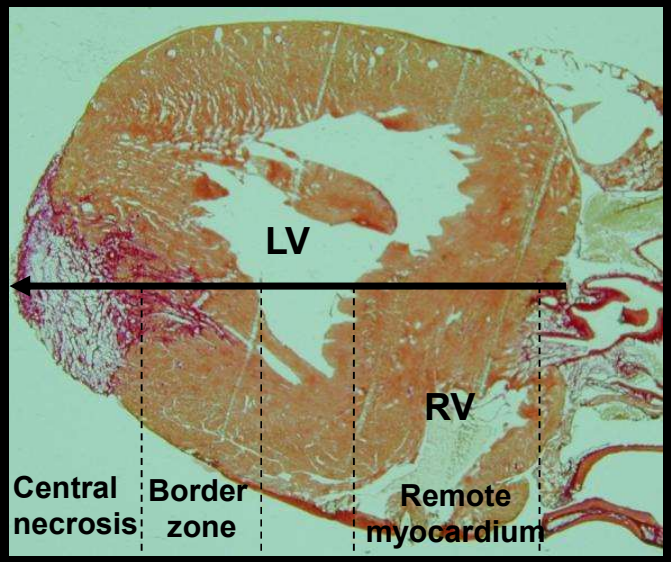
Ottawa FIVE subgroup:

- experienced centers with
- ready access to ^{18}F-FDG and
- integration with imaging, heart failure, and revascularization teams

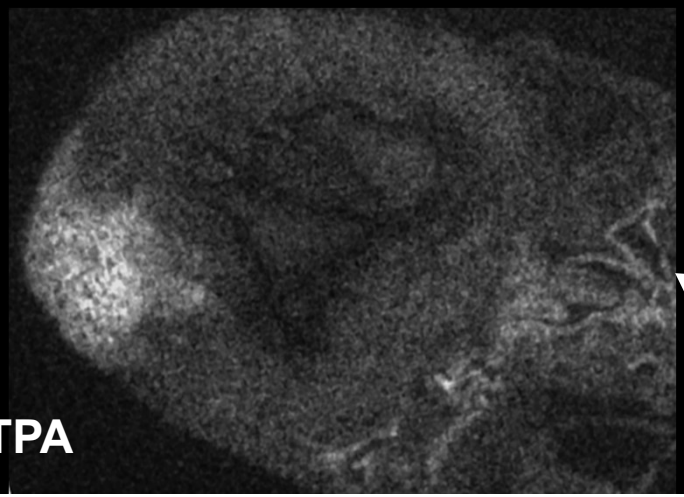
Abraham A et al, JNM 2010

Delayed retention relates to an enhanced interstitial distribution volume of tracers (decrease in the size of cellular compartment)

Sirius red
Collagen fibrosis



2-months after coronary occlusion in rats
Maskali F. J Nucl Cardiol 2005



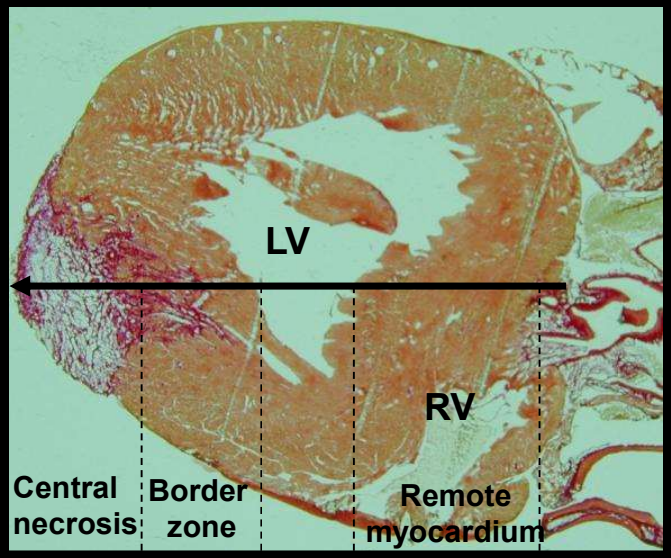
^{111}In-DTPA

Injection before sacrifice of
- ^{111}In-DTPA
- ^{99m}Tc-Sestamibi
- ^{18}F-FDG

µ-imager

Necrotic areas exhibit a dramatic decrease in myocardial perfusion
(decrease in Sestamibi uptake)

Sirius red
Collagen fibrosis



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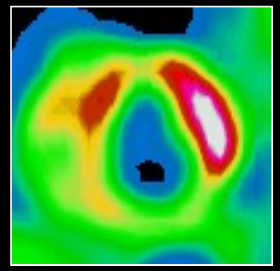
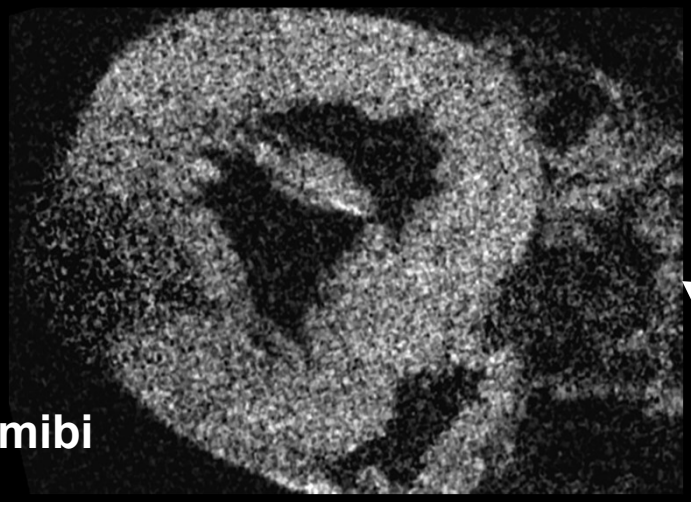




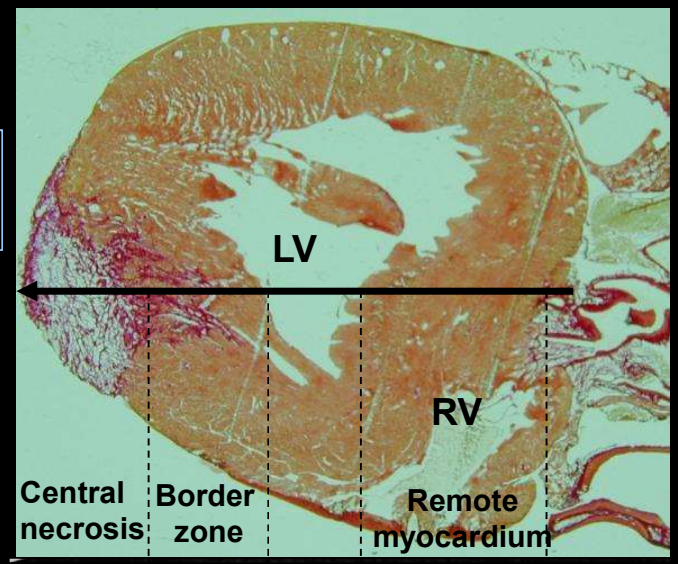
^{99m}Tc-Sestamibi

Injection before sacrifice of
- ^{111}In-DTPA
- ^{99m}Tc-Sestamibi
- ^{18}F-FDG

µ-imager

Necrotic areas exhibit a dramatic decrease in metabolic activity
(decrease in FDG uptake)

Sirius red
Collagen fibrosis



2-months after coronary occlusion in rats
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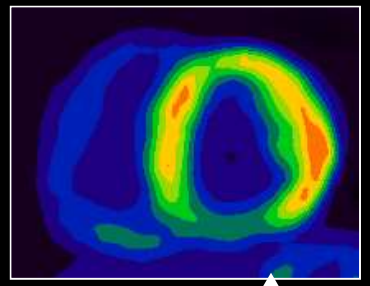
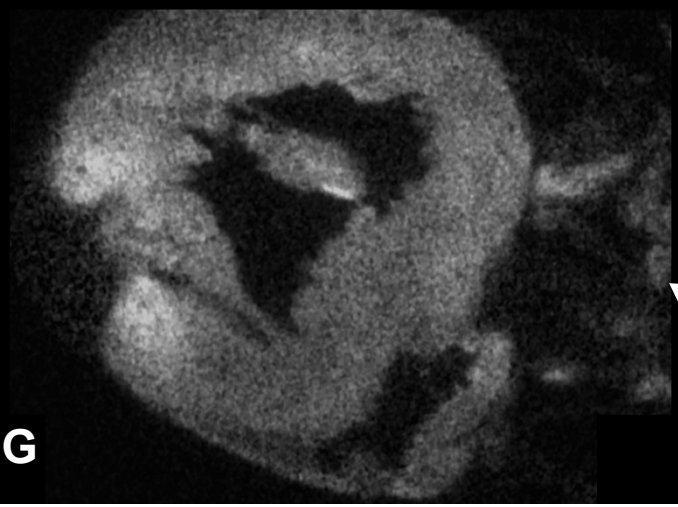




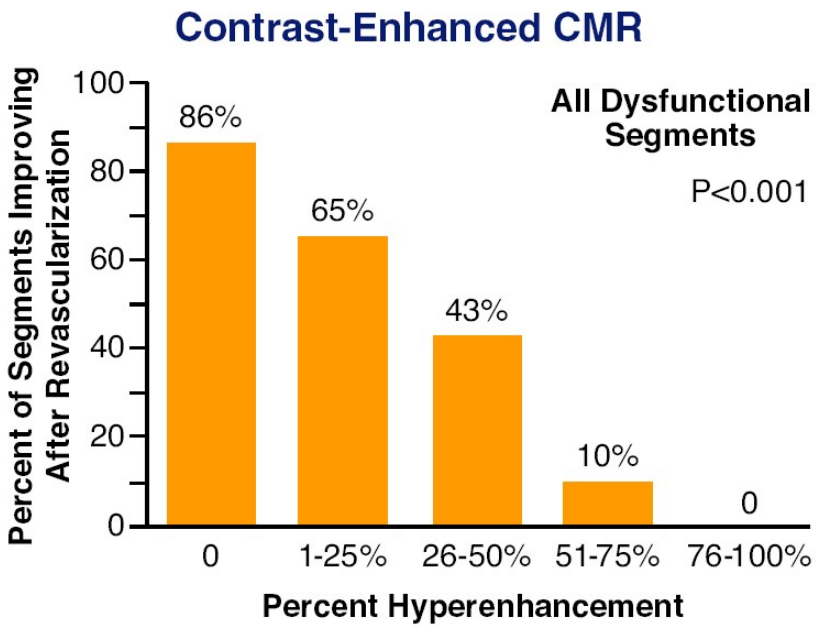
^{18}F-FDG

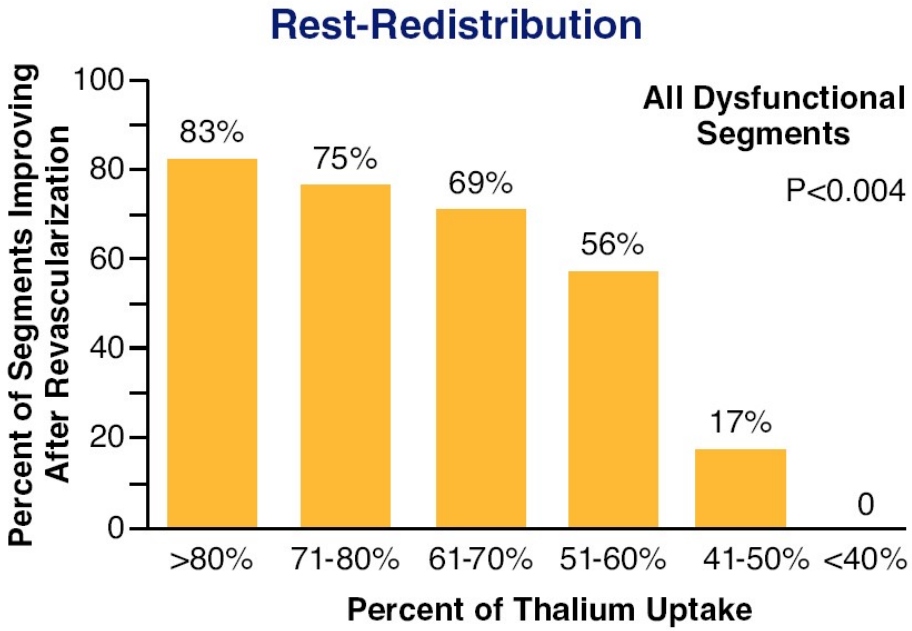
Injection before sacrifice of
- ^{111}In-DTPA
- ^{99m}Tc-Sestamibi
- ^{18}F-FDG

µ-imager

Threshold value ?

Functional recovery: continuum dependant on the ratio of viable to scarred myocardium

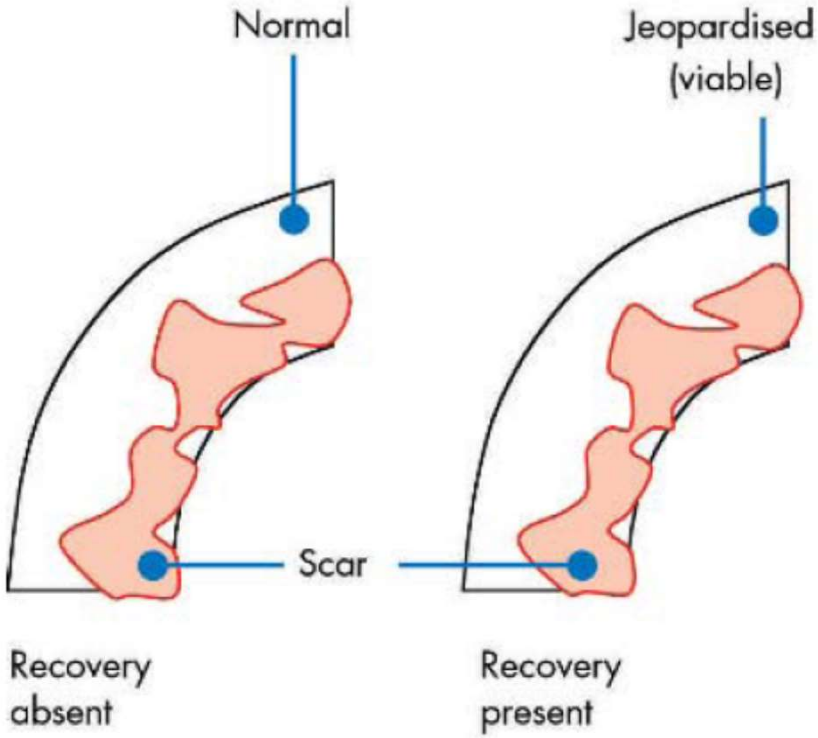




Modified from Dilsizian V, J Nucl Cardiol 2007

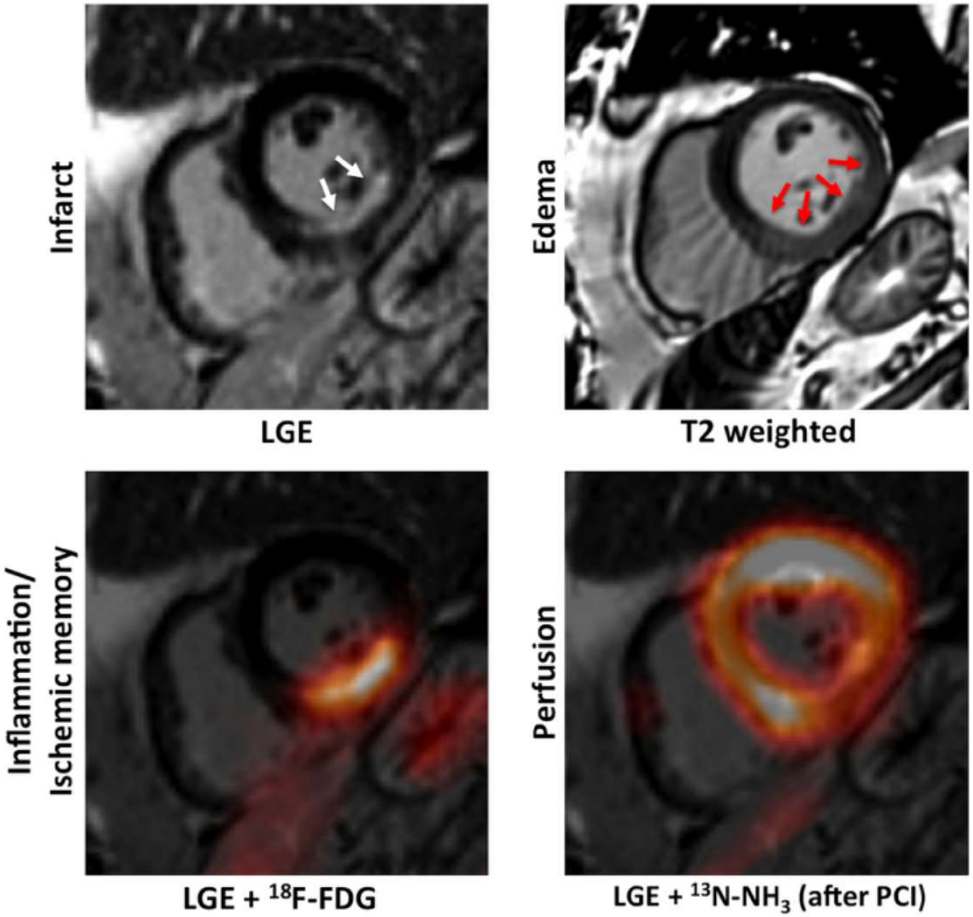
Threshold value ?

Functional recovery: continuum dependant on the ratio of viable to scarred myocardium



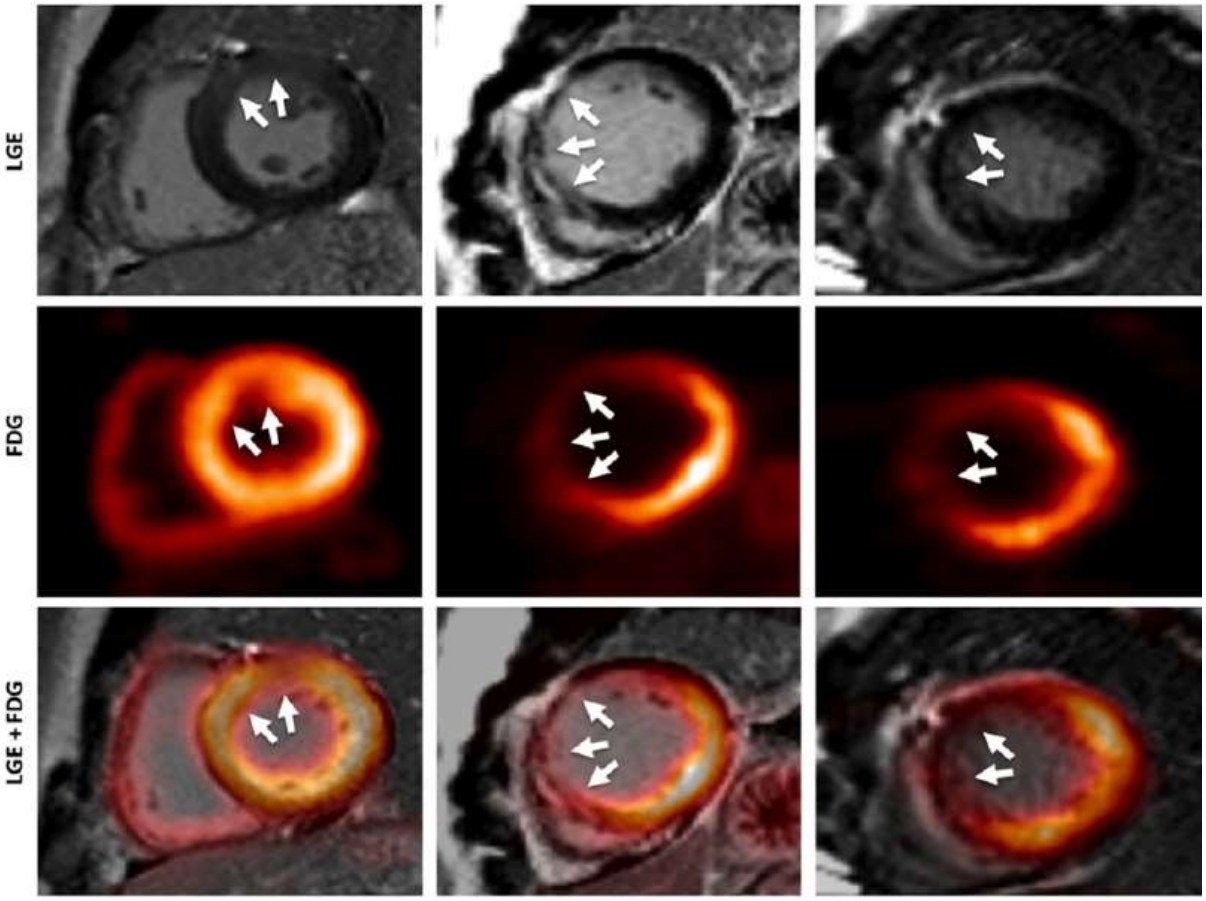
Kaandorp TAM et al, Heart 2005

Combined PET/MR



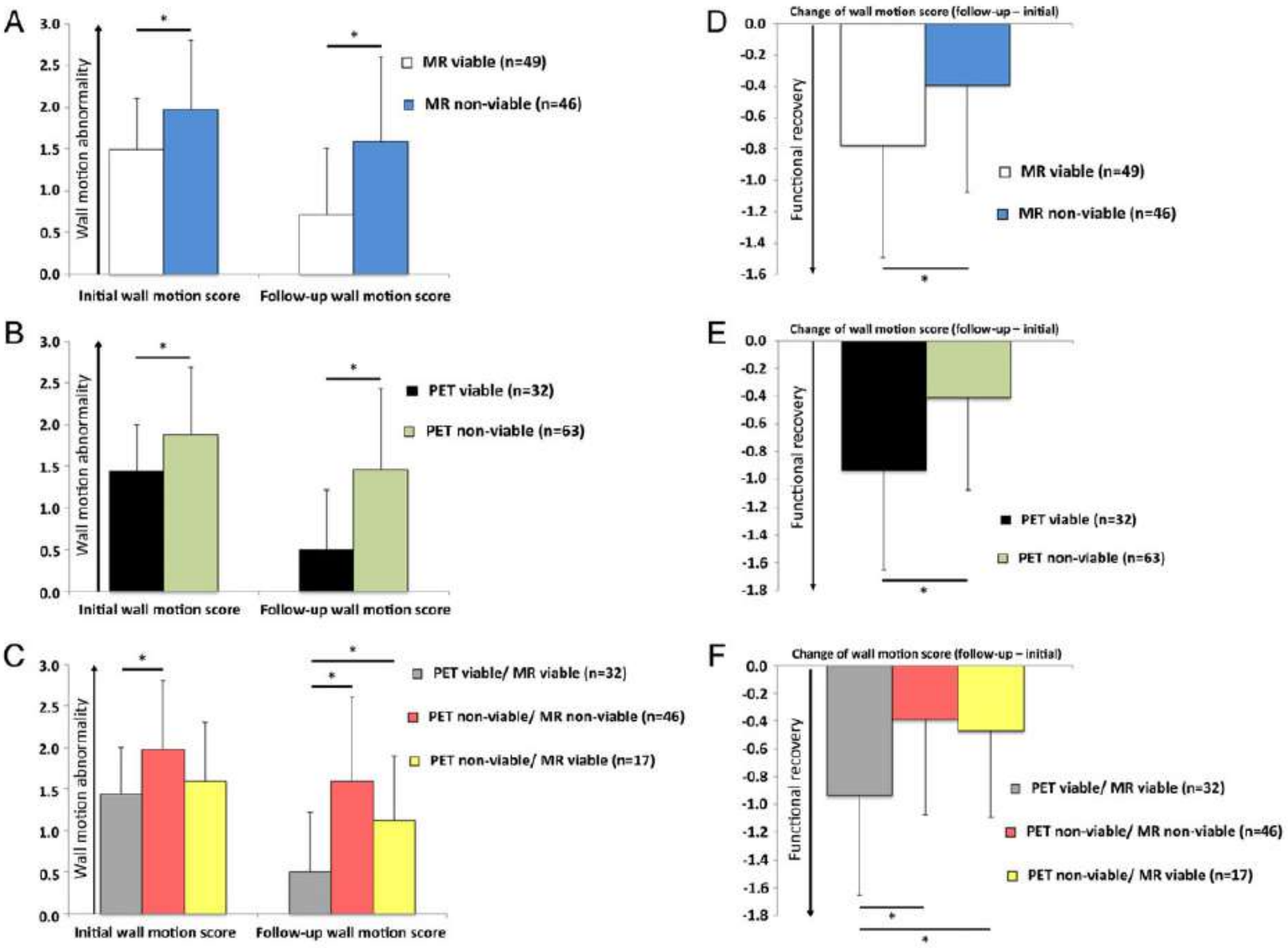
Rischpler C et al, Sem Nucl Med 2015

PET/MRI early after myocardial infarction



PET viable/ MR viable | PET non-viable/ MR non-viable | PET non-viable/ MR viable

Rischpler C et al, EHJ CVI 2015


A
Wall motion abnormality
3.0
2.5
2.0
1.5
1.0
0.5
0.0
*
*
MR viable (n=49)
MR non-viable (n=46)
Initial wall motion score
Follow-up wall motion score
B
Wall motion abnormality
*
*
PET viable (n=32)
PET non-viable (n=63)
Initial wall motion score
Follow-up wall motion score
C
Wall motion abnormality
*
*
*
PET viable/ MR viable (n=32)
PET non-viable/ MR non-viable (n=46)
PET non-viable/ MR viable (n=17)
Initial wall motion score
Follow-up wall motion score
D
Change of wall motion score (follow-up – initial)
Functional recovery
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
MR viable (n=49)
MR non-viable (n=46)
*
E
Change of wall motion score (follow-up – initial)
Functional recovery
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
PET viable (n=32)
PET non-viable (n=63)
*
F
Change of wall motion score (follow-up – initial)
Functional recovery
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
PET viable/ MR viable (n=32)
PET non-viable/ MR non-viable (n=46)
PET non-viable/ MR viable (n=17)
*
*

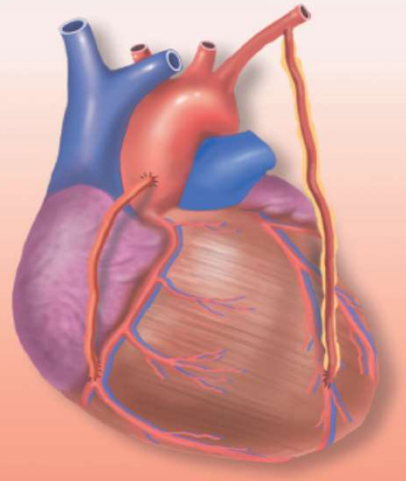
2013 ACCF/AHA Guideline for the Management of Heart Failure

Table 32. Recommendations for Surgical/Percutaneous/Transcatheter Interventional Treatments of HF

Recommendations	COR	LOE	References
CABG or percutaneous intervention is indicated for HF patients on GDMT with angina and suitable coronary anatomy, especially significant left main stenosis or left main equivalent	I	C	10,12,14,848
CABG to improve survival is reasonable in patients with mild to moderate LV systolic dysfunction and significant multivessel CAD or proximal LAD stenosis when viable myocardium is present	IIa	B	848–850
CABG or medical therapy is reasonable to improve morbidity and mortality for patients with severe LV dysfunction (EF <35%), HF, and significant CAD	IIa	B	309,851
Surgical aortic valve replacement is reasonable for patients with critical aortic stenosis and a predicted surgical mortality of no greater than 10%	IIa	B	852
Transcatheter aortic valve replacement is reasonable for patients with critical aortic stenosis who are deemed inoperable	IIa	B	853
CABG may be considered in patients with ischemic heart disease, severe LV systolic dysfunction, and operable coronary anatomy whether or not viable myocardium is present	IIb	B	307–309
Transcatheter mitral valve repair or mitral valve surgery for functional mitral insufficiency is of uncertain benefit	IIb	B	854–857
Surgical reverse remodeling or LV aneurysmectomy may be considered in HF/EF for specific indications, including intractable HF and ventricular arrhythmias	IIb	B	858

CABG indicates coronary artery bypass graft; CAD, coronary artery disease; COR, Class of Recommendation; EF, ejection fraction; GDMT, guideline-directed medical therapy; HF, heart failure; HF/EF, heart failure with reduced ejection fraction; LAD, left anterior descending; LOE, Level of Evidence; and LV, left ventricular.

Favors Medical Therapy



Favors CABG + Medical Therapy

- Severe Renal Insufficiency
- Smaller LVESVI (<79 ml/m^2)
- Higher LVEF (>28%)
- Single-Vessel Coronary Disease
- Limited Functional Capacity (6MWD <300 meters, KCCQ Physcial Ability Score ≤55)
- More Viable Myocardium
- Ischemic Burden
- Biomarker Level (BNP, STNFR-1)
- Less Viable Myocardium
- Increased MI Risk
- Increased Risk of Sudden Cardiac Death
- Moderate to Severe Mitral Regurgitation
- Preserved Functional Capacity (6MWD ≥300 meters, KCCQ Physical Ability Score >55)
- Lower LVEF (≤27%)
- Three-Vessel Coronary Disease
- Larger LVESVI (≥79ml/m^2)

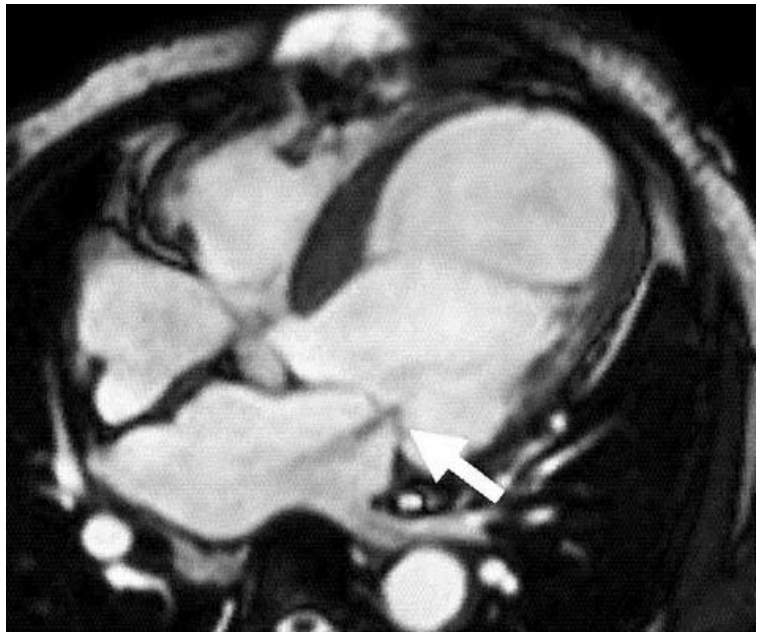
Velasquez EJ, Bonow RO, JACC 2015

MR & additional informations

Provided by morphological imaging (MRI / Echo)

LV aneurysm + thrombus

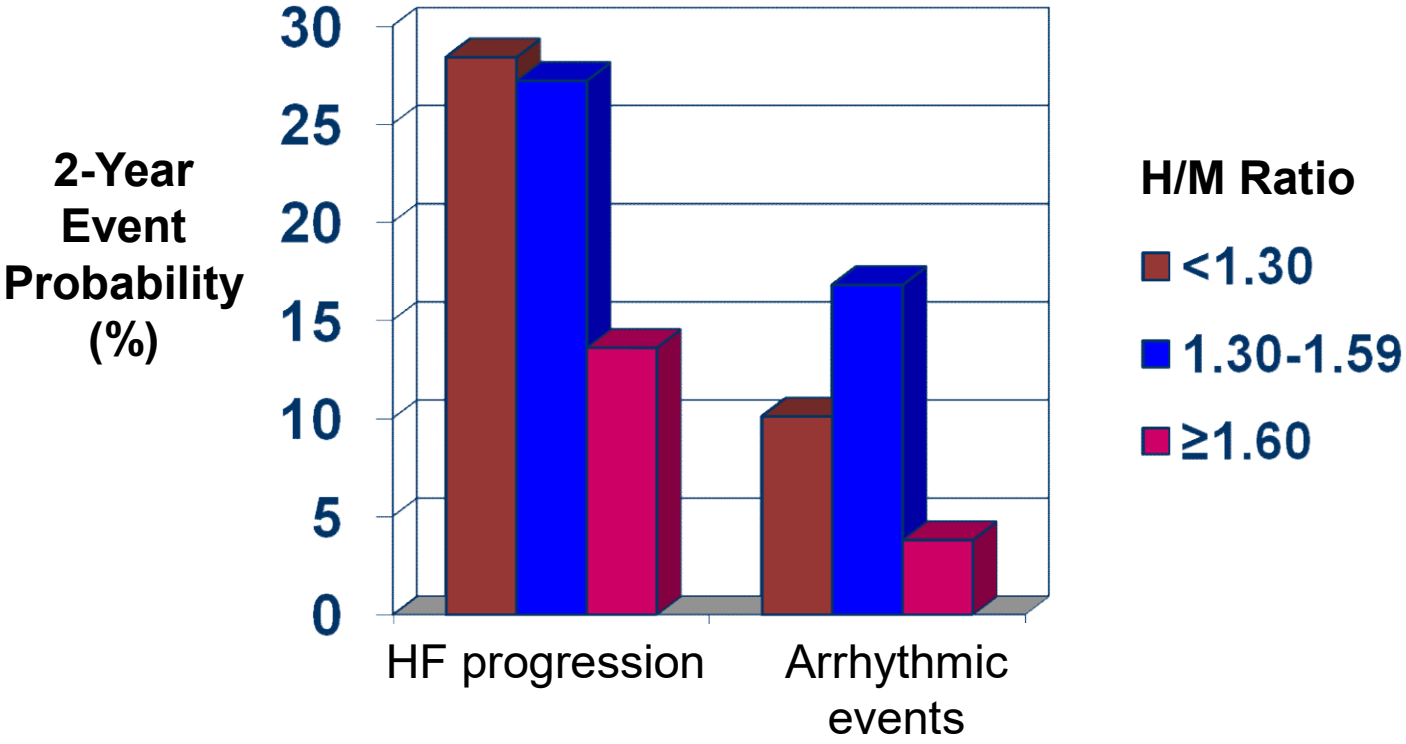
Mitral regurgitation



Kaandorp TAM et al, Heart 2005

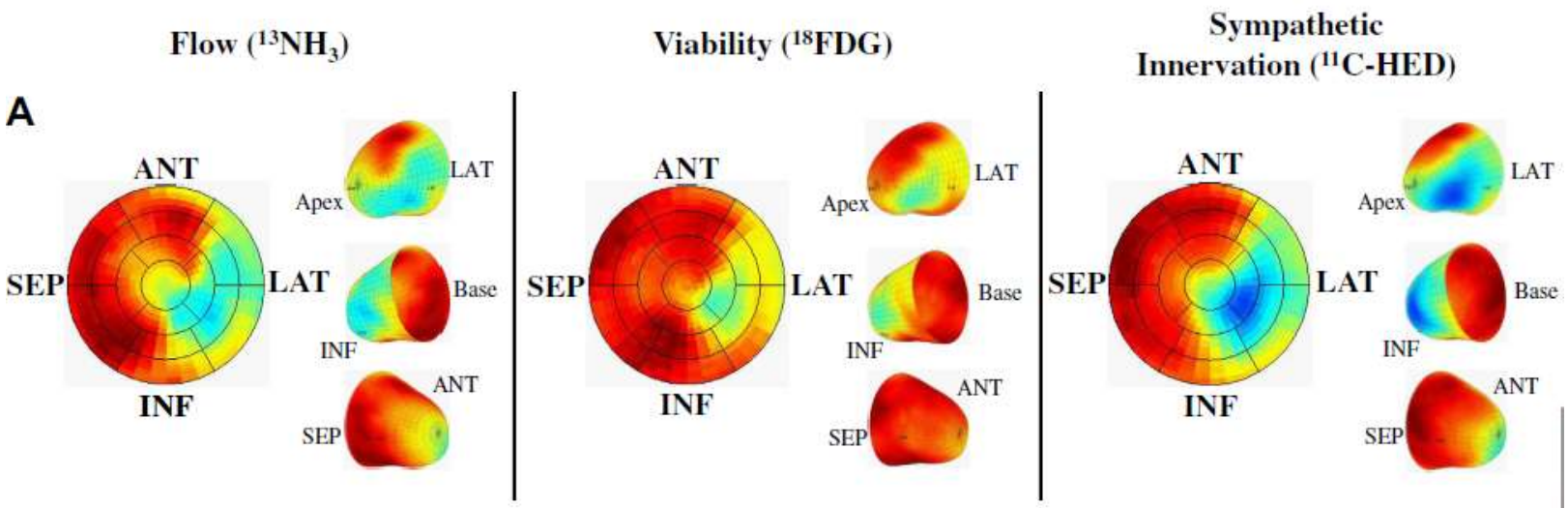
Sudden cardiac death

ADMIRE-HF : prognostic value of MIBG in heart failure



Differences between H/M≥1.60 and other groups are all significant ($p<0.05$).
Differences between H/M<1.30 and 1.30-1.59 are both $p>0.05$.

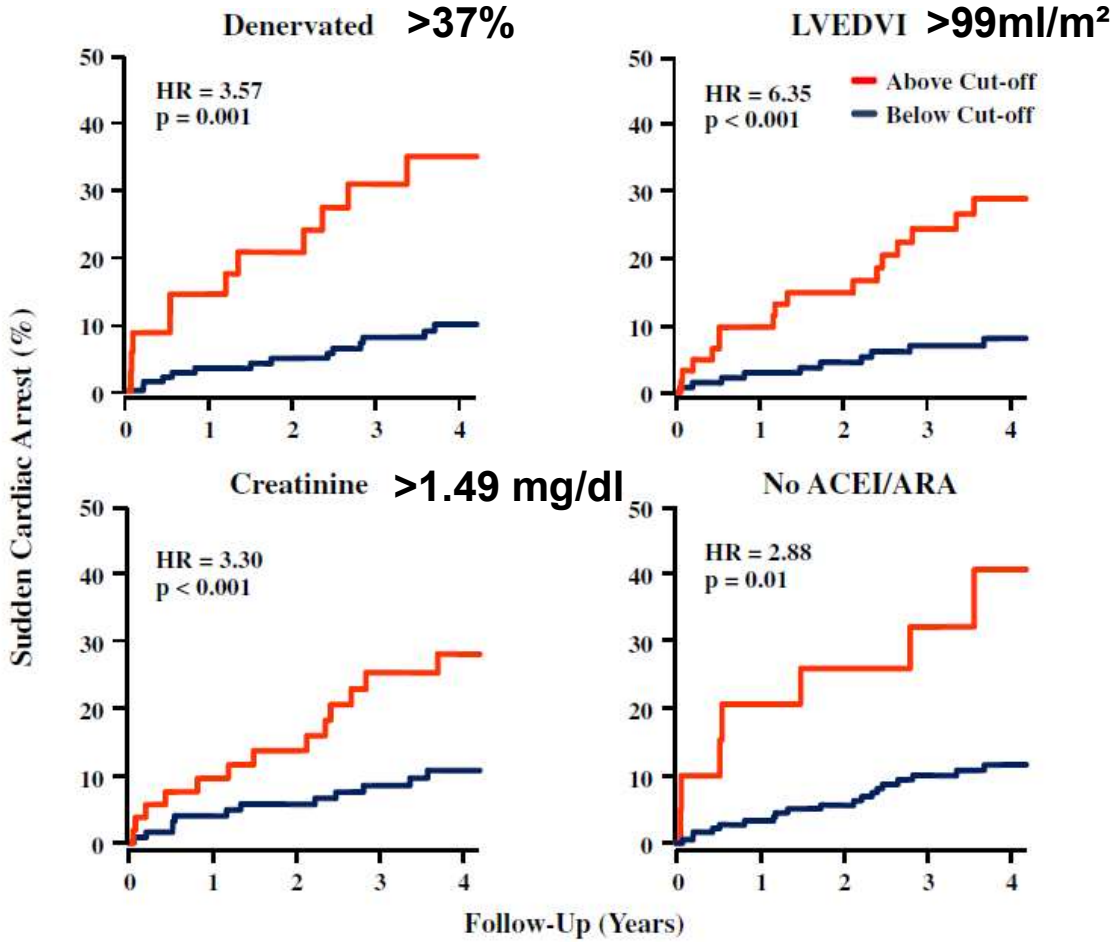
Jacobson et al, JACC 2010



Fallavollita JA et al, JACC 2014

	SCA (n = 33)	No SCA (n = 171)	p Value
PET parameters (% LV)			
Denervated myocardium	33 ± 10	26 ± 11	0.001
Infarcted myocardium	22 ± 7	19 ± 9	0.18
Viable, denervated myocardium	10 ± 6	7 ± 5	0.02
Hibernating myocardium	3 ± 2	3 ± 3	0.50
Echocardiography			
LV ejection fraction (%)	24 ± 8	28 ± 9	0.053
LV end-diastolic volume index (ml/m^2)	107 ± 28	86 ± 30	<0.001
LV end-systolic volume index (ml/m^2)	81 ± 21	63 ± 26	<0.001
LV mass index (g/m^2)	167 ± 37	150 ± 48	0.07
Mitral regurgitation	2.0 ± 1.2	1.6 ± 1.1	0.04

Cardiac denervation



Fallavollita JA et al, JACC 2014

In summary

- Assessment of myocardial viability alone should not be the deciding factor in selecting the best therapy
- Should be included in an individual assessment of the expected benefit derived from revascularization
  - 3-vessel disease,
  - Severe LV dysfunction,
  - LV remodeling (ESVi)
- When present, the extent of viable myocardium is a key parameter
- In some subsets, optimal medical therapy may be as effective as revascularization

In summary

- Which modality ? “ The differences in performance between the various imaging techniques are small, and experience and availability commonly determine which technique is used.” (2014 ESC/EACTS Guidelines on myocardial revascularization)
- Change modality in case of inconclusive result
- Morphological analysis (Echo / MRI)
  - Recent ACS: wall thickness measurement (probably best predictor)
  - Assessment of a secondary mitral regurgitation
- Metabolic approach
  - Severe remodelling
  - Assessment of the arrhythmic risk
- **Integration in the heart team**