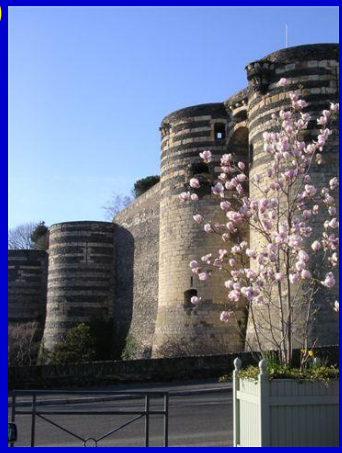
# IRM et Cardiopathies Ischémiques



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CHU et Université d'Angers

# Quelques chiffres

- Prévalence des cardiopathies ischémiques 3,9 %
- Incidence des SCA : 100 000 cas / an
- Mortalité 46 000 décès / an
- ALD 13 (Maladie coronaire) : 780 000
  - 77 500 nouveaux cas / an
- 250 000 coronarographies (20-35 % normales)
  - 60 % ATC
  - 9,4 % PAC
  - 30,6 % Traitement médical

# Fonction VG et VD globale
# Cardiopathies ischémiques

- Fonction VG
  - Patient peu échogène +++
  - Discordances écho, ventriculographie +++
  - Indication du défibrillateur (FE précise)
  - Post-infarctus (viabilité)
  - Etiologie d'une insuffisance cardiaque
- Fonction VD +++
- Recherche clinique

# IRM et cardiopathies ischémiques

- Les syndromes coronariens aigus
  - Sus-décalage du segment ST
    - Complications (Thrombus et anévrysme VG)
    - Viabilité myocardique
    - Marqueurs pronostiques après reperfusion
      - Taille de l'infarctus, No-reflow, Hémorragie myocardique
  - Sans sus-décalage du segment ST
  - MINOCA
- Viabilité myocardique
- Douleur thoracique et suspicion d'angor stable

# La place de l'IRM cardiaque dans les cardiopathies ischémiques

- Dans le post-infarctus
  - **Fonction VG globale et régionale + + +**
  - Diagnostic des complications
    - Anévrysme VG, Thrombus
  - Ischémie résiduelle
    - Fonction VG régionale sous dobutamine
    - Perfusion myocardique régionale sous dipyridamole
    - Réserve coronaire sous adénosine
  - **Viabilité myocardique + + +** I
  - Perméabilité de l'artère responsable

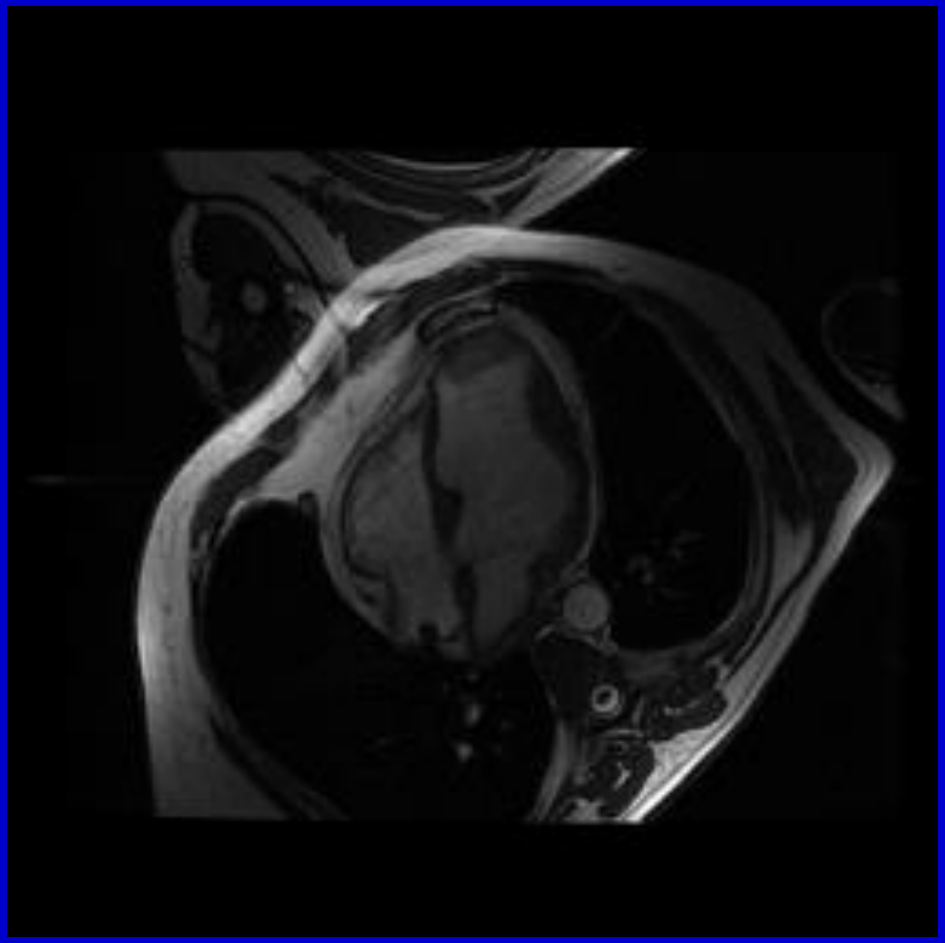
# Thrombus VG et IRM

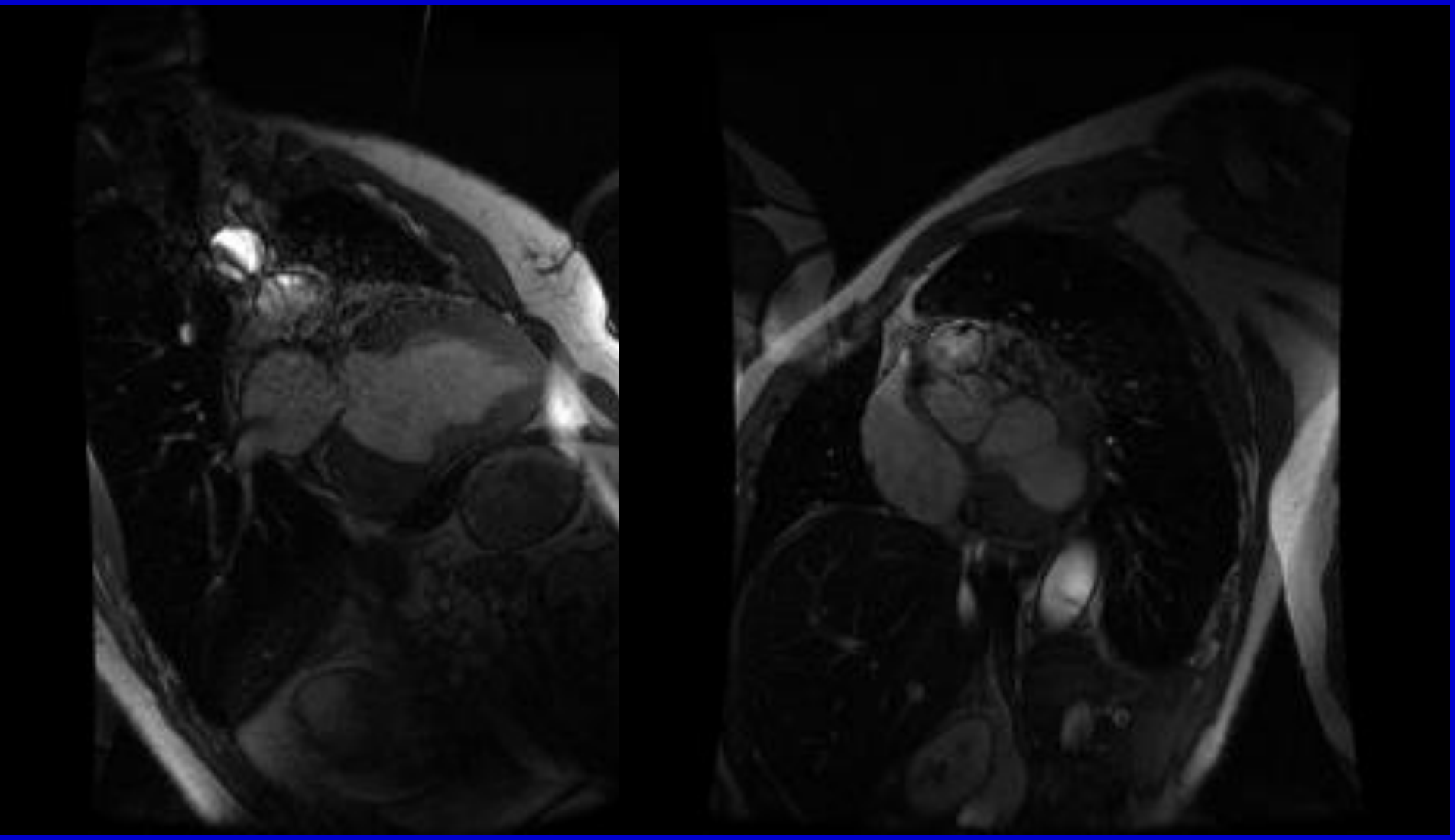
| | Total (n) | MRI | TTE | TEE |
|---|---|---|---|---|
| Sensitivity | 48 | 88% (79%-97%) | 23% (11%-35%) | 40% (26%-54%) |
| Specificity | 112 | 99% (97%-100%) | 96% (92%-99.6%) | 96% (92%-99.6%) |

Ninety-five percent confidence intervals are shown in parentheses.

*Srichai MB et al. Am Heart J 2006*

# Thrombus ventriculaire gauche apical





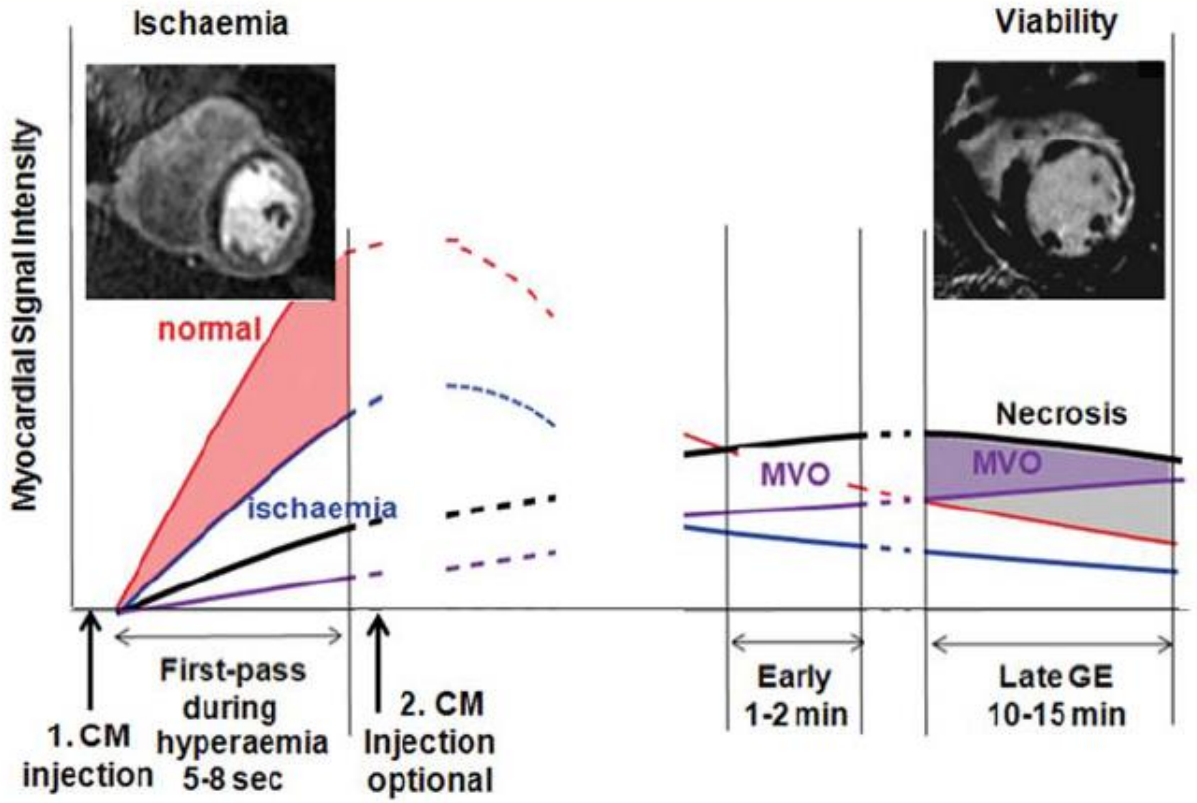
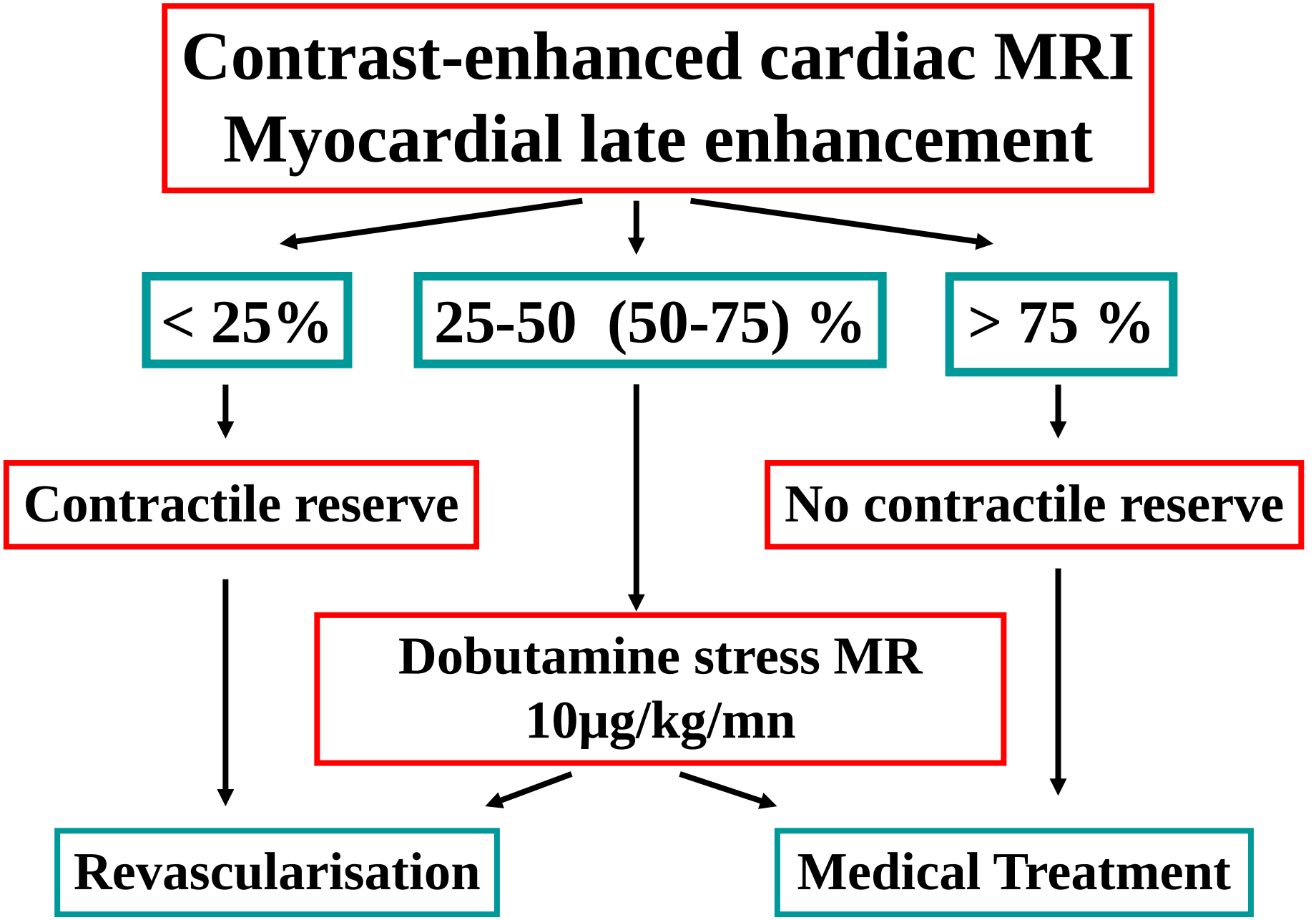



**Figure 1** A schematic explains the various time points of image acquisition relative to contrast medium administration to assess ischaemia and necrosis/scar tissue. Red line corresponds to normal non-ischaemic myocardium, blue line the ischaemic myocardium, black line the necrotic tissue in the acute myocardial infarction (fibrotic tissue in chronic myocardial infarction), and purple line the tissue with microvascular obstruction (MVO).


Contrast-enhanced cardiac MRI
Myocardial late enhancement
< 25%
25-50 (50-75) %
> 75 %
Contractile reserve
No contractile reserve
Dobutamine stress MR
10µg/kg/mn
Revascularisation
Medical Treatment

# Viabilité et Marqueurs pronostiques en phase aiguë d'infarctus

- Infarctus pris en charge tardivement
  - avant ou après coronarographie (FE altérée)
  - IRM réhaussement tardif J3 - J5
    - Infarctus non transmural discuter revascularisation
    - Absence de viabilité : risque de sur-estimation de la taille de l'infarctus (oedème myocardique)
    - Nouvelle IRM à 3 mois
    - Ou IRM initiale > J7
- Marqueurs pronostiques après reperfusion
  - IRM J3 – J5

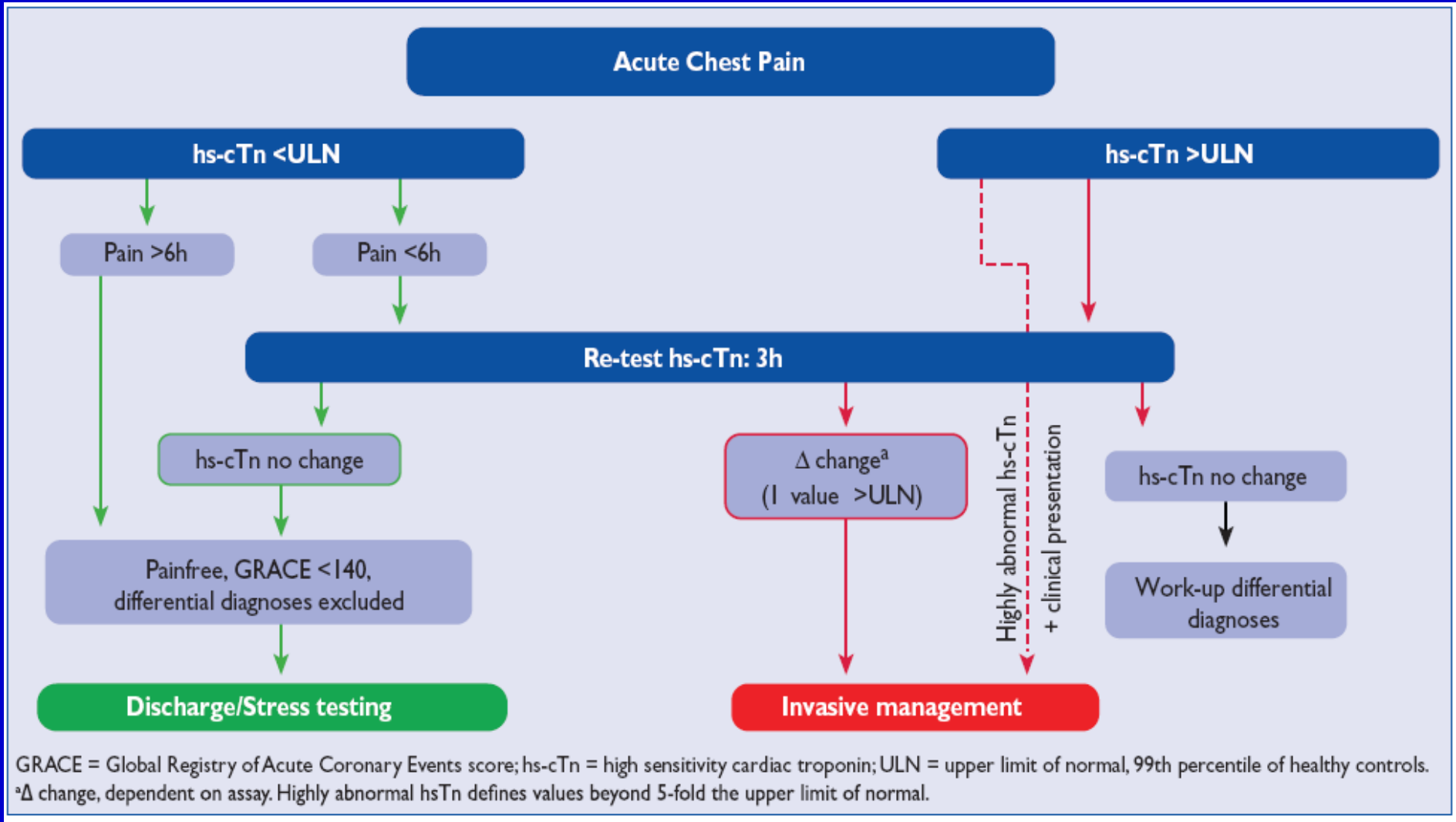
# Les SCA non ST+

# Acute coronary syndromes MRI in patients with non STEMI

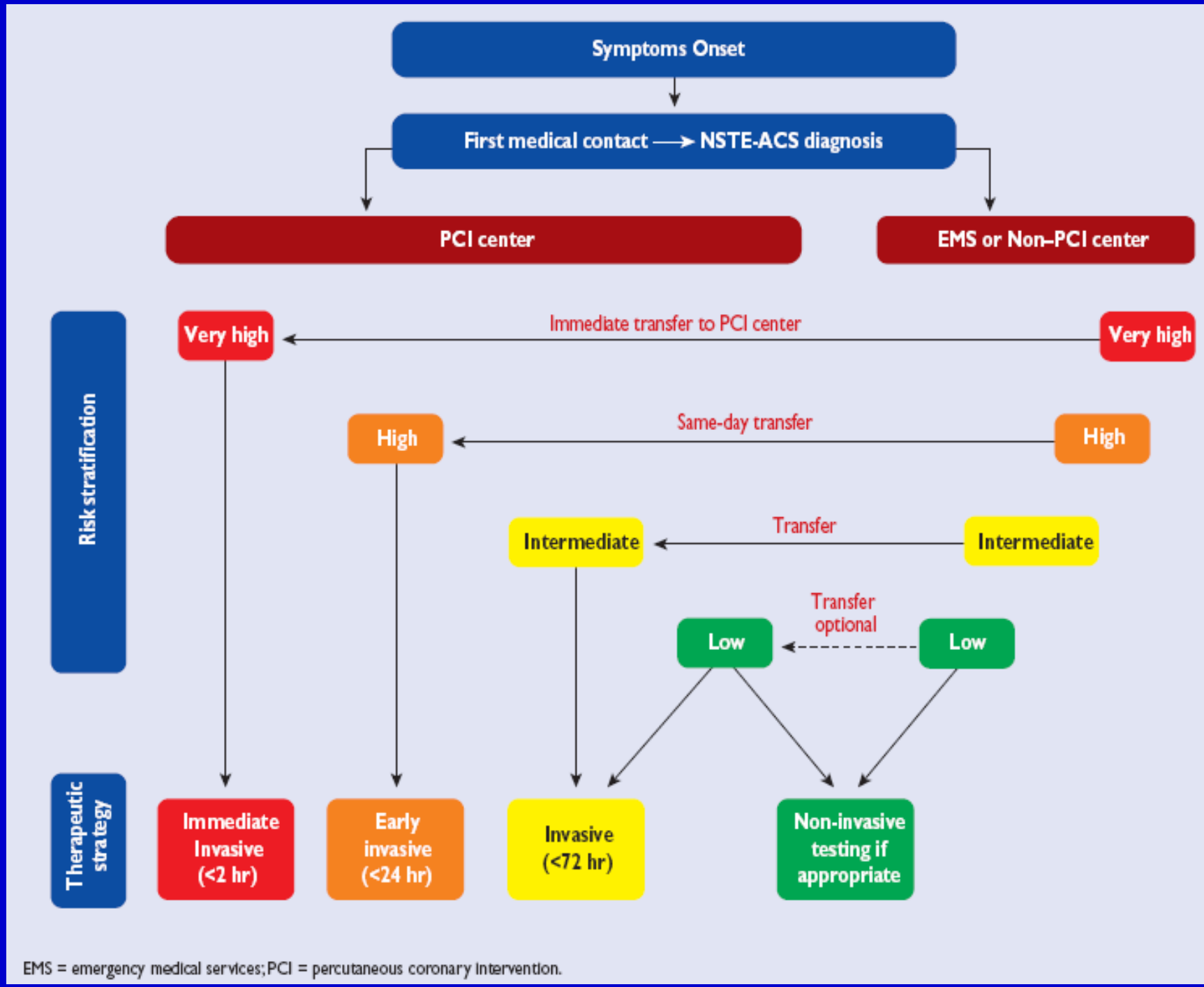
- Non-invasive approach

- Low risk non STEMI
  - ESC and AHA guidelines
- In patients with severe co-morbidities
  - AHA guidelines

# IRM et SCA non ST+




ESC Guidelines 2015




EMS = emergency medical services; PCI = percutaneous coronary intervention.

| Very-high-risk criteria |
| --- |
| • Haemodynamic instability or cardiogenic shock |
| • Recurrent or ongoing chest pain refractory to medical treatment |
| • Life-threatening arrhythmias or cardiac arrest |
| • Mechanical complications of MI |
| • Acute heart failure |
| • Recurrent dynamic ST-T wave changes, particularly with intermittent ST-elevation |
| **High-risk criteria** |
| • Rise or fall in cardiac troponin compatible with MI |
| • Dynamic ST- or T-wave changes (symptomatic or silent) |
| • GRACE score >140 |

| Intermediate-risk criteria |
| --- |
| • Diabetes mellitus |
| • Renal insufficiency (eGFR <60 mL/min/1.73 $m^2$) |
| • LVEF <40% or congestive heart failure |
| • Early post-infarction angina |
| • Prior PCI |
| • Prior CABG |
| • GRACE risk score >109 and <140 |
| **Low-risk criteria** |
| • Any characteristics not mentioned above |

# Stepwise approach for decision making in patients with unknown CAD

- Step 2 : Non-invasive stress testing

| | Asymptomatic[a] | | Symptomatic | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Probability of significant disease[b] | | | | | | |
| | | | Low (<15%) | | Intermediate (15–85%) | | High (>85%) | | |
| | Class[c] | Level[d] | Class[c] | Level[d] | Class[c] | Level[d] | Class[c] | Level[d] | Ref[e] |
| **Anatomical detection of CAD** | | | | | | | | | |
| Invasive angiography | III | A | III | A | IIb | A | I | A | 50–52,54 |
| CT angiography[f,g] | III | B | III | C | IIa | A | III | B | 57–62 |
| **Functional test** | | | | | | | | | |
| Stress echo | III | A | III | A | I | A | III | A | 63–65 |
| Nuclear imaging | III | A | III | A | I | A | III | A | 60,66–70 |
| Stress MRI | III | B | III | C | I | A | III | B | 71–75 |
| PET perfusion | III | B | III | C | I | A | III | B | 67,69,70,76,77 |
| **Combined or hybrid imaging test** | | | | | | | | | |
| | III | C | III | C | IIa | B | III | B | 78–83 |

**Detecting Acute Coronary Syndrome in the Emergency Department With Cardiac Magnetic Resonance Imaging**

Raymond Y. Kwong, Adam E. Schussheim, Suresh Rekhraj, Anthony H. Aletras, Nancy Geller, Janice Davis, Timothy F. Christian, Robert S. Balaban and Andrew E. Arai

- 161 patients, DT ≥ 30 min compatible avec un syndrome coronarien aigu dans les 12h avant l'admission (SCA ST+ exclus)
- Objectif : identifier les patients présentant un SCA

  → SCA ST- (troponine +) et angor instable (sténose > 70% ou test ischémique +)

- 85% des IRM réalisés avant le résultat de la 2$^{e}$ troponine
- 100% des IRM réalisés dans les 12h, avant la coronarographie et les tests de provocation.
- 25 SCA (16%) : 10 SCA ST-, 15 angor instable

Circulation. 2003;107:531-537.

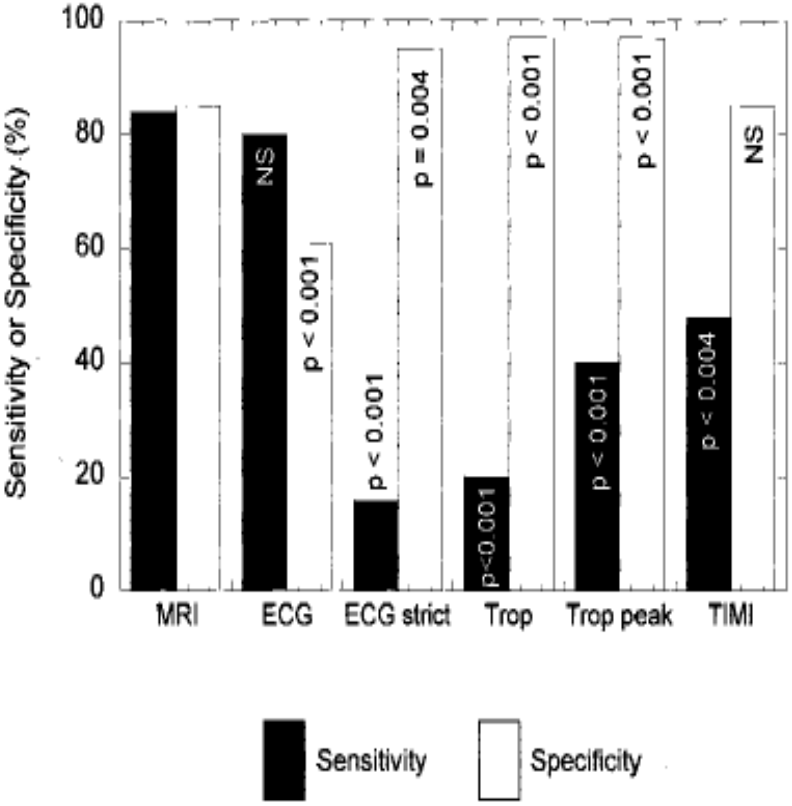



**Figure 2.** Sensitivity and specificity of various parameters for ACS. Probability values summarize the z-test, which was

IRM : analyse qualitative :

- Se = 84% ; Sp = 85% pour la détection des pts présentant un SCA
- Se = 100% pour la détection des SCA ST-

Circulation. 2003;107:531-537.

**TABLE 2. Receiver-Operator Characteristic Curve Analysis of Quantitative MRI Parameters to Predict ACS**

| | Threshold | Sensitivity, % | Specificity, % | Accuracy, % |
|---|---|---|---|---|
| Regional wall motion abnormality | | | | |
| Absolute thickening (mm) | 3 | 83 | 83 | 82 |
| S/D thickness ratio | 1.4 | 74 | 82 | 76 |
| Change in thickness (%) | 30 | 70 | 61 | 66 |
| Systolic thickness (mm) | 12 | 78 | 74 | 77 |
| Diastolic thickness (mm) | 7 | 61 | 80 | 67 |
| Left ventricular ejection fraction (%) | 55 | 62 | 94 | 78 |
| Delayed hyperenhancement | | | | |
| Contrast ratio | 3 | 73 | 91 | 79 |
| Contrast difference index | 5 | 73 | 86 | 60 |

## IRM : analyse quantitative :

- épaississement (seuil : 3mm) détecte 83% des SCA, 100% des SCA ST-

Circulation. 2003;107:531-537.

**TABLE 3. Logistic Regression Models for ACS**

| Variable | DF | Coefficient Estimate | Wald $\chi^2$ | P | Odds Ratio |
|---|---|---|---|---|---|
| Model a for Probability of ACS Without MRI (25 events)* | | | | | |
| Intercept | 1 | −4.1026 | 30.18 | 0.0001 | |
| TICRF | 1 | 0.3718 | 4.57 | 0.0325 | 1.5 |
| AbECG | 1 | 1.7606 | 9.70 | 0.0018 | 5.8 |
| AbTn | 1 | 2.2689 | 7.67 | 0.0056 | 9.7 |
| Model b for Probability of ACS With MRI (25 events)† | | | | | |
| Intercept | 1 | −3.8704 | 22.27 | 0.0001 | |
| TICRF | 1 | −0.0196 | 0.0093 | 0.92 | 1.0 |
| AbECG | 1 | 0.9136 | 1.99 | 0.16 | 2.5 |
| AbTn | 1 | 2.0402 | 4.14 | 0.042 | 7.7 |
| AbMRI | 1 | 3.0754 | 19.12 | 0.0001 | 21.7 |

TICRF indicates total cardiac risk factors; AbECG, abnormal ECG; AbTn, abnormal initial troponin; AbMRI, abnormal MRI (see Methods for defining criteria for each variable); and DF, degrees of freedom.

*−2 Log Likelihood=28.00 with 3 DF ($P$=0.0001).

†−2 Log Likelihood=53.36 with 4 DF (p=0.0001).

Mais Troponines US ?

Analyse multivariée : IRM

- meilleur facteur prédictif de SCA
- valeur diagnostique indépendante des paramètres cliniques

Circulation. 2003;107:531-537.

# Cardiac Magnetic Resonance With T2-Weighted Imaging Improves Detection of Patients With Acute Coronary Syndrome in the Emergency Department

Ricardo C. Cury, MD; Khalid Shash, MD; John T. Nagurney, MD, MPH; Guido Rosito, MD, PhD; Michael D. Shapiro, DO; Cesar H. Nomura, MD; Suhny Abbara, MD; Fabian Bamberg, MD; Maros Ferencik, MD, PhD; Ehud J. Schmidt, PhD; David F. Brown, MD; Udo Hoffmann, MD, MPH; Thomas J. Brady, MD

- 62 patients, DT dans les 12h avant l'admission, troponine -, ECG normal
- Objectif : tester un protocole d'IRM avec des séquences T2 pour la détection des patients présentant un SCA

- 13 SCA (21%) : 3 SCA ST-, 10 angor instable (dont 1 évoluant vers SCA ST+ le lendemain)
- 14 coronarographies (13 SCA +1) : 12 présentent des sténoses significatives

Circulation. 2008;118:837-844.

**Table 2. Comparison of Diagnostic Accuracy of Individual MRI Parameters to Detect Patients With ACS**

| | Sensitivity | Specificity | PPV | NPV |
|---|---|---|---|---|
| Cine MRI–RWM | 0.85 (11/13) | 0.86 (42/49) | 0.56 (9/16) | 0.91 (42/46) |
| Perfusion | 0.77 (10/13) | 0.92 (45/49) | 0.71 (4/14) | 0.94 (45/48) |
| DE-MRI | 0.62 (8/13) | 0.84 (41/49) | 0.5 (8/16) | 0.89 (41/46) |
| T2W | 0.69 (9/13) | 1.0 (49/49) | 1.0 (9/9) | 0.92 (49/53) |
| Cine MRI–LVWT | 1.0 (13/13) | 0.1 (5/49) | 0.25 (13/57) | 1.0 (5/5) |

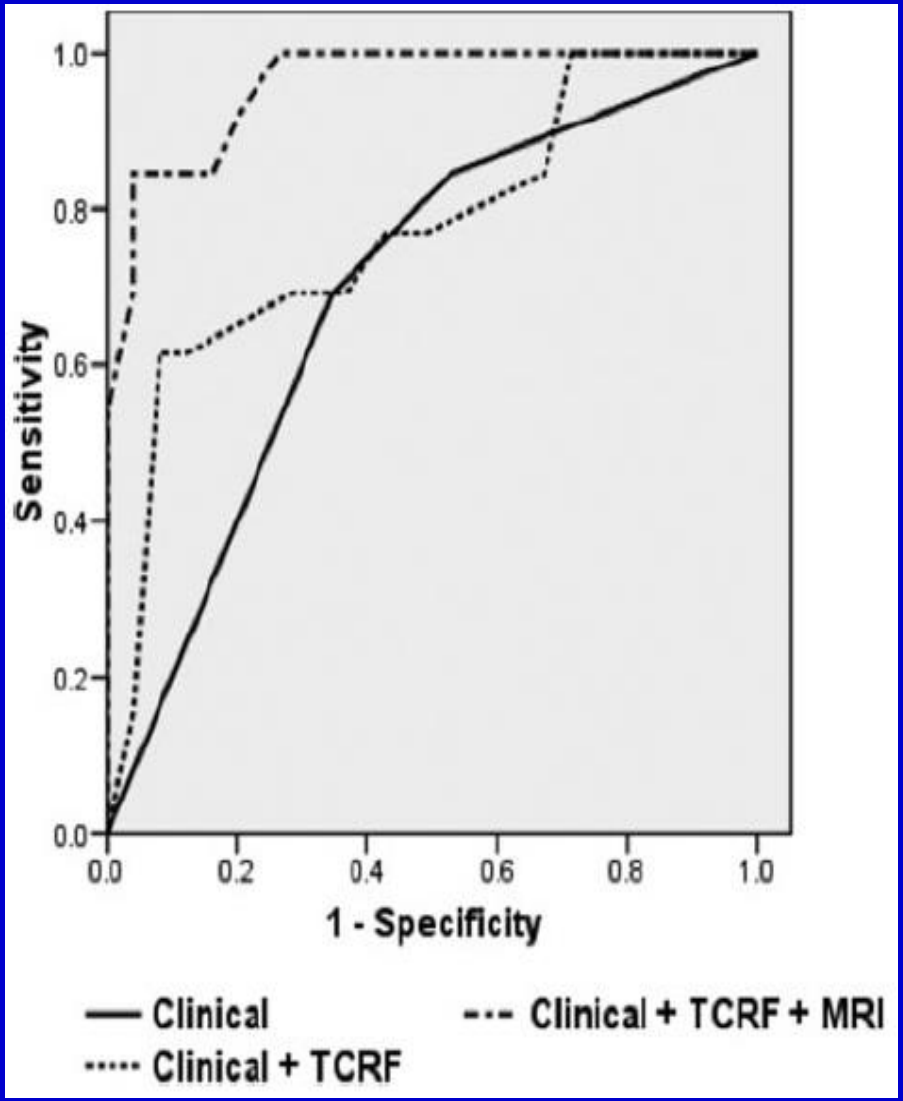
LV Wall Thickness
Regional Wall Motion

Principalement lié à la détection correcte des patients ayant un ATCD d'IDM et pas de SCA (œdème -, amincissement de la paroi)

**Table 3. Comparison of Diagnostic Accuracy Between Standard CMR Protocol (Cine+Perfusion+DE-MRI) and a New CMR Protocol (T2W, Cine, LVWT, Perfusion, and DE-MRI) for Detection of Patients With ACS**

| | Cine+Perfusion+DE-MRI | Cine+Perfusion+DE-MRI+T2W+LVWT |
|---|---|---|
| Sensitivity | 85% (11/13) | 85% (11/13) |
| Specificity | 84% (41/49) | 96% (47/49) |
| PPV | 58% (11/19) | 85% (11/13) |
| NPV | 95% (41/43) | 96% (47/49) |
| Accuracy | 84% (52/62) | 93% (58/62) |

Circulation. 2008;118:837-844.

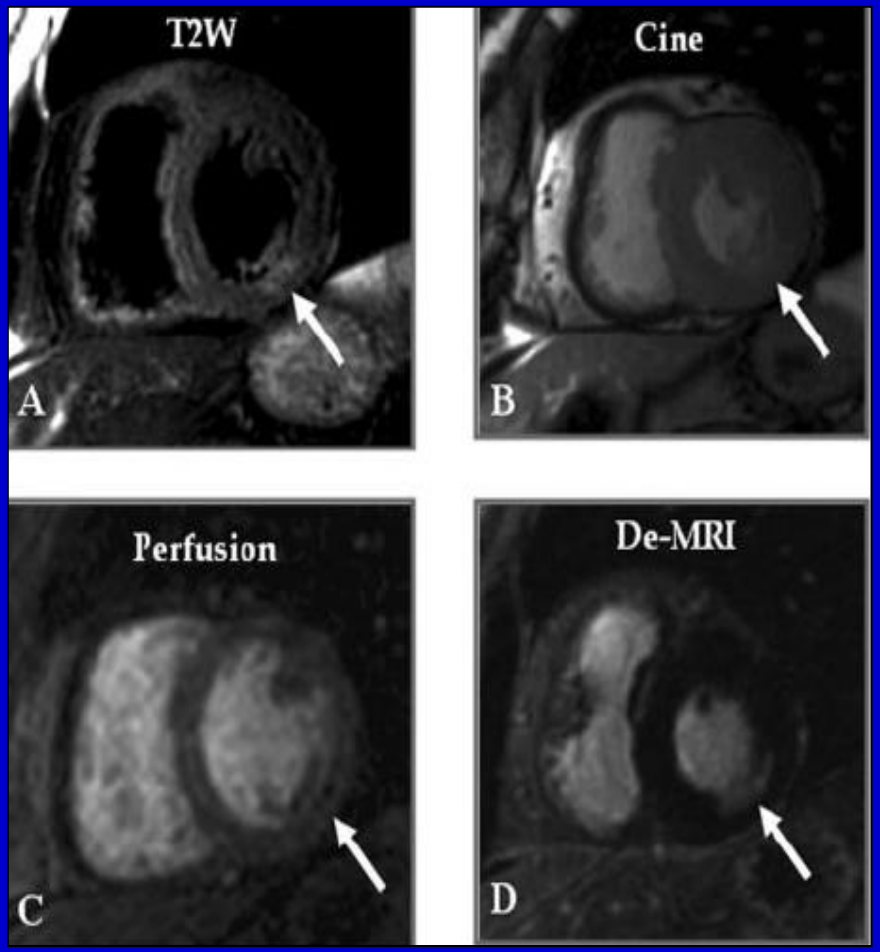



Probabilité des différentes stratégies de diagnostic pour la détection des patients présentant un SCA

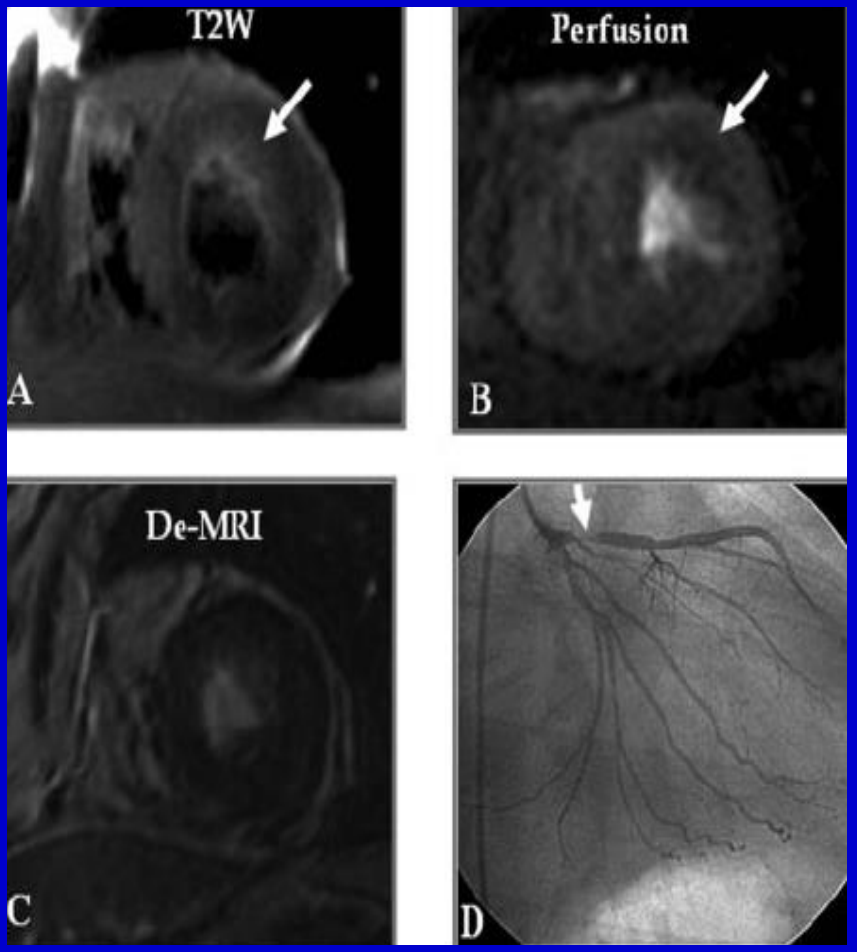
C-statistic
clinique : 0.695
clinique + FDRCV : 0.771 (p = 0.03)
clinique + FDRCV + IRM : 0.958 (p < 0.0001)

<u>Analyse multivariée :</u> IRM (T2) : facteur prédictif indép. de SCA.

Circulation. 2008;118:837-844.

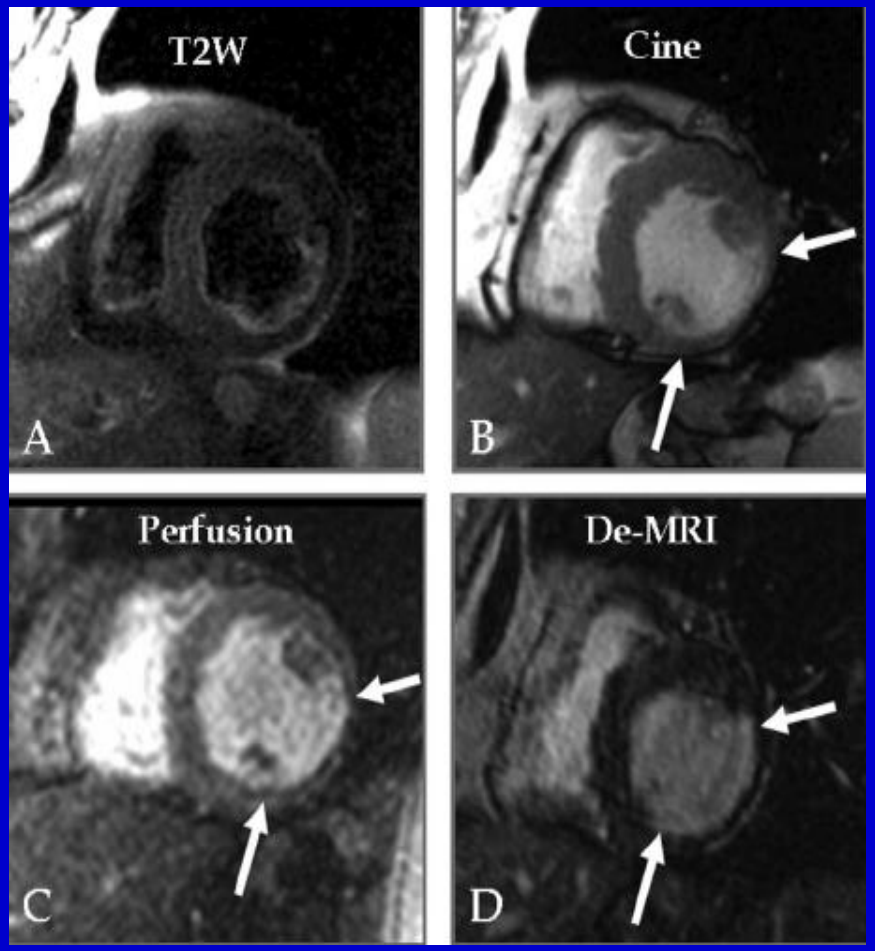



- Œdème / hypokinésie / hypoperfusion / RT+ sous endo.
- Troponine H7 +
- Tri-tronculaire, sténose 95%RVP




- Œdème / hypoperfusion / RT- / scinti. : ischémie antérieure
- Troponine -
- Sténose 90% IVA p

Circulation. 2008;118:837-844.




- ATCD IDM, stent Cx
- SCA exclu
- Pas d'œdème / amincissement / hypoperfusion / RT+ sous endo.

Circulation. 2008;118:837-844.

**Table 2.** Comprehensive CMR Analysis and Analysis of Individual CMR Components for the Detection of the Presence of Significant CAD*

| | Sensitivity (%) | Specificity (%) | PPV (%) | NPV (%) | Overall Accuracy (%) |
|---|---|---|---|---|---|
| Comprehensive analysis | 96 (92–100) | 83 (62–100) | 96 (91–100) | 83 (62–100) | 94 (88–100) |
| Individual component analysis | | | | | |
| Perfusion | 88 (79–96) | 83 (62–100) | 96 (91–100) | 59 (35–82) | 87 (79–95) |
| Coronaries | 84 (74–94) | 75 (51–100) | 94 (87–100) | 50 (27–73) | 82 (73–92) |
| Wall motion | 68 (56–80) | 75 (51–100) | 93 (85–100) | 50 (27–73) | 69 (58–80) |
| Late contrast enhancement | 57 (44–70) | 83 (62–100) | 94 (86–100) | 42 (25–58) | 62 (50–73) |

$\Rightarrow$ « Comprehensive analysis »

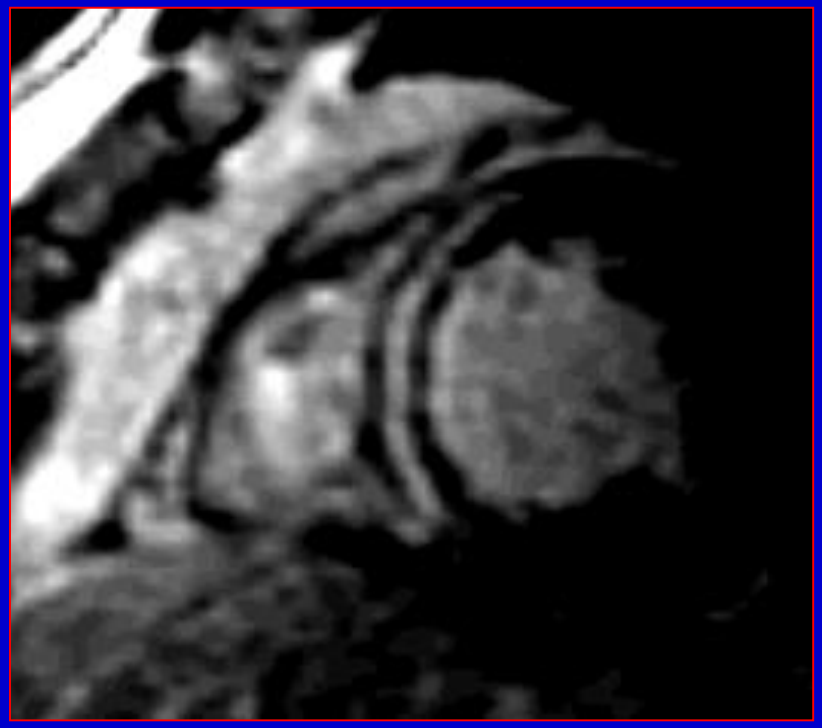
significativement meilleure que l'analyse individuelle

J Am Coll Cardiol 2004;44:2173– 81

# SCA non ST+ et IRM

- Indications limitées de l'IRM
- Une indication possible
  - SCA à bas risque : test fonctionnel
- Une indication majeure
  - SCA à coronaires saines +++

# Infarctus à coronaires saines



**Myocardite** **Infarctus sous-endocardique**

**Cardiomyopathie de stress (Tako-Tsubo)**
**Absence d'hypersignal**

# SCA à coronaires saines

| | Ciné-IRM | T2 | T1 et T2 mapping | Réhaussement Tardif |
|---|---|---|---|---|
| Infarctus | segmentaire | Œdème (récent) | Augmenté | Oui sous-endocardique |
| Myocardite | +/- segmentaire | Œdème (récent) | Augmenté | Oui sous-épicardique ou intra-mural |
| Tako Tsubo | Hypokinésie apicale large | Œdème | Augmenté | Non |

# Myocardite
# Présentations cliniques

- Syndromes coronariens aigus
  - ECG, troponines, échocardiographie non spécifiques
  - Infection respiratoire ou gastro-intestinale
  - Marqueurs de l'inflammation
  - Coronarographie : absence d'obstruction coronaire
  - IRM indispensable pour faire le diagnostic
    - Infarctus à coronaires saines : vasospasme ou embolie

# Les syndromes coronariens aigus à coronaires saines

- Infarctus aigu sans obstruction coronaire
- Myocardial Infarction with Non Obstructive Coronary Arteries : MINOCA

# Les syndromes coronariens aigus à coronaires saines

- Prévalence moyenne 6-10 % (Pasupathy 2016)
- Absence de spécificité clinique hormis :
  - Patients un peu plus jeunes 55 ans, 40 % de femmes
- 1/3 SCA ST+, 2/3 SCA ST-
- Pronostic
  - Mortalité hospitalière 0,9 %, **Mortalité à 1 an 4,7 %**
  - Même traitement que SCA, Diagnostic +++
- Diagnostic par excès d'infarctus avec corollaires sociaux, professionnels, psychologiques, …Dg ≠

# MINOCA : Diagnostic

- Critères d'infarctus aigu
  - Augmentation des troponines
  - Signes d'ischémie
    - Douleur thoracique ± dyspnée
    - Modifications ECG (ST, BBG, ondes Q)
    - Perte de viabilité (imagerie de perfusion)
    - Dysfonction VG régionale
- Coronarographie normale
  - Strictement normale 50 % des cas (artères lisses)
  - Athérome non sténosant 50 % des cas
- Absence d'autres étiologies : IRM +++
  - Myocardite, Tako Tsubo

# Le traitement est modifié par l'IRM dans 32 % des cas

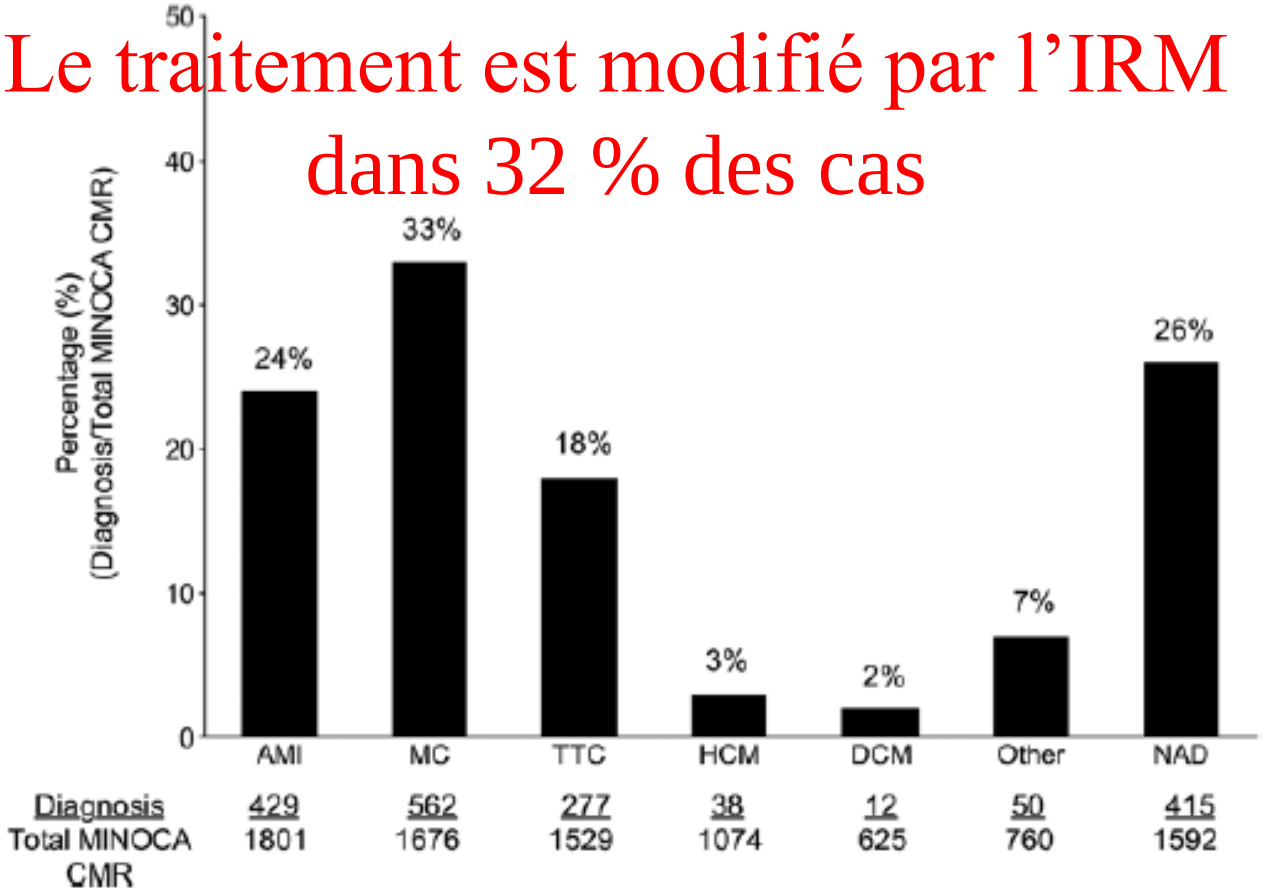
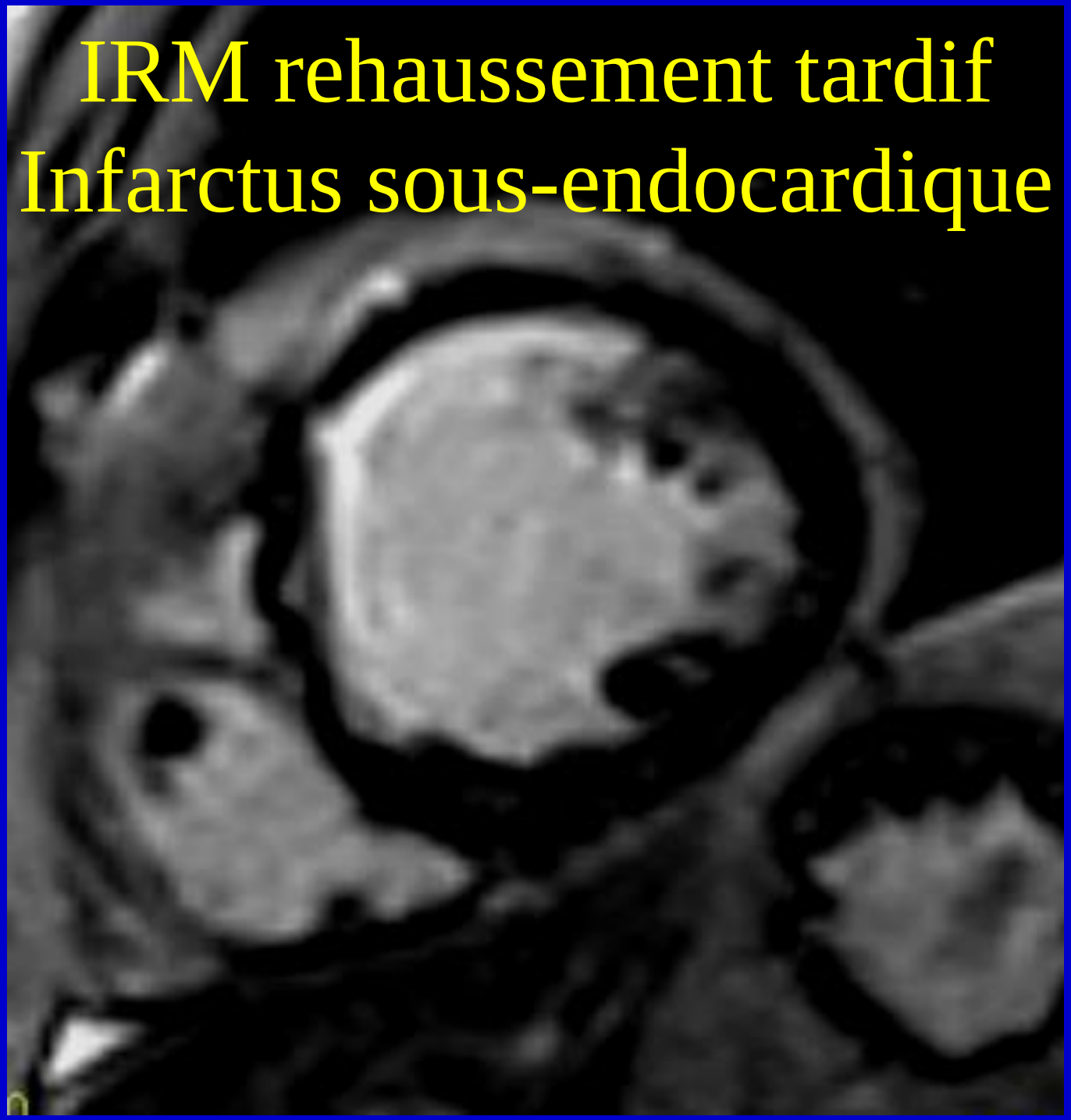


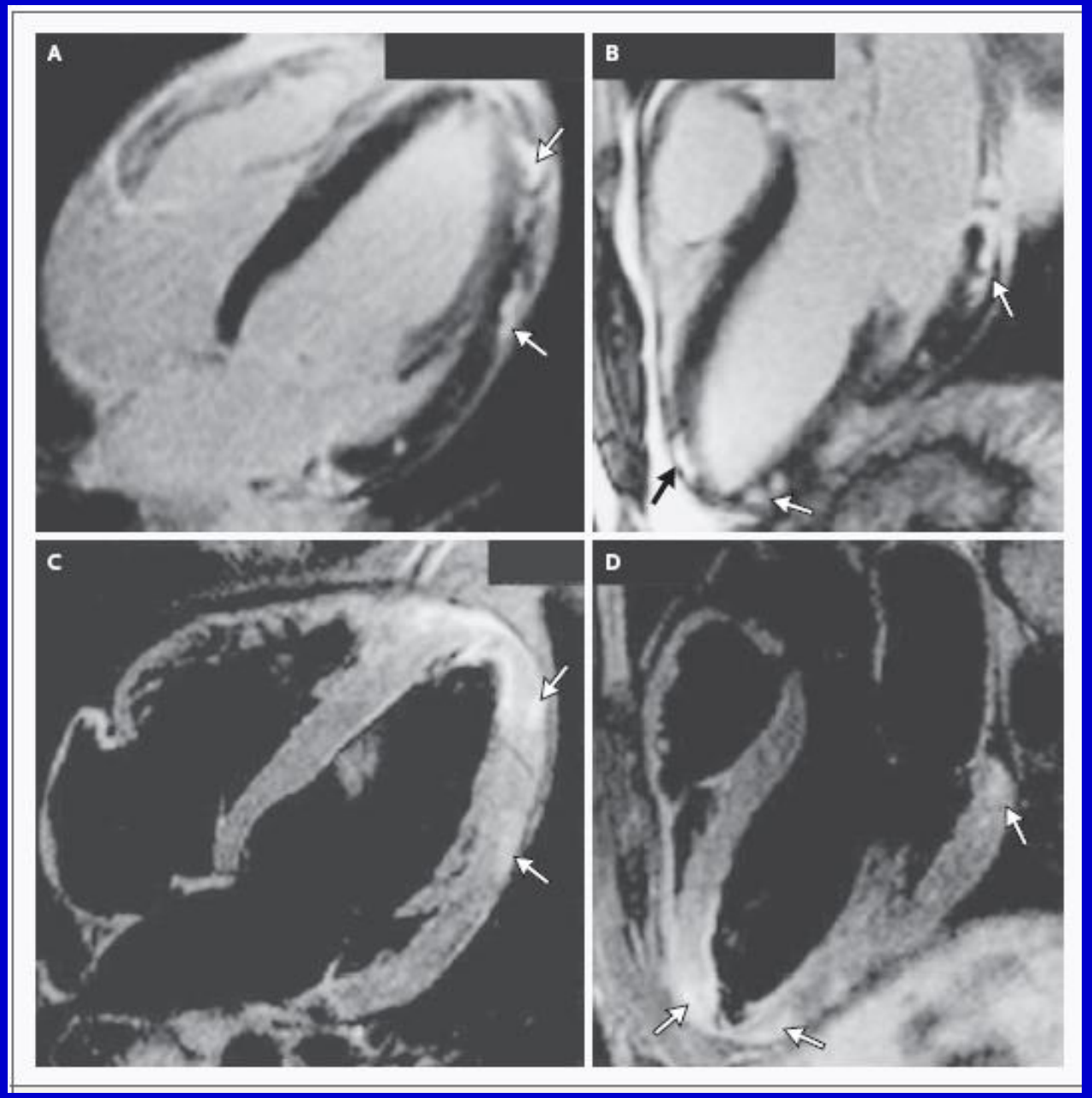

**Figure 4.** Cardiac magnetic resonance (CMR) imaging findings in patients with myocardial infarction with nonobstructive coronary arteries (MINOCA). Bar graph of published studies showing the diagnostic significance of CMR imaging in MINOCA patients. Data presented as percentage (%). AMI indicates acute myocardial infarction; MC, Myocarditis; TTC, Tako-tsubo cardiomyopathy; DCM, dilated cardiomyopathy; HCM, hypertrophic cardiomyopathy; and NAD, diagnosis not available.

Pasupathy S et al. *Circulation 2015*

# IRM rehaussement tardif
# Infarctus sous-endocardique

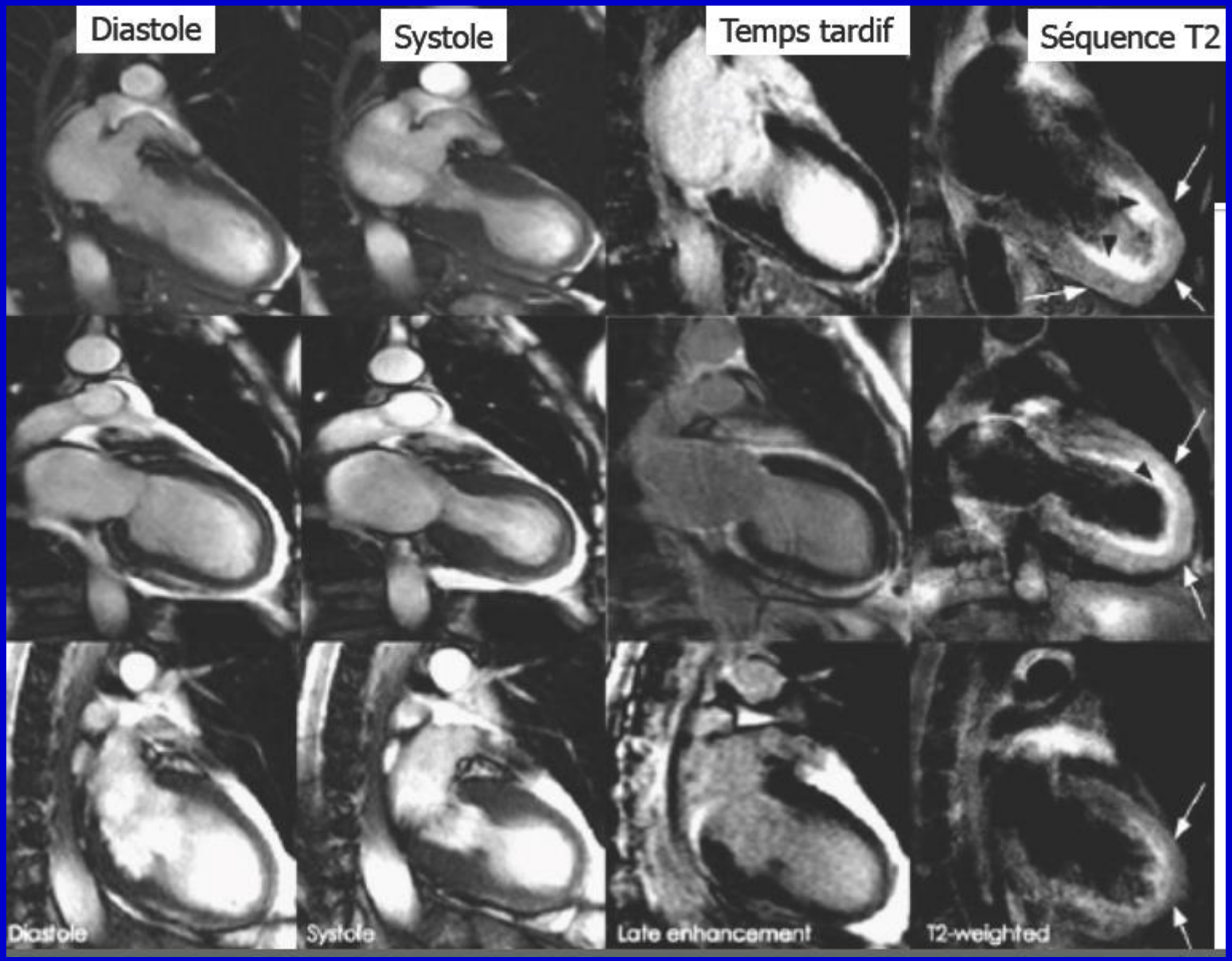


# Myocardite




Cooper LT *N Engl J Med 2009*

# Tako Tsubo


Diastole
Systole
Temps tardif
Séquence T2
Diastole
Systole
Late enhancement
T2-weighted

# Les séquences de T1et T2 mapping

| | | T1 | T2 | Réhaussement Tardif |
|---|---|---|---|---|
| Oedème | Infarctus aigu Myocardite aiguë | Augmenté | Augmenté | oui |
| Oedème | Tako Tsubo | Augmenté | Augmenté | non |
| Fibrose | Focale ou diffuse | Augmenté | Normal | Oui si focal |

# MINOCA - *'a working diagnosis'*

## Myocardial Infarction with Non-Obstructive Coronary Arteries

### Differential diagnosis work up

- Thrombophilia screen
  - No coagulation abnormalities detected
- **Cardiac Magnetic Resonance (CMR) imaging**

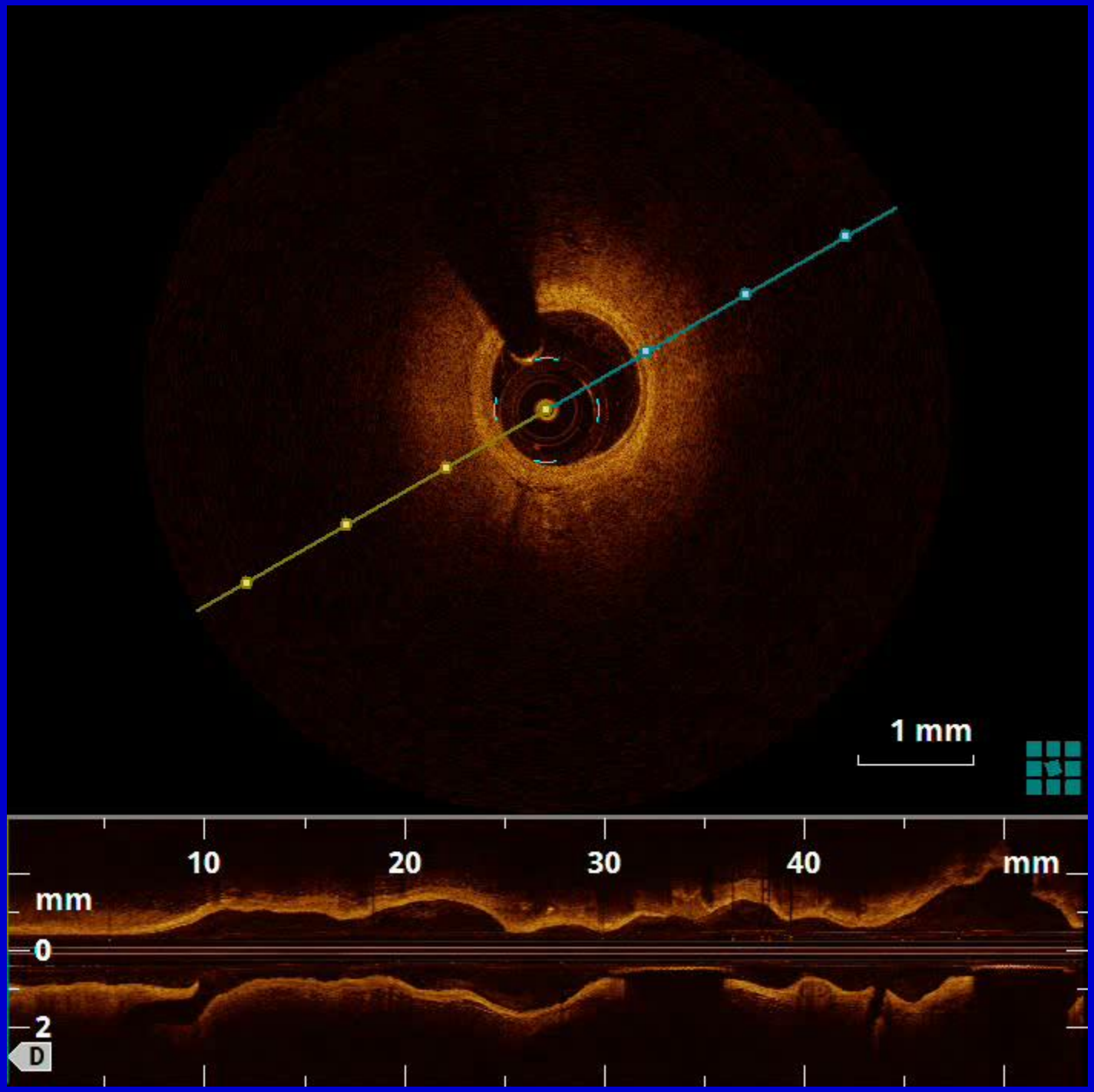
Subendocardial enhancement

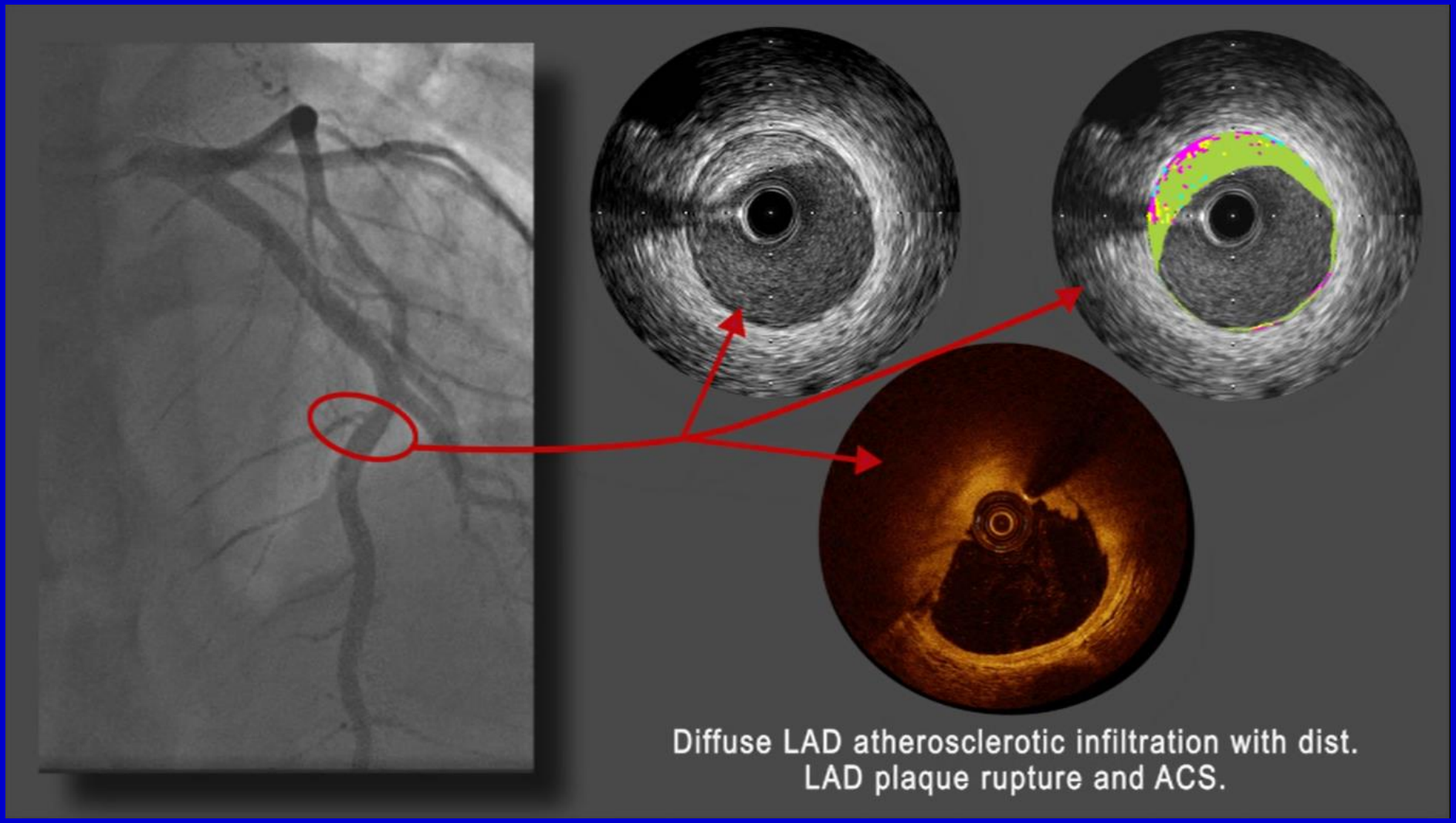
- Intravascular ultrasound imaging
- Provocation spasm test

**Final Diagnosis**
**Anterior Subendocardial Myocardial infarct**

# Infarctus à coronaires saines
## IRM : Hypersignal sous-endocardique

- Spasmes coronaires 28 %
  - Cocaïne, Amphétamines
  - Spasme épicardique ou microvasculaire
    - Test au Méthergin ou à l'acétylcholine
- Anomalies coronaires OCT ou IVUS
  - Thrombus intra-coronaire
  - Rupture de plaque d'athérome
  - Dissection coronaire spontanée


1 mm
10
20
30
40
mm
mm
0
2
D


Diffuse LAD atherosclerotic infiltration with dist.
LAD plaque rupture and ACS.

# Infarctus à coronaires saines
## IRM : Hypersignal sous-endocardique

- Cause thrombo-embolique
  - ACFA
  - Thrombus intracardiaque

- Thrombophilie 14 %
  - Facteur V de Leiden
  - Résistance à la protéine C activée, …

**Table 2. All-Cause Mortality in Patients With MINOCA or MI-CAD**

| All-Cause Mortality | Comparative Studies | | | All MINOCA Studies |
|---|---|---|---|---|
| | MI-CAD % (95% CI) | MINOCA % (95% CI) | OR (95% CI) *P* Value | |
| In-hospital | 3.2% (1.8%, 4.6%) | 1.1% (-0.1%, 2.2%) | 0.37 (0.2–0.67) *P*=0.001 | 0.9% (0.5%, 1.3%) |
| 12-month | 6.7% (4.3%, 9.0%) | 3.5% (2.2%, 4.7%) | 0.59 (0.41–0.83) *P*=0.003 | 4.7% (2.6%, 6.9%) |

Data presented as percentage (%) and 95% confidence intervals (%) with odds ratio (OR) and *P* values. MI-CAD indicates myocardial infarction with coronary artery disease; and MINOCA, myocardial infarction with nonobstructive coronary arteries

Pasupathy S et al. *Circulation 2015*

# Douleur thoracique
# Suspicion d'angor stable

# Le message clinique à ne pas oublier

- En l'absence d'ischémie myocardique significative, le traitement médical fait mieux que la revascularisation par angioplastie ou pontage

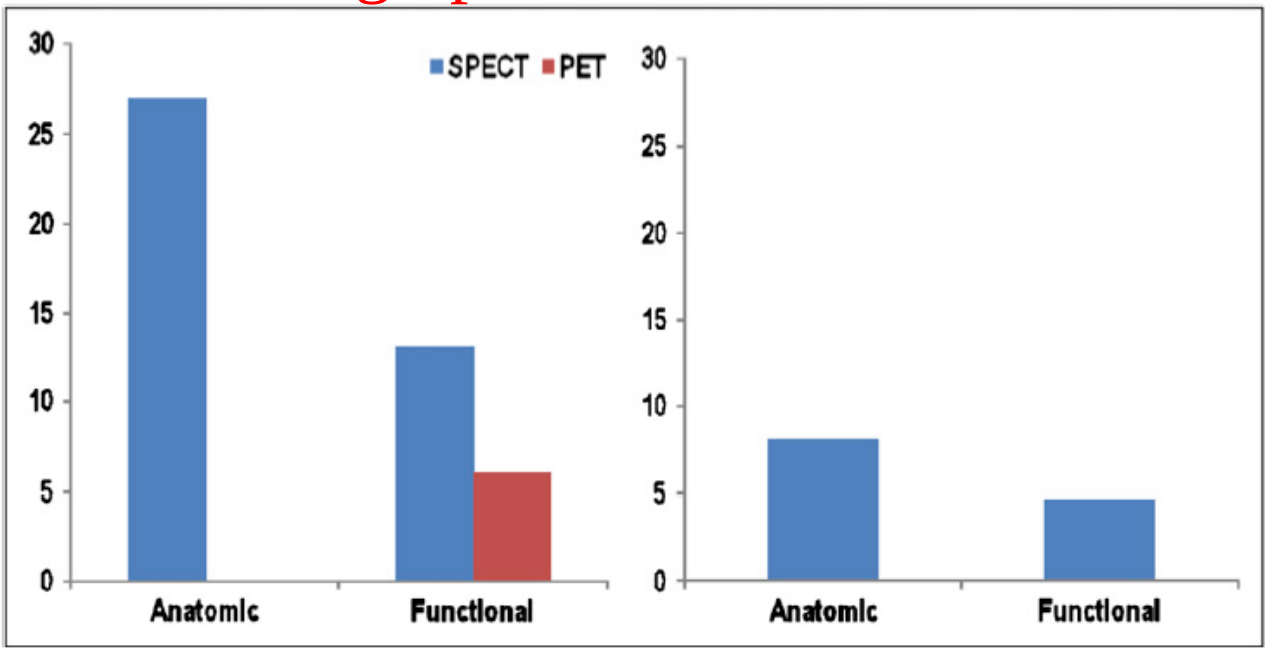
- Etude COURAGE

# Douleur thoracique
# Stratégie diagnostique

**FIGURE 4.** Comparative analysis of use of coronary revascularization in patients referred for direct anatomic testing or direct functional testing. (Left) Earlier data showing higher rate (more than 2-fold) of revascularization with direct invasive angiography than with myocardial perfusion SPECT (MPS). (Right) Comparison of initial anatomic testing with CCTA and functional testing with MPS. These more recent data revealed rates of revascularization lower than those obtained with invasive anatomic strategies. Importantly, however, anatomic testing with CCTA resulted in higher rates of revascularization than did functional testing with MPS.

Coronarographie

Coroscanner



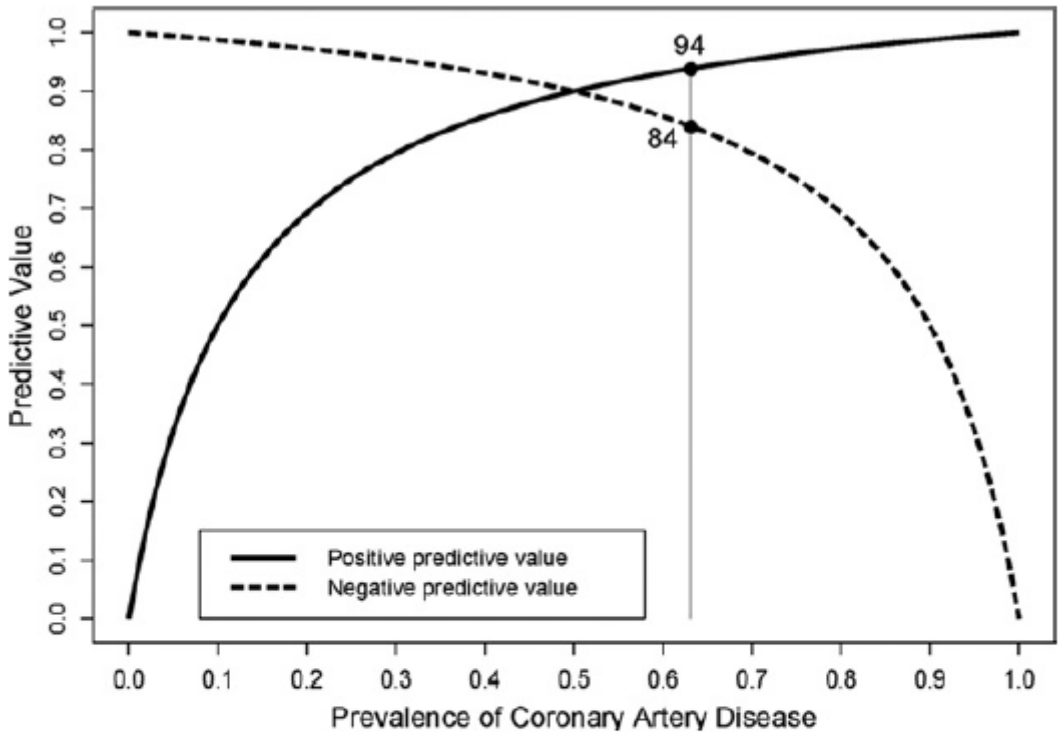



**Figure 3** **Predictive Values of a Diagnostic Test According to Disease Prevalence**

Shown are positive predictive values **(solid line)** and negative predictive values **(dashed line)** as a function of disease prevalence, ranging from 0% to 100% for a diagnostic test with a sensitivity and specificity of 90%, chosen as arbitrary but typical values. The **reference line** indicates the disease prevalence observed in this study (63%). One can appreciate the large shifts in predictive values according to low versus high disease prevalence.

Arbab-Zadeh A et al. JACC 2012; 59: 379

# Diagnostic performance of CTCA

| Risk level | CAD Prevalence | Sensitivity | Specificity | PPV | NPV | LR+ | LR- |
|---|---|---|---|---|---|---|---|
| 1-30 % | 21 % | 86 % | 49 % | 31 % | 93 % | 1.69 | 0.29 |
| 31–70 % | 44 % | 87 % | 55 % | 61 % | 84 % | 1.94 | 0.264 |
| 71–100 % | 69 % | 92 % | 45 % | 79 % | 73 % | 1.67 | 0.17 |
| p value | | NS | NS | <0.001 | 0.006 | <0.001 | |

EVASCAN Am J Cardiol 2013; 111: 471

# Rapport de vraisemblance

- LR = 1 – ( Sensibilité / Spécificité)

- Exemple (LR -)
- LR = 0,05
- Probabilité pré-test = 30 %
- Risque d’ erreur = 0,3 X 0,05 = 1,5 %

**Table 1 Percentage of people estimated to have coronary artery disease according to typicality of symptoms, age, sex and risk factors**

| | Non-anginal chest pain | | | | Atypical angina | | | | Typical angina | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Men | | Women | | Men | | Women | | Men | | Women | |
| Age (years) | Lo | Hi | Lo | Hi | Lo | Hi | Lo | Hi | Lo | Hi | Lo | Hi |
| 35 | 3 | 35 | 1 | 19 | 8 | 59 | 2 | 39 | 30 | 88 | 10 | 78 |
| 45 | 9 | 47 | 2 | 22 | 21 | 70 | 5 | 43 | 51 | 92 | 20 | 79 |
| 55 | 23 | 59 | 4 | 25 | 45 | 79 | 10 | 47 | 80 | 95 | 38 | 82 |
| 65 | 49 | 69 | 9 | 29 | 71 | 86 | 20 | 51 | 93 | 97 | 56 | 84 |

For men older than 70 with atypical or typical symptoms, assume an estimate > 90%.

For women older than 70, assume an estimate of 61–90% EXCEPT women at high risk AND with typical symptoms where a risk of > 90% should be assumed.

Values are per cent of people at each mid-decade age with significant coronary artery disease (CAD)[1].

Hi = High risk = diabetes, smoking and hyperlipidaemia (total cholesterol > 6.47 mmol/litre).

Lo = Low risk = none of these three.

NICE 2010

**Table 13 Clinical pre-test probabilities[a] in patients with stable chest pain symptoms[108]**

| | Typical angina | | Atypical angina | | Non-anginal pain | |
|---|---|---|---|---|---|---|
| Age | Men | Women | Men | Women | Men | Women |
| 30–39 | 59 | 28 | 29 | 10 | 18 | 5 |
| 40–49 | 69 | 37 | 38 | 14 | 25 | 8 |
| 50–59 | 77 | 47 | 49 | 20 | 34 | 12 |
| 60–69 | 84 | 58 | 59 | 28 | 44 | 17 |
| 70–79 | 89 | 68 | 69 | 37 | 54 | 24 |
| >80 | 93 | 76 | 78 | 47 | 65 | 32 |

ECG = electrocardiogram; PTP = pre-test probability; SCAD = stable coronary artery disease.

[a] Probabilities of obstructive coronary disease shown reflect the estimates for patients aged 35, 45, 55, 65, 75 and 85 years.

- Groups in white boxes have a PTP <15% and hence can be managed without further testing.
- Groups in blue boxes have a PTP of 15–65%. They could have an exercise ECG if feasible as the initial test. However, if local expertise and availability permit a non-invasive imaging based test for ischaemia this would be preferable given the superior diagnostic capabilities of such tests. In young patients radiation issues should be considered.
- Groups in light red boxes have PTPs between 66–85% and hence should have a non-invasive imaging functional test for making a diagnosis of SCAD.
- In groups in dark red boxes the PTP is >85% and one can assume that SCAD is present. They need risk stratification only.

ESC 2013

# Stepwise approach for decision making in patients with unknown CAD

- Step 1 : Pre-test probability of CAD ESC 2018

**Table 13** Clinical pre-test probabilities[a] in patients with stable chest pain symptoms[108]

| | Typical angina | | Atypical angina | | Non-anginal pain | |
|---|---|---|---|---|---|---|
| Age | Men | Women | Men | Women | Men | Women |
| 30–39 | 59 | 28 | 29 | 10 | 18 | 5 |
| 40–49 | 69 | 37 | 38 | 14 | 25 | 8 |
| 50–59 | 77 | 47 | 49 | 20 | 34 | 12 |
| 60–69 | 84 | 58 | 59 | 28 | 44 | 17 |
| 70–79 | 89 | 68 | 69 | 37 | 54 | 24 |
| >80 | 93 | 76 | 78 | 47 | 65 | 32 |

< 15%

15-65%

>85%

66-85%

# Stepwise approach for decision making in patients with unknown CAD

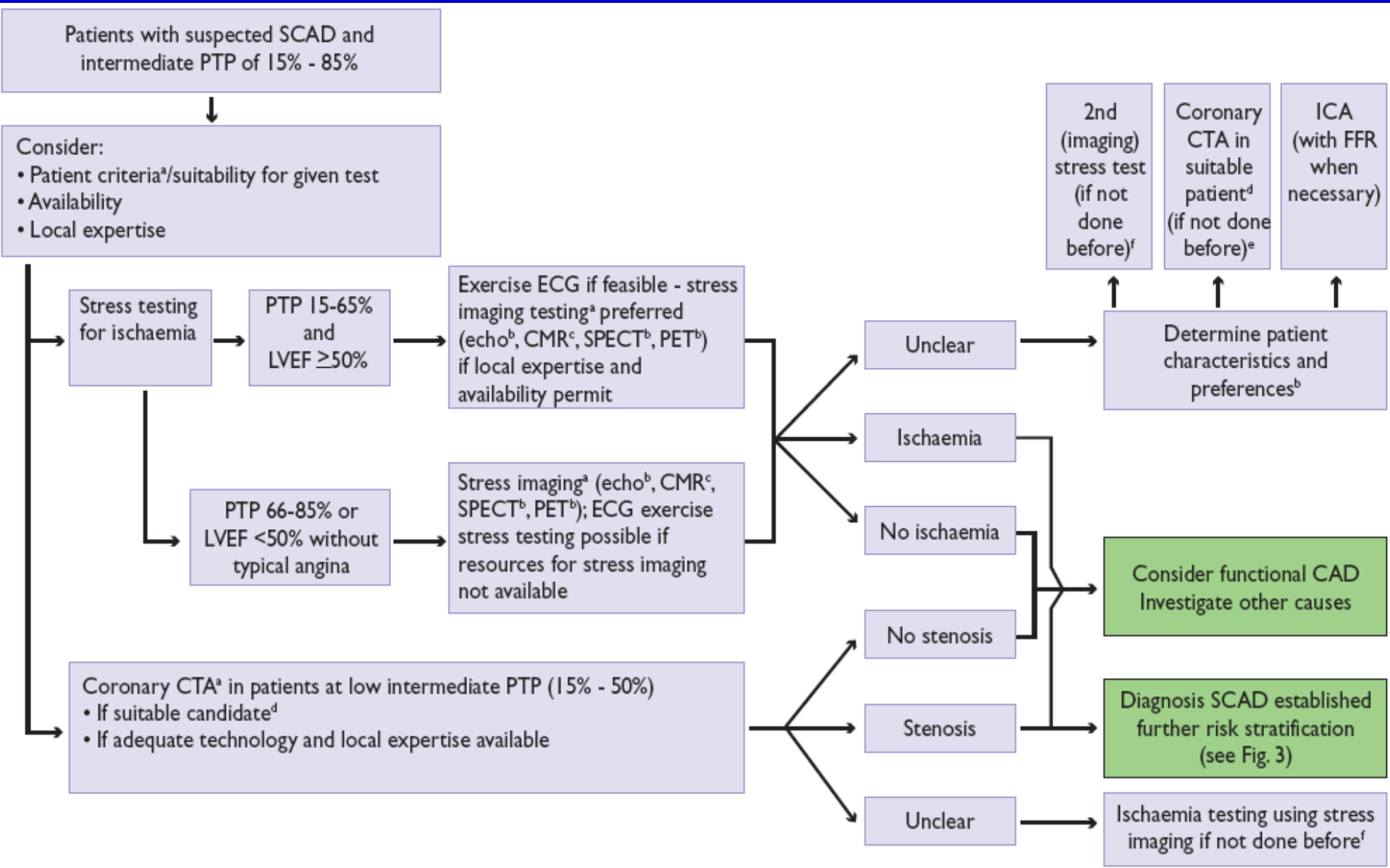
- Step 2 : Non-invasive stress testing

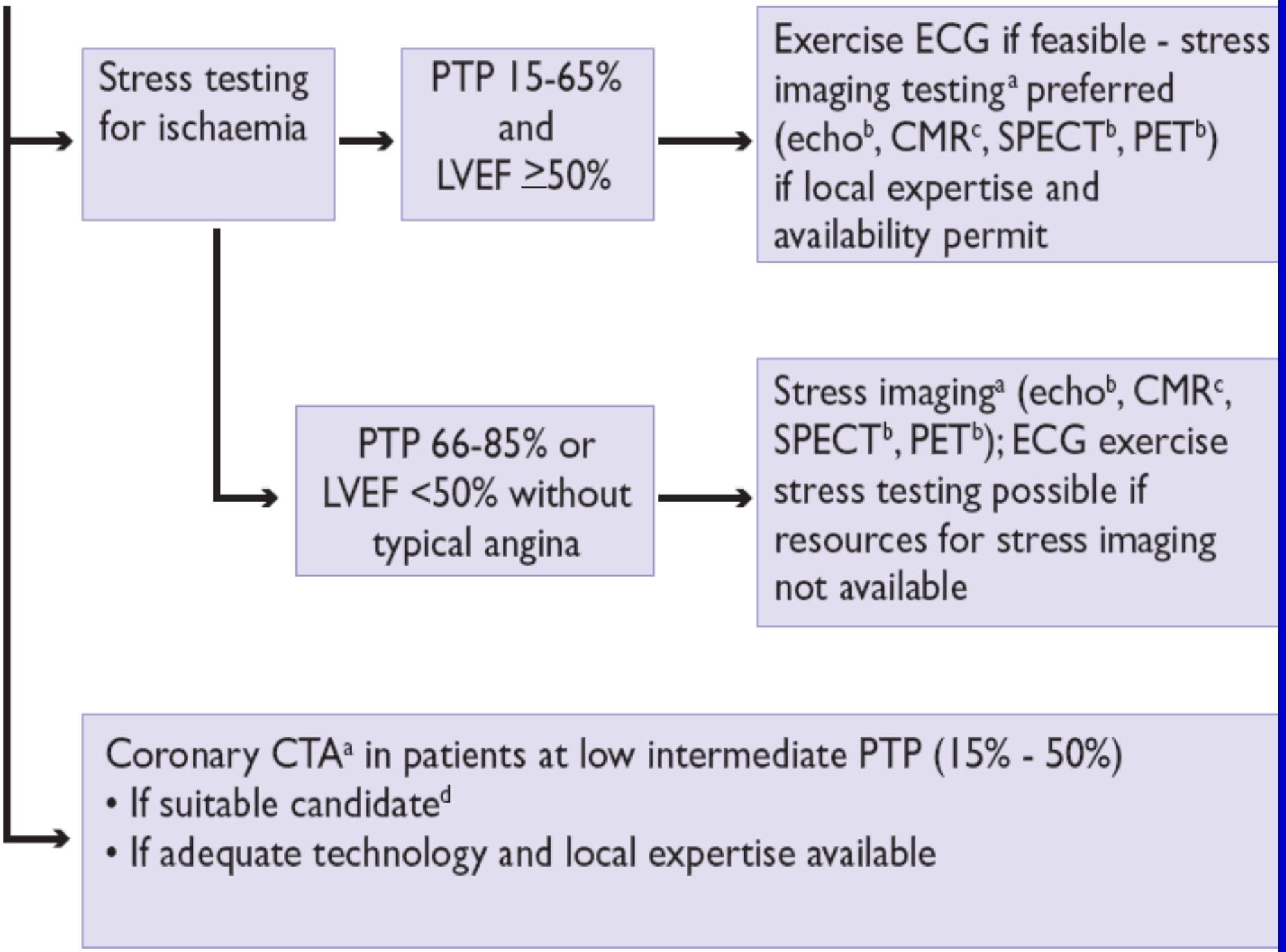
| | Asymptomatic[a] | | Symptomatic | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Probability of significant disease[b] | | | | | | |
| | | | Low (<15%) | | Intermediate (15–85%) | | High (>85%) | | |
| | Class[c] | Level[d] | Class[c] | Level[d] | Class[c] | Level[d] | Class[c] | Level[d] | Ref[e] |
| **Anatomical detection of CAD** | | | | | | | | | |
| Invasive angiography | III | A | III | A | IIb | A | I | A | 50–52,54 |
| CT angiography[f,g] | III | B | III | C | IIa | A | III | B | 57–62 |
| **Functional test** | | | | | | | | | |
| Stress echo | III | A | III | A | I | A | III | A | 63–65 |
| Nuclear imaging | III | A | III | A | I | A | III | A | 60,66–70 |
| Stress MRI | III | B | III | C | I | A | III | B | 71–75 |
| PET perfusion | III | B | III | C | I | A | III | B | 67,69,70,76,77 |
| **Combined or hybrid imaging test** | | | | | | | | | |
| | III | C | III | C | IIa | B | III | B | 78–83 |

**Table 12** Characteristics of tests commonly used to diagnose the presence of coronary artery disease

| | Diagnosis of CAD | |
|---|---|---|
| | Sensitivity (%) | Specificity (%) |
| Exercise ECG [a, 91, 94, 95] | 45–50 | 85–90 |
| Exercise stress echocardiography[96] | 80–85 | 80–88 |
| Exercise stress SPECT[96-99] | 73–92 | 63–87 |
| Dobutamine stress echocardiography[96] | 79–83 | 82–86 |
| Dobutamine stress MRI[b,100] | 79–88 | 81–91 |
| Vasodilator stress echocardiography[96] | 72–79 | 92–95 |
| Vasodilator stress SPECT[96, 99] | 90–91 | 75–84 |
| Vasodilator stress MRI[b,98, 100-102] | 67–94 | 61–85 |
| Coronary CTA[c,103-105] | 95–99 | 64–83 |
| Vasodilator stress PET[97, 99, 106] | 81–97 | 74–91 |

# ESC guidelines 2014




Stress testing for ischaemia
PTP 15-65% and LVEF ≥50%
Exercise ECG if feasible - stress imaging testing[a] preferred (echo[b], CMR[c], SPECT[b], PET[b]) if local expertise and availability permit
PTP 66-85% or LVEF <50% without typical angina
Stress imaging[a] (echo[b], CMR[c], SPECT[b], PET[b]); ECG exercise stress testing possible if resources for stress imaging not available
Coronary CTA[a] in patients at low intermediate PTP (15% - 50%)
• If suitable candidate[d]
• If adequate technology and local expertise available

# Exercise or pharmacologic stress imaging

| | | | |
|---|---|---|---|
| Exercise stress testing is recommended rather than pharmacologic testing whenever possible. | I | C | - |

- Exercise provides additional physiological data
  - Exercise time and workload
  - Changes in heart rate, BP, ECG
  - Only if
    - Performed without the influence of anti-ischaemic drugs
    - When 85% of maximum HR is achieved in the absence of symptoms or signs of ichaemia

**Table 12** Characteristics of tests commonly used to diagnose the presence of coronary artery disease

| | Diagnosis of CAD | |
|---|---|---|
| | Sensitivity (%) | Specificity (%) |
| Exercise ECG [a, 91, 94, 95] | 45–50 | 85–90 |
| Exercise stress echocardiography[96] | 80–85 | 80–88 |
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| Dobutamine stress echocardiography[96] | 79–83 | 82–86 |
| Dobutamine stress MRI[b,100] | 79–88 | 81–91 |
| Vasodilator stress echocardiography[96] | 72–79 | 92–95 |
| Vasodilator stress SPECT[96, 99] | 90–91 | 75–84 |
| Vasodilator stress MRI[b,98, 100-102] | 67–94 | 61–85 |
| Coronary CTA[c,103-105] | 95–99 | 64–83 |
| Vasodilator stress PET[97, 99, 106] | 81–97 | 74–91 |

# Echocardiographie de stress

| Test évalué | Sensibilité % [IC 95 %] | Spécificité % [IC 95 %] |
|---|---|---|
| Echocardiographie de stress (effort) | 82,7 % [80,2-85,2] | 84,0 % [80,4-87,6] |
| Echocardiographie de stress (adénosine) | 79,2 % [72,1-86,3] | 91,5 % [87,3-95,7] |
| Echocardiographie de stress (dipyridamole) | 71,9 % [68,6-75,2] | 94,6 % [92,9-96,3] |
| Echocardiographie de stress (dobutamine) | 81,0 % [79,1-82,9] | 84,1 % [82,0-86,1] |
| **Total** | **79,1 % [77,6-80,5]** | **87,1 % [85,7-88,5]** |

## Risque faible à intermédiaire

### Forte valeur prédictive positive

*Méta-analyse Heijenbrok-Kal et al.*

# Scintigraphie myocardique

| Test évalué | Sensibilité % [IC 95 %] | Spécificité % [IC 95 %] |
|---|---|---|
| TEMP de stress (effort) | 88,1 % [85,8-90,3] | 68,8 % [62,8-74,8] |
| TEMP de stress (adénosine) | 90,5 % [89,0-91,9] | 81,0 % [73,5-88,6] |
| TEMP de stress (dipyridamole) | 90,4 % [87,3-93,5] | 75,4 % [66,2-84,6] |
| TEMP de stress (dobutamine) | 83,6 % [78,4-88,8] | 75,1 % [71,1-79,0] |
| **Total** | **88,1 % [86,6-89,6]** | **73,0 % [69,1-76,9]** |

## Risque intermédiaire à élevé

### Forte valeur prédictive négative

*Méta-analyse Heijenbrok-Kal et al.*

# Population à risque intermédiaire

Scintigraphie myocardique

=

Echocardiographie de stress

*Méta-analyse Heijenbrok-Kal et al.*

# Douleur thoracique
# La place de l'IRM

# La place de l'IRM de stress
## Détection de l'ischémie myocardique

Dobutamine 40 µg/kg/mn + Atropine

| Dobutamine 40 | Sensitivity | Specificity |
|---|---|---|
| Hundley 1999 | 83 % | 83 % |
| Kuijpers 2003 | 96 % | 95 % |
| Nagel 1999 | 86 % | 86 % |
| Paetsch 2004 | 89 % | 80 % |
| Schalla 2002 | 88 % | 83 % |
| Wahl 2004 | 89 % | 84 % |
| Syed 2005 | 89 % | 100 % |

# IRM de perfusion 1er passage

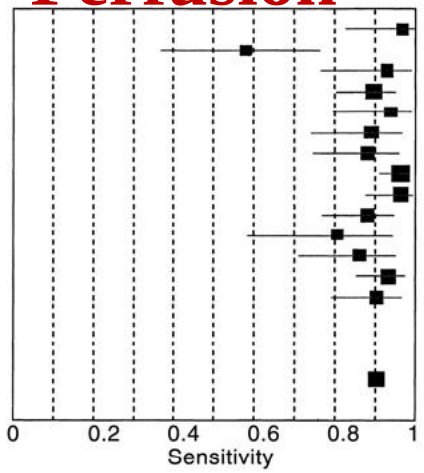
## *Détection de l'ischémie myocardique*

- 21 études, 559 patients, Adénosine ou Dipyridamole

| | Sensibilité | Spécificité |
|---|---|---|
| vs Coronarographie | 82 % | 82 % |
| vs Tomoscintigraphie | 84 % | 93 % |
| vs TEP | 82 % | 87 % |

# Meta-analysis comparing stress MRI with X-ray angiography

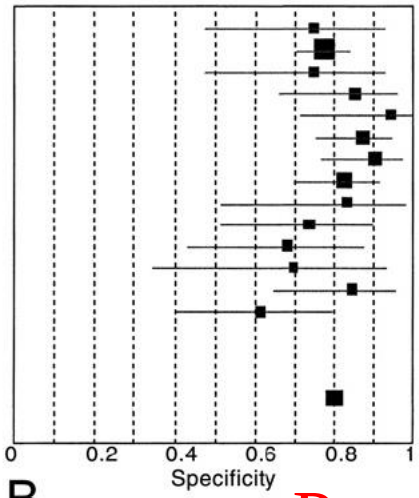
## Perfusion




A

| | Sensitivity (95% CI) |
|---|---|
| Cury (8) | 0.97 (0.83 - 1.00) |
| Doyle (9) | 0.58 (0.37 - 0.77) |
| Giang (10) | 0.93 (0.76 - 0.99) |
| Ishida (12) | 0.90 (0.81 - 0.95) |
| Kawase (13) | 0.94 (0.80 - 0.99) |
| Klem (14) | 0.89 (0.75 - 0.97) |
| Nagel (15) | 0.88 (0.75 - 0.96) |
| Pilz (18) | 0.96 (0.91 - 0.99) |
| Plein (19) | 0.96 (0.88 - 1.00) |
| Plein (20) | 0.88 (0.77 - 0.95) |
| Sakuma (22) | 0.81 (0.58 - 0.95) |
| Schwitter (23) | 0.86 (0.71 - 0.95) |
| Takase (25) | 0.93 (0.85 - 0.98) |
| Paetsch-PI (32) | 0.91 (0.79 - 0.97) |

**91 %**



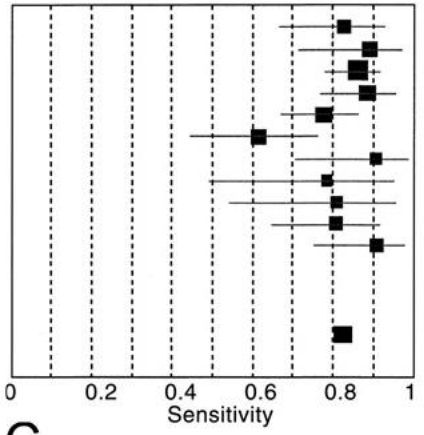

B

| | Specificity (95% CI) |
|---|---|
| Cury (8) | 0.75 (0.48 - 0.93) |
| Doyle (9) | 0.78 (0.71 - 0.84) |
| Giang (10) | 0.75 (0.48 - 0.93) |
| Ishida (12) | 0.85 (0.66 - 0.96) |
| Kawase (13) | 0.94 (0.71 - 1.00) |
| Klem (14) | 0.87 (0.76 - 0.95) |
| Nagel (15) | 0.90 (0.77 - 0.97) |
| Pilz (18) | 0.83 (0.71 - 0.91) |
| Plein (19) | 0.83 (0.52 - 0.98) |
| Plein (20) | 0.74 (0.52 - 0.90) |
| Sakuma (22) | 0.68 (0.43 - 0.87) |
| Schwitter (23) | 0.70 (0.35 - 0.93) |
| Takase (25) | 0.85 (0.65 - 0.96) |
| Paetsch-PI (32) | 0.62 (0.41 - 0.80) |

**81 %**

Prevalence 57.4 %

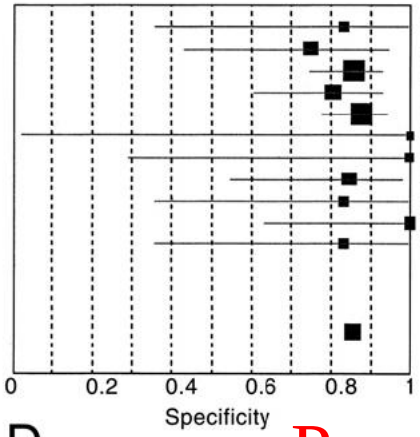
## Wall motion




C

| | Sensitivity (95% CI) |
|---|---|
| Hundley (29) | 0.83 (0.66 - 0.93) |
| Jahnke (30) | 0.89 (0.72 - 0.98) |
| Nagel (31) | 0.86 (0.78 - 0.92) |
| Paetsch-WMA (32) | 0.89 (0.77 - 0.96) |
| Paetsch (33) | 0.78 (0.67 - 0.87) |
| Pennell (34) | 0.62 (0.45 - 0.77) |
| Pennell (35) | 0.91 (0.71 - 0.99) |
| Rerkpattanapipat (36) | 0.79 (0.49 - 0.95) |
| Schalla (37) | 0.81 (0.54 - 0.96) |
| van Rugge (38) | 0.81 (0.65 - 0.92) |
| van Rugge (39) | 0.91 (0.76 - 0.98) |

**83 %**




D

| | Specificity (95% CI) |
|---|---|
| Hundley (29) | 0.83 (0.36 - 1.00) |
| Jahnke (30) | 0.75 (0.43 - 0.95) |
| Nagel (31) | 0.86 (0.75 - 0.93) |
| Paetsch-WMA (32) | 0.81 (0.61 - 0.93) |
| Paetsch (33) | 0.88 (0.78 - 0.94) |
| Pennell (34) | 1.00 (0.03 - 1.00) |
| Pennell (35) | 1.00 (0.29 - 1.00) |
| Rerkpattanapipat (36) | 0.85 (0.55 - 0.98) |
| Schalla (37) | 0.83 (0.36 - 1.00) |
| van Rugge (38) | 1.00 (0.63 - 1.00) |
| van Rugge (39) | 0.83 (0.36 - 1.00) |

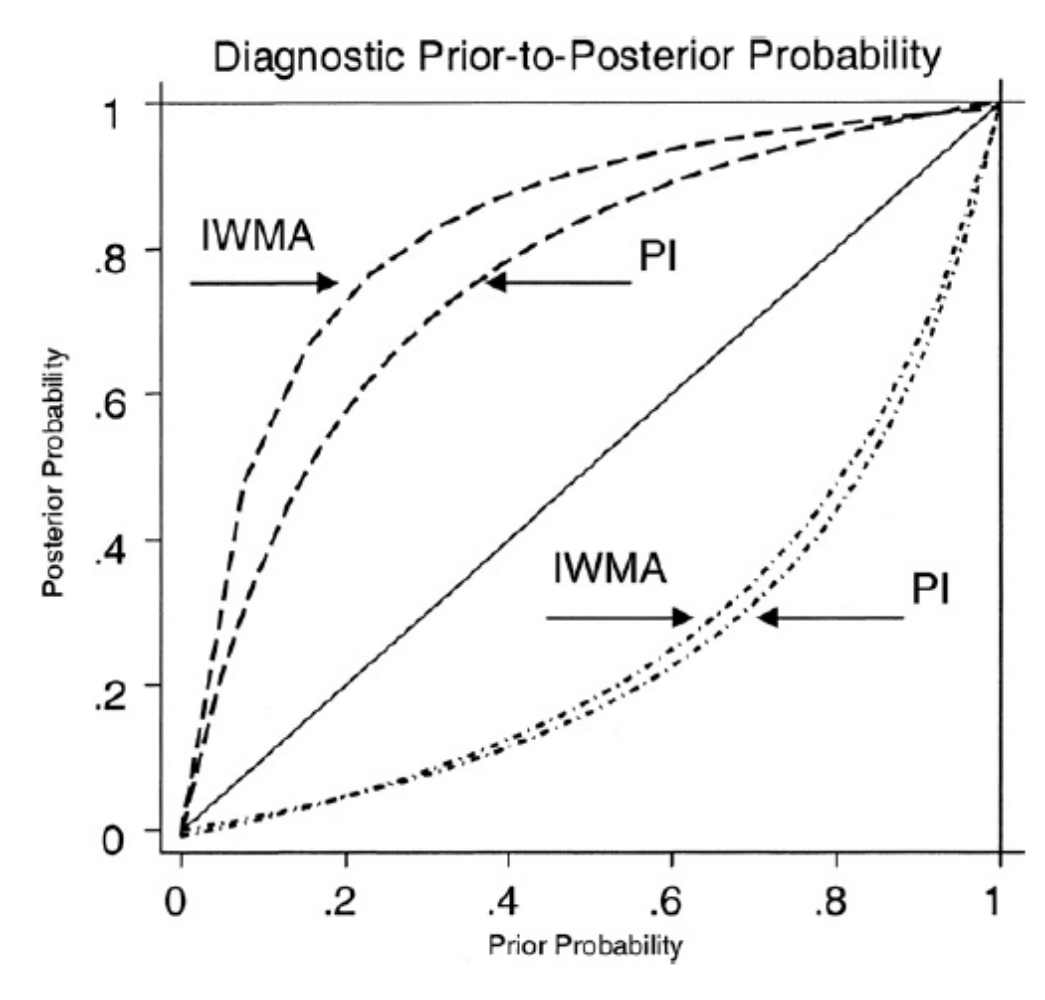
**86 %**

Prevalence 70.5 %

n = 2191

Nandalur *JACC 2007; 50:1343*

# Rapports de vraisemblance




Perfusion (PI)

**LR+ 5.1**

**LR-0.11**

Wall motion (IWMA)

**LR+ 5.2**

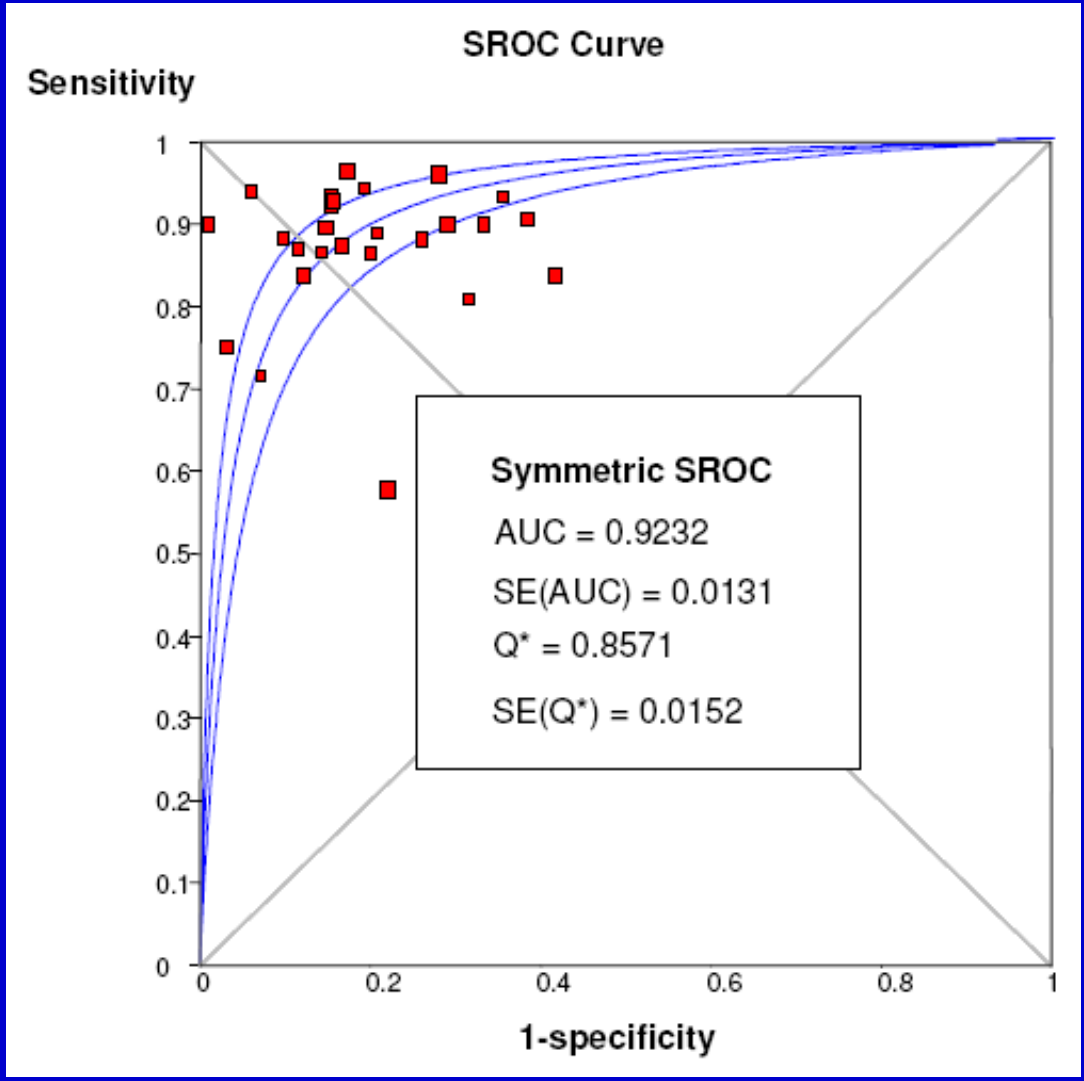
**LR-0.19**

Nandalur *JACC 2007; 50:1343*

# Les indications de l'IRM Dobutamine

- Viabilité myocardique (classe I)
  - Réhaussement 50-75 %
  - Echographie dobutamine +++ si patient échogène
- Dépistage de l'ischémie myocardique (classe II)
  - IRM de perfusion +++ > IRM dobutamine

# Diagnostic performance of CMR perfusion imaging




Sensitivity 89 %
Specificity 80 %
False + Perfusion defect

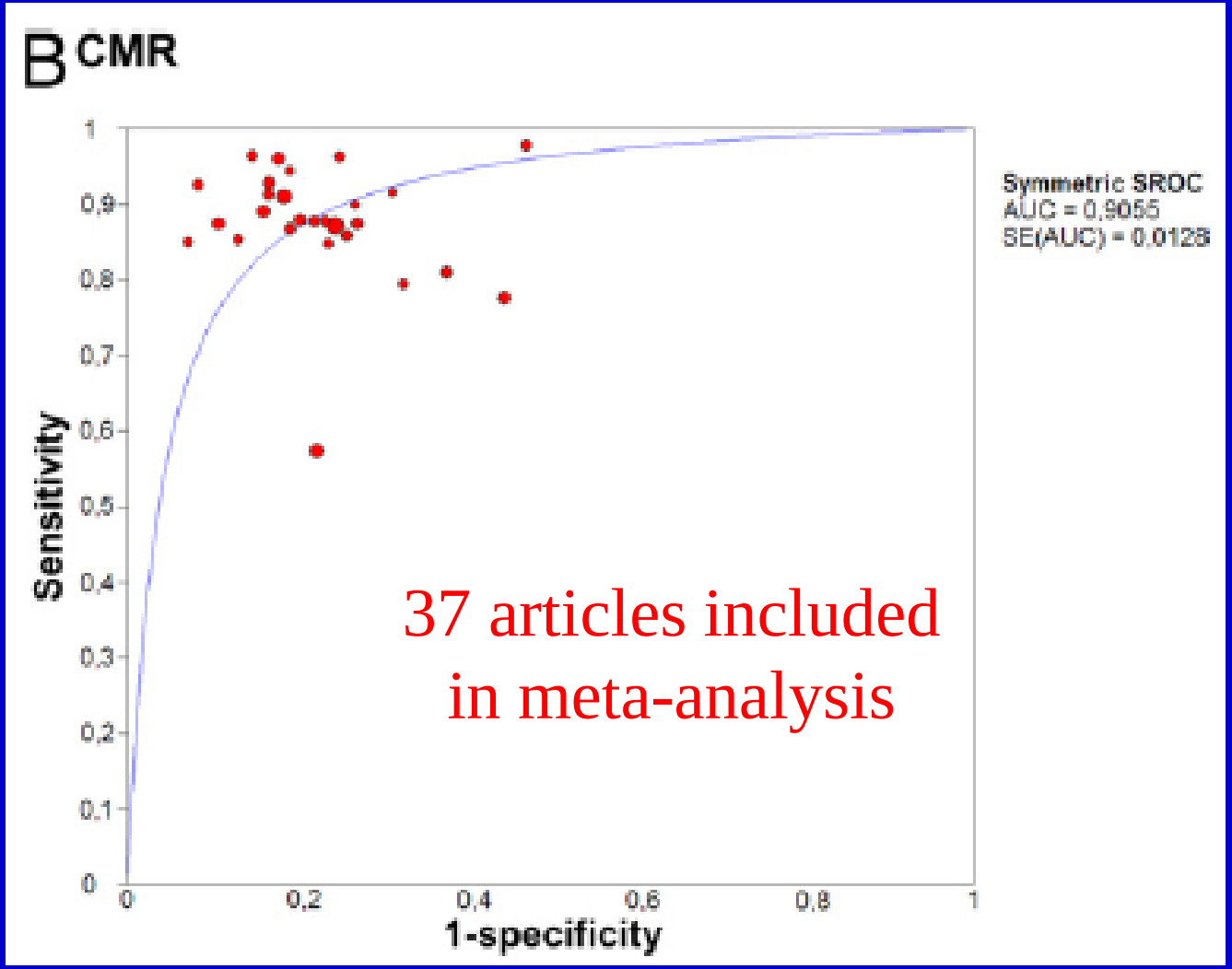
Prevalence CAD 57 %

Hamon Michèle et al *JCMR 2010*

# False positive perfusion defects

- Dark rim artefact
- Microvascular obstruction after MI
- Microvascular disease

# Diagnostic performance of CMR perfusion imaging




Sensitivity 89 %
Specificity 76 %

Jaarsma C et al *JACC 2012*

# Diagnostic performance of SPECT, CMR and PET perfusion imaging

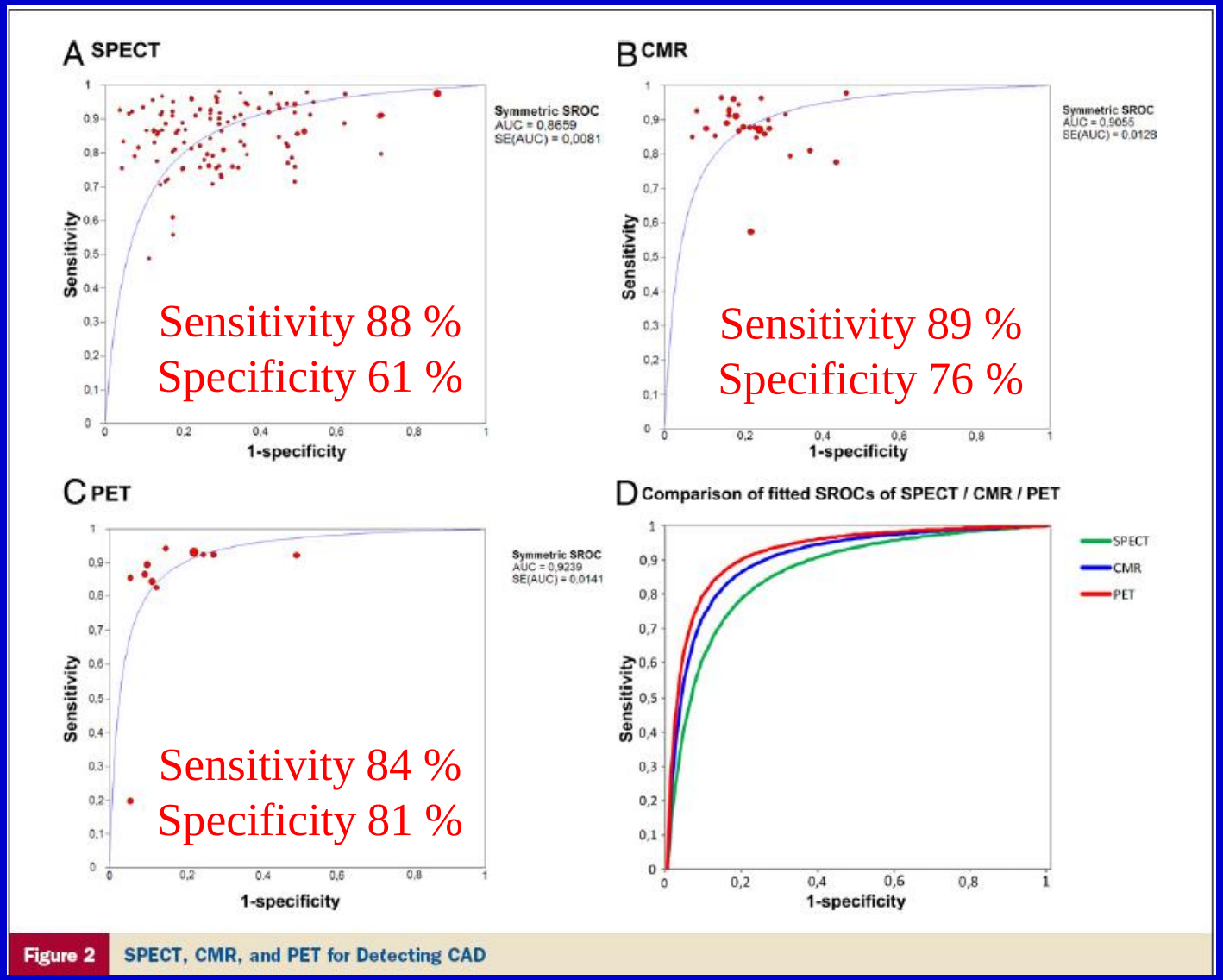



**Figure 2** SPECT, CMR, and PET for Detecting CAD

Jaarsma C et al *JACC 2012*

# CE-MARC trial

Prevalence 39 %

## Sensitivity

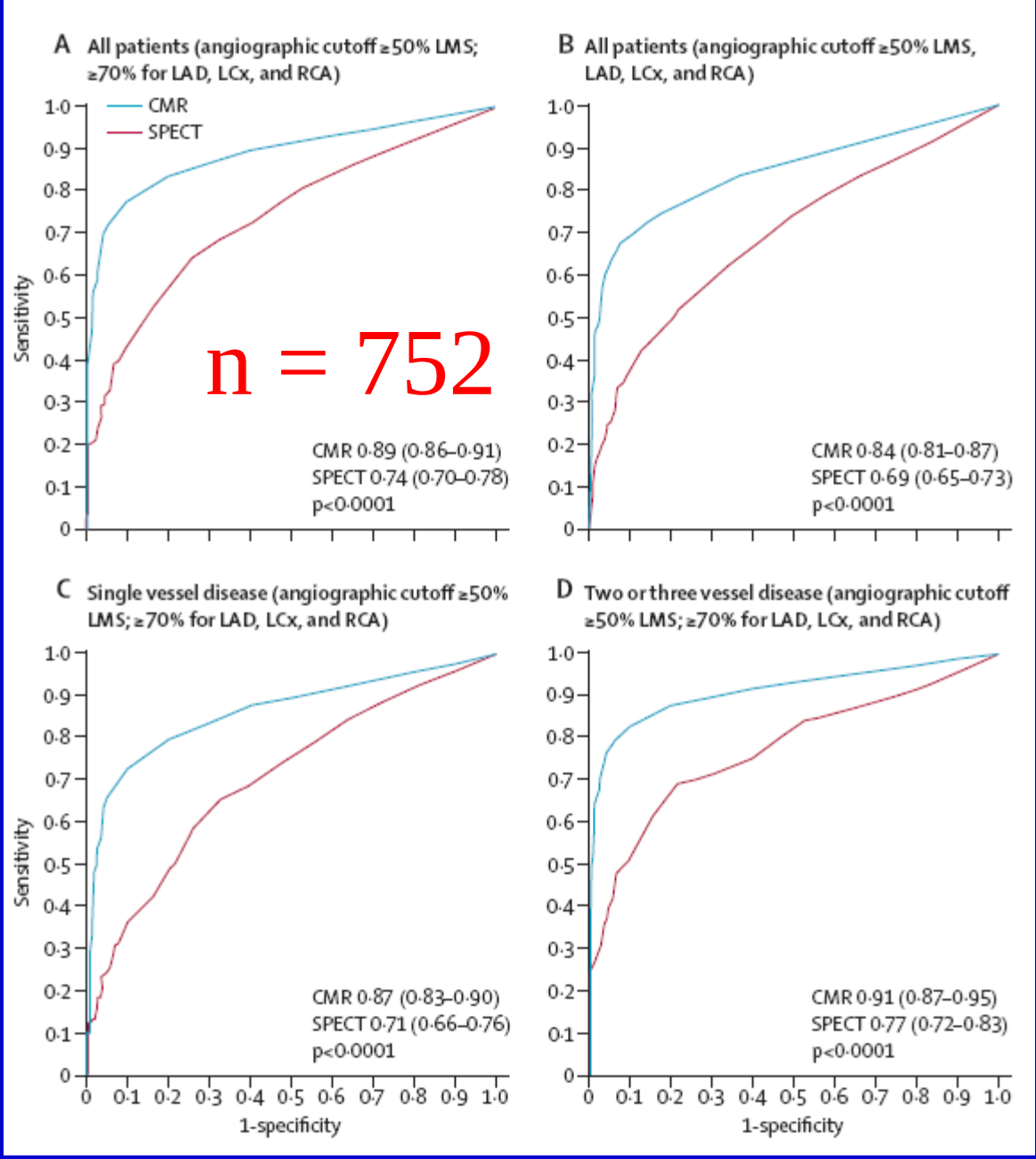
CMR 86.5 %

SPECT 66.5 %

## Specificity

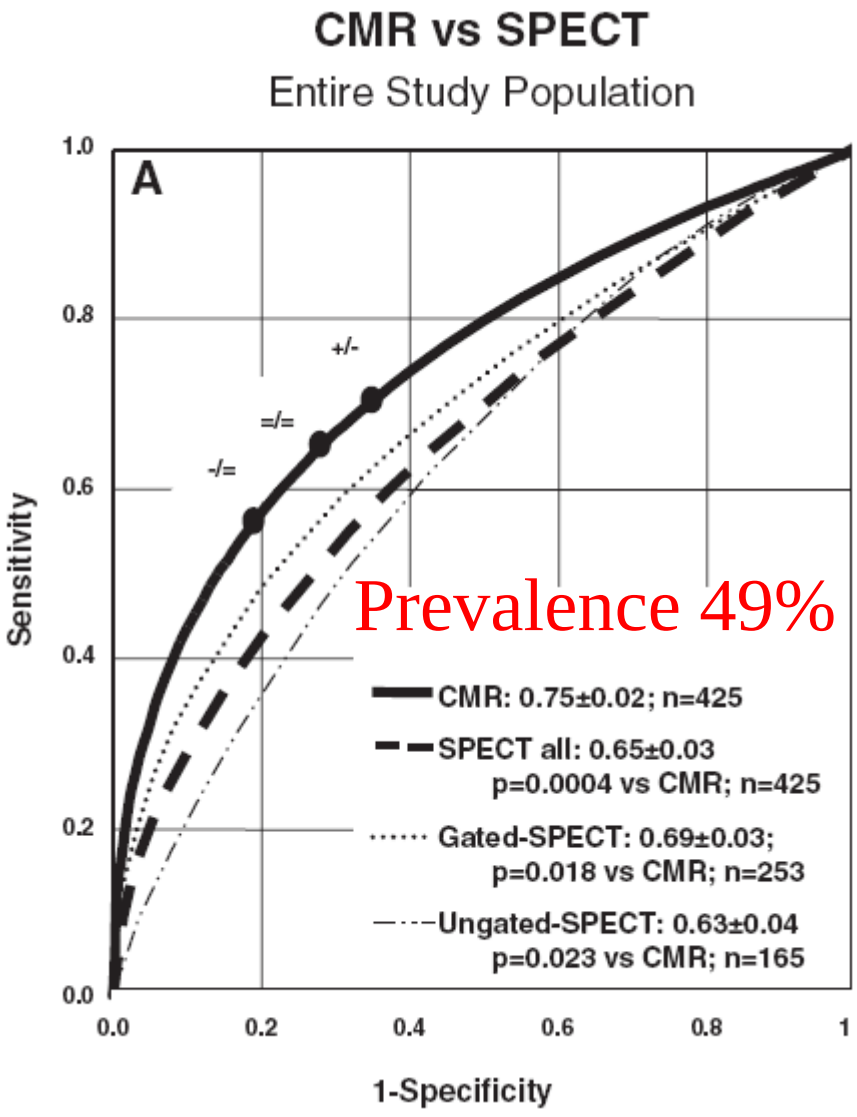
CMR 83.4 %

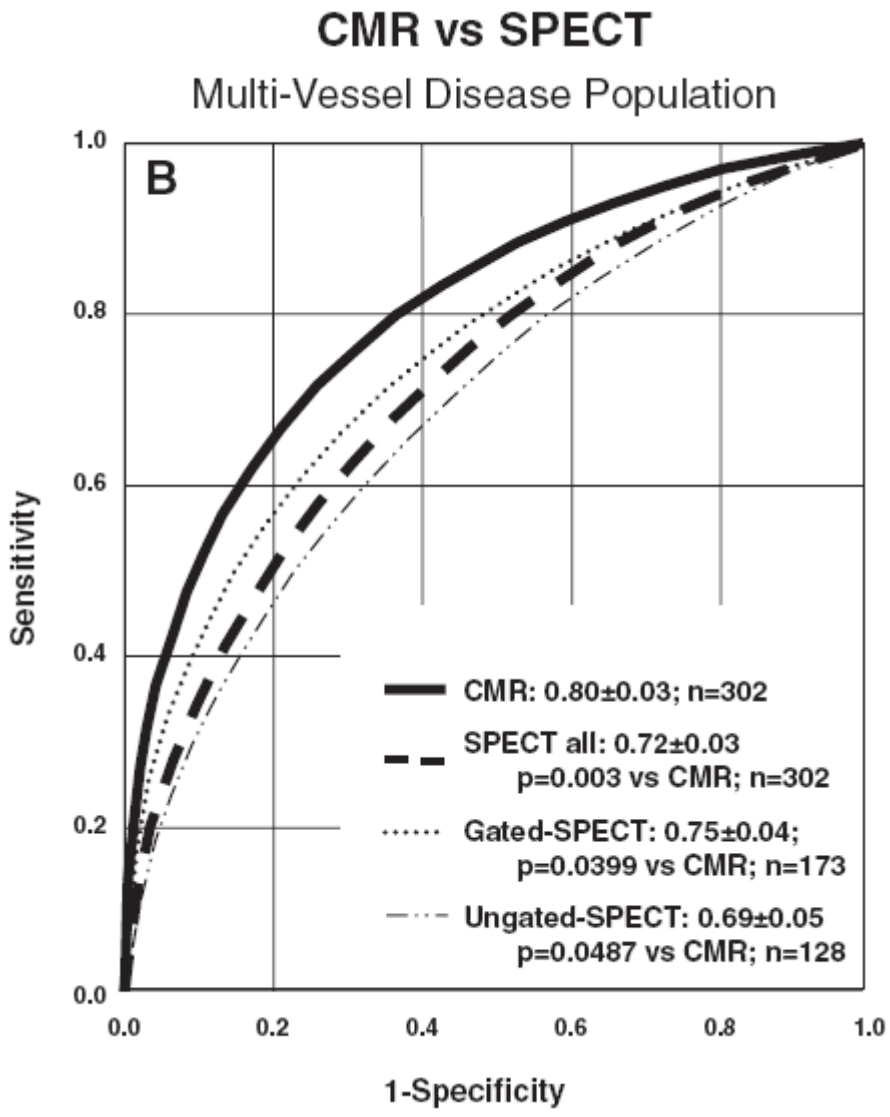
SPECT 82.6 %




Greenwood JP et al *Lancet 2012*

# MR-IMPACT II

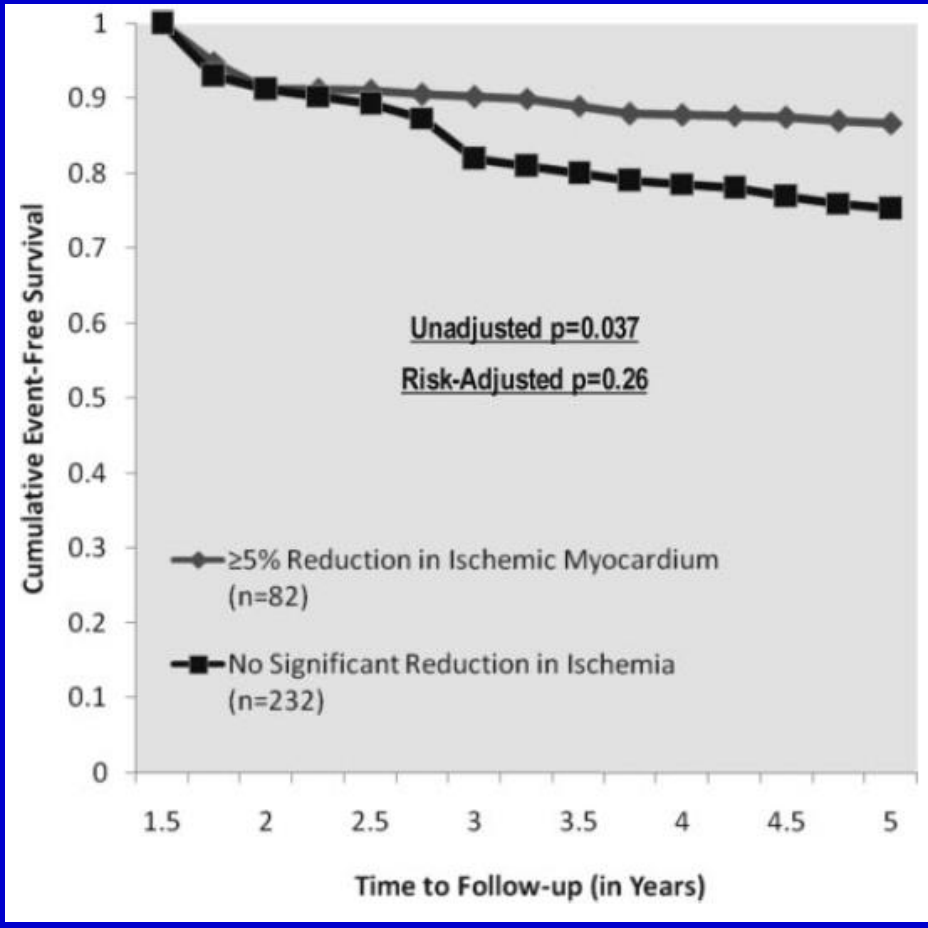


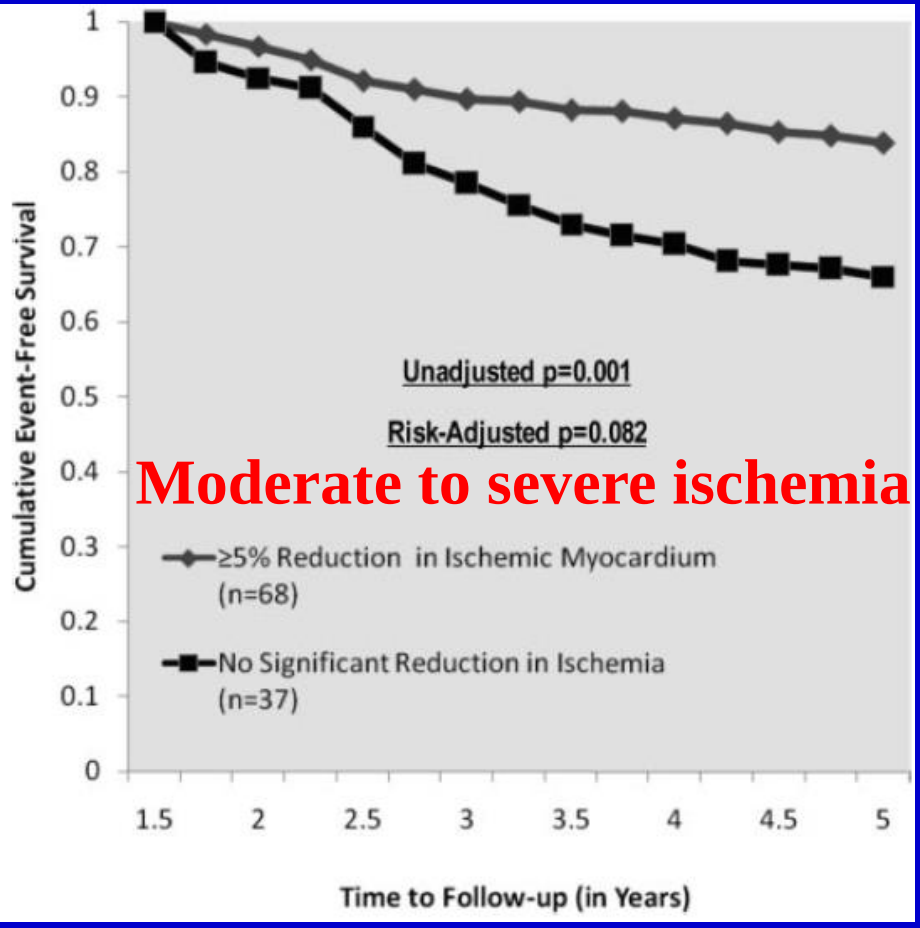



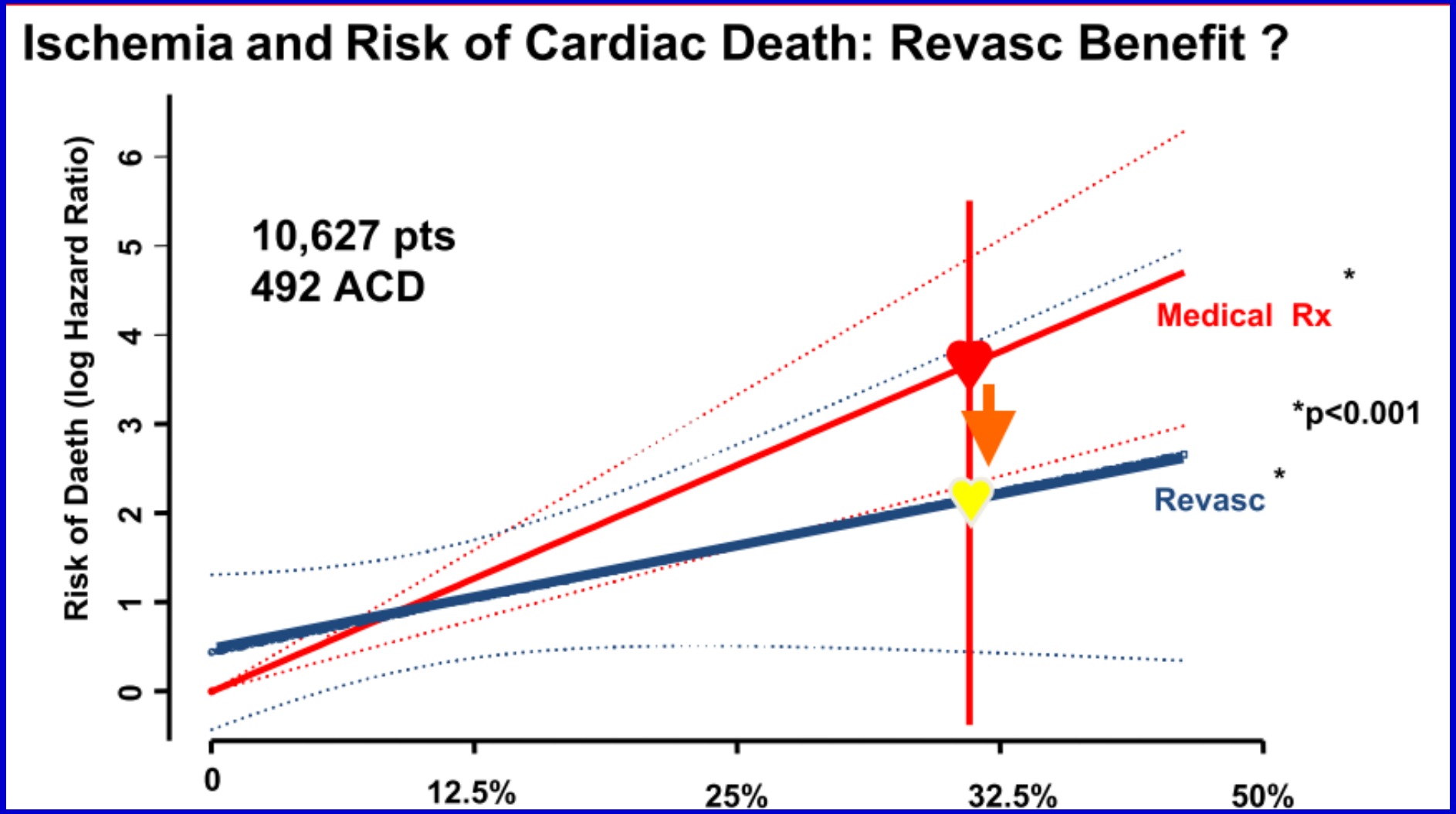

Schwitter J et al *JCMR 2012*

# Imaging in a post-COURAGE world
## Knowledge of the extent of ischemia

- COURAGE nuclear sub-study



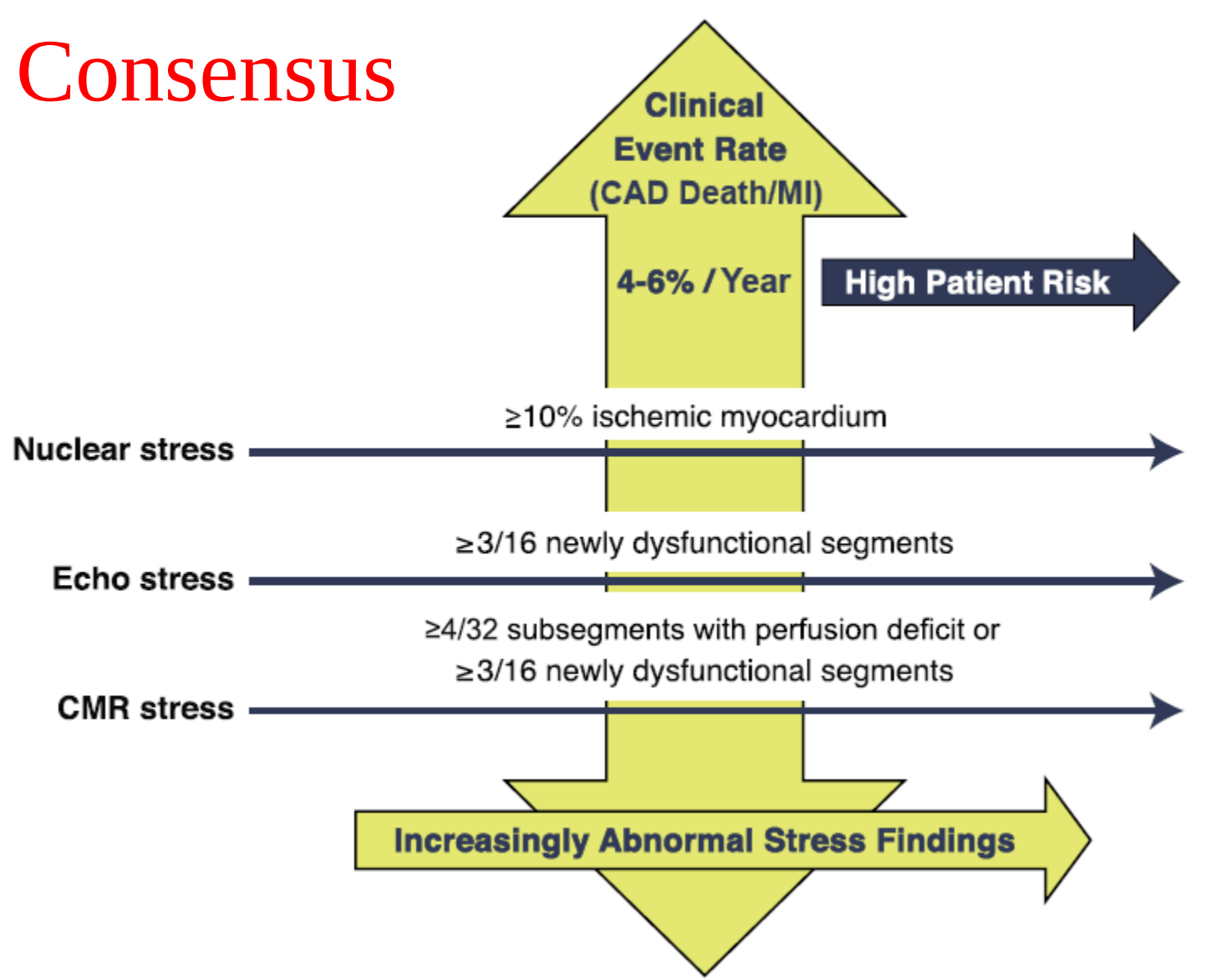






% myocarde ischémique

Hachamovitch LJ *Circulation 2003*

# Definition of Moderate-Severe ischemia




Shaw LJ et al *JACC Imaging 2014*

**Table 7** Summary CMR findings

| | Independent Prognostic CMR Finding (Group 1) | No Independent Prognostic CMR Finding (Group 2) |
|---|---|---|
| Patients with recent MI | | |
| Hard events | None | None |
| MACE | LVEF | MVO NOS<br>Infarct size (presence/extent) |
| Patients with suspected or known CAD | 18 212 patients / 958 hard events | |
| Hard events | LVEF<br>WMA induced (presence/segments)<br>Perfusion induced (presence/segments)<br>Infarct size (presence/extent/transmurality) | WMA rest (presence/segments) |
| MACE | Perfusion induced (presence)<br>Infarct size (presence/extent) | LVEF<br>WMA rest (score) |

El Aidi H et al *JACC 2014*

# Ancillary high-risk markers

- Important in patients with low ischemia
  - Functional capacity
  - LV dysfunction (EF, EDV, …) (CMR better)
  - Transient ischemic dilation of the LV
  - Extent of myocardial scarring (CMR better)
- Patients with known CAD, had higher cardiac event rates despite a normal stress perfusion imaging
  - Prospective studies are required to establish the safety profile of normal MPI in pts with known CAD

**Tableau 9.** Efficacité des différentes techniques d'imagerie à prédire la survenue de décès d'origine cardiaque et d'IDM non fatals

| Taux annuel de survenue de décès ou d'IDM non fatal | Coro-TDM | IRM | TEP-TDM $^{82}$Rb | TEMP | ETT de stress |
|---|---|---|---|---|---|
| Examen normal | 0,08 % | 1,1 % | 0,7 % | 0,6 % | 0,8 % |
| Examen anormal | N.D | 6,05 % | 3,8 % | 4 % | 5 % |
| Examen anormal à faible risque | 0,96 % | N.D | 2,6 % | 0,85 % | 2,8 % |
| Examen anormal à haut risque | 4,3 % | N.D | 7 % | 5,9 % | 5,3 % |
| Effectif global | 4 556 | 2 621 | 1 896 | >70 000* | 12 266* |
| Suivi médian (ans) | 1,7 (1,1-3,3) | 2,9 (1,5-3) | 3 (1-3) | 4 (1-15) | 3 (1-10) |

*dont des méta-analyses incluant de nombreuses études antérieures

# Cost-effectiveness

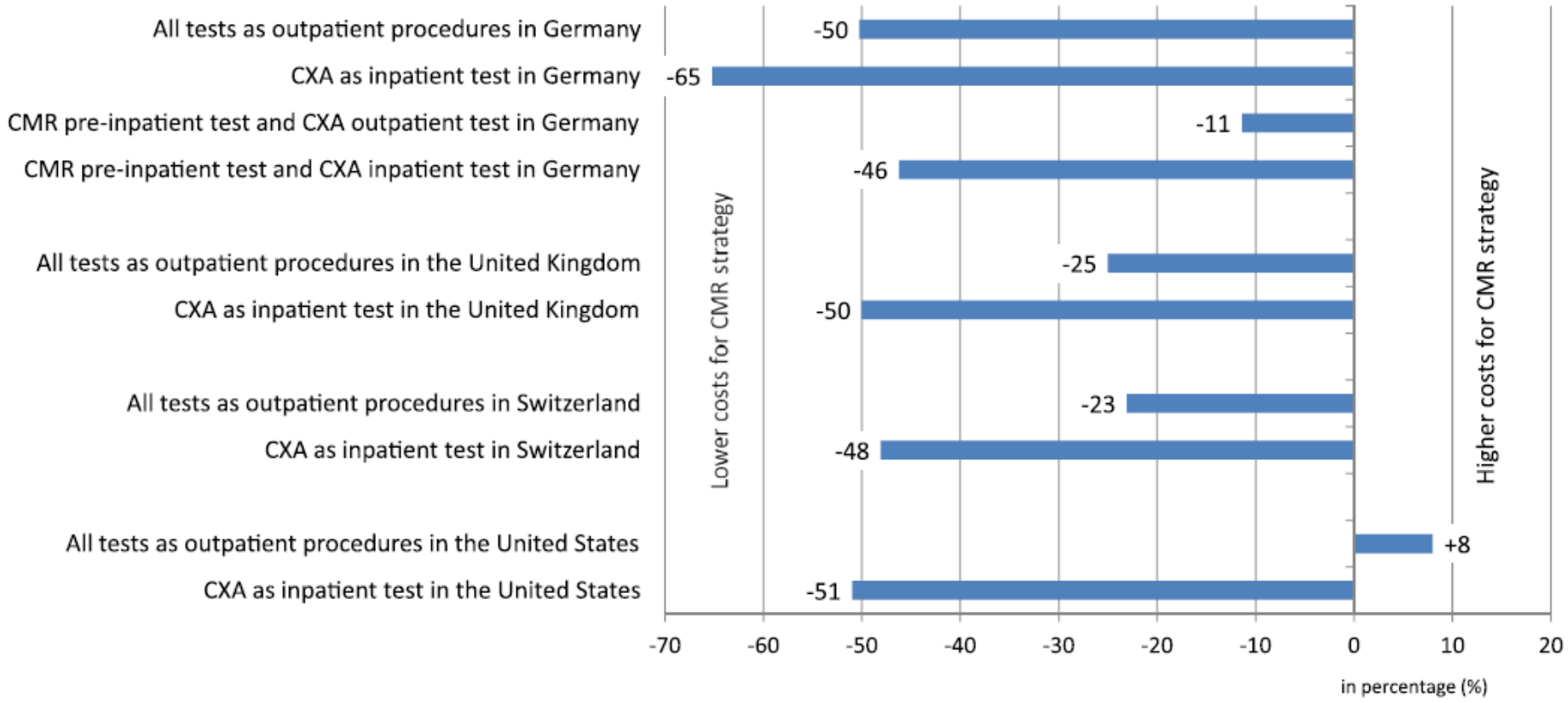



**Figure 2 Percentage of cost variation between CMR strategy and CXA strategy.** When all tests are performed as outpatient procedures in Germany the CMR strategy is 50% less costly than the CXA strategy. By contrast, when all tests are performed as inpatient procedures in the United States, CMR strategy is 8% more costly than the CXA strategy.

Moschetti K et al *JCMR 2012*

# Cost-effectiveness

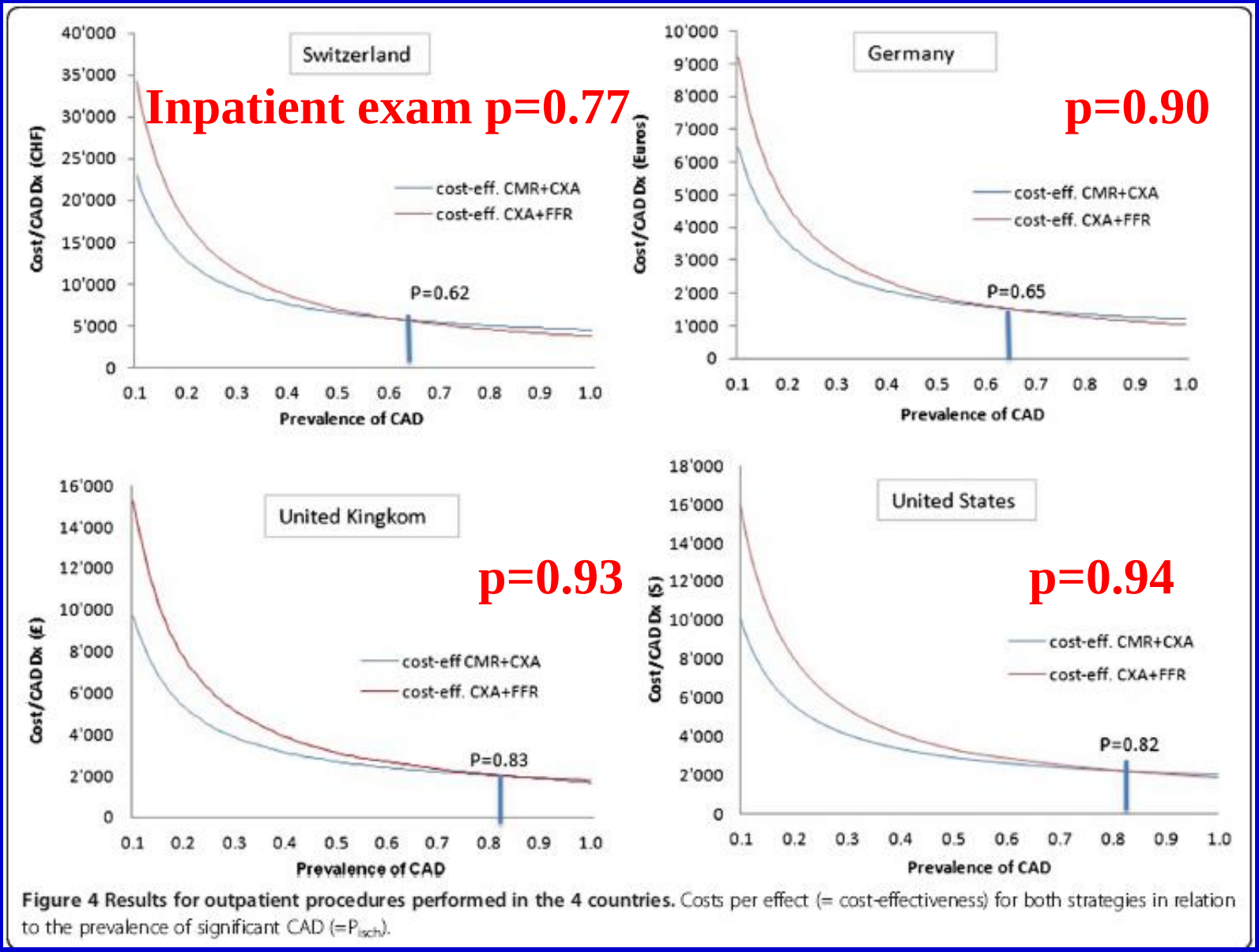


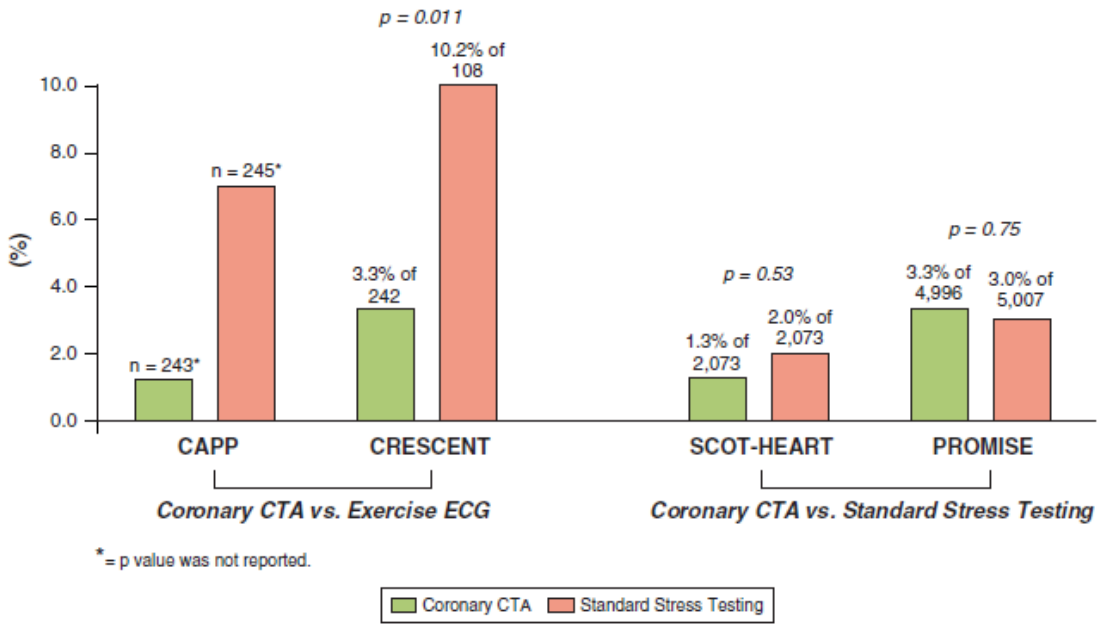

**Figure 4 Results for outpatient procedures performed in the 4 countries.** Costs per effect (= cost-effectiveness) for both strategies in relation to the prevalence of significant CAD (=$P_{isch}$).

Moschetti K et al *JCMR 2014*

# La stratégie diagnostique influence le pronostic ?

# Stratégie diagnostique et pronostic

**FIGURE 1** Highlighted Endpoint Findings Among Imaging Randomized Clinical Trials for Stable Ischemic Heart Disease That Compared Coronary CTA With Standard Stress Testing




The CAPP and CRESCENT trials randomized patients to coronary CTA versus exercise ECG. The SCOT-HEART randomized patients to coronary CTA versus standard care, and the PROMISE trial randomized patients to coronary CTA versus functional stress testing. Follow-up was 1.0, 1.2, 1.7, and 2.1 years, respectively, for the CAPP, CRESCENT, SCOT-HEART, and PROMISE trials. Varied endpoints were used: CAPP (all-cause mortality, emergency department visit with coronary artery disease hospitalization), CRESCENT (all-cause mortality, MI, major stroke, unstable angina, unplanned coronary artery disease evaluation, late revascularization), SCOT-HEART (coronary heart disease death, MI), and PROMISE (death, MI, unstable angina, procedural complications). The all-cause death or MI rate for PROMISE was 0.6% for coronary CTA versus 0.8% ($p = 0.35$), lower than that observed in the SCOT-HEART trial. CAPP = Cardiac CT for Assessment of Pain and Plaque; CRESCENT = Computed Tomography vs. Exercise Testing in Suspected Coronary Artery Disease; CTA = computed tomographic angiography; ECG = electrocardiogram; MI = myocardial infarction; PROMISE = Prospective Multicenter Imaging Study for Evaluation of Chest Pain; SCOT-HEART = Scottish Computed Tomography of the HEART.

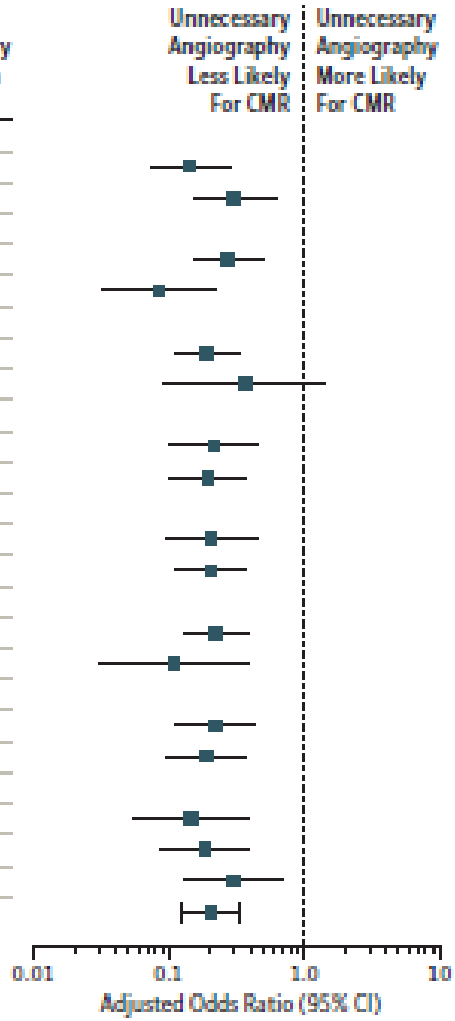
*Shaw LJ JACC Cardiovasc Imaging* 2017

# CE-MARC 2 trial
# Coronarographie inutile

Figure 2. Effect of Specific Patient Characteristics on Results for CMR-Guided Care vs NICE Guidelines-Directed Care and MPS-Guided Care Among Patients With Suspected Coronary Heart Disease

A Cardiovascular magnetic resonance vs NICE guidelines

| Subgroup | Cardiovascular Magnetic Resonance: Unnecessary Angiography, No. | Cardiovascular Magnetic Resonance: Participants, No. | NICE Guidelines: Unnecessary Angiography, No. | NICE Guidelines: Participants, No. | Adjusted Odds Ratio of Unnecessary Angiography Within 12 mo (95% CI) |
|---|---|---|---|---|---|
| Sex | | | | | |
| Men | 15 | 254 | 41 | 128 | 0.14 (0.07-0.28) |
| Women | 21 | 227 | 28 | 112 | 0.31 (0.15-0.61) |
| Age group, y | | | | | |
| 30-64 | 26 | 389 | 44 | 192 | 0.28 (0.15-0.49) |
| ≥65 | 10 | 92 | 25 | 48 | 0.09 (0.03-0.22) |
| Race/ethnicity (white vs nonwhite) | | | | | |
| White | 31 | 443 | 63 | 221 | 0.19 (0.11-0.33) |
| Asian, black, other, or not stated | 5 | 38 | 6 | 19 | 0.37 (0.09-1.42) |
| Hypertension | | | | | |
| Yes | 13 | 177 | 28 | 99 | 0.22 (0.10-0.45) |
| No | 23 | 304 | 41 | 141 | 0.19 (0.10-0.37) |
| Smoking Status | | | | | |
| Never smoked | 15 | 197 | 25 | 93 | 0.21 (0.10-0.45) |
| Former or current smoker | 21 | 284 | 44 | 147 | 0.20 (0.11-0.37) |
| Diabetes | | | | | |
| No diabetes | 32 | 428 | 58 | 216 | 0.22 (0.13-0.38) |
| Type I or type II | 4 | 53 | 11 | 24 | 0.11 (0.03-0.39) |
| Known family history of CHD | | | | | |
| No or not known | 19 | 229 | 31 | 100 | 0.22 (0.11-0.44) |
| Yes | 17 | 252 | 38 | 140 | 0.19 (0.10-0.37) |
| BMI | | | | | |
| 0-25 | 7 | 101 | 16 | 52 | 0.15 (0.06-0.39) |
| 26-30 | 18 | 196 | 35 | 101 | 0.18 (0.09-0.38) |
| >30 | 11 | 184 | 18 | 87 | 0.30 (0.13-0.68) |
| Overall | 36 | 481 | 69 | 240 | 0.21 (0.12-0.34) |

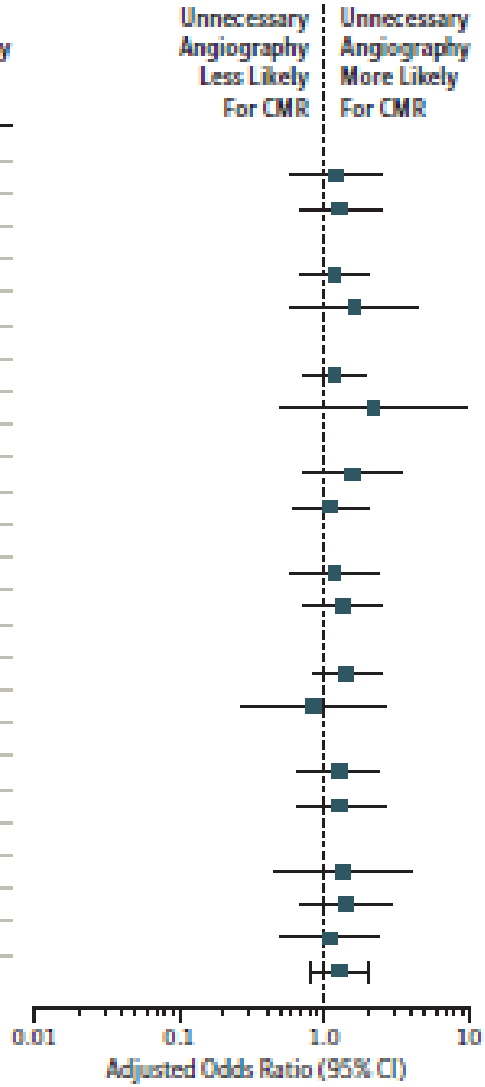



*JAMA* 2016

# CE-MARC 2 trial
# Coronarographie inutile

B Cardiovascular magnetic resonance vs myocardial perfusion scintigraphy

| Subgroup | Cardiovascular Magnetic Resonance: Unnecessary Angiography, No. | Cardiovascular Magnetic Resonance: Participants, No. | Myocardial Perfusion Scintigraphy: Unnecessary Angiography, No. | Myocardial Perfusion Scintigraphy: Participants, No. | Adjusted Odds Ratio of Unnecessary Angiography Within 12 mo (95% CI) |
|---|---|---|---|---|---|
| Sex | | | | | |
| Men | 15 | 254 | 15 | 256 | 1.23 (0.60-2.52) |
| Women | 21 | 227 | 19 | 225 | 1.30 (0.68-2.49) |
| Age group, y | | | | | |
| 30-64 | 26 | 389 | 26 | 388 | 1.18 (0.69-2.01) |
| ≥65 | 10 | 92 | 8 | 93 | 1.61 (0.60-4.36) |
| Race/ethnicity (white vs nonwhite) | | | | | |
| White | 31 | 443 | 31 | 443 | 1.18 (0.72-1.95) |
| Asian, black, other, or not stated | 5 | 38 | 3 | 38 | 2.21 (0.50-9.74) |
| Hypertension | | | | | |
| Yes | 13 | 177 | 11 | 182 | 1.57 (0.73-3.39) |
| No | 23 | 304 | 23 | 299 | 1.11 (0.61-2.02) |
| Smoking Status | | | | | |
| Never smoked | 15 | 197 | 15 | 210 | 1.19 (0.58-2.43) |
| Former or current smoker | 21 | 284 | 19 | 271 | 1.33 (0.72-2.48) |
| Diabetes | | | | | |
| No diabetes | 32 | 428 | 25 | 408 | 1.43 (0.84-2.44) |
| Type I or type II | 4 | 53 | 9 | 73 | 0.86 (0.28-2.67) |
| Known family history of CHD | | | | | |
| No or not known | 19 | 229 | 19 | 222 | 1.26 (0.67-2.38) |
| Yes | 17 | 252 | 15 | 259 | 1.30 (0.65-2.61) |
| BMI | | | | | |
| 0-25 | 7 | 101 | 7 | 103 | 1.35 (0.46-3.92) |
| 26-30 | 18 | 196 | 14 | 197 | 1.40 (0.68-2.89) |
| >30 | 11 | 184 | 13 | 181 | 1.09 (0.50-2.35) |
| Overall | 36 | 481 | 34 | 481 | 1.27 (0.79-2.03) |




*JAMA* 2016

# FFR CT

**DISCOVER-FLOW**
- Completed 2011
- N=104 patients

**Diagnosis of Ischemia-Causing Coronary Stenoses by Noninvasive Fractional Flow Reserve Computed From Coronary Computed Tomographic Angiograms**

Results From the Prospective Multicenter DISCOVER-FLOW (Diagnosis of Ischemia-Causing Stenoses Obtained Via Noninvasive Fractional Flow Reserve) Study

Bon-Kwon Koo, MD, PhD,* Andrejs Erglis, MD, PhD,† Joon-Hyung Doh, MD, PhD,‡ David V. Daniels, MD,§ Sanda Jegere, MD,‖ Hyo-Soo Kim, MD, PhD,* Allison Dunning, MD,¶ Tony DeFrance, MD,# Alexandra Lansky, MD,** Jonathan Leipsic, BSc, MD,†† James K. Min, MD‡‡

*Seoul and Goyang, South Korea; Riga, Latvia; Palo Alto, San Francisco, and Los Angeles, California; New York, New York; New Haven, Connecticut; and Vancouver, British Columbia, Canada*

**DeFACTO**
- Completed 2012
- N=252 patients

ONLINE FIRST

**Diagnostic Accuracy of Fractional Flow Reserve From Anatomic CT Angiography**

*JAMA. 2012;308(12):doi:10.1001/2012.jama.11274*

**NXT**
- Completed 2013
- N~254 patients

CLINICAL RESEARCH Cardiac Imaging

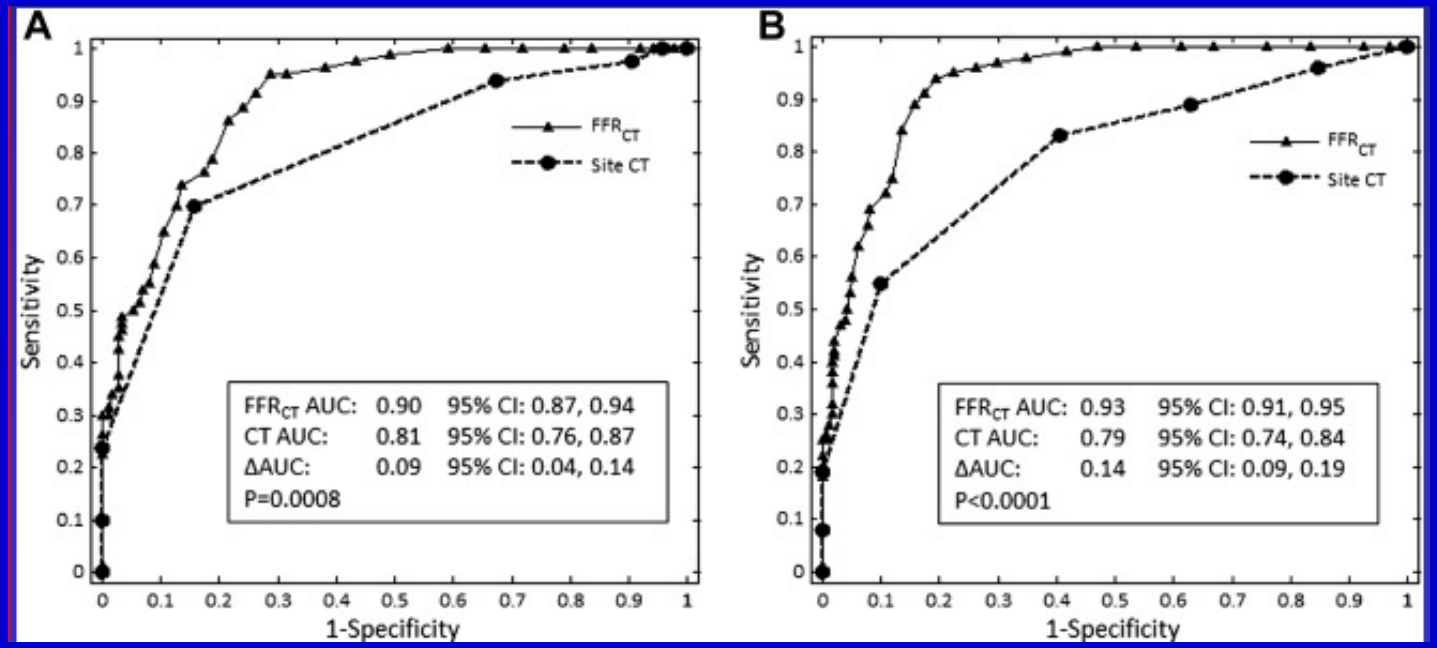
**Diagnostic Performance of Noninvasive Fractional Flow Reserve Derived From Coronary Computed Tomography Angiography in Suspected Coronary Artery Disease**

The NXT Trial (Analysis of Coronary Blood Flow Using CT Angiography: Next Steps)

Bjarne L. Norgaard, MD, PhD,* Jonathon Leipsic, MD, PhD,† Sara Gaur, MD,* Sigrún Seneviratne, MBBS,† Brian S. Ko, MBBS, PhD,‡ Hiroshi Ito, MD, PhD,§ Jesper M. Jensen, MD, PhD,* Laura Mauri, MD, PhD,‖ Bernard De Bruyne, MD, PhD,¶ Hiram Bezerra, MD, PhD,# Kazuhiro Osawa, MD,§ Mohamed Marwan, MD, PhD,** Christoph Naber, MD, PhD,†† Andrejs Erglis, MD, PhD,‡‡ Seung-Jung Park, MD, PhD,§§ Evald H. Christiansen, MD, PhD,* Arne Kaltoft, MD, PhD,* Jens F. Lassen, MD, PhD,* Hans Erik Bøtker, MD, DMSci,* Stephan Achenbach, MD, PhD,** on behalf of the NXT Trial Study Group

*Aarhus, Denmark; Vancouver, British Columbia, Canada; Victoria, Australia; Okayama, Japan; Boston, Massachusetts; Aalst, Belgium; Cleveland, Ohio; Erlangen and Essen, Germany; Riga, Latvia; and Seoul, South Korea*

| | $FFR_{CT}$ ≤0.80 | Coronary CTA Stenosis >50% | p Value |
|---|---|---|---|
| Accuracy | 80 (75–85) | 51 (44–57) | <0.0001 |
| Sensitivity | 85 (74–91) | 93 (85–97) | 0.058 |
| Specificity | 79 (72–84) | 32 (26–40) | <0.0001 |
| PPV | 63 (53–72) | 37 (31–44) | <0.0001 |
| NPV | 92 (87–96) | 91 (81–96) | 0.42 |




*Norgaard BL NXT trial JACC* 2014

# Scanner des coronaires ± FFR CT
# Méta-analyse (FFR référence)

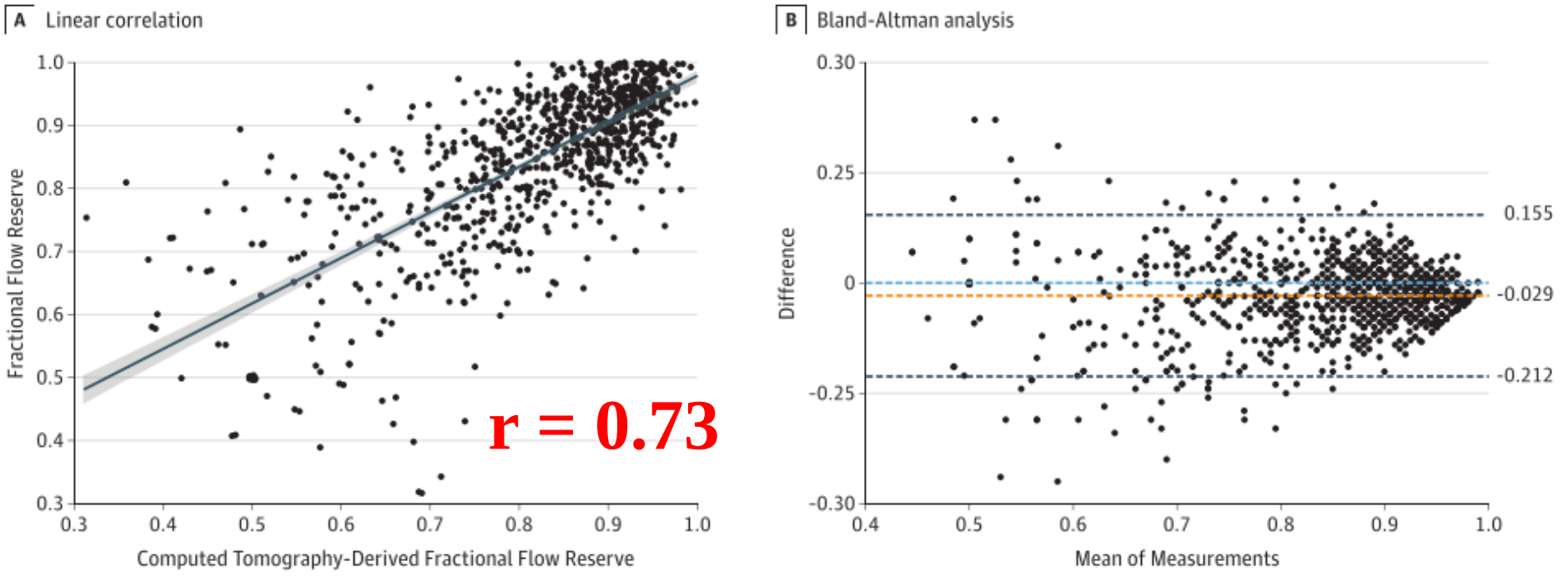
**TABLE 2** Outcome Summary Per-Patient

| Imaging Modality | N | Sensitivity (%) (95% CI) | Specificity (%) (95% CI) | +LR (95% CI) | −LR (95% CI) |
|---|---|---|---|---|---|
| CTA | 3,101 | 0.94 (0.91-0.97) | 0.48 (0.37-0.59) | 1.85 (1.48-2.36) | 0.12 (0.06-0.19) |
| CTP | 697 | 0.83 (0.71-0.92) | 0.79 (0.68-0.87) | 4.10 (2.46-7.01) | 0.22 (0.09-0.40) |
| CTA and CTP | 619 | 0.89 (0.78-0.96) | 0.81 (0.73-0.90) | 4.75 (3.16-6.99) | 0.14 (0.04-0.30) |
| $FFR_{CT}$ | 1,069 | 0.89 (0.85-0.92) | 0.76 (0.69-0.82) | 3.76 (2.76-5.21) | 0.15 (0.10-0.21) |
| CTA and $FFR_{CT}$ | NA | NA | NA | NA | NA |
| TAG | 188 | 0.69 (0.22-0.97) | 0.39 (0.07-0.82) | 1.55 (0.32-4.72) | 1.36 (0.07-5.42) |
| CTA and TAG | NA | NA | NA | NA | NA |

*Celeng C JACC Cardiovasc Imaging* 2018

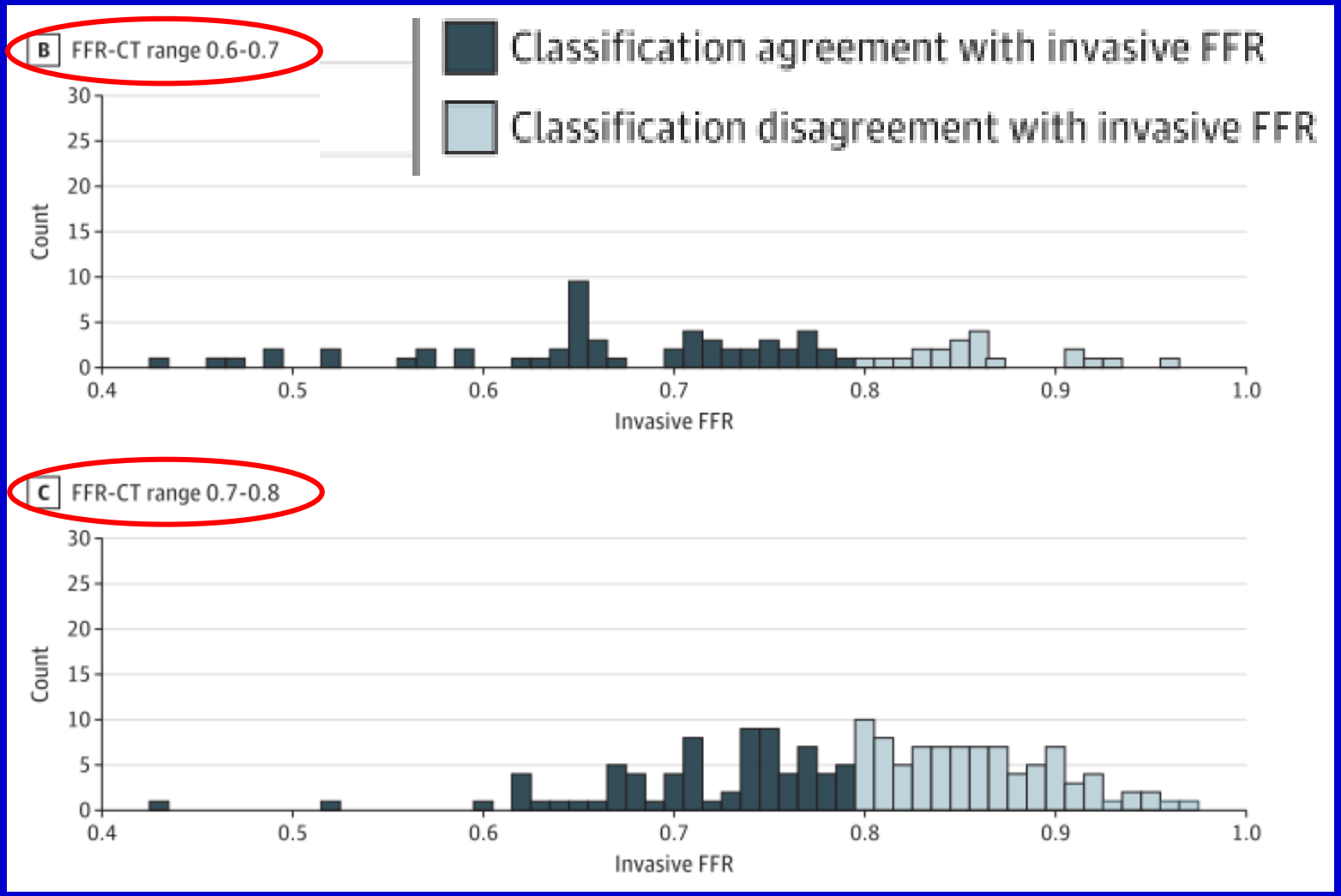
# FFR et FFR CT

Figure 2. Scatterplot Showing the Overall Association Between Computed Tomography–Derived Fractional Flow Reserve (FFR-CT) and FFR




A, The solid blue line represents the line of best fit between FFR-CT and FFR. The gray shaded area represents the 95% CI for the line of best fit; $r^2$ = 0.54; 95% CI, 0.50-0.58; $P$ < .001. B, Bland-Altman plot of differences against the means for FFR. The zero line is displayed in red. The mean bias is represented by the solid blue line (with the 95% CI represented by the dashed blue lines).

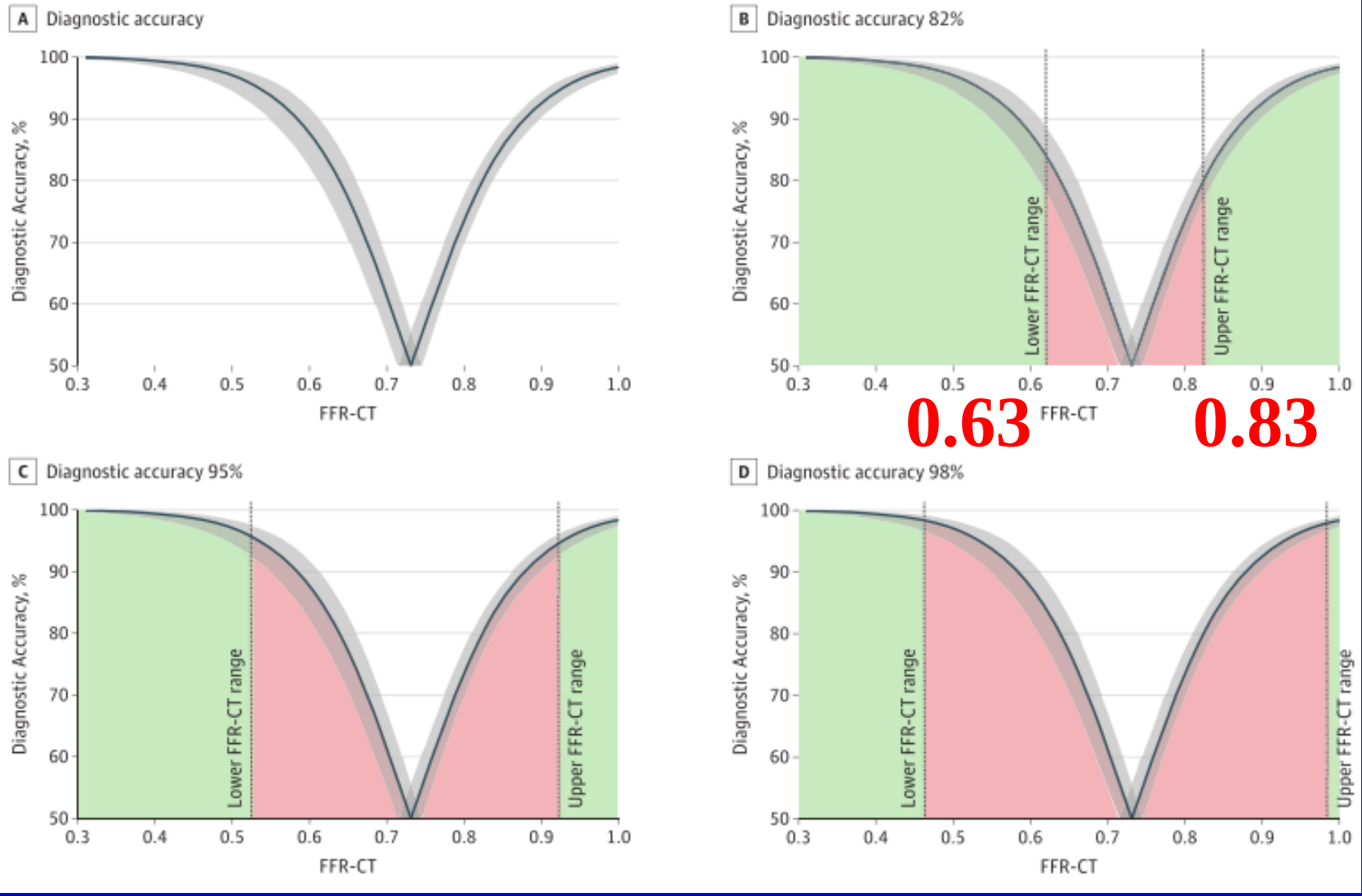
*Cook CM JAMA Cardiology* 2017




FFR CT ≤ 0.60 87.5 % FFR ≤ 0.80

FFR CT > 0.90 97.8 % FFR > 0.80

*Cook CM JAMA Cardiology* 2017



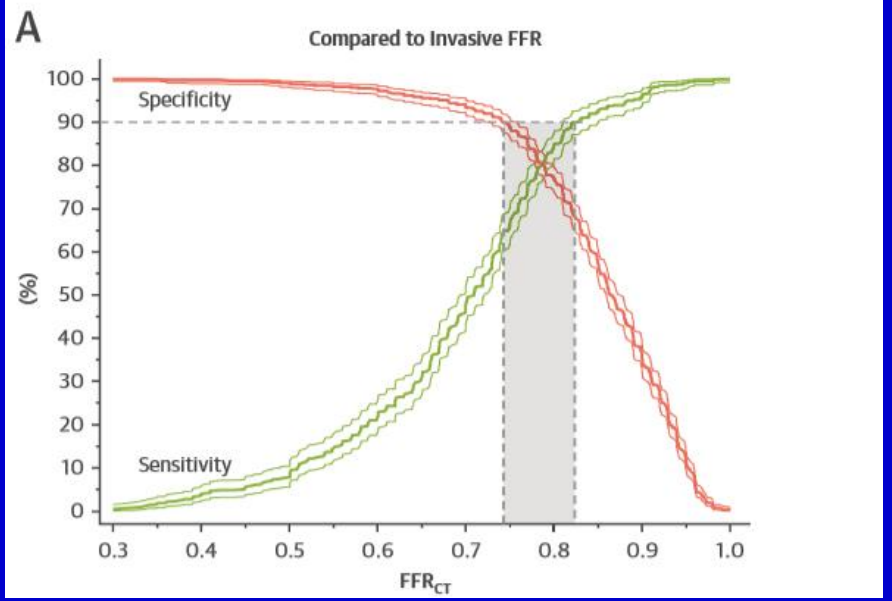

*Cook CM JAMA Cardiology* 2017

**TABLE 1** Outcome Summary Per Vessel

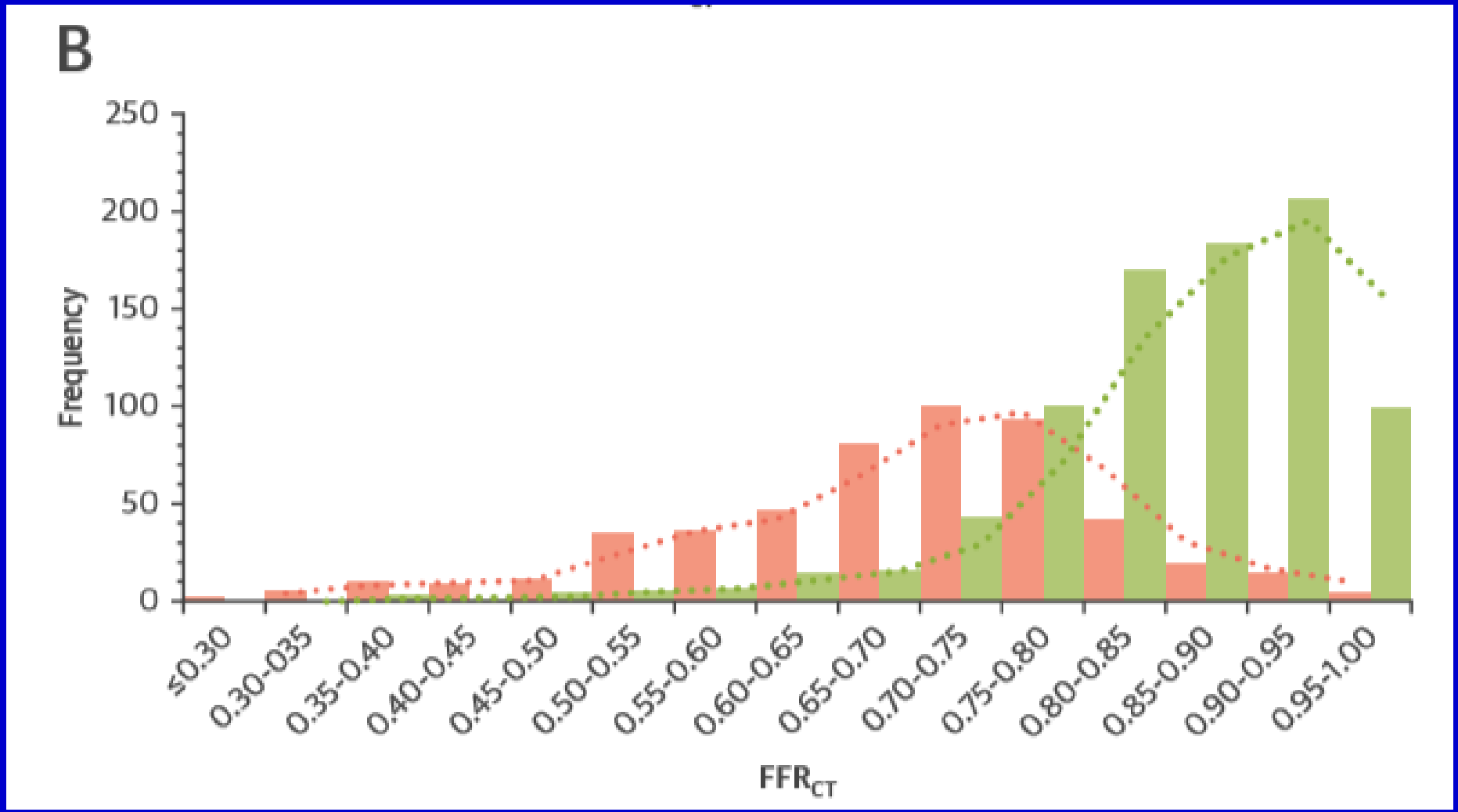
**Méta-analyse**

| Imaging Modality | Number of Vessels | Sensitivity (%) (95% CI) | Specificity (%) (95% CI) | +LR (95% CI) | −LR (95% CI) |
|---|---|---|---|---|---|
| CTA | 6,400 | 0.87 (0.84–0.91) | 0.61 (0.54–0.68) | 2.27 (1.87–2.76) | 0.21 (0.15–0.27) |
| CTP | 2,118 | 0.81 (0.72–0.88) | 0.86 (0.76–0.93) | 6.28 (3.17–11.91) | 0.23 (0.13–0.34) |
| CTA and CTP | 1,785 | 0.82 (0.76–0.87) | 0.88 (0.81–0.92) | 6.97 (4.29–11.39) | 0.21 (0.13–0.30) |
| $FFR_{CT}$ | 2,432 | 0.85 (0.82–0.87) | 0.78 (0.72–0.83) | 3.86 (2.91–5.22) | 0.20 (0.16–0.24) |
| CTA and $FFR_{CT}$ | 362 | 0.76 (0.50–0.93) | 0.80 (0.69–0.88) | 4.00 (1.85–7.05) | 0.31 (0.08–0.69) |
| TAG | 726 | 0.59 (0.46–0.72) | 0.77 (0.61–0.89) | 2.89 (1.41–5.98) | 0.53 (0.33–0.76) |
| CTA and TAG | 327 | 0.70 (0.46–0.87) | 0.92 (0.77–0.99) | 15.98 (2.63–59.63) | 0.33 (0.12–0.63) |

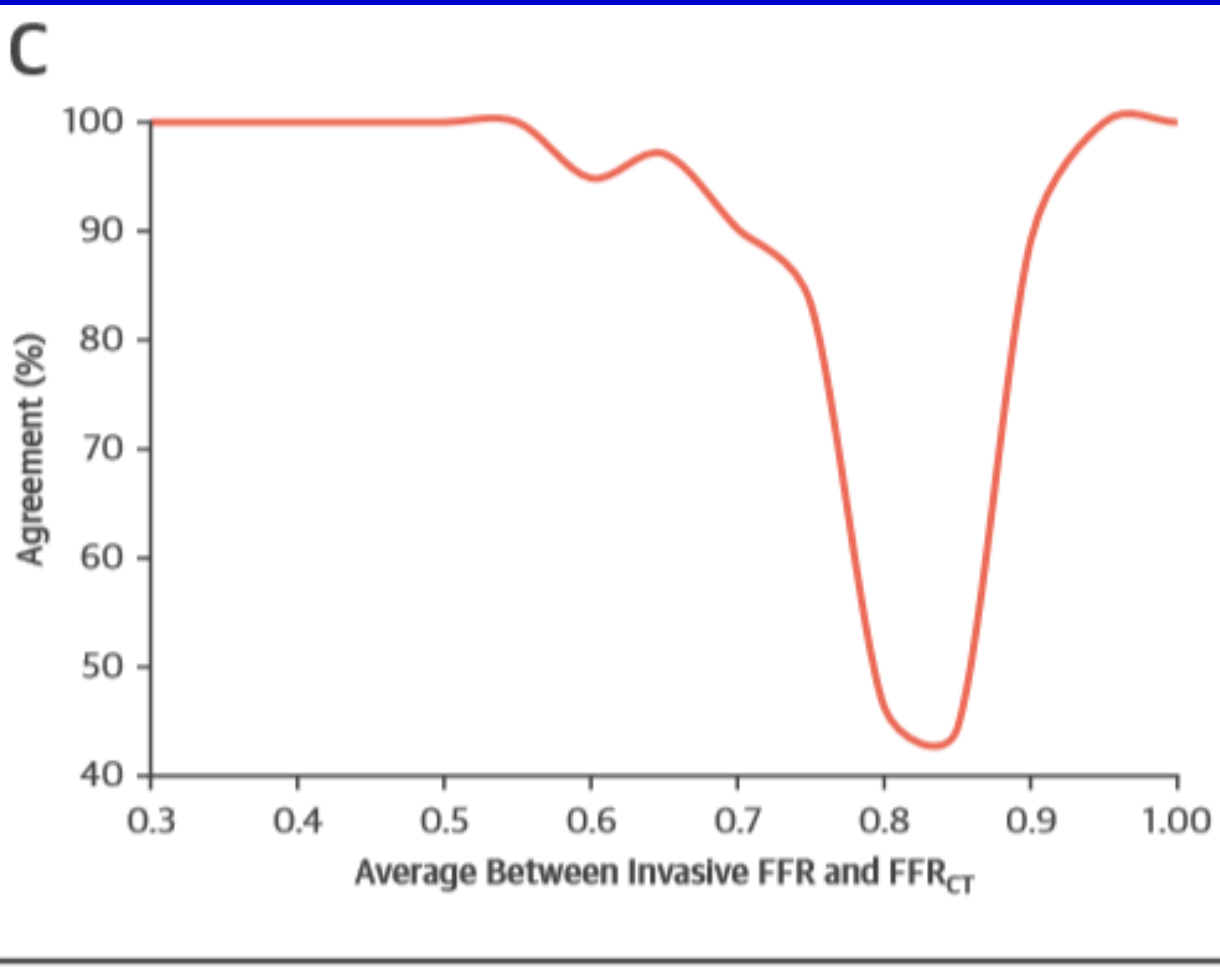
**FIGURE 5** Individual $FFR_{CT}$ Values




Celeng C et al. *JACC imaging 2018*




Celeng C et al. *JACC imaging 2018*




**(A)** Sensitivity and specificity (with 95% confidence intervals) at different $FFR_{CT}$ values. **(B)** The frequency of invasive FFR ≤0.80 **(orange)** and invasive FFR >0.80 **(green)** at different $FFR_{CT}$ values. The **dotted line** represents the moving average trendline. **(C)** Per-range agreement by plotting agreement against the average of invasive FFR and $FFR_{CT}$ value. Abbreviations as in **Figure 1**.

Celeng C et al. *JACC imaging 2018*

# FFR CT
# ESC guidelines 2018

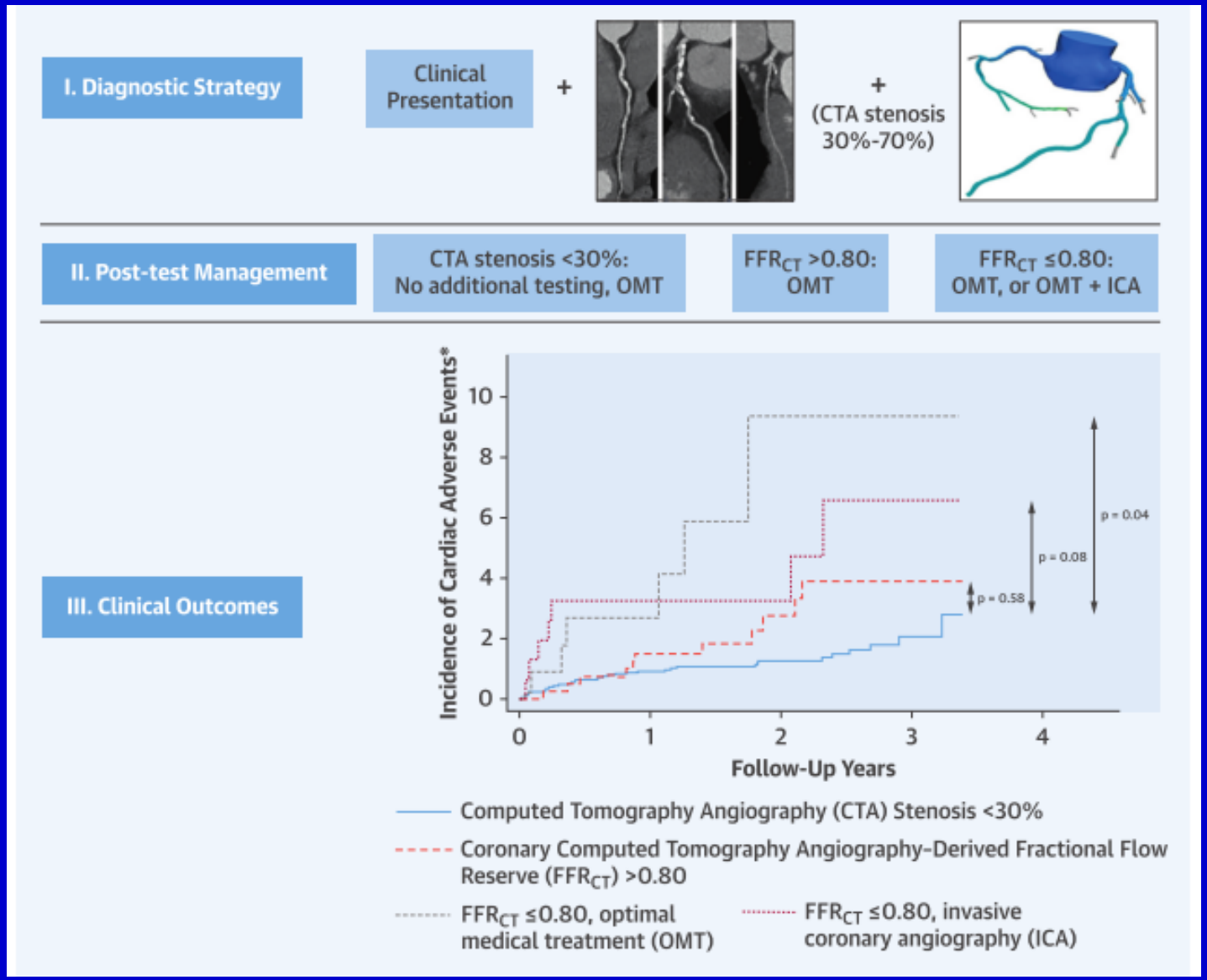
## 3.1 Non-invasive diagnostic tools

### 3.1.1 Assessment of myocardial ischaemia

coronary angiograms compared with standard care.[4] Currently, clinical trial data with CT-FFR are insufficient to make a recommendation for its use in clinical practice.

ESC 2018

# Scanner des coronaires + FFR CT




*Norgaard BL JACC* 2018

# Infarctus et IRM
## Les indications SFC / SFR en 2010

- Dans le post-infarctus
  - **Fonction VG globale et régionale** **I**
  - **Diagnostic des complications**
    - Thrombus intra-VG et Anévrysme VG **I**
  - **Infarctus à coronaires saines** **I**
  - **Viabilité myocardique** **I**
  - Ischémie résiduelle II
    - Fonction VG régionale sous dobutamine
    - Perfusion myocardique régionale sous adénosine

# Les indications SFC / SFR en 2010

**Tableau I**
Indications de l'IRM dans la maladie coronaire.

| Indication | Classe |
|---|---|
| Évaluation de la fonction ventriculaire droite et gauche | I |
| Détection de la maladie coronaire : | |
| – Fonction VG régionale sous Dobutamine | II |
| – Perfusion myocardique (Adénosine ou Dipyridamole) si ECG ininterprétable ou épreuve d'effort impossible | I |
| – Coro-IRM | INV |
| Infarctus du myocarde et syndromes coronaires aigus | |
| – Détection | I |
| – Viabilité myocardique | I |
| – Complications : fuite mitrale, CIV | III |
| – Thrombus ventriculaire | I |
| – Syndrome coronaire aigu | INV |

# Conclusion

- Estimation de la probabilité de coronaropathie
- Pas de coroscanner ou d'imagerie fonctionnelle si Probabilité <15 % ou >85 % (stratégie diagnostique)
- Entre 15 et 85 %
  - Un test d'ischémie est indispensable pour définir la stratégie thérapeutique
  - Privilégier un test fonctionnel pour le diagnostic
  - Privilégier un test d'effort + imagerie
    - Echo d'effort +++, Scintigraphie d'effort
  - IRM de perfusion > IRM dobutamine
  - IRM de perfusion > Scintigraphie myocardique

# Conclusion

- Entre 15 et 85 %
  - VPN du coroscanner diminue quand la prévalence de la coronaropathie augmente
  - Pas de coroscanner si Probabilité >50 % Faux - et Faux +
  - Pas de coroscanner si Probabilité >30 % et score calcique élevé > 100-400

- Un test d'ischémie est indispensable pour définir la stratégie thérapeutique après un coroscanner positif

# Conclusion

- Validation des stratégies diagnostiques +++
  - Coronarographie inutile
  - Taux de revascularisation
  - Évènements cardio-vasculaires à 1 an

# In Vivo Cardiovascular Catheterization Under Real-Time MRI Guidance

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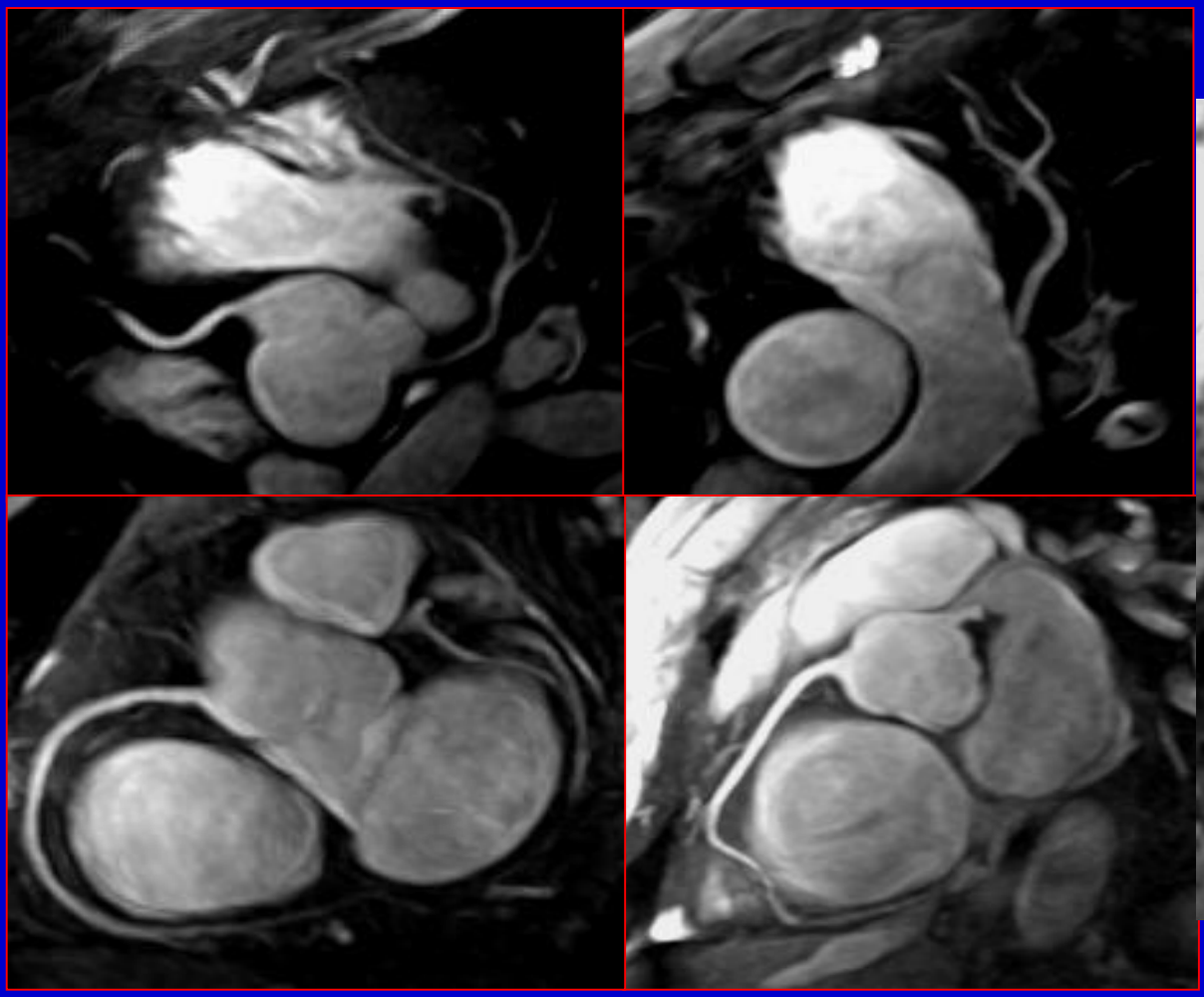

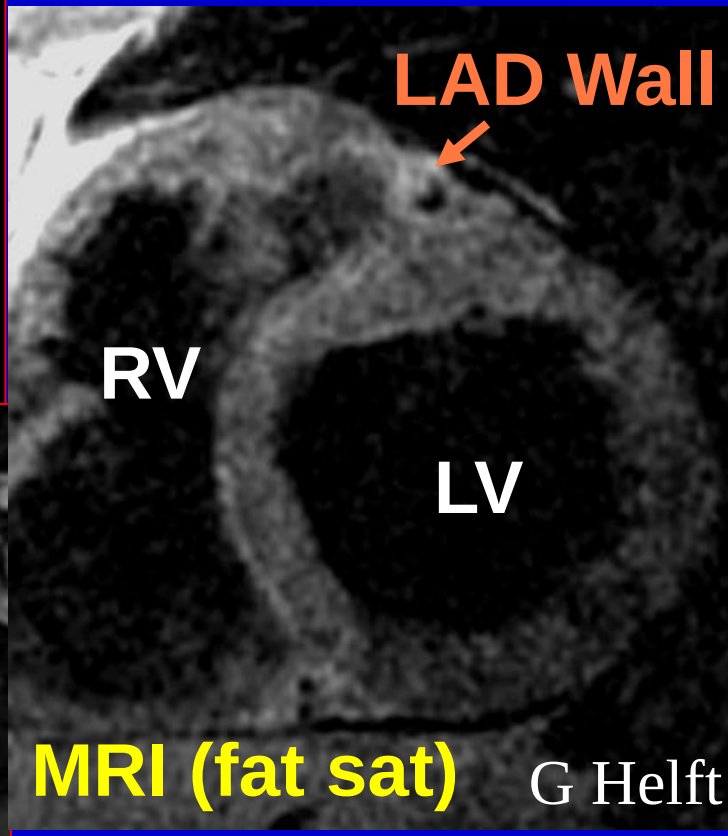

# Coro-IRM

**Tableau 13.** Performances diagnostiques per segment de la coro-IRM comparativement à la coronarographie, d'après Schuijf *et al.*

| Sous groupes | Sensibilité % [IC 95 %] | Spécificité % [IC 95 %] | VPP % [IC 95 %] | VPN % [IC 95 %] |
|---|---|---|---|---|
| Segments évaluables uniquement | 72 [69-75] | 87 [86-88] | 65 [62-68] | 90 [89-91] |
| Tous segments (ITD) | 58 [53-63] | 70 [68-72] | 37 [33-41] | 85 [83-87] |

Pourcentage important de segments non évaluables

17 à 27 % (médiane 22 %)

Résolution spatiale insuffisante 1 mm

Coro-scanner : 0,5 mm

Coronarographie : 0,2 mm

# Use of coronary CTA for the diagnosis of SCAD

| Recommendations | Class | Level |
|---|---|---|
| Coronary CTA should be considered as an alternative to stress imaging techniques for ruling out SCAD in patients within the lower range of intermediate PTP for SCAD in whom good image quality can be expected. | IIa | C |
| Coronary CTA should be considered in patients within the lower range of intermediate PTP for SCAD after a non-conclusive exercise ECG or stress imaging test or who have contraindications to stress testing in order to avoid otherwise necessary invasive coronary angiography if fully diagnostic image quality of coronary CTA can be expected. | IIa | C |
| Coronary calcium detection by CT is not recommended to identify individuals with coronary artery stenosis. | III | C |
| Coronary CTA is not recommended in patients with prior coronary revascularization. | III | C |
| Coronary CTA is not recommended as a 'screening' test in asymptomatic individuals without clinical suspicion of coronary artery disease. | III | C |

CT = computed tomography; CTA = computed tomography angiography; ECG = electrocardiogram; PTP = pre-test probability; SCAD = stable coronary artery disease.
This slide corresponds to Table 16 in the full text



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