# Myocardite et IRM
## DIU Imagerie cardiaque en coupes

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# Myocardite aiguë

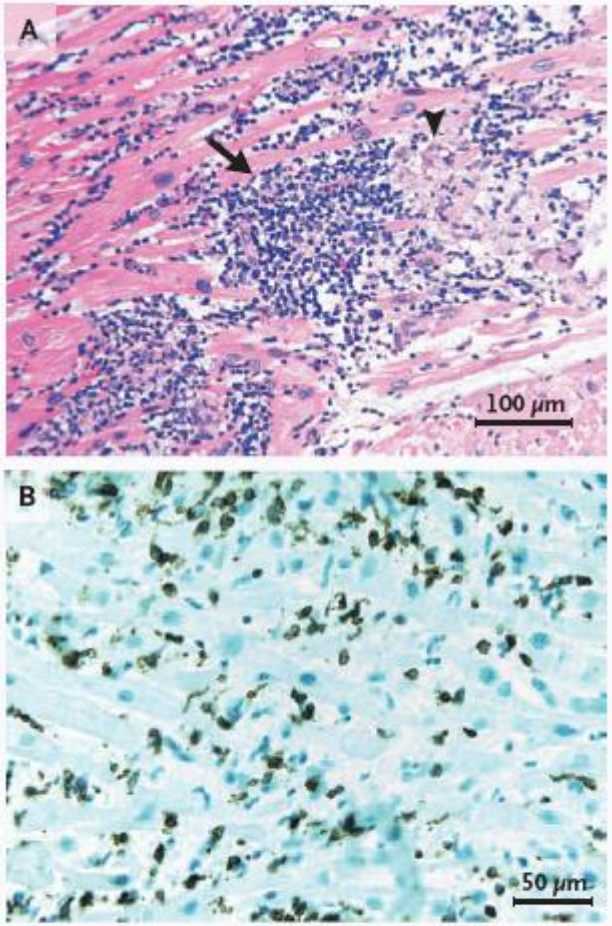


Figure 1. Lymphocytic and Histiocytic Infiltrate and T Lymphocytes in Heart-Tissue Sections from Patients with Acute Myocarditis.

Lymphocytic and histiocytic infiltrate
Myocyte dommage

CD3 immunostaining of T lymphocytes

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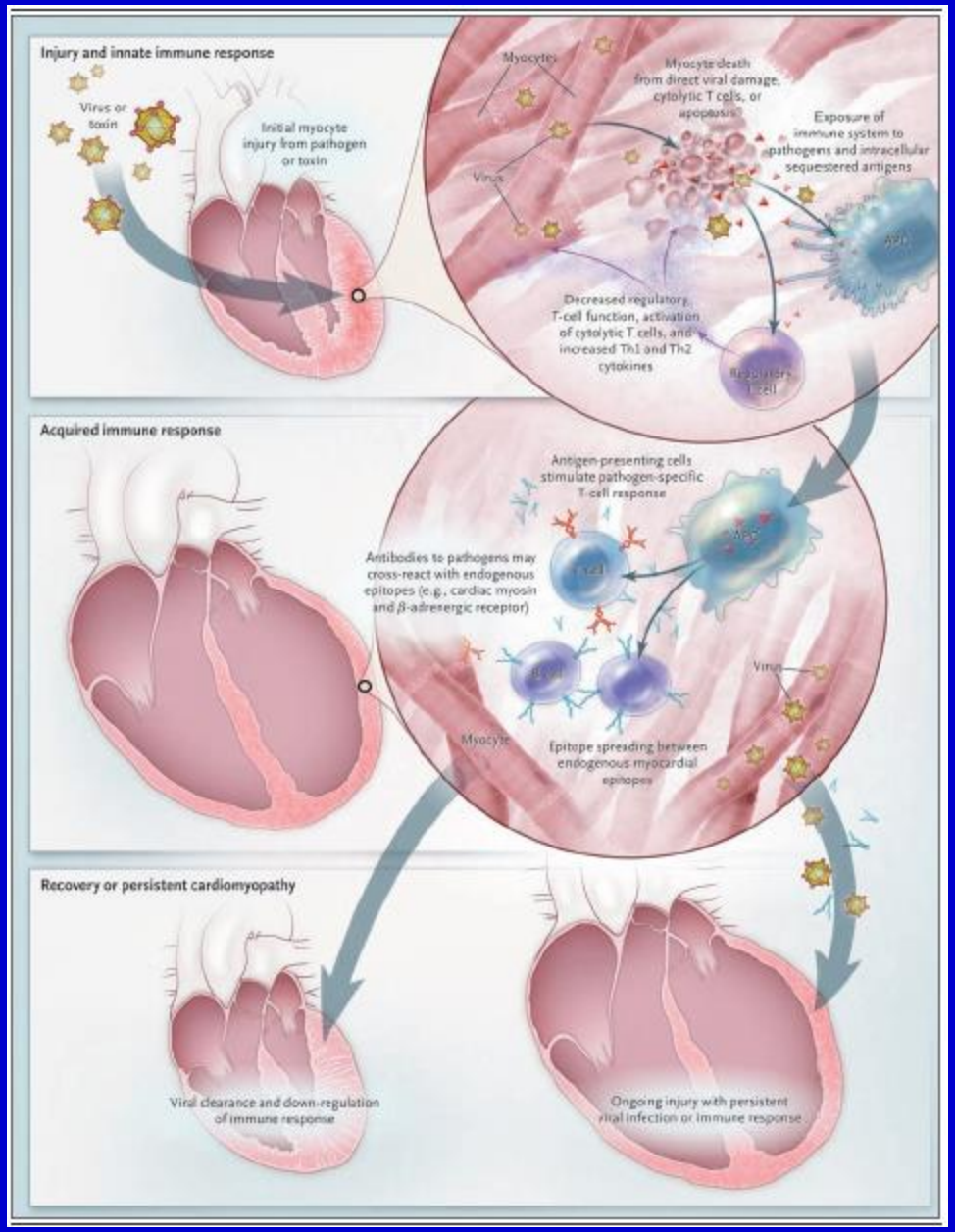


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**Table 5**

## Indications for Cardiovascular Magnetic Resonance in Patients With Suspected Myocarditis

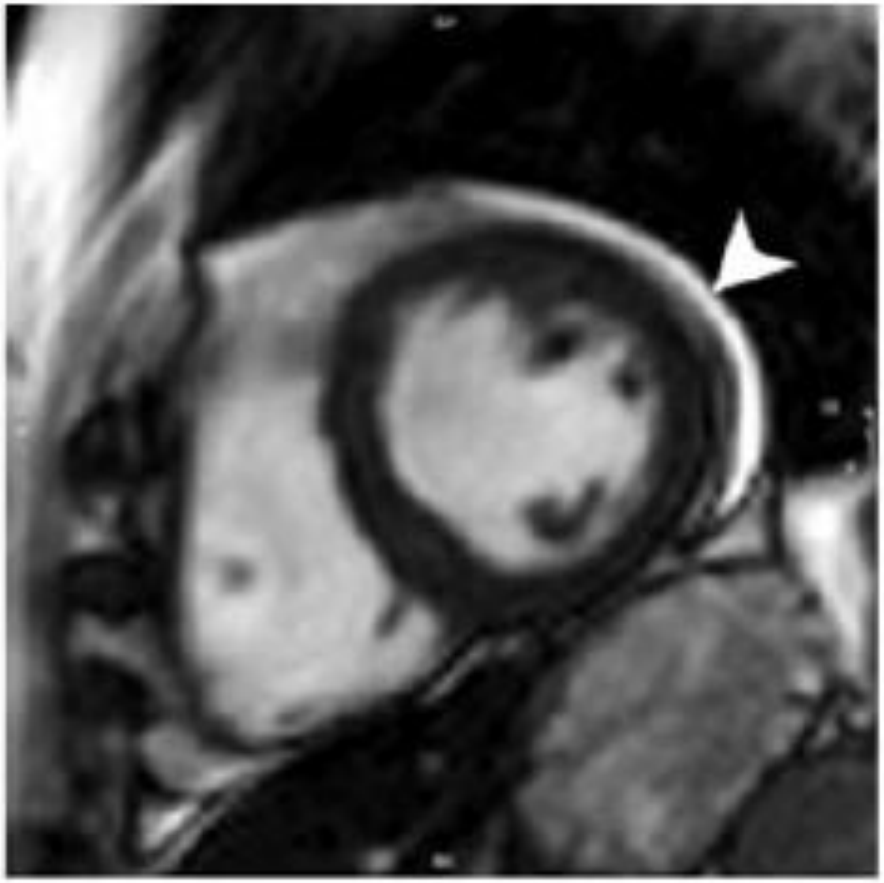
| New Onset or Persisting Symptoms Suggestive of Myocarditis | Plus | Evidence for Recent/Ongoing Myocardial Injury | Plus | Suspected Viral Etiology |
|---|---|---|---|---|
| Dyspnea<br>*or*<br>orthopnea<br>*or*<br>palpitations<br>*or*<br>effort intolerance/malaise<br>*or*<br>chest pain | | Ventricular dysfunction<br>*or*<br>new or<br>persisting ECG<br>abnormalities<br>*or*<br>elevated troponin | | History of recent systemic viral disease or previous myocarditis<br>*or*<br>absence of risk factors for coronary artery disease or age <35 yrs<br>*or*<br>symptoms not explained by coronary stenosis on coronary angiogram<br>*or*<br>recent negative ischemic stress test |

# Myocardite et IRM
# Ciné-IRM

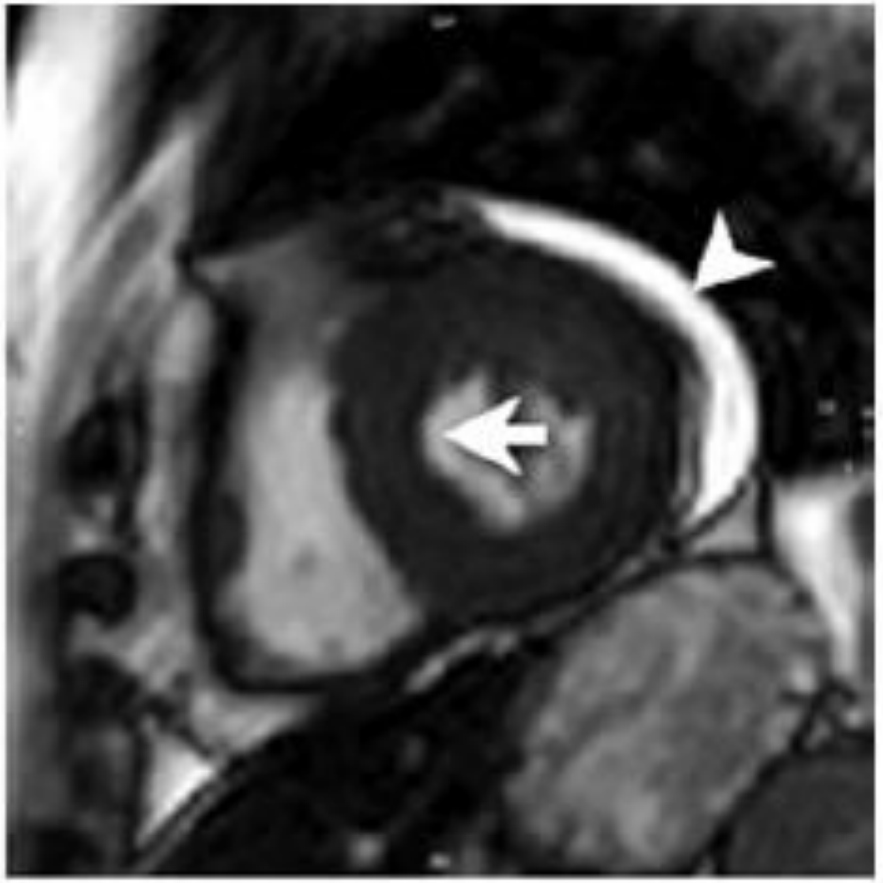
- Fonction VG globale
- Troubles de cinétique segmentaires
- Epanchement péricardique (32 à 57 %)
- Thrombus intra VG

# Epanchement péricardique

## Ciné-IRM (Hypersignal, Hyposignal T1, Hyper ou hypo LGE)



SSFP - Diastole



SSFP - Systole

Diagnostic différentiel : Graisse épicardique

# Myocardite et IRM
# Caractérisation tissulaire

## Les objectifs

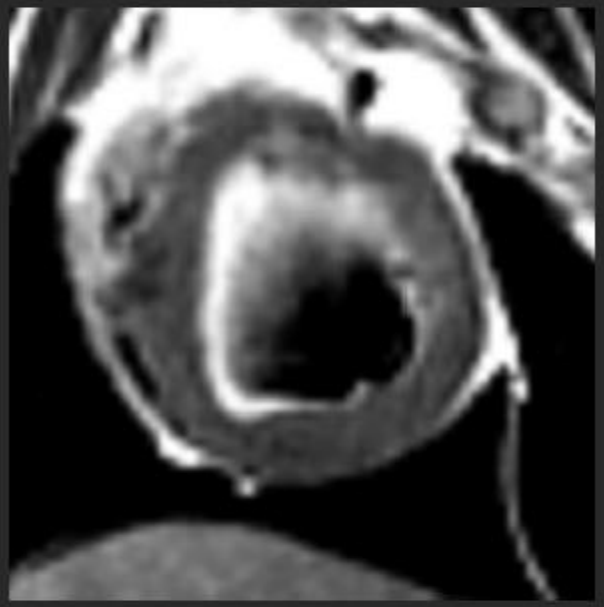
- Œdème myocardique (T2)
- Hyperémie et perméabilité capillaire (T1)
- Nécrose myocardique (Réhaussement tardif)
- Fibrose myocardique(Réhaussement tardif)

# Myocardite et IRM
# Caractérisation tissulaire

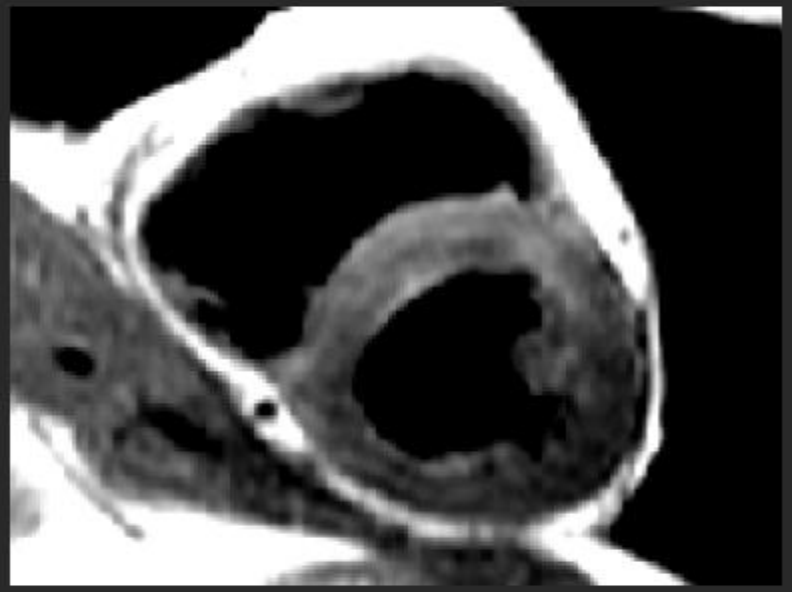
## Les séquences T1 et T2

- Antenne corps entier
- Antennes de surface
  - Inhomogénéité du signal
  - Faux négatif paroi latérale
  - Faux positif septum
  - Algorithme de correction de l'intensité du signal

# DIR-TSE Artifacts



Non-moving blood



Posterior wall signal loss

# Myocardite et IRM
# Les séquences

- Séquences pondérées T1
  - Avant et après injection de gadolinium (1 min)
  - Hyperémie et augmentation de la perméabilité capillaire : Fixation importante du Gadolinium
- Augmentation de l'intensité du signal myocardique après gadolinium
  - Signal myocardique Gd / Signal myocardique
  - ≥ 45 %
- Limite : Phase précoce

**Figure 1**

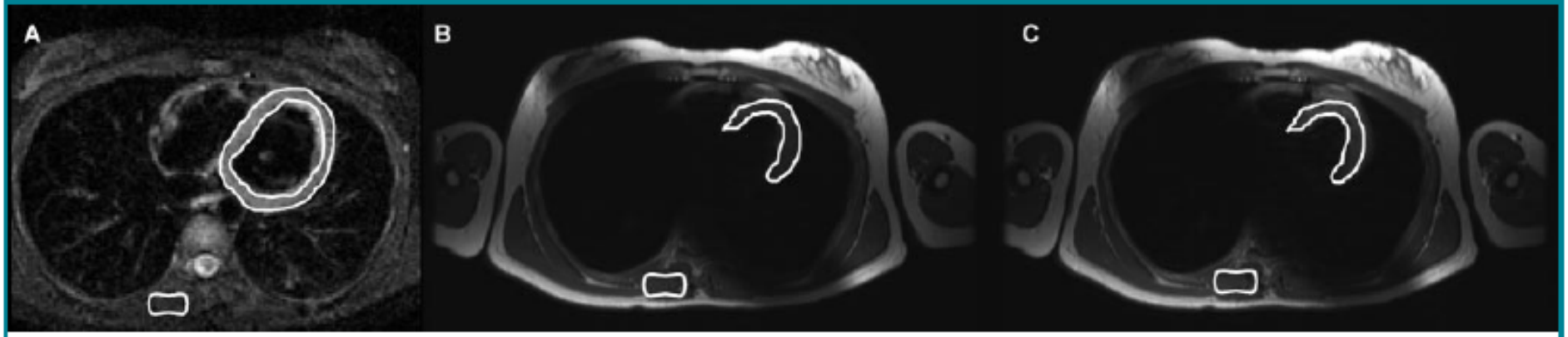
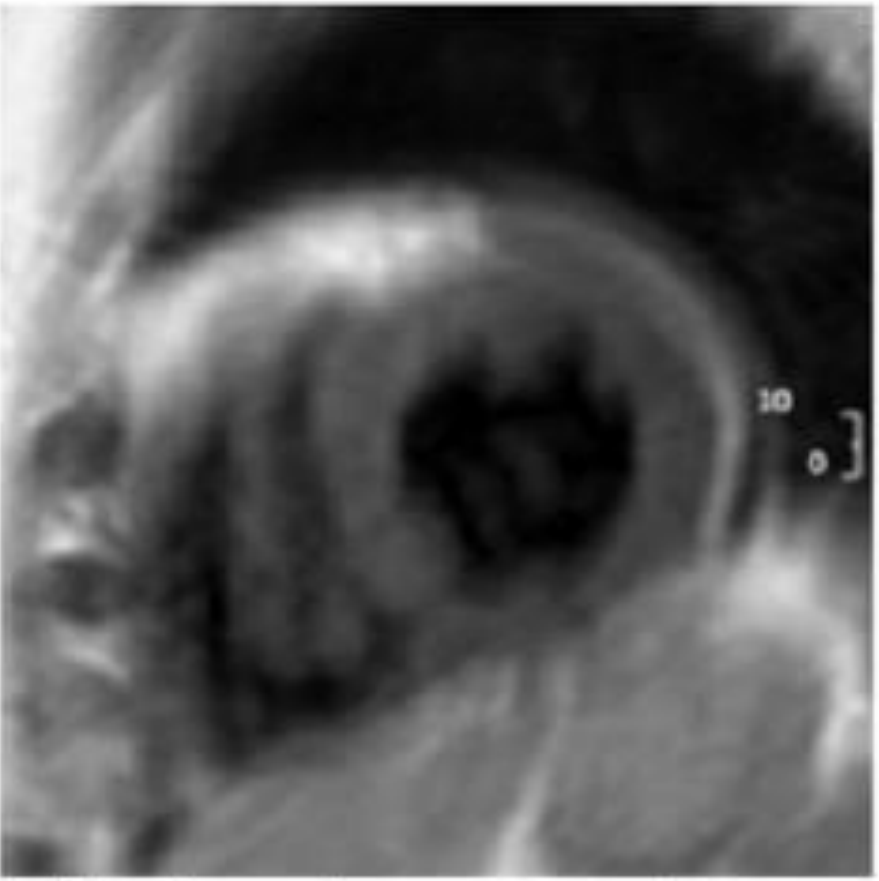
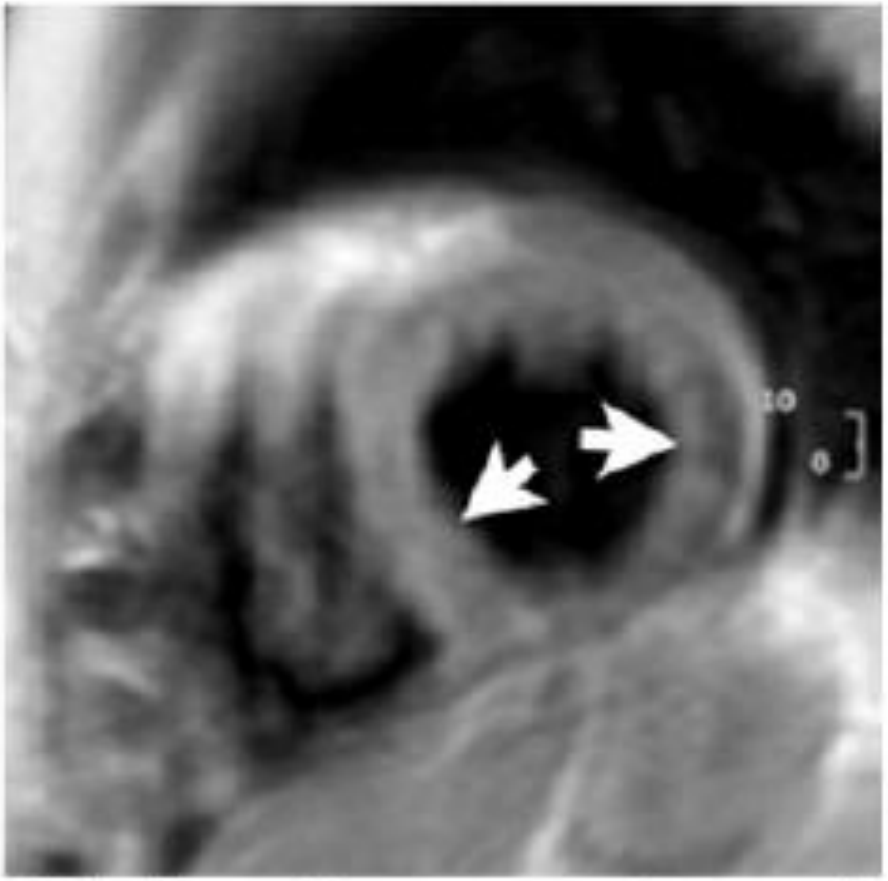



**Figure 1:** *A*, Transverse T2-weighted triple-inversion-recovery MR image (repetition time of two R-R intervals, 65-msec echo time) used to calculate ER, with manually outlined borders around LV myocardium and right erector spinae muscle. *B*, Precontrast, and, *C*, postcontrast transverse T1-weighted fast spin-echo MR images (repetition time of one R-R interval, 21-msec echo time) used to calculate gRE from the mean signal intensities within the manually outlined borders around the LV myocardium and right erector spinae muscle. ER and gRE were calculated according to method of Friedrich et al (9). An additional saturation section is positioned across the atria to reduce signal from slow-flowing blood (9).

# IRM Myocardite
# SE T1



Early enhancement - pre



Early enhancement - post

# Myocardite et IRM
# Les séquences pondérées T1

$$\mathrm{gRE} = \mathrm{RE}_{\mathrm{myo}}/\mathrm{RE}_{\mathrm{skm}}$$

$$= \frac{(\mathrm{postSI}_{\mathrm{myo}} - \mathrm{preSI}_{\mathrm{myo}})/\mathrm{preSI}_{\mathrm{myo}}}{(\mathrm{postSI}_{\mathrm{skm}} - \mathrm{preSI}_{\mathrm{skm}})/\mathrm{preSI}_{\mathrm{skm}}}$$

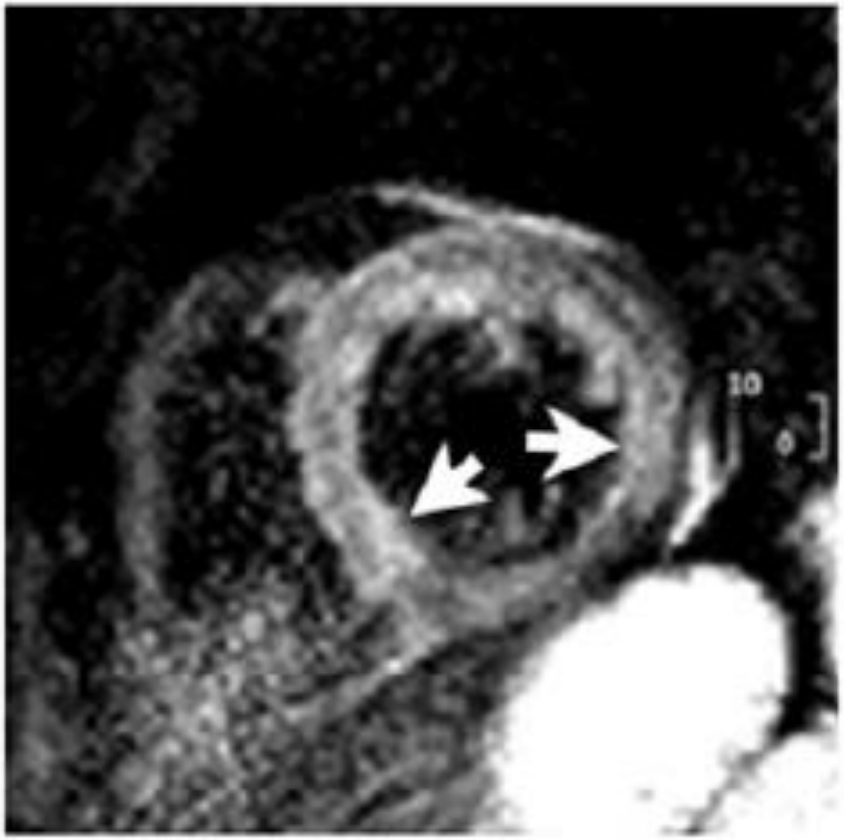
> 4

# Myocardite et IRM
# Les séquences

- Séquences pondérées T2
  - Turbo SE avec triple IR (suppression graisse et sang)
  - Œdème régional ou global (analyse quantitative +++)
  - Hypersignal
  - Signal myocardique / Signal muscle squelettique > 2

  - Zones localisées qui correspondent au rehaussement tardif mais sont plus étendues

# IRM Myocardite
# SE T2 et Réhaussement tardif



T2

Late enhancement

# Myocardite et IRM

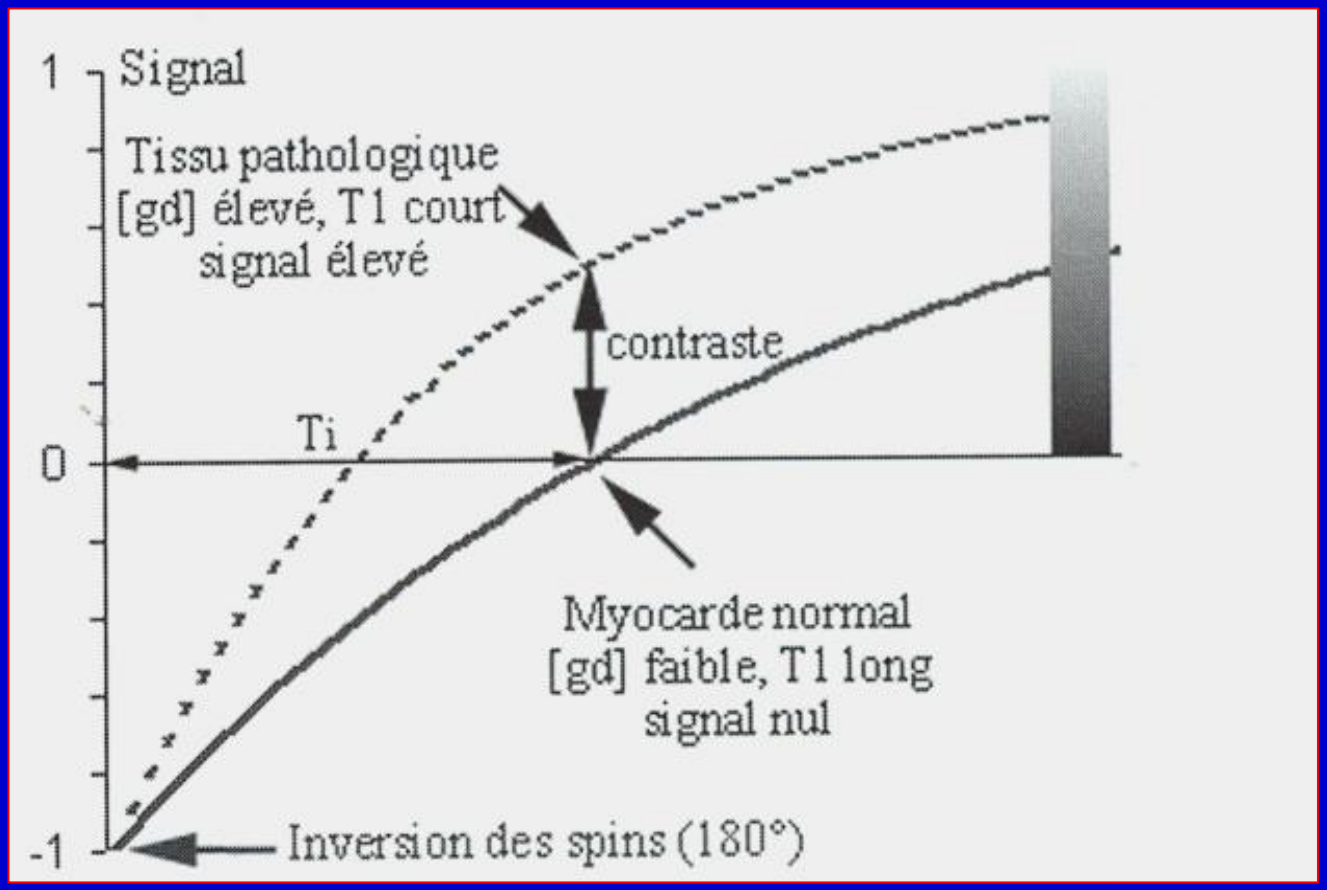
- Séquences pondérées T1
  - Sensibilité 80 %, Spécificité 68 %
- Séquences pondérées T2
  - Sensibilité 84 %, Spécificité 74 %

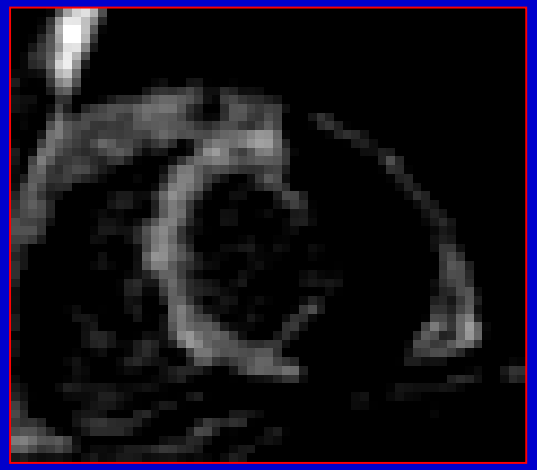
# Principe du réhaussement tardif

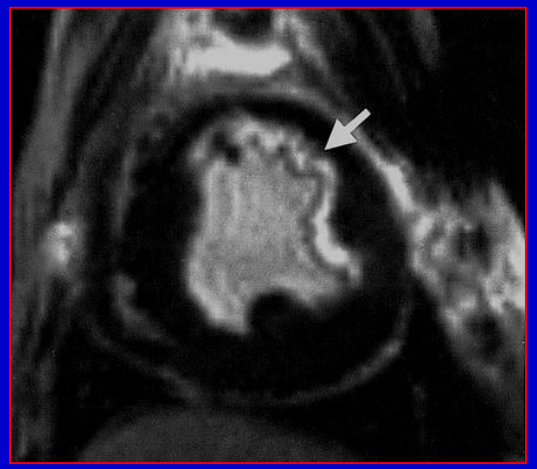
- Gadolinium 0,1-0,2 mmol/kg
  - Raccourcissement T1
  - Accroissement du signal des images pondérées T1
- Séquences pondérées T1
  - Basées sur une inversion-récupération
  - Segmentées Acquisition pendant une apnée
  - Impulsion initiale d'inversion
    - Temps d'inversion Ti

# IRM de Rehaussement tardif

## Delayed hyperenhancement





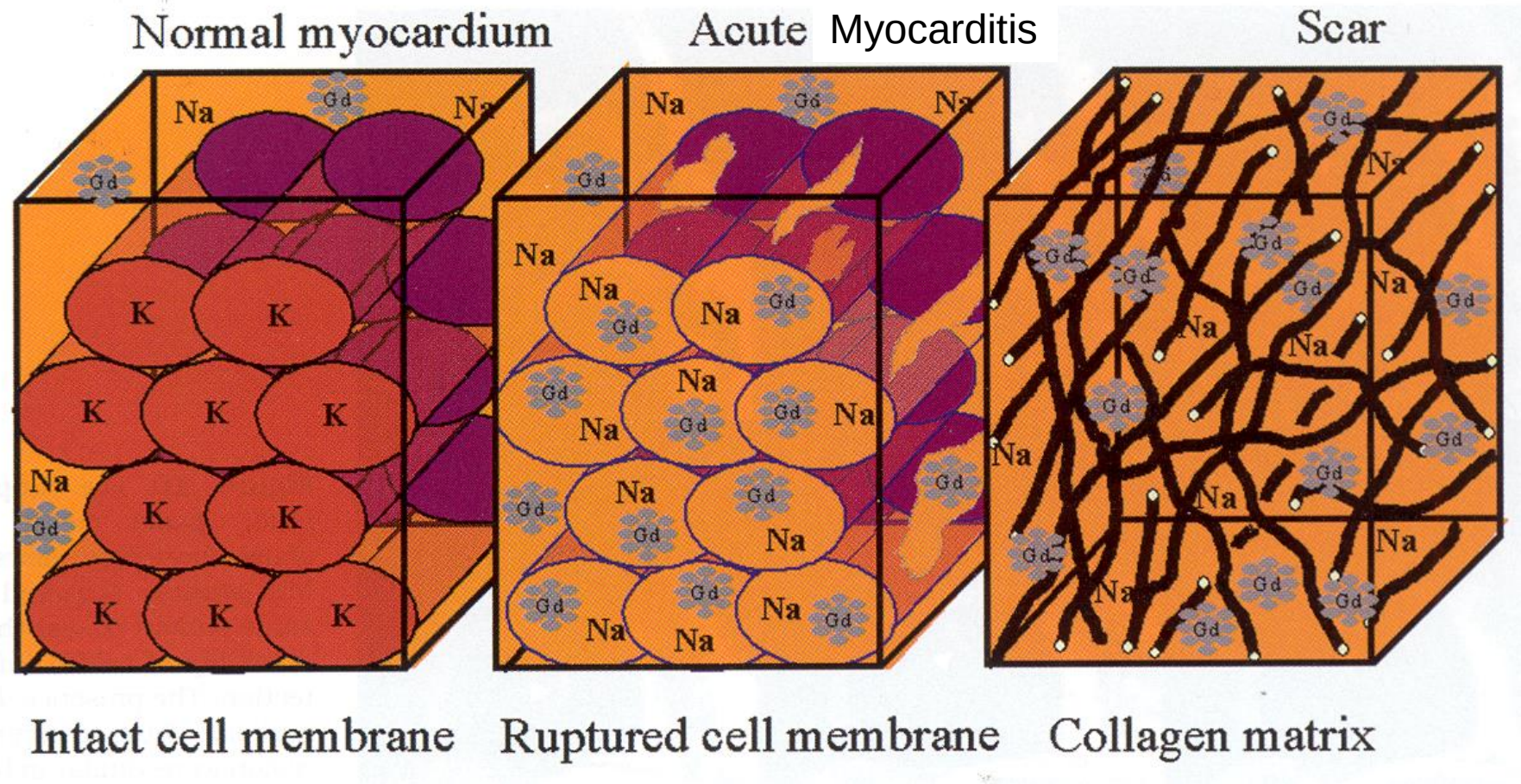
500 to 1000 % increase in the signal intensity
of infarcted compared to remote regions

# Rétention du gadolinium

- Distribution dans le compartiment extracellulaire
- Myocardite aiguë
  - Diminution du wash-out dans les tissus inflammatoires et oedématiés
  - Accroissement du volume de distribution
    - Compartiment intracellulaire détruit
    - Inflammation, oedème

# Myocardite cicatrisée

- Augmentation du volume de distribution extracellulaire par accroissement de l'espace interstitiel (cicatrice fibreuse)



# Les conséquences d'un mauvais Ti

- si le Ti est trop court
  - Sous-estimation de l'hypersignal
- si le Ti est trop long
  - Diminution du contraste

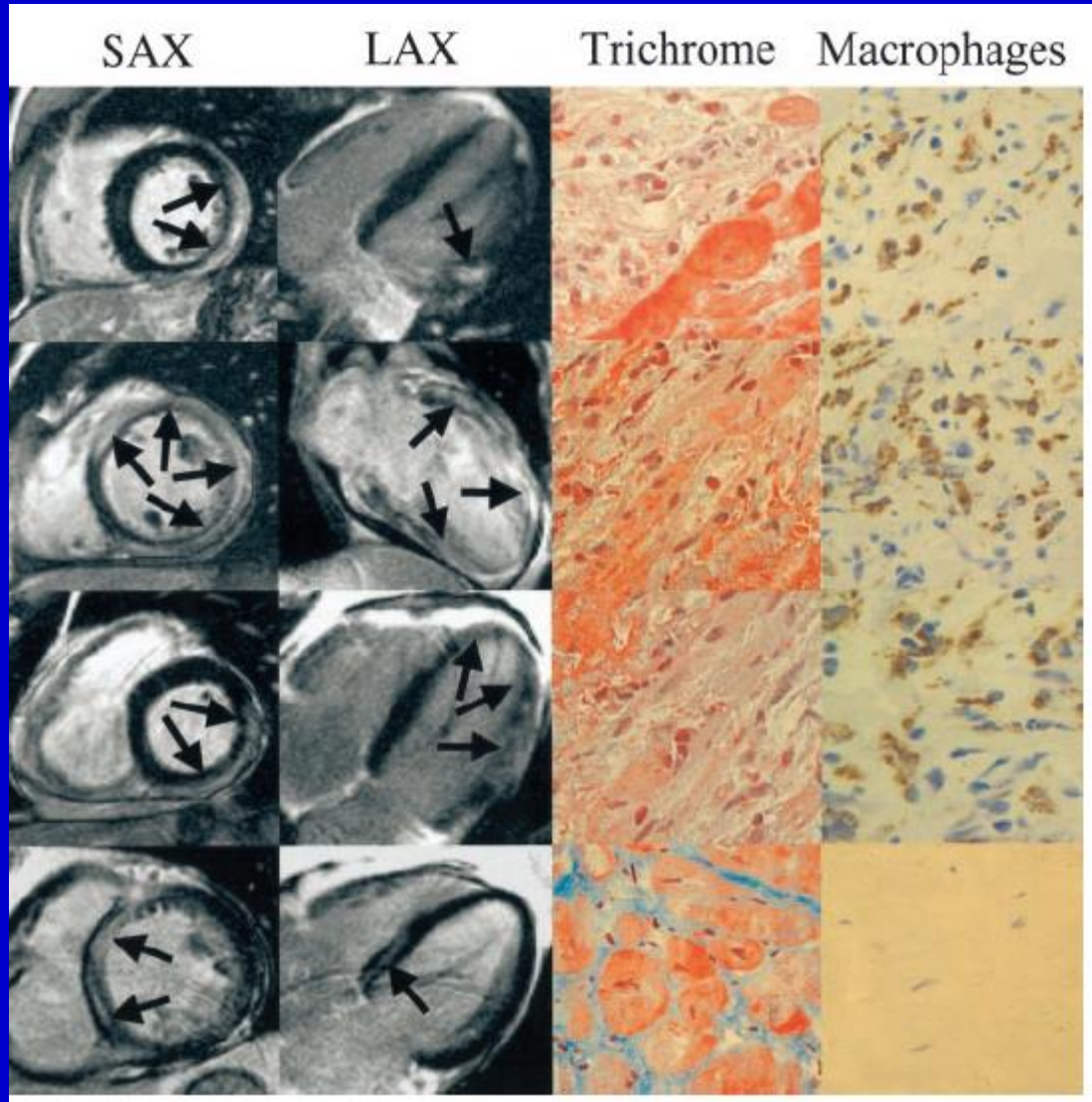
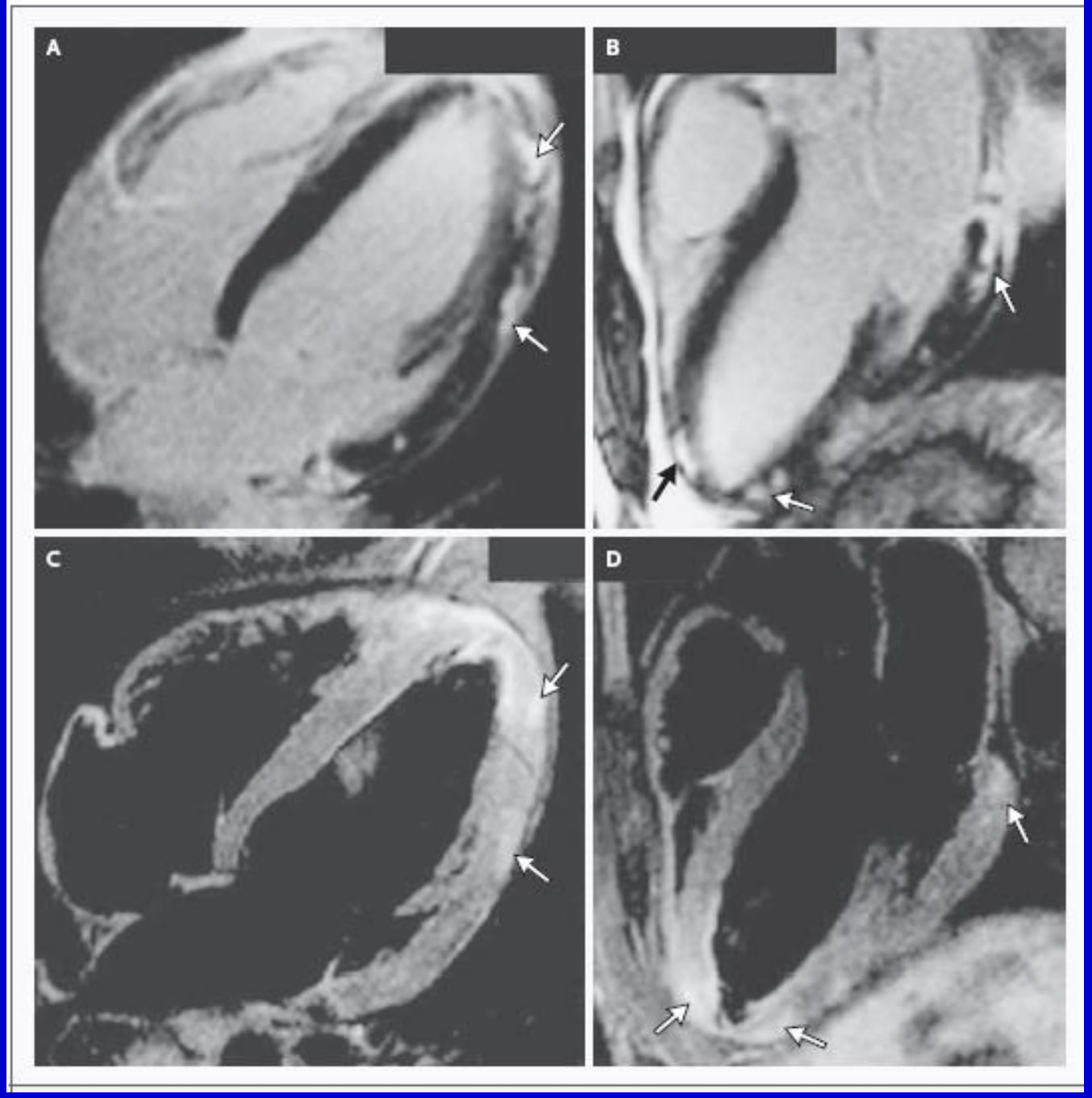



**Figure 3.** Results of CMR and histopathology of typical patients in whom biopsies were obtained from area of contrast enhancement. Top 3 panels show cases (patients 6, 7, and 14) of active myocarditis with myocyte damage and infiltration of macrophages; bottom panel shows a patient (patient 18) without active myocarditis who was diagnosed with HCM. SAX indicates short axis; LAX, long axis.

# Myocardite et IRM
# Rehaussement tardif

- Présence de nécrose et/ou d'inflammation
- Sensibilité 98 %
- Topographie de l'hypersignal
  - Sous-épicardique ou intramyocardique
    - Nodulaires ou en bande épaisse
  - Paroi latérale +++
  - Atteinte initiale focale sous-épicardique < 5 jours puis atteinte diffuse et diagnostic plus difficile
- Biopsie endomyocardique guidée
- Séquences TSE T2 TE 100 msec : oedème




Cooper LT *N Engl J Med 2009*

## Overview of the Diagnostic Accuracy of Individual Tissue Criteria as Assessed in Controlled Trials

| | Validation | Sensitivity (%) | Specificity (%) | Accuracy (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|---|
| Early myocardial gadolinium enhancement | | | | | | |
| Friedrich et al., *Circulation* 1998 (9) | Clinical | 84 | 89 | 86 | 89 | 84 |
| Laissy et al., *Chest* 2002 (11) | Clinical | 85 | 100 | 89 | 100 | 70 |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 80 | 68 | 74 | 74 | 75 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 63 | 86 | 72 | 86 | 63 |
| Pooled data (n = 194) | | 74 | 83 | 78 | 86 | 70 |
| T2 | | | | | | |
| Rieker et al., *Rofo* 2002 (36) | Clinical | 100 | 50 | 76 | 69 | 100 |
| Laissy et al., *Chest* 2002 (11) | Clinical | 45 | 100 | 59 | 100 | 39 |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 84 | 74 | 79 | 78 | 81 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 67 | 69 | 67 | 74 | 60 |
| Pooled data (n = 178) | | 70 | 71 | 70 | 77 | 63 |
| Late enhancement | | | | | | |
| Rieker et al., *Rofo* 2002 (36) | Clinical | 45 | 60 | 52 | 56 | 50 |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (18) | Clinical | 44 | 100 | 71 | 78 | 62 |
| Mahrholdt et al., *Circulation* 2006 (40) | Histology | 95 | 96 | 96 | 99 | 81 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 27 | 80 | 49 | 65 | 44 |
| Yilmaz et al., *Heart* 2008 (43) | Histology | 35 | 83 | 51 | 81 | 38 |
| Pooled data (n = 336) | | 59 | 86 | 68 | 89 | 53 |

Friedrich MG et al. *JACC 2009*

## Overview of the Diagnostic Accuracy of Several Combinations of Tissue Criteria

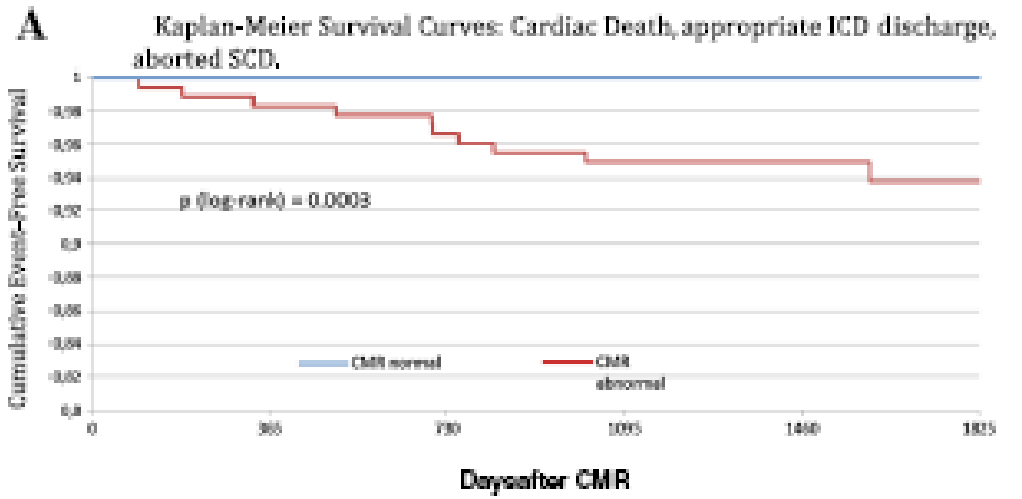
| | Validation | Sensitivity (%) | Specificity (%) | Accuracy (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|---|
| T2 + LGE | | | | | | |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 40 | 100 | 69 | 100 | 61 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 17 | 91 | 48 | 73 | 44 |
| Pooled data (n = 130) | | 25 | 95 | 56 | 86 | 50 |
| T2 and/or LGE | | | | | | |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 88 | 74 | 81 | 100 | 85 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 50 | 57 | 52 | 80 | 25 |
| Pooled data (n = 130) | | 60 | 66 | 62 | 79 | 43 |
| Any 1 of 3 | | | | | | |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 100 | 48 | 75 | 68 | 100 |
| Gutberlet et al., *Radiology* 2008 (42) | Histology | 81 | 49 | 67 | 68 | 65 |
| Pooled data (n = 130) | | 88 | 48 | 70 | 68 | 76 |
| Any 2 of 3 | | | | | | |
| Abdel-Aty et al., *J Am Coll Cardiol* 2005 (13) | Clinical | 76 | 96 | 85 | 95 | 79 |
| Gutberlet et al., *Radiology* 2008 (34) | Histology | 63 | 89 | 73 | 88 | 63 |
| Pooled data (n = 130) | | 67 | 91 | 78 | 91 | 69 |

Friedrich MG et al. *JACC 2009*

# Myocardite et IRM
# Rehaussement tardif

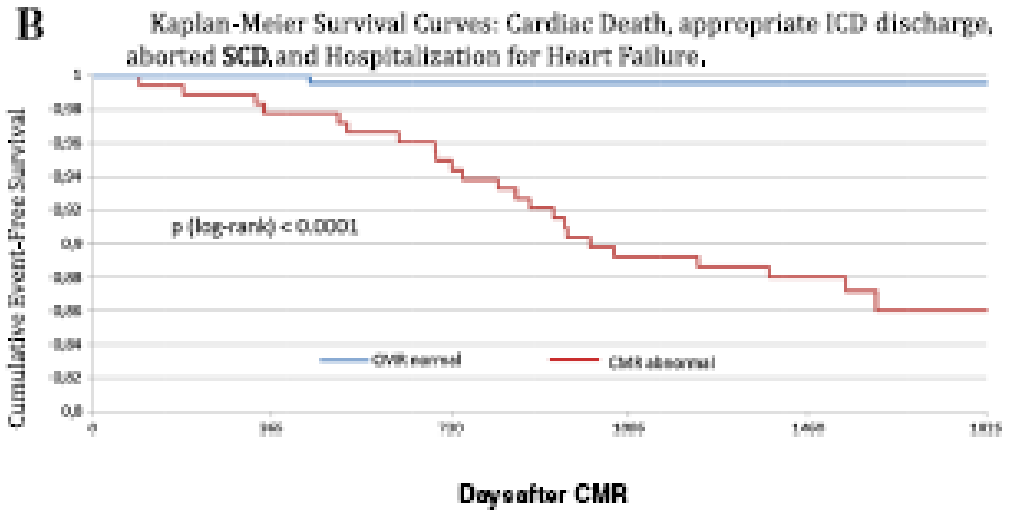
- Parvovirus B 19 :
  - Sous-épicardique, Paroi latérale
  - Tableau clinique de type infarctus, Bon pronostic

- Virus herpétique HHV 6 ou co-infection
  - Intra-myocardique, Paroi antéro-septale ou septale
  - Insuffisance cardiaque, Pronostic plus réservé




*Patients at risk*

| | | | | | |
|---|---|---|---|---|---|
| CMR normal | 223 | 220 | 217 | 182 | 17 |
| CMR abnormal | 175 | 172 | 162 | 140 | 15 |




*Patients at risk*

| | | | | | |
|---|---|---|---|---|---|
| CMR normal | 223 | 219 | 216 | 181 | 17 |
| CMR abnormal | 174 | 169 | 152 | 131 | 15 |

**Figure 5** Kaplan-Meier survival curves with regard to cardiac death, appropriate ICD discharge, aborted SCD (A), and cardiac death, appropriate ICD discharge, aborted SCD and hospitalization for heart failure (B). The number of patients at risk is shown at the bottom of the figures. Abbreviations as in Table 1.

# Myocardite et IRM

- Persistance de l'hypersignal : Pronostic ?
- Hypersignal à distance de la phase aiguë
  - Nécrose et / ou inflammation
    - Myocardite chronique active
  - Fibrose
  - Séquence d'echo de spin avec triple inversion-récupération pondérées T2 :
    - œdème myocardique = hypersignal

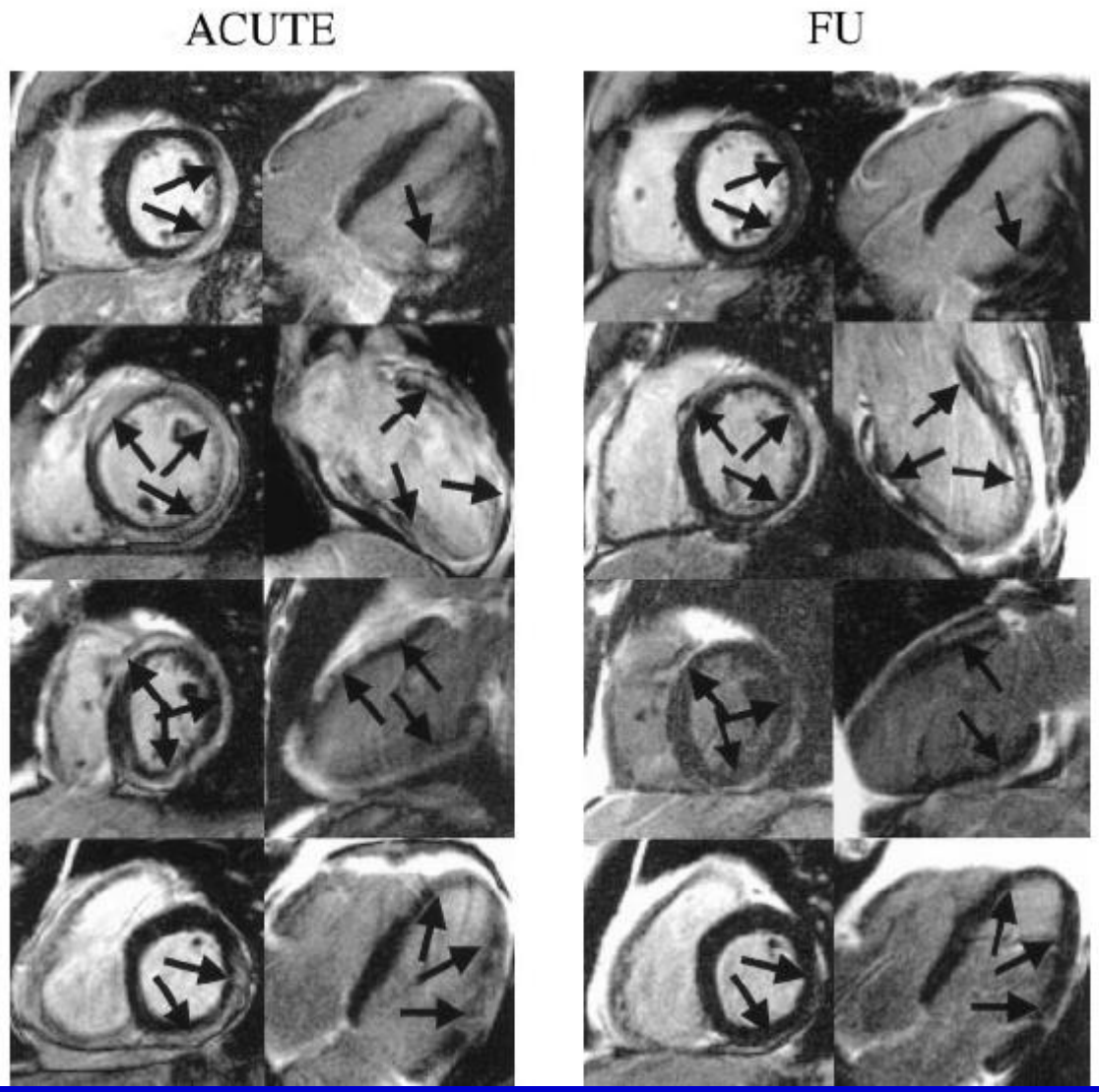



**Figure 5.** Results of CMR in acute (left) vs results of CMR at follow-up (FU; right). Note that areas of contrast enhancement decreased at follow-up (right) as average EF and average EDV returned toward normal (compare with Table 2).

# Myocardite chronique

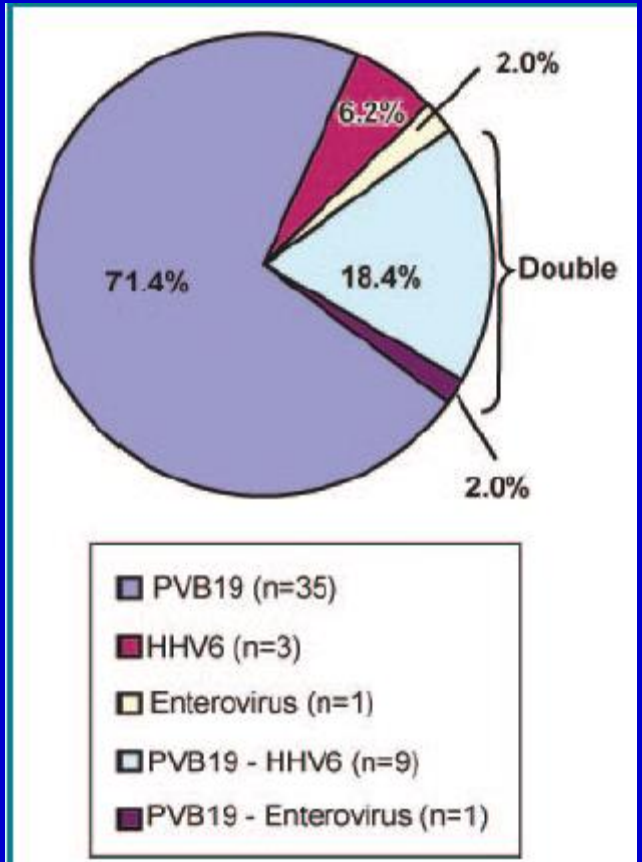



**Figure 4:** Pie chart illustrates the distribution of cardiotropic viruses detected at PCR assay of EMB specimens from 49 patients with virus-positive findings. Parvovirus B19 *(PVB19)*, followed by human herpes virus 6 *(HHV6)* and enterovirus, was the most frequently detected virus. Thirty-nine (80%) of the 49 patients with viral genomes had a monoinfection, and 10 (20%) had dual infections.

- Séquences T1
- Séquences T2
- Réhaussement tardif

Gutber et al *Radiology 2008*

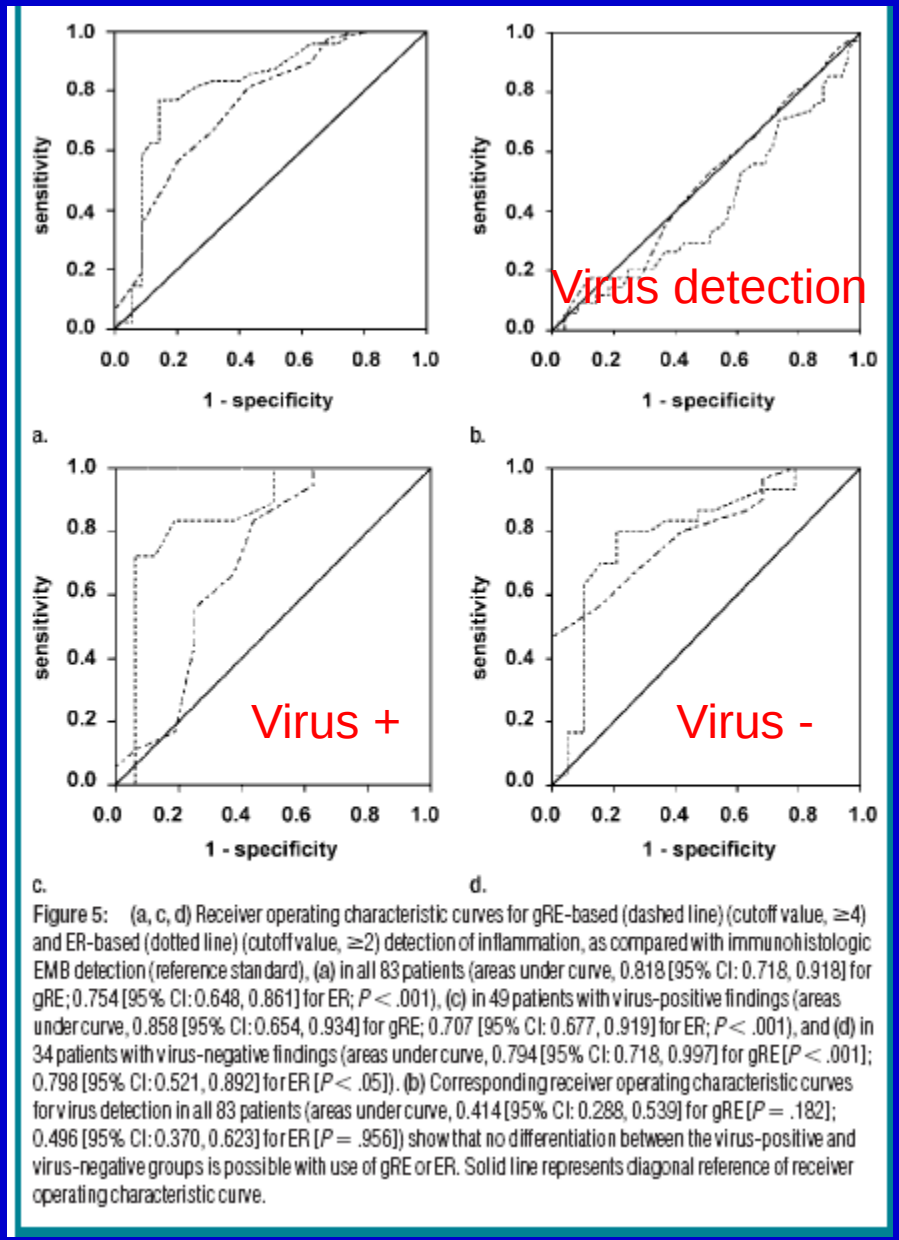



Figure 5: (a, c, d) Receiver operating characteristic curves for gRE-based (dashed line) (cutoff value, ≥4) and ER-based (dotted line) (cutoff value, ≥2) detection of inflammation, as compared with immunohistologic EMB detection (reference standard), (a) in all 83 patients (areas under curve, 0.818 [95% CI: 0.718, 0.918] for gRE; 0.754 [95% CI: 0.648, 0.861] for ER; $P < .001$), (c) in 49 patients with virus-positive findings (areas under curve, 0.858 [95% CI: 0.654, 0.934] for gRE; 0.707 [95% CI: 0.677, 0.919] for ER; $P < .001$), and (d) in 34 patients with virus-negative findings (areas under curve, 0.794 [95% CI: 0.718, 0.997] for gRE [$P < .001$]; 0.798 [95% CI: 0.521, 0.892] for ER [$P < .05$]). (b) Corresponding receiver operating characteristic curves for virus detection in all 83 patients (areas under curve, 0.414 [95% CI: 0.288, 0.539] for gRE [$P = .182$]; 0.496 [95% CI: 0.370, 0.623] for ER [$P = .956$]) show that no differentiation between the virus-positive and virus-negative groups is possible with use of gRE or ER. Solid line represents diagonal reference of receiver operating characteristic curve.

gRE > 4
ER > 2

Endomyocardial biopsy

Gutber et al *Radiology 2008*

**Diagnostic Accuracy of MR Parameters in a Single or Combined Approach for Detection of Myocardial Inflammation, with Immunohistologic Analysis as Reference Standard**

| MR Detection Approach | Sensitivity (%) | Specificity (%) | Accuracy (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|
| Single approach | | | | | |
| gRE | 62 (30/48) | 86 (30/35) | 72 (60/83) | 86 (30/35) | 62 (30/48) |
| ER | 67 (32/48) | 69 (24/35) | 68 (56/83) | 74 (32/43) | 60 (24/40) |
| LE | 27 (13/48) | 80 (28/35) | 49 (41/83) | 65 (13/20) | 44 (28/63) |
| Combined approach* | | | | | |
| Any one, any two, or all three parameters | 81 (39/48) | 49 (17/35) | 68 (56/83) | 68 (39/57) | 65 (17/26) |
| Any two parameters | 62 (30/48) | 89 (31/35) | 74 (61/83) | 88 (30/34) | 63 (31/49) |
| Any one of two specific parameters (gRE or ER above cutoff) | 79 (38/48) | 63 (22/35) | 72 (60/83) | 74 (38/51) | 69 (22/32) |

Note.—The numerators and denominators used to calculate the percentages are in parentheses. NPV = negative predictive value, PPV = positive predictive value.

* Refers to various combinations of gRE, ER, and LE.

Gutber et al *Radiology 2008*

# IRM de rehaussement tardif
# Maladies inflammatoires

- Sarcoïdose
  - Sensibilité 100 %, Spécificité 78 %
  - *Smedema et al JACC 2005*
- Maladie de Churg-Strauss
- Polymyosites, …


- Efficacité de la corticothérapie et des immuno-suppresseurs +++

# Analyse de l'hypersignal

- Localisation
  - Transmural, Sous-endocardique
  - Médio-ventriculaire, Sous-épicardique

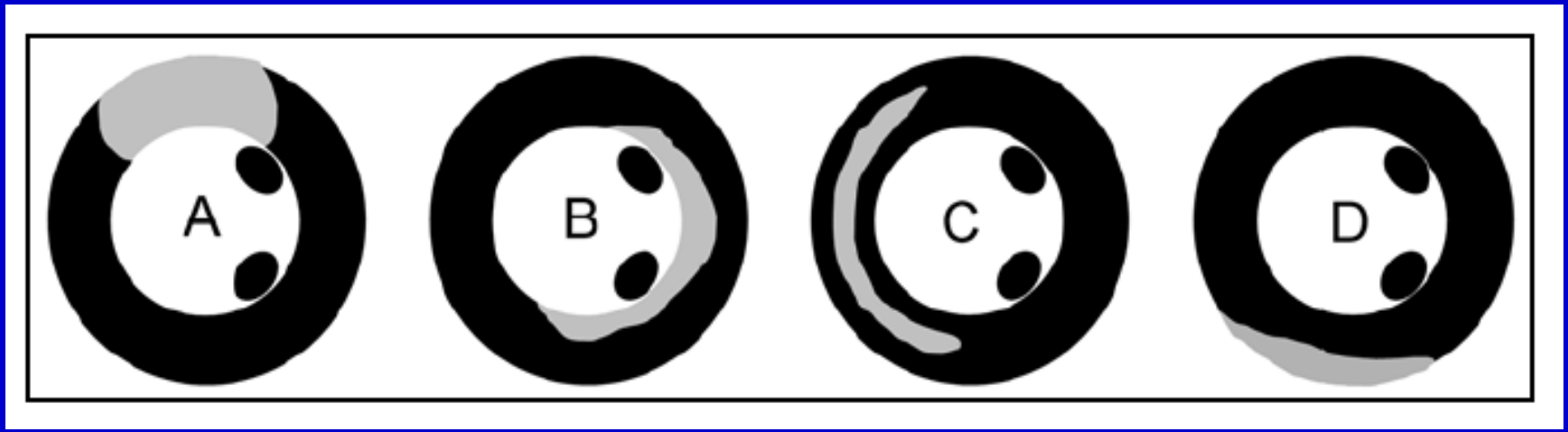


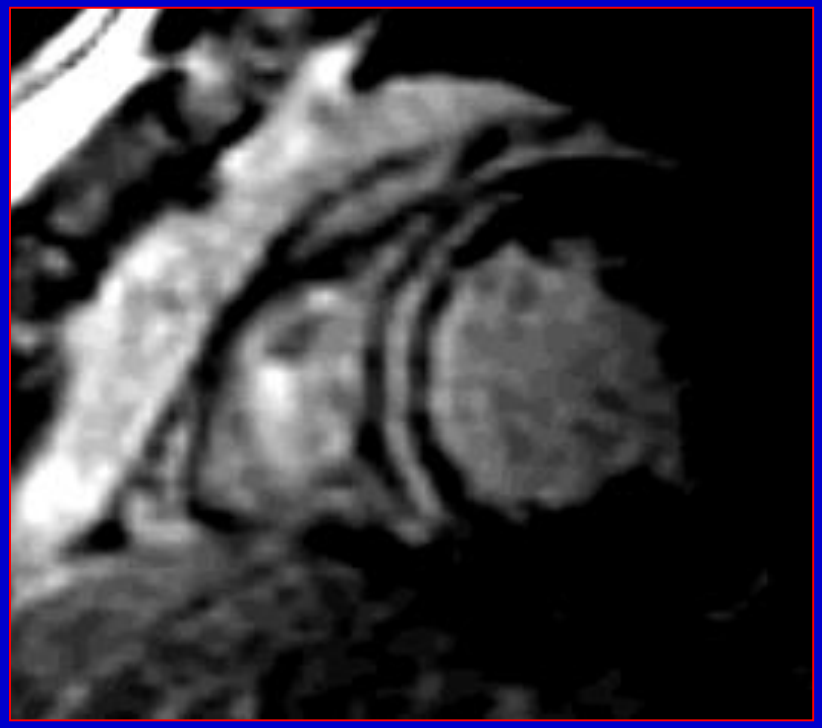
**TABLE 2**
**Distribution and Characteristics of Myocardial Anomalies**

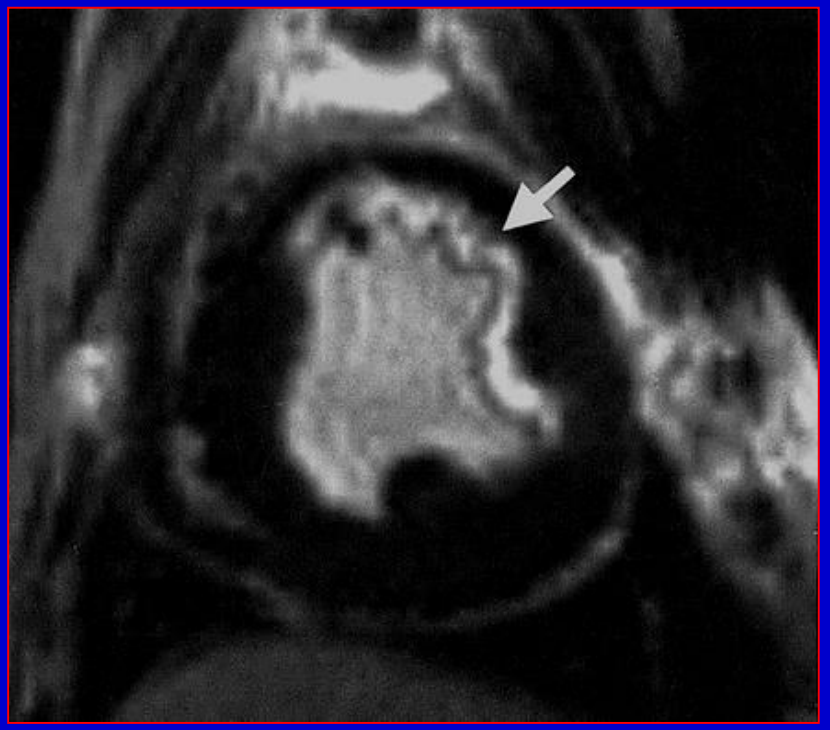
| Characteristic or Distribution | AMI Group ($n$ = 31)* | Myocarditis Group ($n$ = 24)* | $P$ value† |
|---|---|---|---|
| Early first-pass enhancement defect‡ | 31 (100) | 1 (4) | <.001 |
| No. of segments with delayed enhancement§ | 3.3 ± 0.3 | 4.0 ± 0.2 | .058 |
| Abnormal delayed enhancement | | | <.001 |
| None | 3 (10) | 1 (4) | |
| Subendocardial | 12 (39) | 0 (0) | |
| Transmural | 16 (52) | 4 (17) | |
| Subepicardial | 0 (0) | 17 (71) | |
| Centromyocardial | 0 (0) | 2 (8) | |
| Disease location | | | <.001 |
| Anterior | 15 (48) | 3 (12) | |
| Inferior | 10 (32) | 3 (12) | |
| Lateral and inferior | 6 (19) | 17 (71) | |
| One disease focus | 31 (100) | 9 (38) | <.001 |
| Multiple disease foci | 0 | 15 (62) | |
| Vascular segmental distribution | 31 (100) | 1 (4) | <.001 |
| Contrast enhancement pattern | | | <.001 |
| Bandlike | 26 (84) | 0 | |
| Nodular, patchy | 0 | 20 (83) | |
| Thick, transmural | 5 (16) | 4 (17) | |
| Contractile functional abnormalities | | | |
| No. of patients | 19 (61) | 11 (46) | NS |
| Located in area of delayed enhancement | 19 (61) | 4 (17) | |
| Located in remote lesions | | 7 (29) | <.001 |
| Pericardial effusion | 2 (6) | 5 (21) | NS |

* Unless otherwise noted, data are numbers of patients, with percentages in parentheses.
† NS = not significant.
‡ In 30 of the 31 patients with AMI and in the one patient with myocarditis, the early first-pass enhancement defect was subendocardial.
§ Data are mean numbers of abnormal segments ± standard errors of the mean.

*Laissy et al* Radiology 2005

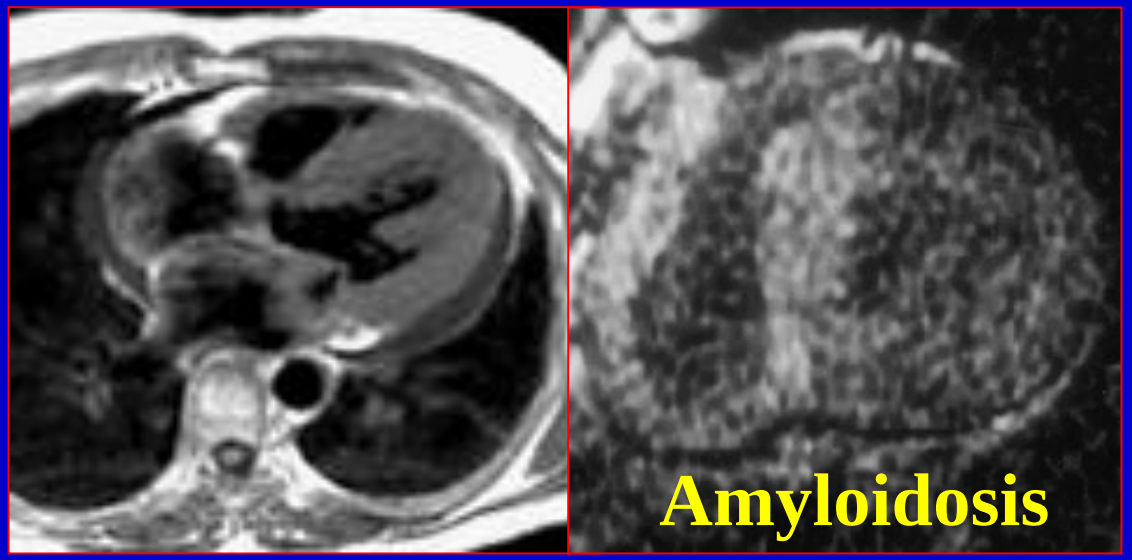
# Infarctus à coronaires saines

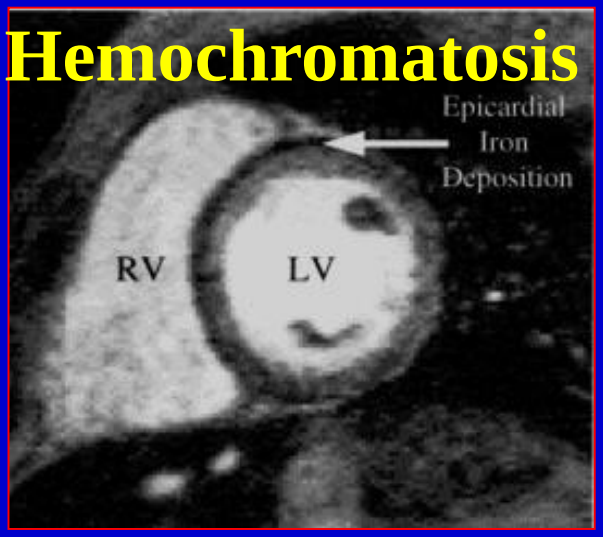




**Myocardite** **Infarctus sous-endocardique**

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



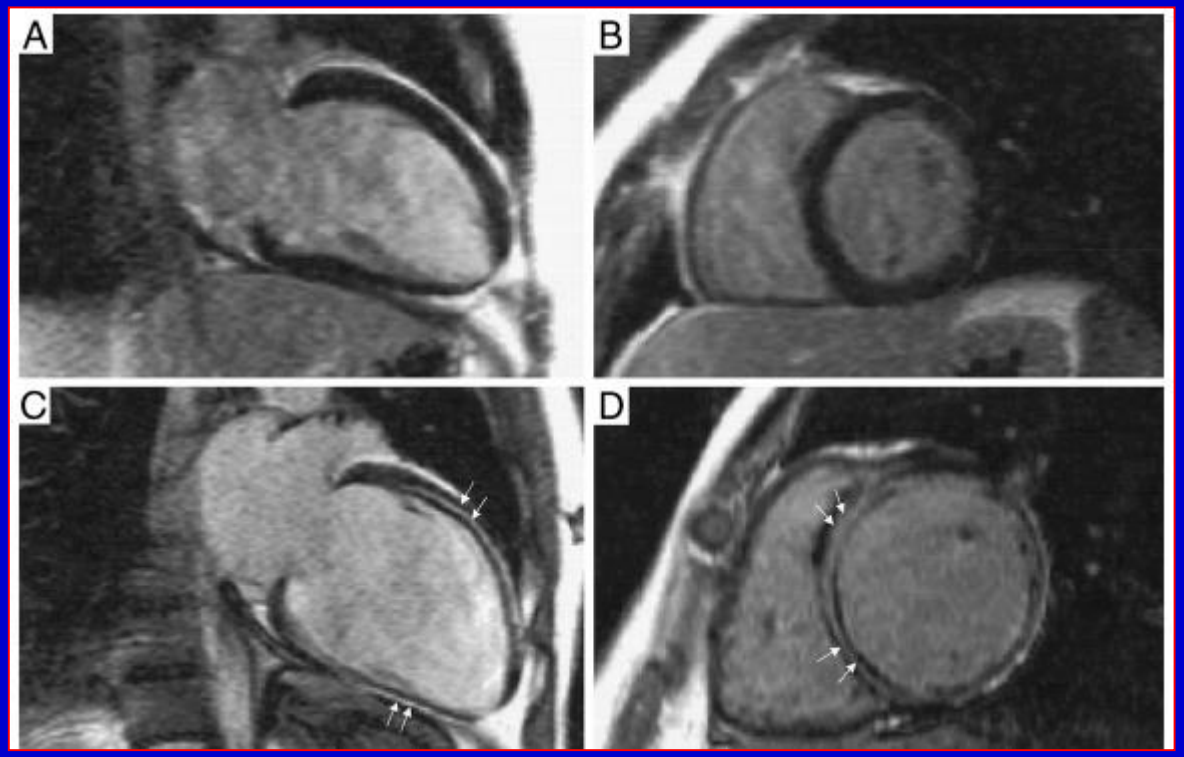

*Hunold et al. AJR 2005*

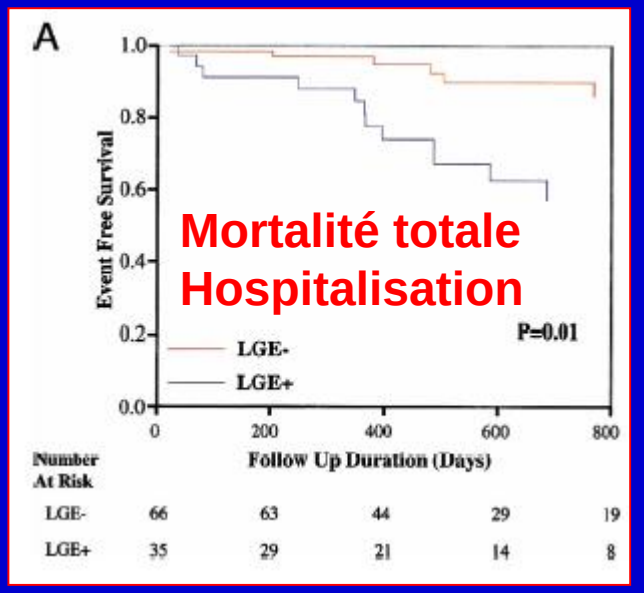
# Cardiomyopathie dilatée Primitive ou ischémique ?

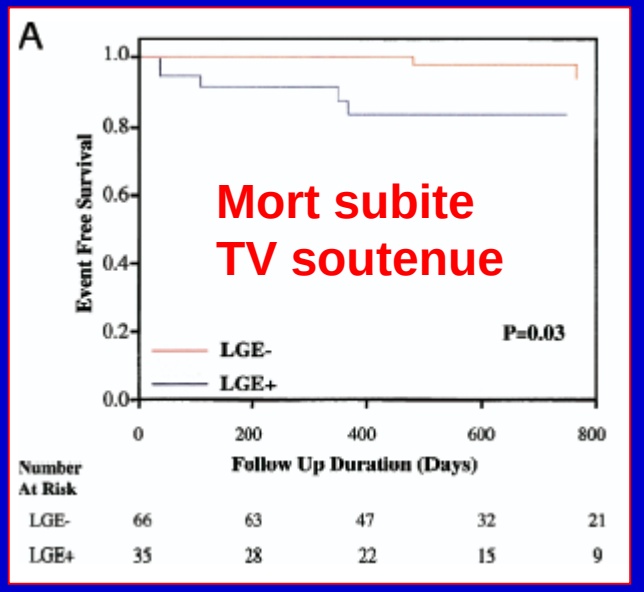
- Cardiopathies ischémiques
  - Hypersignal sous-endocardique ou transmural dans 100% cas
- Cardiomyopathies primitives
  - 59% Absence d'hypersignal
  - 28% Hypersignal partie moyenne du myocarde
  - 13% idem cardiopathies ischémiques

*McCrohon et al.* Circulation 2003; 108: 54-59

# Cardiomyopathie dilatée

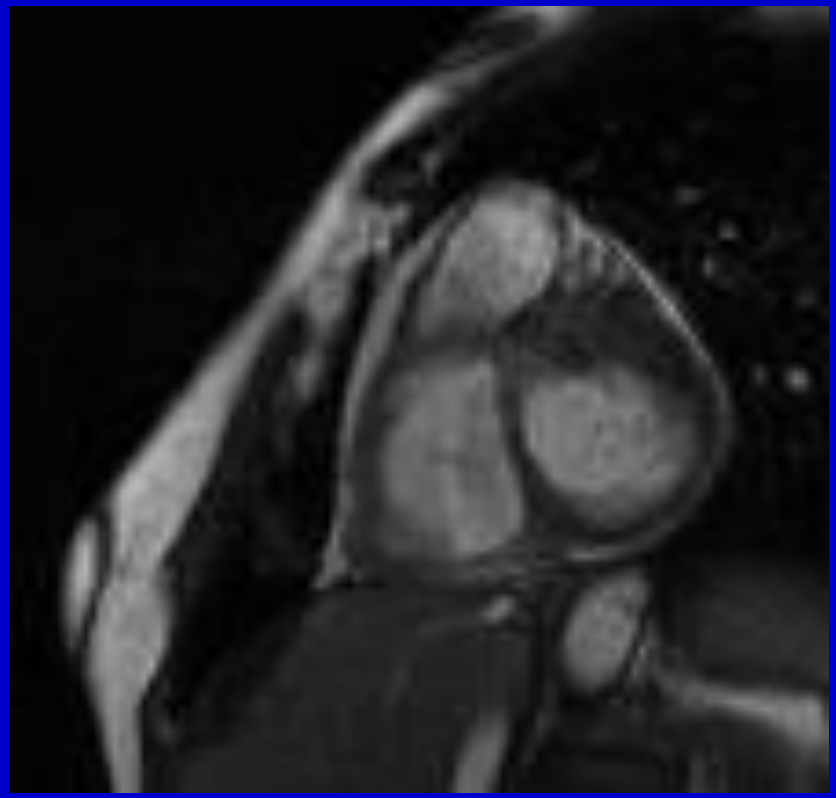


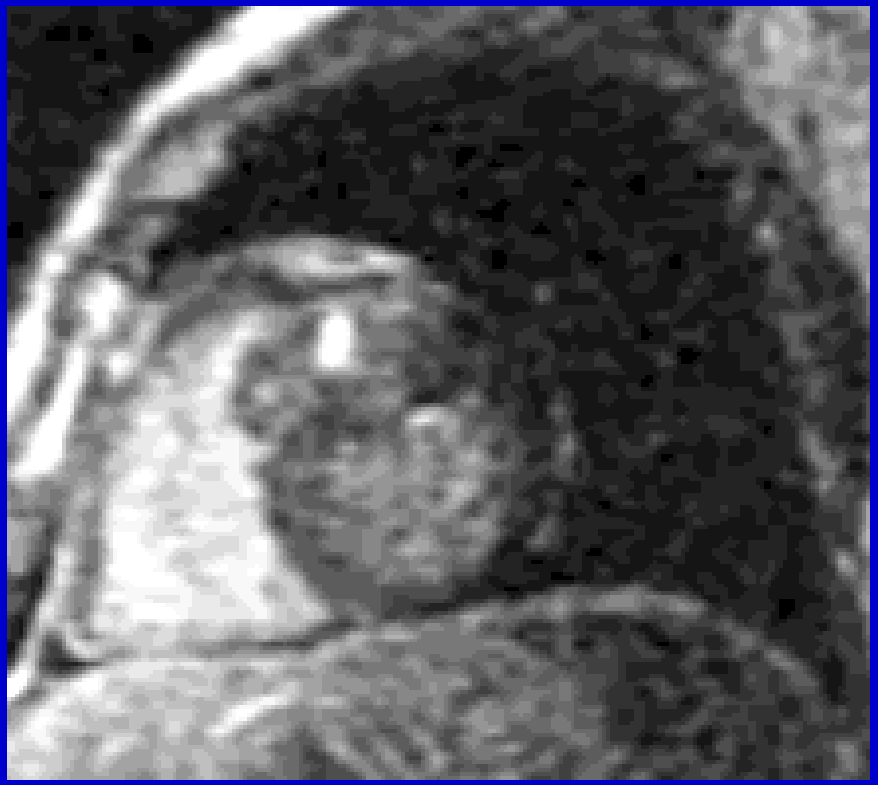




*Assomull et al. JACC 2006*

# Cardiomyopathie hypertrophique





# Current state of knowledge on aetiology, diagnosis, management, and therapy of myocarditis: a position statement of the European Society of Cardiology Working Group on Myocardial and Pericardial Diseases

FREE

Alida L. P. Caforio ✉; Sabine Pankuweit; Eloisa Arbustini; Cristina Basso; Juan Gimeno-Blanes; Stephan B. Felix; Michael Fu; Tiina Heliö; Stephane Heymans; Roland Jahns; ... Show more

Eur Heart J (2013) 34 (33): 2636-2648. **DOI:** https://doi.org/10.1093/eurheartj/eht210

**Published:** 03 July 2013 **Article history** ▾

ESC 2013

In the setting of clinically suspected myocarditis (*Tables 3–4*), CMR findings are consistent with myocardial inflammation, if at least two of the following criteria are present:

1. Regional or global myocardial signal intensity increase in T2-weighted oedema images[a]
2. Increased global myocardial early gadolinium enhancement ratio between myocardium and skeletal muscle in gadolinium-enhanced T1-weighted images[b]
3. There is at least one focal lesion with non-ischaemic regional distribution in inversion recovery-prepared gadolinium-enhanced T1-weighted images (late gadolinium enhancement)[c]

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A CMR study is consistent with myocyte injury and/or scar caused by myocardial inflammation if Criterion 3 is present

---

A repeat CMR study between 1 and 2 weeks after the initial CMR study is recommended if

- • None of the criteria are present, but the onset of symptoms has been very recent and there is strong clinical evidence for myocardial inflammation
- • One of the criteria is present

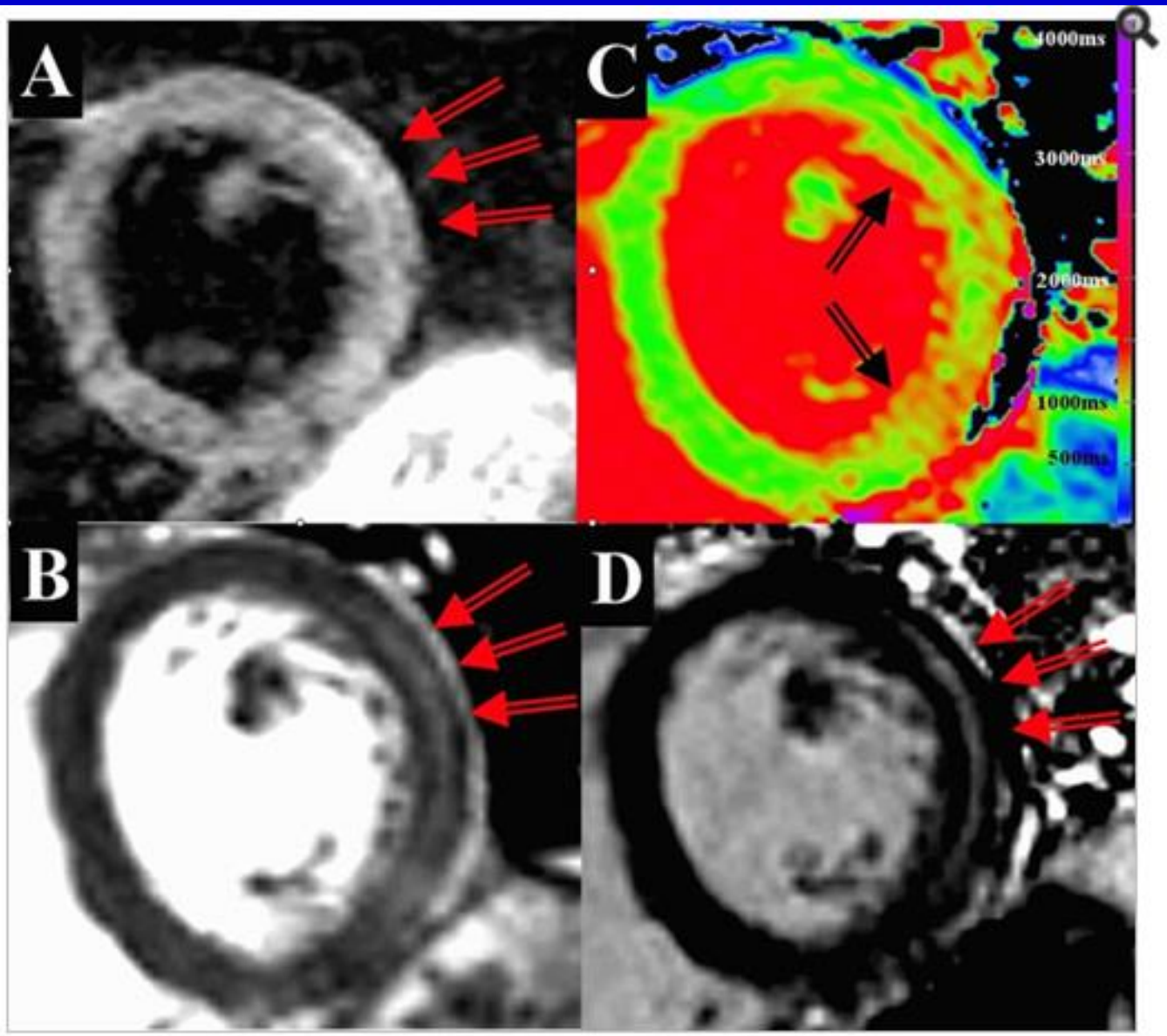
---

The presence of LV dysfunction or pericardial effusion provides additional, supportive evidence for myocarditis

Recommendations

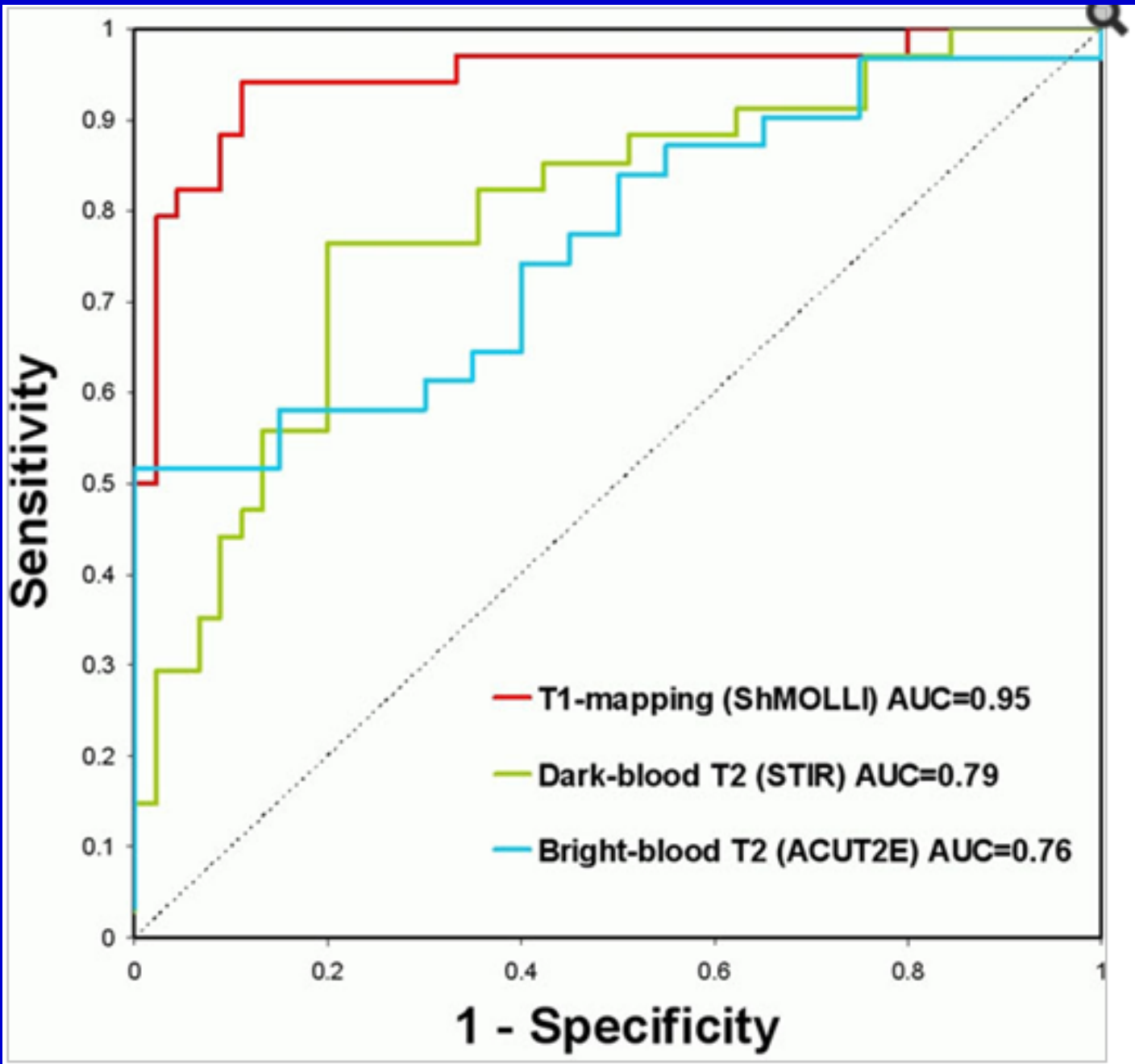
5. Cardiovascular magnetic resonance findings consistent with myocarditis should be based on Lake-Louise criteria (*Table 5*).

6. Cardiovascular magnetic resonance may be considered in clinically stable patients prior to EMB. Cardiovascular magnetic resonance does not replace EMB in the diagnosis of myocarditis and should not delay EMB in life-threatening presentations.




# T1 Mapping

Acute myocarditis. (A) Dark-blood T2W-CMR showing increased signal intensity in the lateral wall. (B) Bright-blood T2W-CMR showing increased signal intensity in the mid lateral wall (C) T1-map showing increased T1 values (1100-1200 ms) in the lateral wall. (D) LGE imaging showing mid-wall enhancement in the lateral wall.




T1 Mapping

ROC curves for ShMOLLI T1-mapping, dark-blood T2W and bright-blood T2W-CMR in the detection of acute myocarditis.

**Table 2 Diagnostic performance of CMR tissue characterization methods in the detection of suspected acute myocarditis**

| Tissue criteria | Sensitivity (%) | Specificity (%) | Accuracy (%) | PPV (%) | NPV (%) |
|---|---|---|---|---|---|
| **Individual** | | | | | |
| T1-mapping* | 90 | 88 | 89 | 90 | 88 |
| Dark-blood T2* | 48 | 86 | 66 | 81 | 58 |
| LGE | 72 | 97 | 81 | 98 | 67 |
| **Combination (with LGE)** | | | | | |
| Dark-blood T2 and LGE (2 out of 2)[†‡] | 45 | 97 | 64 | 96 | 51 |
| Dark-blood T2 or LGE (Any 1 of 2) | 75 | 86 | 79 | 90 | 67 |
| T1-mapping and LGE (2 out of 2)[†] | 67 | 97 | 78 | 98 | 63 |
| T1-mapping or LGE (Any 1 of 2) | 95 | 83 | 91 | 91 | 91 |
| T1-mapping, dark-blood T2 or LGE (Any 1 of 3) | 95 | 71 | 86 | 85 | 89 |
| T1-mapping, dark-blood T2 or LGE (Any 2 of 3) | 70 | 97 | 80 | 98 | 65 |
| T1-mapping and dark-blood T2 and LGE (3 out of 3) | 45 | 97 | 64 | 96 | 51 |
| **Combination (without LGE)** | | | | | |
| T1-mapping and dark-blood T2 (2 out of 2)[‡] | 48 | 98 | 71 | 97 | 61 |
| T1-mapping or dark-blood T2 (Any 1 of 2) | 90 | 76 | 84 | 82 | 86 |

*statistically different ($p < 0.05$); [†‡]no statistical difference ($p = ns$). T1-mapping: myocardial injury is detected when T1 is ≥ 990 ms; Dark-blood T2-weighted imaging: edema is diagnosed when the T2 SI ratio ($T2\ SI_{myocardium\ :\ skeletal\ muscle}$) is ≥ 2:1; Late gadolinium enhancement (LGE) is detected when myocardial SI is ≥ 2 SD above mean SI of remote myocardium. For each technique, only contiguous areas of myocardium ≥40 $mm^2$ above the stated threshold were considered relevant; involvement of ≥5% of any segment on a per-subject basis was the threshold used for comparison of methods. PPV = positive predictive value; NPV = negative predictive value.

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# Comprehensive Cardiac Magnetic Resonance Imaging in Patients With Suspected Myocarditis

## The MyoRacer-Trial

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## ABSTRACT

**BACKGROUND** Data suggest that $T_1$ and $T_2$ mapping have excellent diagnostic accuracy in patients with suspected myocarditis. However, the true diagnostic performance of comprehensive cardiac magnetic resonance (CMR) mapping versus endomyocardial biopsy (EMB) has not been determined.

**OBJECTIVES** This study assessed the performance of CMR imaging, including $T_1$ and $T_2$ mapping, compared with EMB in an unselected, consecutive patient cohort with suspected myocarditis. It also examined the potential role of CMR field strength by comparing 1.5-T versus 3.0-T imaging.

**METHODS** Patients underwent biventricular EMB, cardiac catheterization (for exclusion of coronary artery disease), and CMR imaging on 1.5- and 3-T scanners. The CMR protocol included current standard Lake Louise criteria (LLC) for myocarditis as well as native $T_1$, calculation of extracellular volume fraction (ECV), and $T_2$ mapping (only on 1.5-T). Patients were divided into 2 groups according to symptom duration (acute: ≤14 days vs. chronic: >14 days).

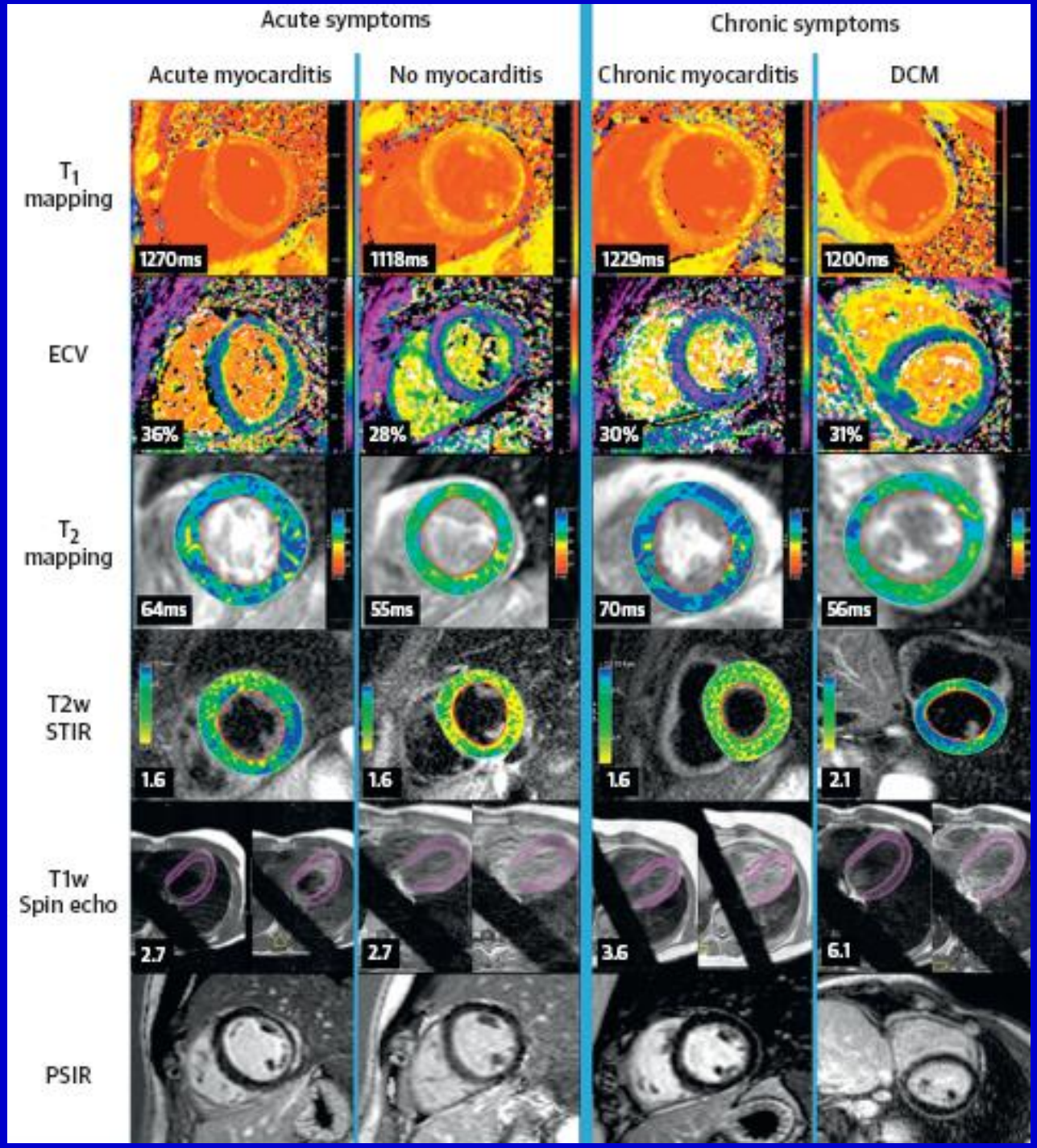

Acute symptoms
Chronic symptoms
Acute myocarditis
No myocarditis
Chronic myocarditis
DCM
T1 mapping
ECV
T2 mapping
T2w STIR
T1w Spin echo
PSIR
1270ms
1118ms
1229ms
1200ms
36%
28%
30%
31%
64ms
55ms
70ms
56ms
1.6
1.6
1.6
2.1
2.7
2.7
3.6
6.1

**TABLE 3 CMR Imaging Techniques**

| | Acute Group | | | Chronic Group | | |
|---|---|---|---|---|---|---|
| | Acute Myocarditis | No Myocarditis | p Value | Acute Myocarditis | No Myocarditis | p Value |
| 1.5-T | | | | | | |
| Edema ratio | 1.97 ± 0.37 | 1.81 ± 0.42 | 0.225 | 1.94 ± 0.44 | 1.80 ± 0.40 | 0.19 |
| Early enhancement | 4.63 ± 2.23 | 5.69 ± 4.45 | 0.762 | 7.69 ± 15.99 | 6.99 ± 4.70 | 0.82 |
| Presence of LE | 77 | 63 | 0.430 | 69 | 63 | 0.84 |
| LLC | 66 | 53 | 0.394 | 64 | 53 | 0.42 |
| Native $T_1$ | 1,113 ± 67 | 1,044 ± 42 | <0.001 | 1,096 ± 64 | 1,080 ± 79 | 0.46 |
| ECV | 37.2 ± 6.5 | 31.8 ± 4.9 | 0.001 | 35.8 ± 5.3 | 33.8 ± 10.8 | 0.45 |
| $T_2$ | 62.2 ± 4.5 | 56.9 ± 7.2 | 0.007 | 62.8 ± 4.5 | 59.4 ± 2.9 | 0.001 |
| 3.0-T | | | | | | |
| Edema ratio | 1.72 ± 0.51 | 1.43 ± 0.56 | 0.078 | 1.69 ± 0.59 | 1.56 ± 0.51 | 0.39 |
| Early enhancement | 9.02 ± 10.04 | 8.24 ± 8.12 | 0.78 | 8.10 ± 5.22 | 6.5 ± 2.39 | 0.12 |
| Presence of LE | 84 | 88 | 1.0 | 85 | 65 | 0.15 |
| LLC | 78 | 76 | 1.0 | 79 | 63 | 0.31 |
| Native $T_1$ | 1,203 ± 71 | 1,159 ± 62 | 0.027 | 1,185 ± 78 | 1,184 ± 93 | 0.96 |
| ECV | 30.1 ± 5.7 | 25.6 ± 3.7 | 0.006 | 28.9 ± 4.5 | 26.6 ± 6.9 | 0.24 |

Values are mean ± SD or %.

CMR = cardiac magnetic resonance; ECV = extracellular volume; LE = late enhancement; LLC = Lake Louise criteria.

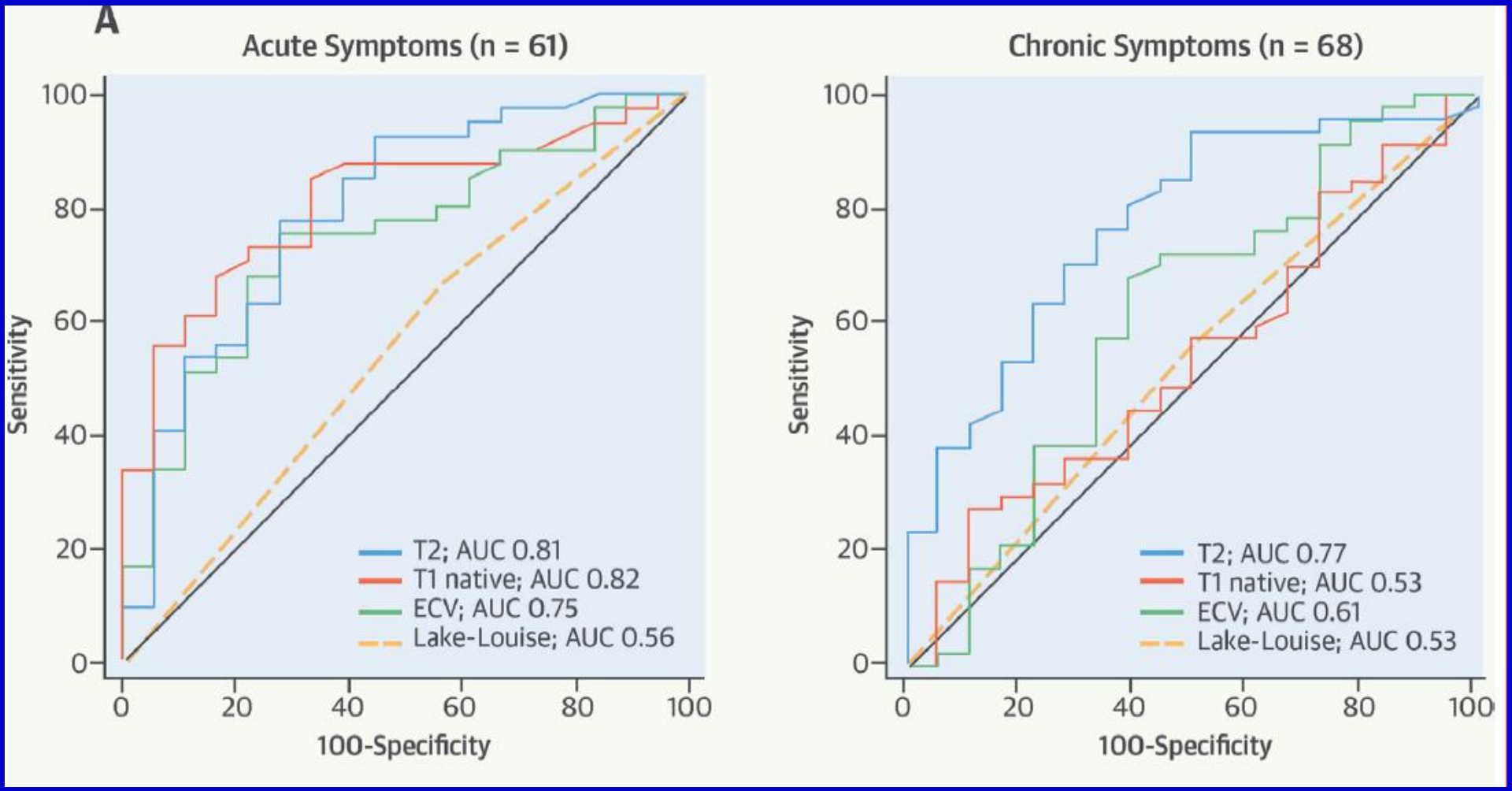

A
Acute Symptoms (n = 61)
Sensitivity
100-Specificity
0
20
40
60
80
100
T2; AUC 0.81
T1 native; AUC 0.82
ECV; AUC 0.75
Lake-Louise; AUC 0.56
Chronic Symptoms (n = 68)
Sensitivity
100-Specificity
T2; AUC 0.77
T1 native; AUC 0.53
ECV; AUC 0.61
Lake-Louise; AUC 0.53

**TABLE 4** Diagnostic Performance of 1.5-T CMR Imaging

| | Acute Group | | | | | |
|---|---|---|---|---|---|---|
| | Youden Index | Sensitivity | Specificity | PPV | NPV | Accuracy |
| Native $T_1$ | >1,058 ms | 88 (74–96) | 67 (41–87) | 86 (71–95) | 71 (44–90) | 81 (73–89) |
| ECV | >0.326 | 75 (60–88) | 72 (47–90) | 86 (71–95) | 57 (35–77) | 75 (69–81) |
| $T_2$ | >58.8 ms | 85 (71–94) | 68 (43–87) | 85 (71–94) | 68 (43–87) | 80 (71–90) |
| LLC | — | 66 (49–80) | 47 (24–71) | 71 (54–85) | 41 (21–64) | 59 (54–65) |

Values are % (interquartile range) unless otherwise indicated.

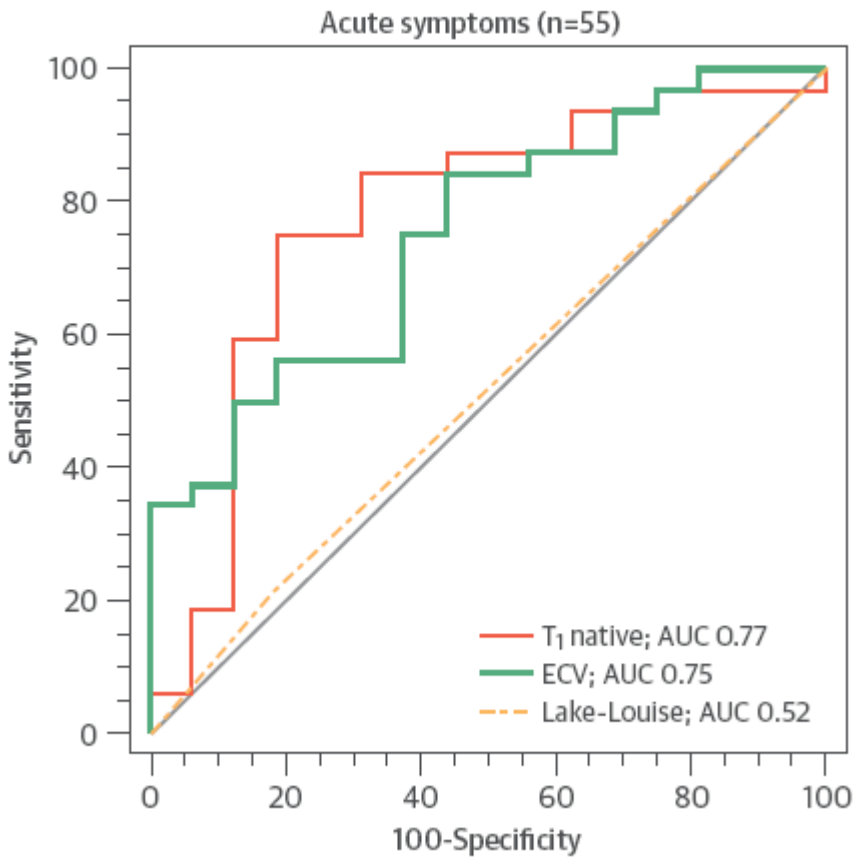
NPV = negative predictive value; PPV = positive predictive value; other abbreviations as in Table 3.

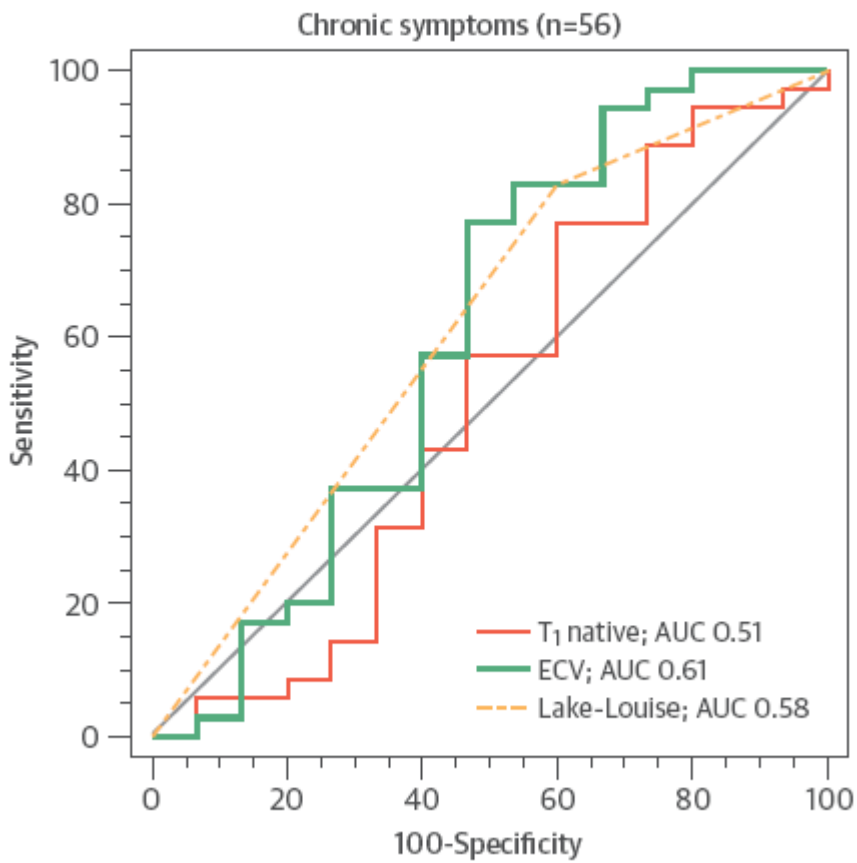
**TABLE 4** Diagnostic Performance of 1.5-T CMR Imaging

| | Chronic Group | | | | |
|---|---|---|---|---|---|
| Youden Index | Sensitivity | Specificity | PPV | NPV | Accuracy |
| >1,142 ms | 27 (15–41) | 94 (21–100) | 93 (66–100) | 32 (20–46) | 45 (39–57) |
| >0.332 | 69 (55–82) | 61 (36–83) | 83 (68–93) | 42 (23–63) | 67 (62–76) |
| >60.2 ms | 71 (57–83) | 72 (47–90) | 88 (73–83) | 48 (29–68) | 73 (66–78) |
| — | 64 (49–77) | 47 (25–71) | 75 (59–87) | 35 (17–56) | 59 (53–65) |

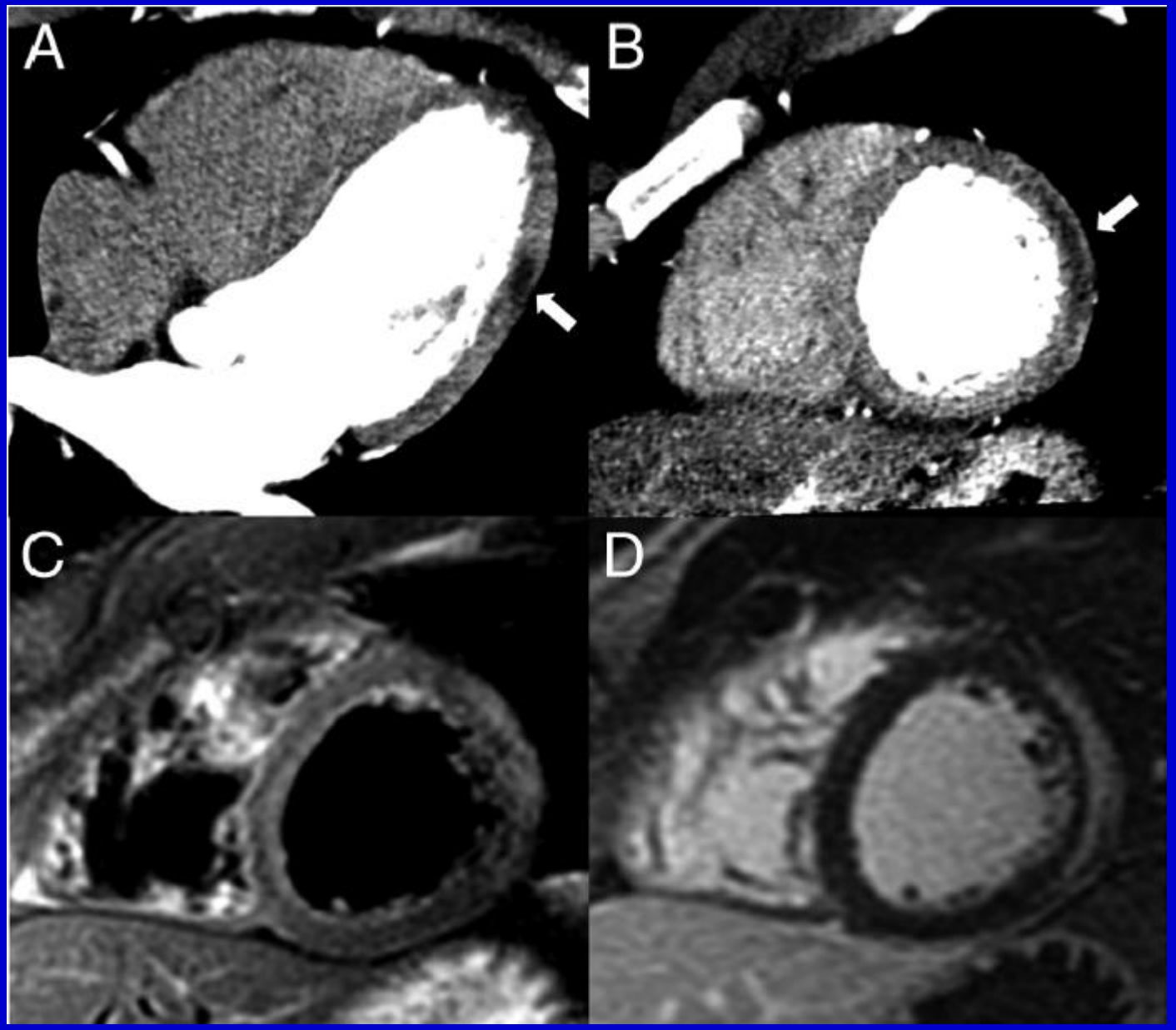
# 3 T versus 1.5 T

**FIGURE 3** Receiver-Operator Curves: 3T Imaging



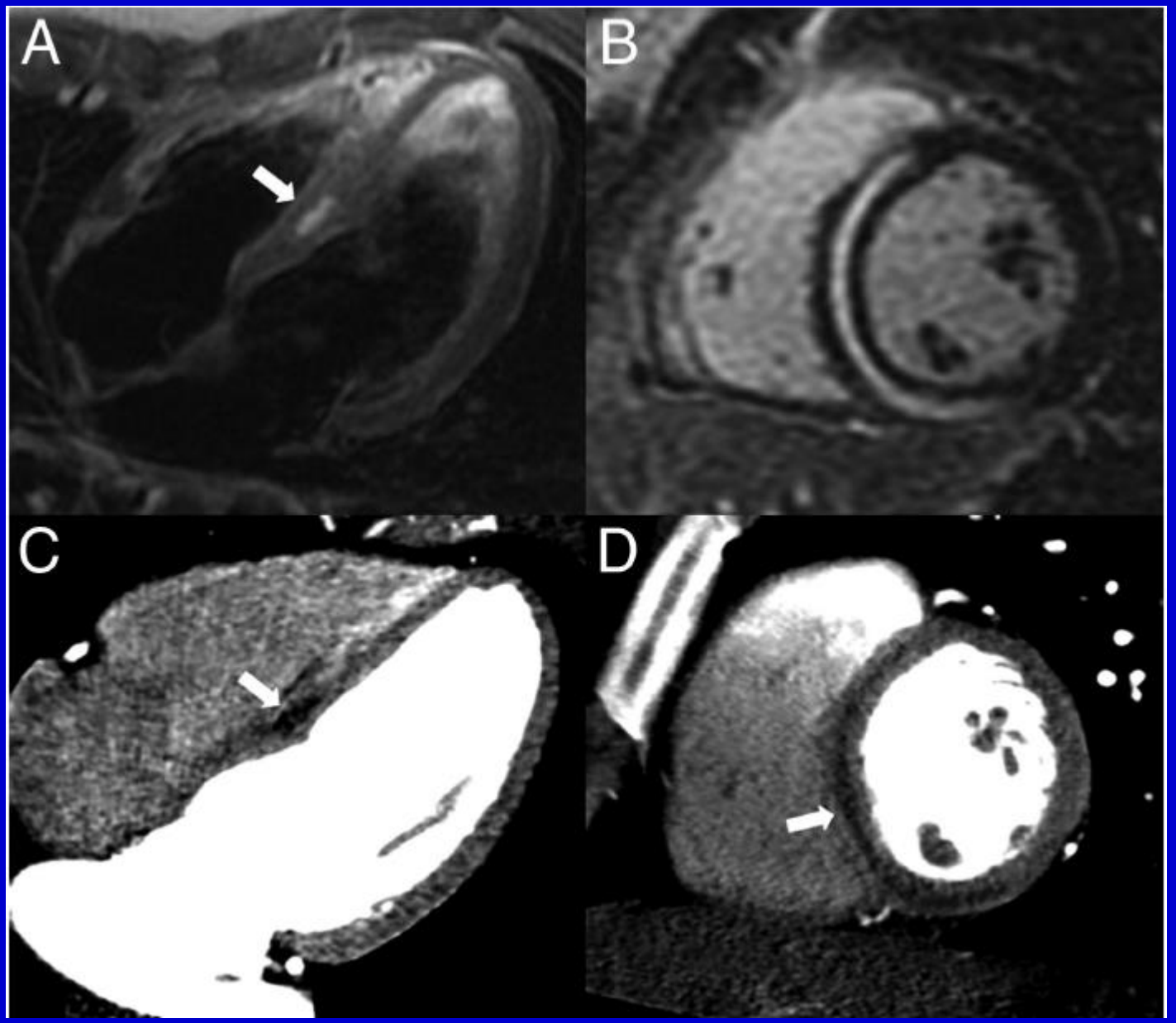



Scanner




Brette NJ et al. Circ Cardiovasc Imaging 2011

Scanner




Brette NJ et al. Circ Cardiovasc Imaging 2011

# IRM de rehaussement tardif
# Conclusion

- Choix du Temps d'Inversion TI
- La présence d'un hypersignal n'est pas spécifique
- Dans l'infarctus du myocarde, l'hypersignal intéresse toujours le sous-endocarde
- En l'absence d'atteinte sous-endocardique, de nombreuses cardiopathies non ischémiques peuvent être incriminées (Pronostic)
- Intérêt des séquences T2 (œdème) pour le diagnostic et le suivi des myocardites

# Conclusion

- Myocardite aiguë (altération fonction VG)
  - T1 et T2 mapping > T1, T2 et rehaussement tardif (Lake louise criteria)
- Myocardite chronique (> 14 jours)
  - T2 mapping > T1 mapping, T1, T2 et rehaussement tardif (Lake louise criteria)
- Résultats identiques 1.5 versus 3 Teslas
- Limites des séquences standards (Lake Louise criteria)
  - Altération fonction VG
  - Atteinte diffuse
  - De nombreux artéfacts