Outils diagnostiques d'imagerie dans l'endocardite : "PET-scan, IRM cérébrale, angio-cérébrale et scanner cardiaque pour tous ?"

Dr Raphaël Lepeule
Unité Transversale de Traitement des Infections
GHU - Henri Mondor

AP-HP.
Hôpitaux universitaires
Henri-Mondor

SOS ENDOCARDITES
APHP- CHU HENRI MONDOR

Evolution de l'épidémiologie

- **Incidence annuelle stable depuis 30 ans (30 cas par million d'habitants)**

- **Evolution du profil épidémiologique des patients atteints d'EI :**

  - ↗ âge moyen (58 ans en 1991, 62 ans en 2008)
  - ↗ des EI sans pathologies valvulaires connues
  - ↗ des EI sur valves prothétiques et des infections sur matériel (pacemaker, défibrillateurs)
  - ↗ des patients avec lourdes comorbidités (diabète, hémodialyse…)
  - ↗ des EI liées aux soins

Duval X et al, J Am Coll Card 2012
Parize P, Mainardi JL, Rev Med Interne 2011
Hoen B, Duval X, LA revue du Praticien 2012

Recommandations européennes

ESC European Society of Cardiology
European Heart Journal (2023) **00**, 1–95
https://doi.org/10.1093/eurheartj/ehad193

ESC GUIDELINES

2023 ESC Guidelines for the management of endocarditis

Developed by the task force on the management of endocarditis of the European Society of Cardiology (ESC)

Endorsed by the European Association for Cardio-Thoracic Surgery (EACTS) and the European Association of Nuclear Medicine (EANM)

AHA Scientific Statement

Infective Endocarditis in Adults: Diagnosis, Antimicrobial Therapy, and Management of Complications

A Scientific Statement for Healthcare Professionals From the American Heart Association

Endorsed by the Infectious Diseases Society of America

2015

Diagnostic : critères de Duke (re)modifiés ?
ESC 2015

Major criteria

1. Blood cultures positive for IE

a. Typical microorganisms consistent with IE from 2 separate blood cultures:
- *Viridans streptococci, Streptococcus gallolyticus (Streptococcus bovis), HACEK group, Staphylococcus aureus;* or
- Community-acquired enterococci, in the absence of a primary focus; or

b. Microorganisms consistent with IE from persistently positive blood cultures:
- ≥2 positive blood cultures of blood samples drawn >12 h apart; or
- All of 3 or a majority of ≥4 separate cultures of blood (with first and last samples drawn ≥1 h apart); or

c. Single positive blood culture for Coxiella burnetii or phase I IgG antibody titre >1:800

2. Imaging positive for IE

a. Echocardiogram positive for IE:
- Vegetation;
- Abscess, pseudoaneurysm, intracardiac fistula;
- Valvular perforation or aneurysm;
- New partial dehiscence of prosthetic valve.

b. Abnormal activity around the site of prosthetic valve implantation detected by ^{18}F-FDG PET/CT (only if the prosthesis was implanted for >3 months) or radiolabelled leukocytes SPECT/CT.

c. Definite paravalvular lesions by cardiac CT.

Minor criteria

1. Predisposition such as predisposing heart condition, or injection drug use.
2. Fever defined as temperature >38°C.
3. Vascular phenomena (including those detected by imaging only): major arterial emboli, septic pulmonary infarcts, infectious (mycotic) aneurysm, intracranial haemorrhage, conjunctival haemorrhages, and Janeway's lesions.
4. Immunological phenomena: glomerulonephritis, Osler's nodes, Roth's spots, and rheumatoid factor.
5. Microbiological evidence: positive blood culture but does not meet a major criterion as noted above or serological evidence of active infection with organism consistent with IE.

Certaine :

2 majeurs

1 majeur + 3 mineurs

5 mineurs

Possible :

1 majeur +1 mineur

3 mineurs

Ne remplace pas le sens clinique

Diagnostic : critères de Duke (re)modifiés ?
ESC 2023

Major criteria

(i) Blood cultures positive for IE

(a) Typical microorganisms consistent with IE from two separate blood cultures:

Oral streptococci, *Streptococcus gallolyticus* (formerly *S. bovis*), HACEK group, *S. aureus*, *E. faecalis*

(b) Microorganisms consistent with IE from continuously positive blood cultures:

- ≥2 positive blood cultures of blood samples drawn >12 h apart.
- All of 3 or a majority of ≥4 separate cultures of blood (with first and last samples drawn ≥1 h apart).

(c) Single positive blood culture for *C. burnetii* or phase I IgG antibody titre >1:800.

(ii) Imaging positive for IE:

Valvular, perivalvular/periprosthetic and foreign material anatomic and metabolic lesions characteristic of IE detected by any of the following imaging techniques:

- Echocardiography (TTE and TOE).
- Cardiac CT.
- [18F]-FDG-PET/CT(A).
- WBC SPECT/CT.

Nouveautés :

- TEP et scintigraphie en l'absence de prothèse ?
- Absence de délai par rapport à la pose de la prothèse ?

  "Therefore, a consensus of experts has concluded that the need for a time interval prior to investigation is questionable but accurate imaging interpretation by proper interpretation criteria is mandatory"

Delgado V et al, European Heart Journal 2023

Diagnostic : critères de Duke (re)modifiés ?
ESC 2023

Minor criteria

(i) Predisposing conditions (i.e. predisposing heart condition at high or intermediate risk of IE or PWIDs)[a]

(ii) Fever defined as temperature >38°C

(iii) Embolic vascular dissemination (including those asymptomatic detected by imaging only):

- Major systemic and pulmonary emboli/infarcts and abscesses.
- Haematogenous osteoarticular septic complications (i.e. spondylodiscitis).
- Mycotic aneurysms.
- Intracranial ischaemic/haemorrhagic lesions.
- Conjunctival haemorrhages.
- Janeway's lesions.

(IV) Immunological phenomena:

- Glomerulonephritis.
- Osler nodes and Roth spots.
- Rheumatoid factor.

(V) Microbiological evidence:

- Positive blood culture but does not meet a major criterion as noted above.
- Serological evidence of active infection with organism consistent with IE.

Delgado V et al, European Heart Journal 2023

Diagnostic : critères de Duke (re)modifiés ?
DUKE-ISCVID

Clinical Infectious Diseases

VIEWPOINTS

The 2023 Duke-International Society for Cardiovascular Infectious Diseases Criteria for Infective Endocarditis: Updating the Modified Duke Criteria

I. MAJOR CRITERIA

B. Imaging Major Criteria

(2) Positron emission computed tomography with 18F-fluorodeoxyglucose ([18F]FDG PET/CT imaging)
Abnormal metabolic activity[k] involving a native or prosthetic valve, ascending aortic graft (with concomitant evidence of valve involvement), intracardiac device leads or other prosthetic material[l,m]

I. MINOR CRITERIA

F. Imaging Criteria

Abnormal metabolic activity as detected by [18F]FDG PET/CT within 3 mo of implantation of prosthetic valve, ascending aortic graft **(with concomitant evidence of valve involvement),** ***intracardiac device leads or other prosthetic material***

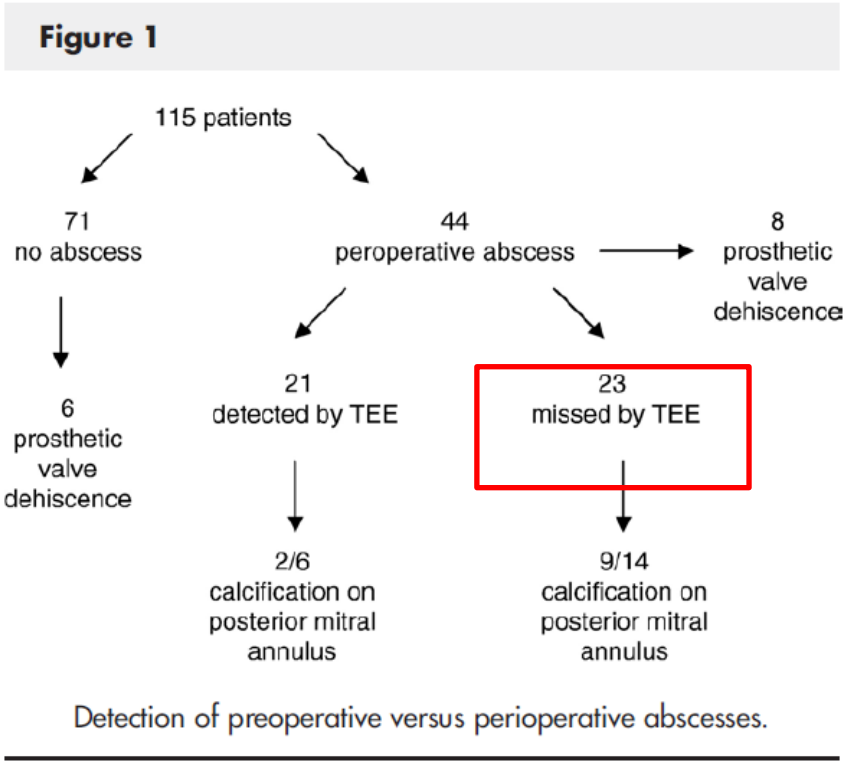
Fowler V et al, Clinical Infectious Diseases 2023

Rôle de l’imagerie en dehors de l’échographie cardiaque

Diagnostic de l’atteinte cardiaque = critère majeur

Diagnostic des atteintes extra cardiaques = critère mineur

Echocardiographie : examen de référence, mais ?



- 115 patients avec EI (valve native n=89; valve prothétique n= 26) opérés et ayant eu une ETO pré opératoire
- Comparaison avec les constatations per opératoires

=> **Seulement 48% des abcès détectés en pré opératoire**

=> Difficultés

- Abcès mitral postérieur
- Calcifications mitrales

Hill et al, American Heart Journal 2007

Apport du TEP TDM : valves prothétiques

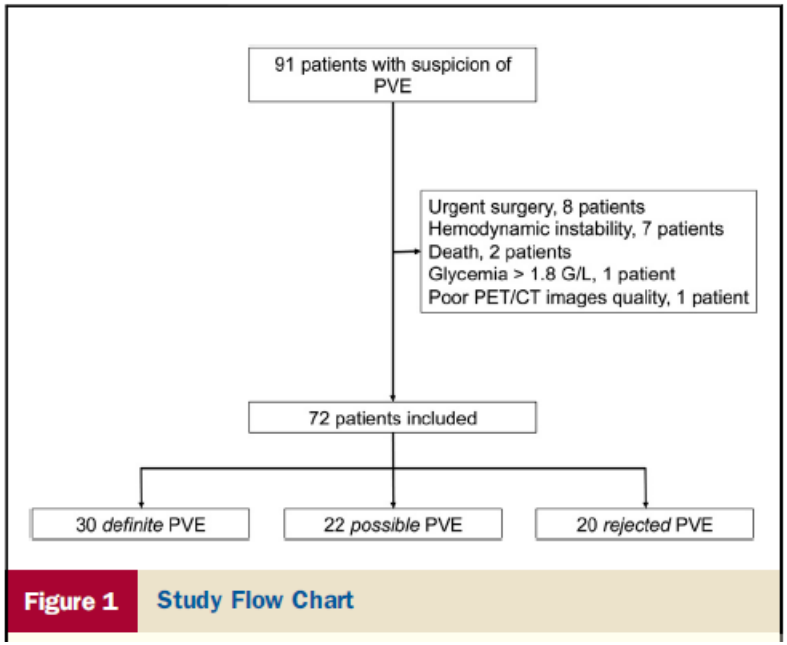


Figure 1 Study Flow Chart

Table 5 Diagnostic Value of the Modified Duke Criteria at Admission With (Duke-PET/CT) and Without the Implementation of the PET/CT Results

	Final Diagnosis		
	Definite PVE	*Possible* PVE	*Rejected* PVE
Duke			
Definite PVE	21 (70)	0 (0)	0 (0)
Possible PVE	8 (27)	22 (100)	10 (50)
Rejected PVE	1 (3)	0 (0)	10 (50)
Duke-PET/CT			
Definite PVE	29 (97)	10 (45)	2 (10)
Possible PVE	1 (3)	12 (55)	10 (50)
Rejected PVE	0	0	8 (40)

Values are n (% of each final diagnosis).
Abbreviations as in Tables 1 and 2.

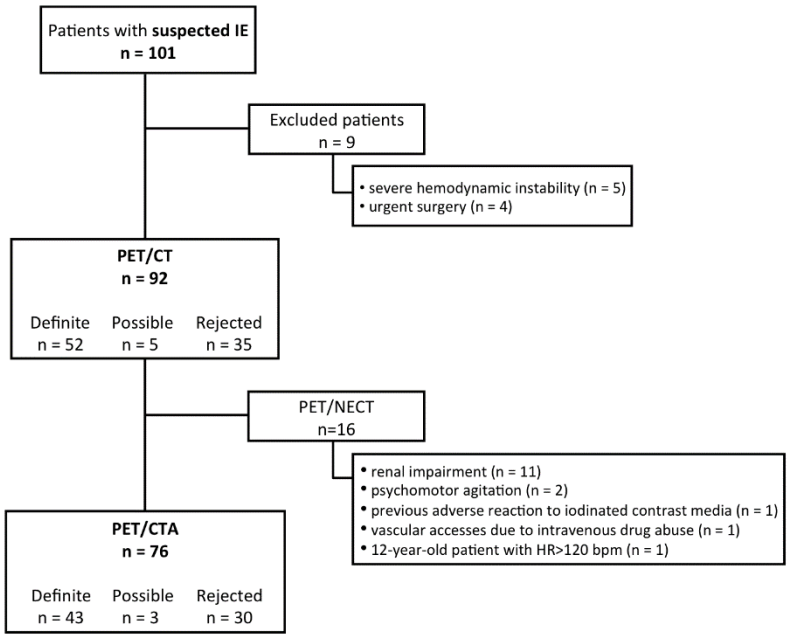
72 patients suspicion d'endocardite sur prothèse

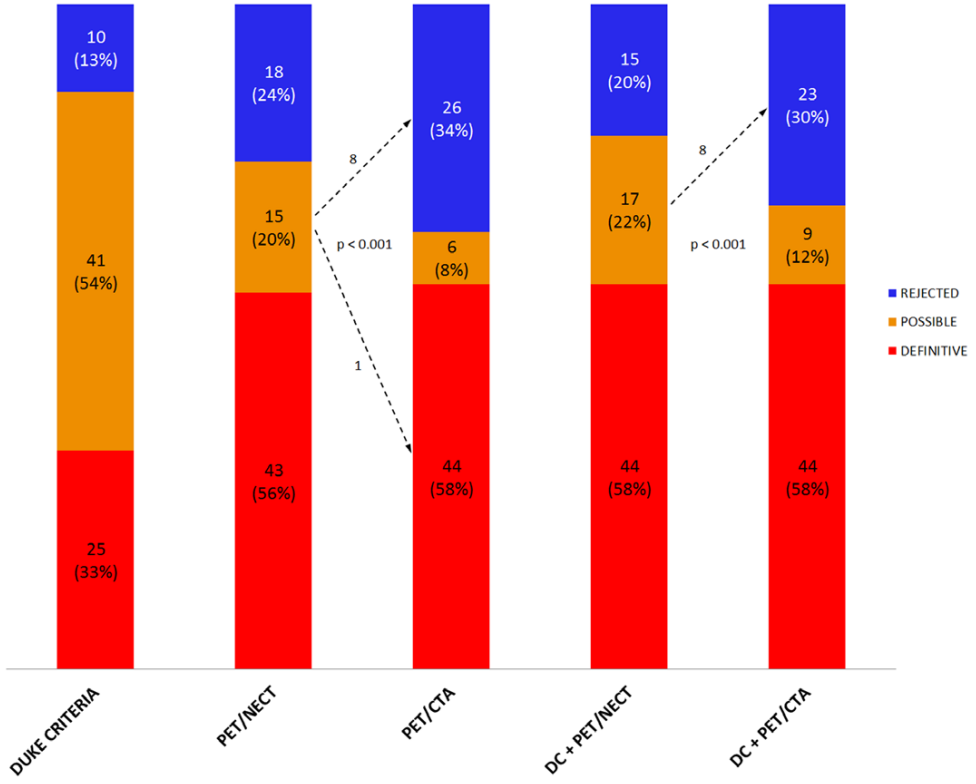
Diagnostic définitif après 3 mois de suivi

Duke avec TEP : sensibilité 70% => 97%

Saby et al. J Am Coll Card 2012

Apport du TEP TDM : valves prothétiques





=> Use of this technique led to an increase in the sensitivity of the modified DC from 52% to 90.7% and resulted in a conclusive diagnosis in 95% of cases.

=> Produit de contraste augmente la spécificité

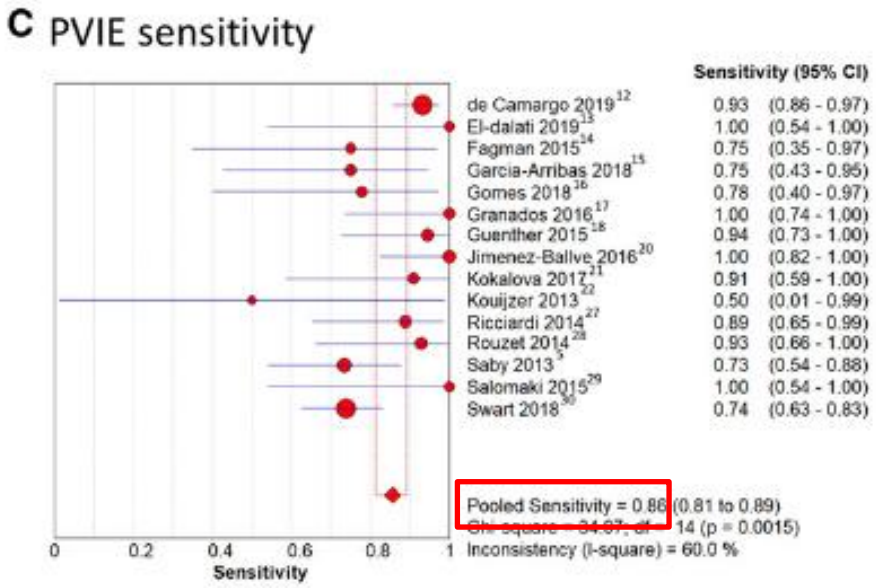
Pizzi et al. Circulation 2015

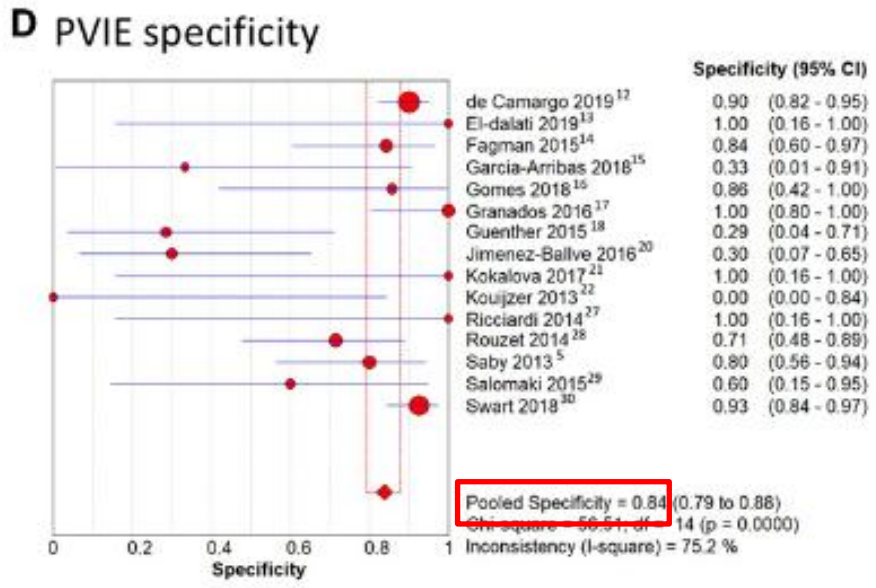
Apport du TEP TDM

Diagnosis of Infective Endocarditis by Subtype Using ^{18}F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography

A Contemporary Meta-Analysis

Valves prothétiques :





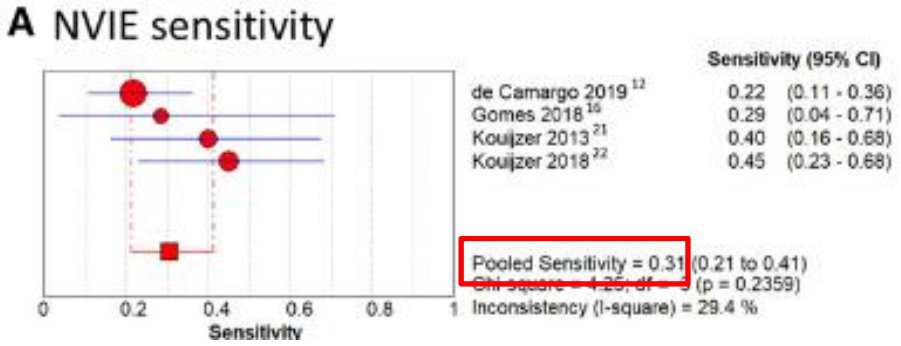
Wang et al. Circ Cardiovasc Imaging. 2020

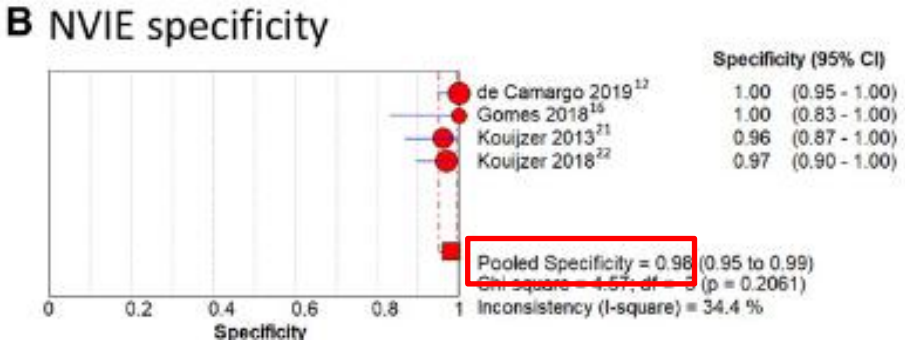
Apport du TEP TDM

Diagnosis of Infective Endocarditis by Subtype Using ^{18}F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography

A Contemporary Meta-Analysis

Valves natives :





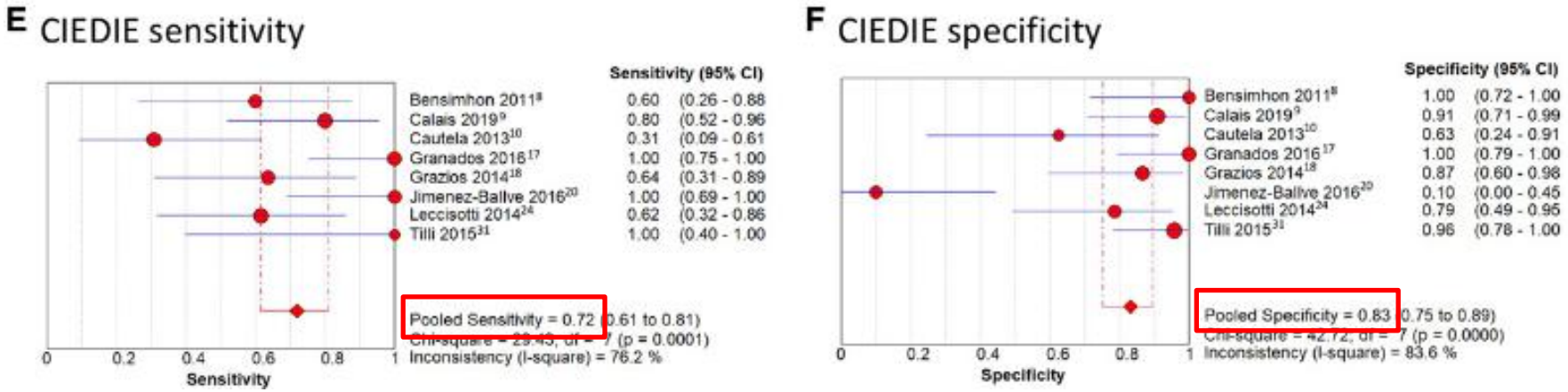
Wang et al. Circ Cardiovasc Imaging. 2020

Apport du TEP TDM

Diagnosis of Infective Endocarditis by Subtype Using ^{18}F-Fluorodeoxyglucose Positron Emission Tomography/Computed Tomography

A Contemporary Meta-Analysis

PM/DAI :



Wang et al. Circ Cardiovasc Imaging. 2020

Apport du TEP TDM : valves natives ?

Impact of Systematic Whole-body ^{18}F-Fluorodeoxyglucose PET/CT on the Management of Patients Suspected of Infective Endocarditis: The Prospective Multicenter TEPvENDO Study

Clinical Infectious Diseases

MAJOR ARTICLE

140 patients avec suspicion d'EI

70 valves natives (VN), 70 valves prothétiques (VP)

Diagnostic définitif après 6 mois de suivi

Impact du TEP sur le diagnostic : modification de la classification ESC

- VN 5,7%
- VP 24, 3%

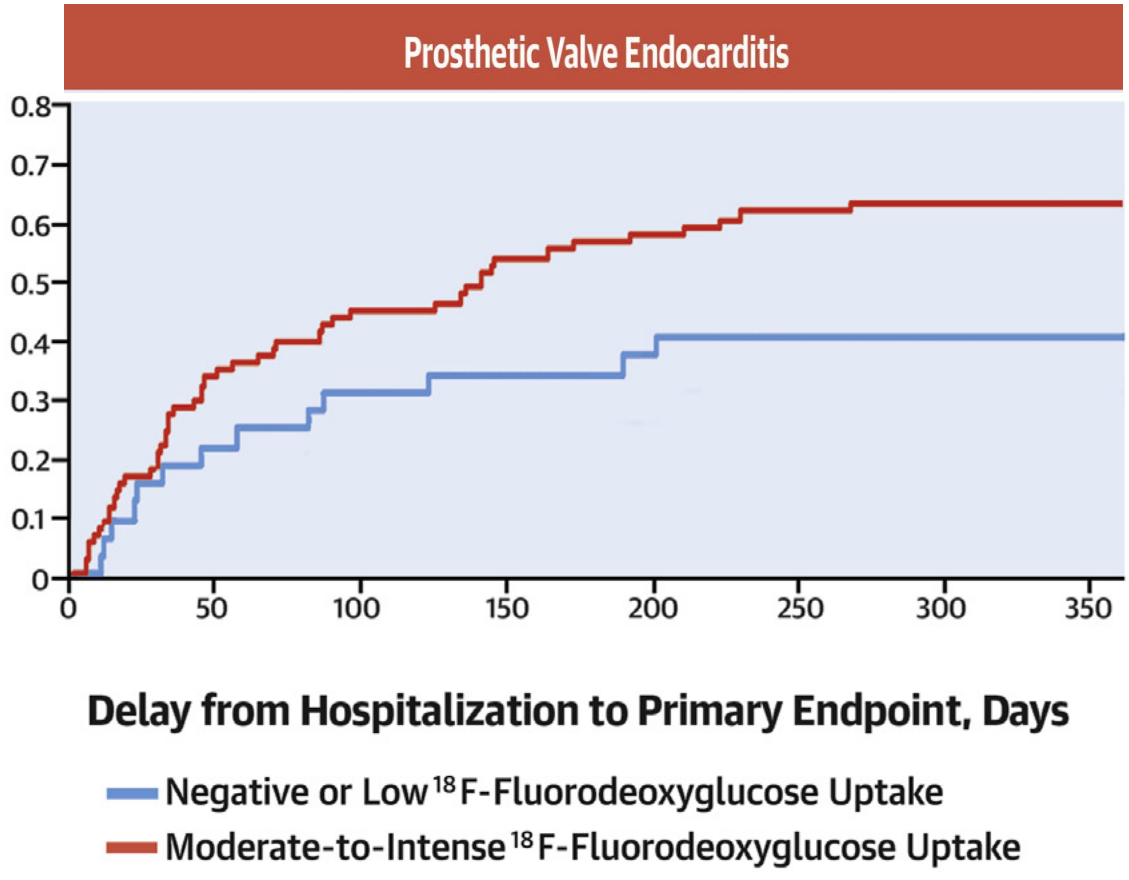
Modification de la prise en charge (ATB ou chir)

- VN 31,4%
- VP 21,4%

=> Détection et caractérisation des **localisations infectieuses extracardiaques**

Duval et al. CID 2020

Apport du TEP TDM : valeur pronostique ?



173 endocardites certaines. VP = 109, VN =64

Impact pronostique de la fixation au TEP retrouvée uniquement dans le groupe VP

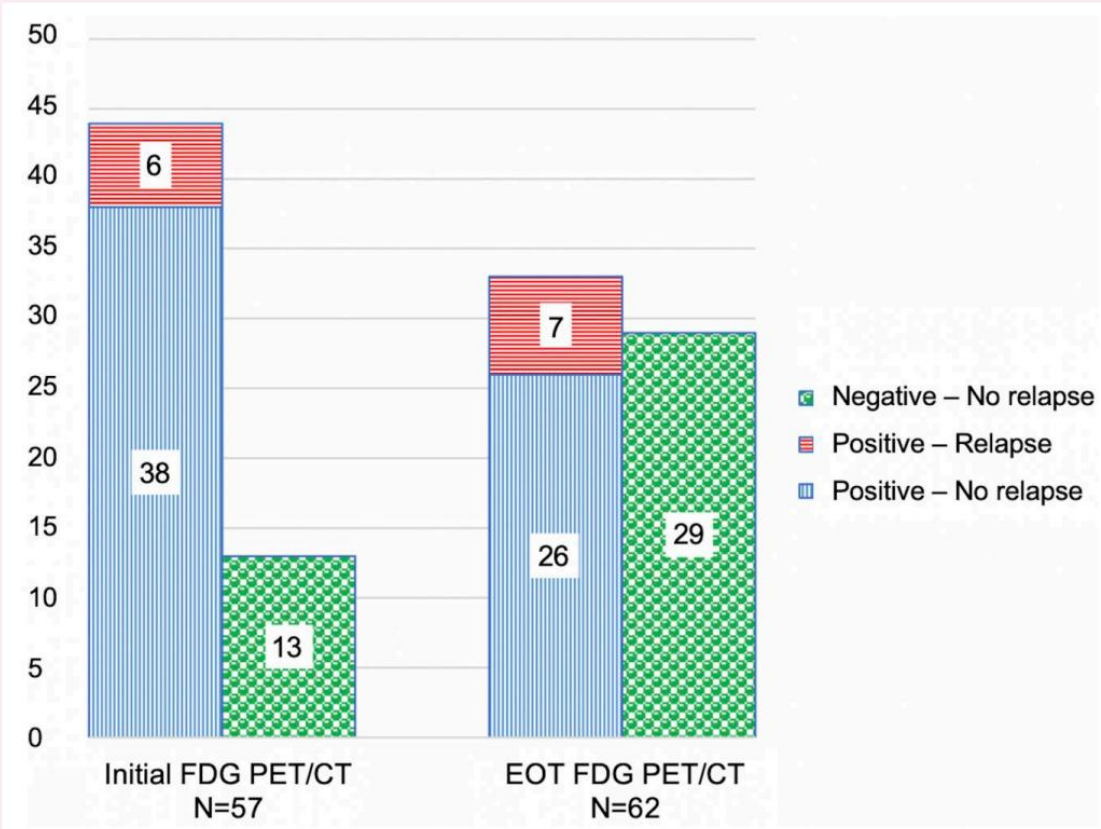
Primary Endpoint

- In-hospital death
- Acute cardiac insufficiency
- 1-year death
- Recurrence
- Re-hospitalization
- New embolic event

San et al. JACC 2019

Apport du TEP TDM : valeur pronostique ?

Absence of infective endocarditis relapse when end-of-treatment fluorodeoxyglucose positron emission tomography/computed tomography is negative



62 patients who underwent an EOT FDG-PET/CT for **non-operated IE** performed between 30 and 180 days of antibiotic therapy initiation

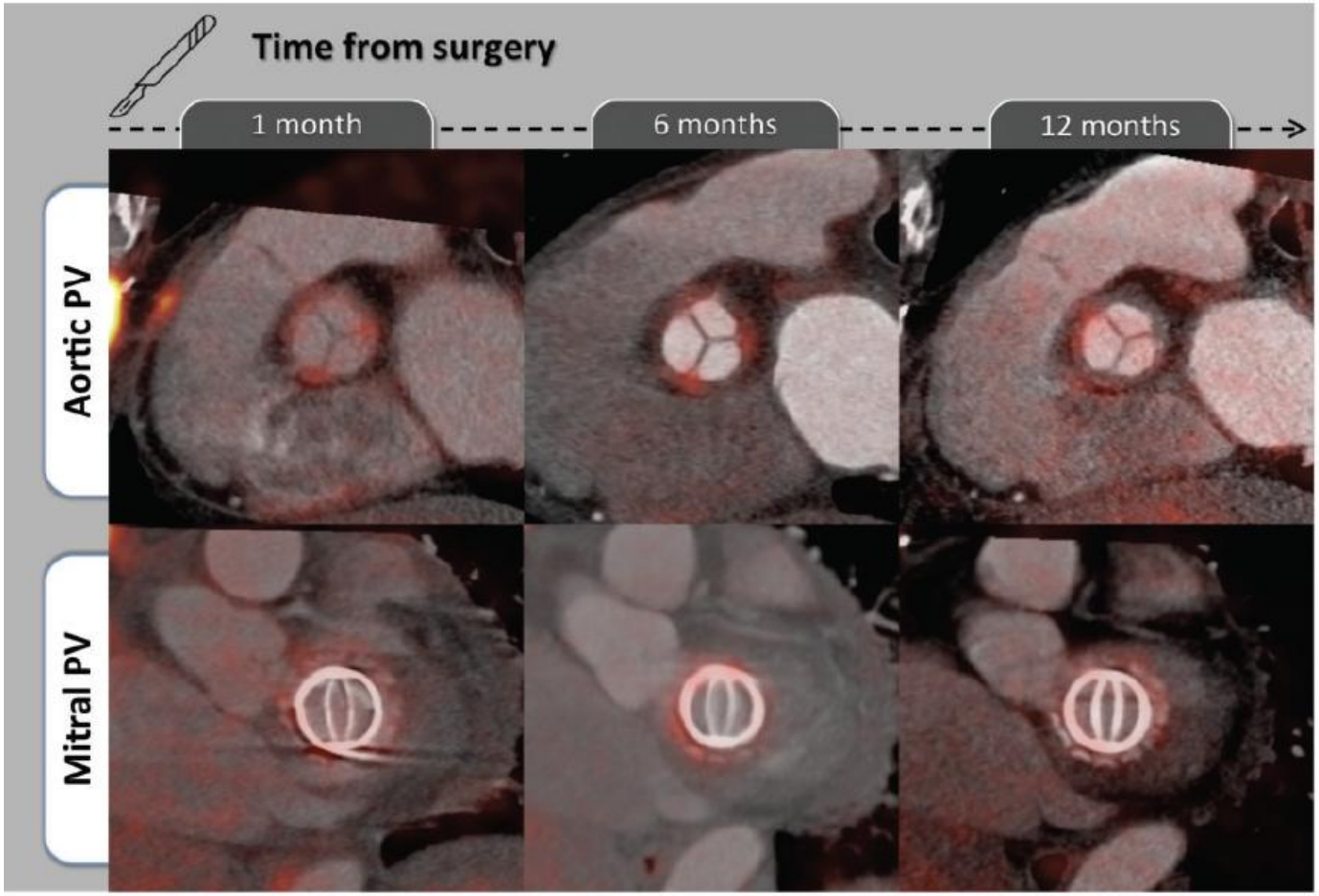
42 (68%) had prosthetic valve IE
20 (32%) had native valve IE

Infective endocarditis **relapse** occurred in 7 **(11%)** patients with a **median delay** between EOT FDG-PET/CT and relapse diagnosis of **10 days**

C. Régis et al. European Heart Journal - Cardiovascular Imaging (2023)

TEP TDM et délais de la chirurgie

Recommandations ESC 2015 : difficultés d'interprétation dans les 3 mois suivant la chirurgie



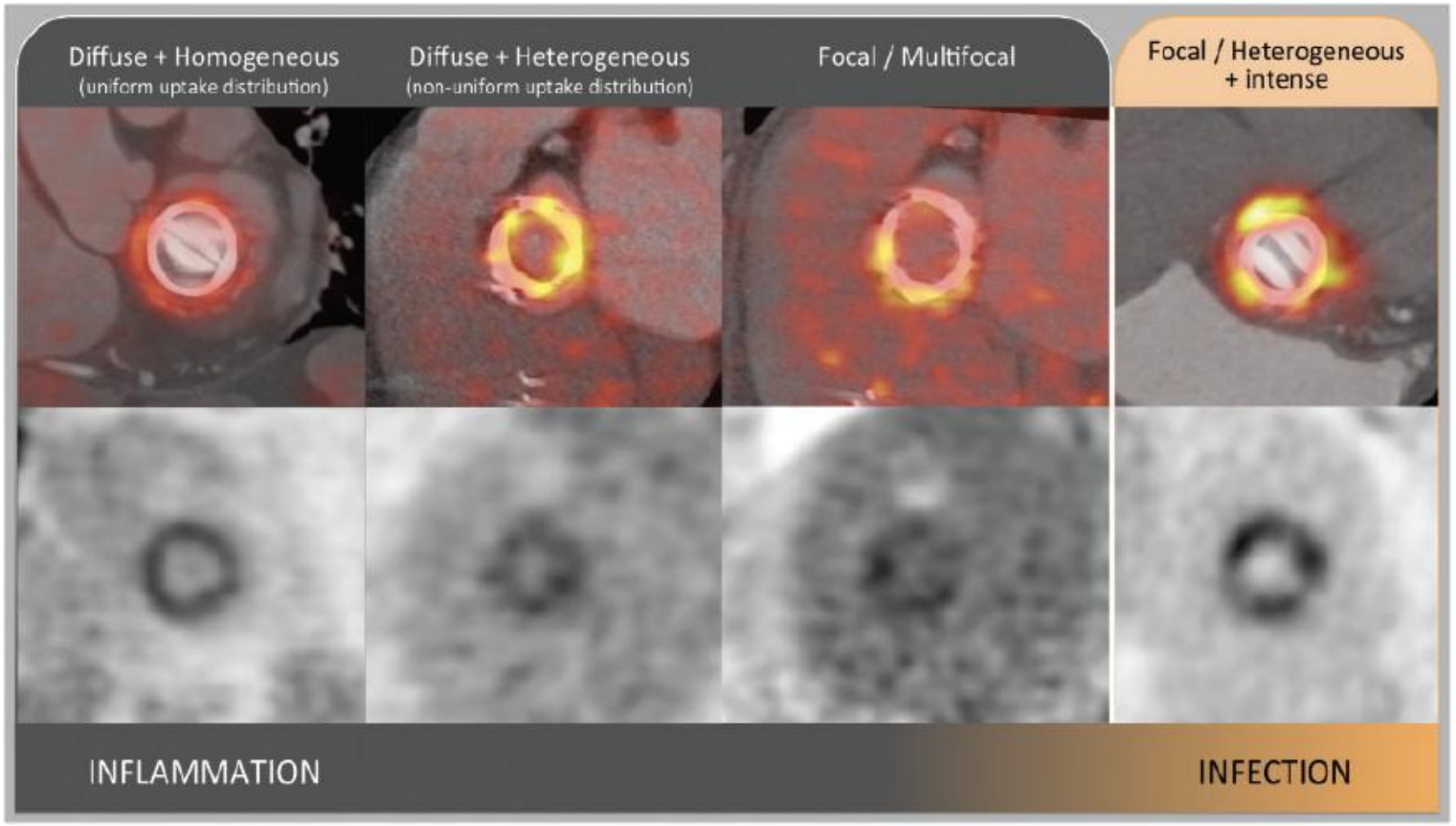
37 patients

TEP scan à M1, M6 et M12 post implantation

=> Fixation post opératoire stable dans l'année qui suit la pose de la prothèse

Roque et al. European Heart Journal - Cardiovascular Imaging 2020

TEP TDM et délais de la chirurgie



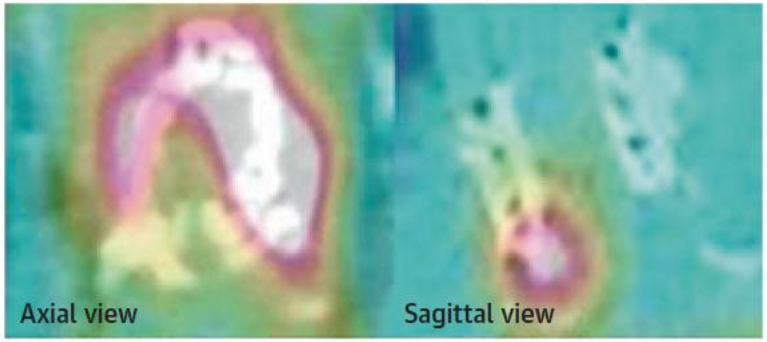
=> L'aspect de la fixation est associée au diagnostic d'EI

Roque et al. European Heart Journal - Cardiovascular Imaging 2020

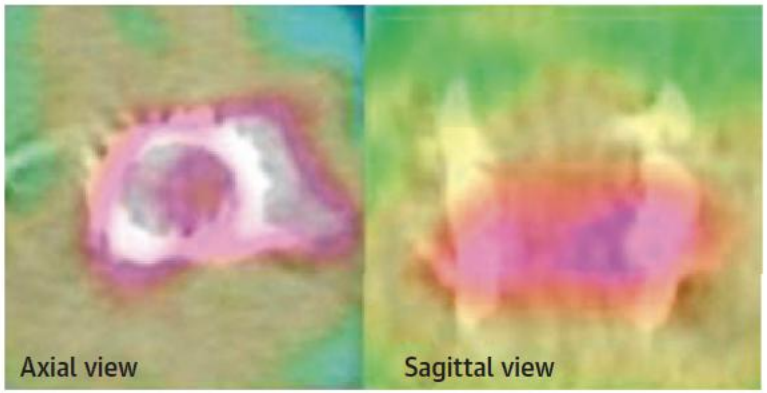
TEP TDM et délais de la chirurgie : TAVI ?

FDG UPTAKE IN CONTROL GROUP

Hemi-circumferential uptake (from 25% to 75%)

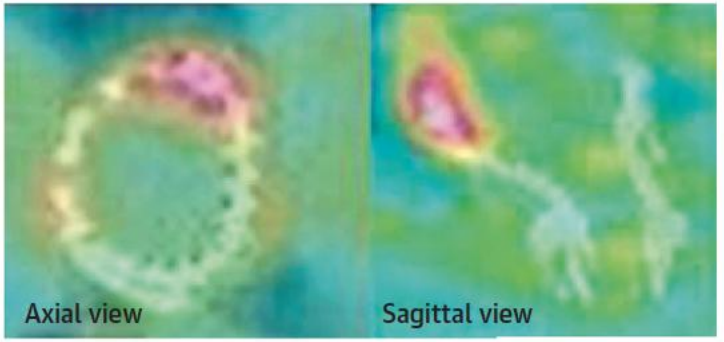


Circumferential uptake (>75%)

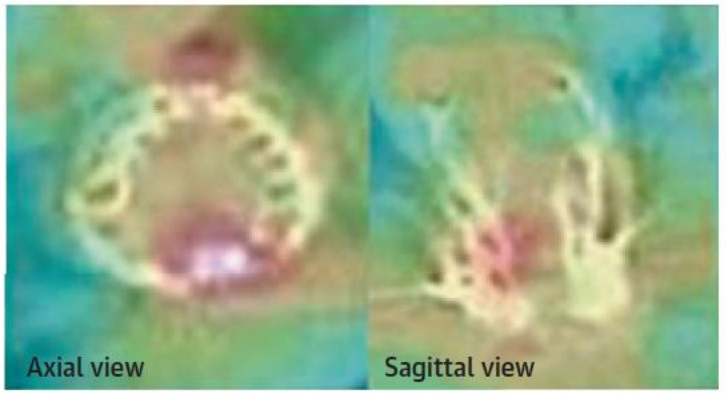


FDG UPTAKE IN DEFINITE IE-TAVI GROUP

Focal uptake (<25%)

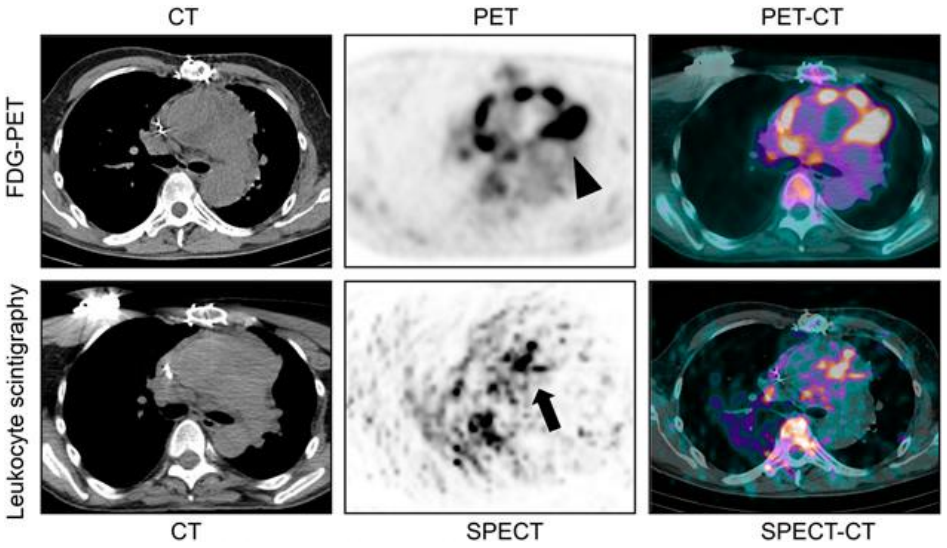


Multifocal uptake



San et al. JACC 2019

Scintigraphie aux leucocytes marqués



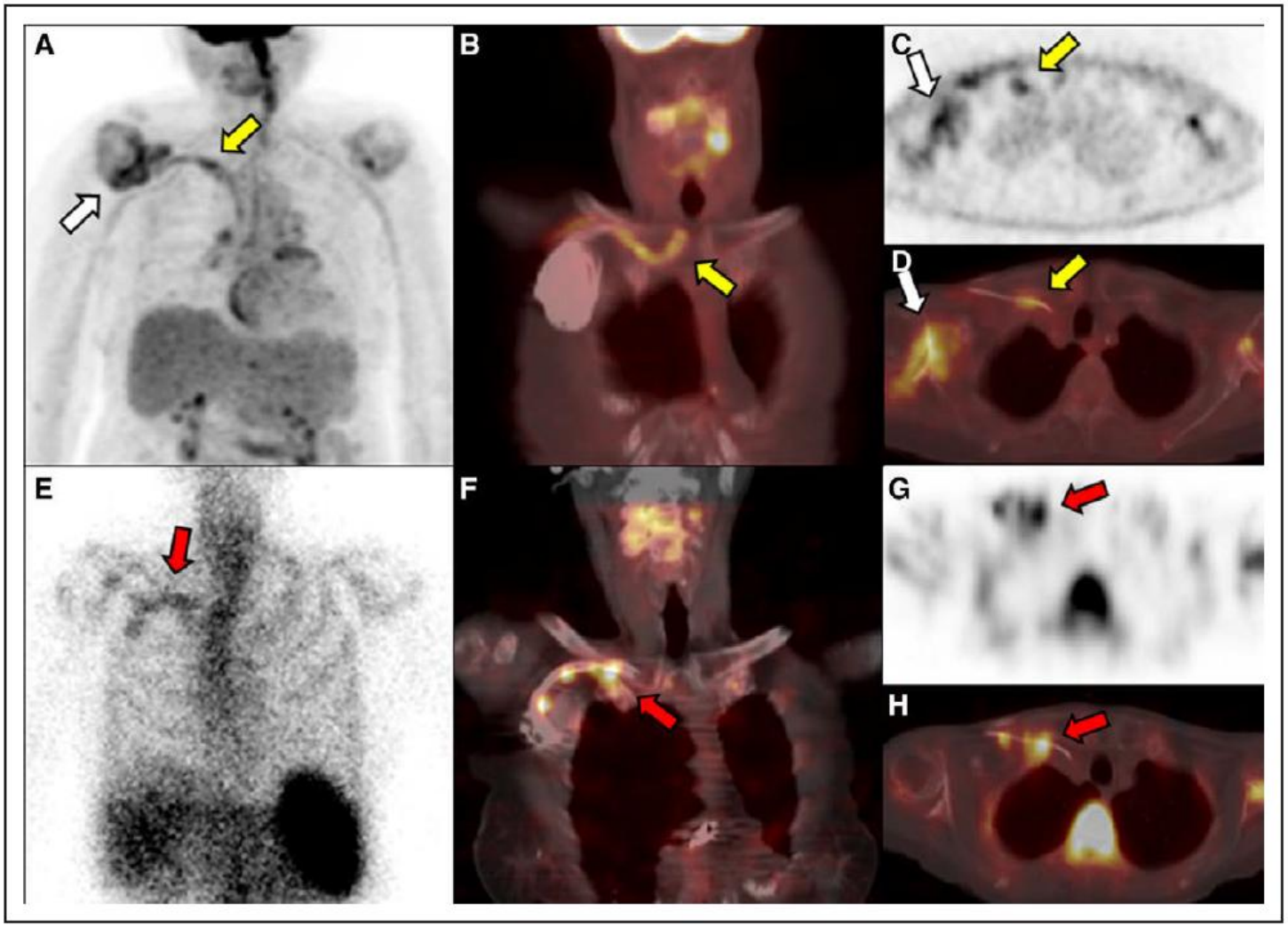
	PET-CT	SPECT-CT
Sensibilité	93%	64%
Spécificité	71%	100%
VPP	68%	100%
VPN	94%	81%

- 39 patients consécutifs Bichat
- Prothèses valvulaires
- Suspicion d'endocardite
- 14 jours à 24 ans après la chirurgie
- 15 jours d'antibiothérapie en moyenne
- **TEP + scinti aux leucos marqués**
- Suivi de 3 mois pour diagnostic définitif

=> 18 diagnostics « redressés »

Rouzet et al. The Journal Of Nuclear Medicine 2014

Scintigraphie aux leucocytes marqués: PM/DAI



Calais et al. Circ Cardiovasc Imaging 2019

Scanner cardiaque multicoupe

- Scanner volumique avec synchronisation ECG
- Atteintes péri valvulaires +++
- Complément de l'ETO en cas de prothèses (cônes d'ombres)
- Synchronisation ECG permet de réaliser un coroscanner

Scanner cardiaque multicoupe

Table 3 Diagnostic Performance of CT

	Percent	95% CI
For the Detection of Vegetations, Paravalvular Abscesses, and Pseudoaneurysms (37 Patients, 73 Valves) in Patients With Possible and Definite IE: Comparison With TEE		
Per-patient–based analysis		
Sensitivity (28/29)	97	82%–100%
Specificity (7/8)	88	47%–100%
Positive predictive value (28/29)	97	82%–100%
Negative predictive value (7/8)	88	47%–100%
Diagnostic accuracy (35/37)	95	82%–100%

Feuchtner et al. JACC 2009

Scanner cardiaque multicoupe

- 68 patients opérés du cœur gauche
- ETO avec reconstruction 3D et scanner cardiaque
- Comparaison aux constatations opératoires

=> impact sur la prise en charge ?

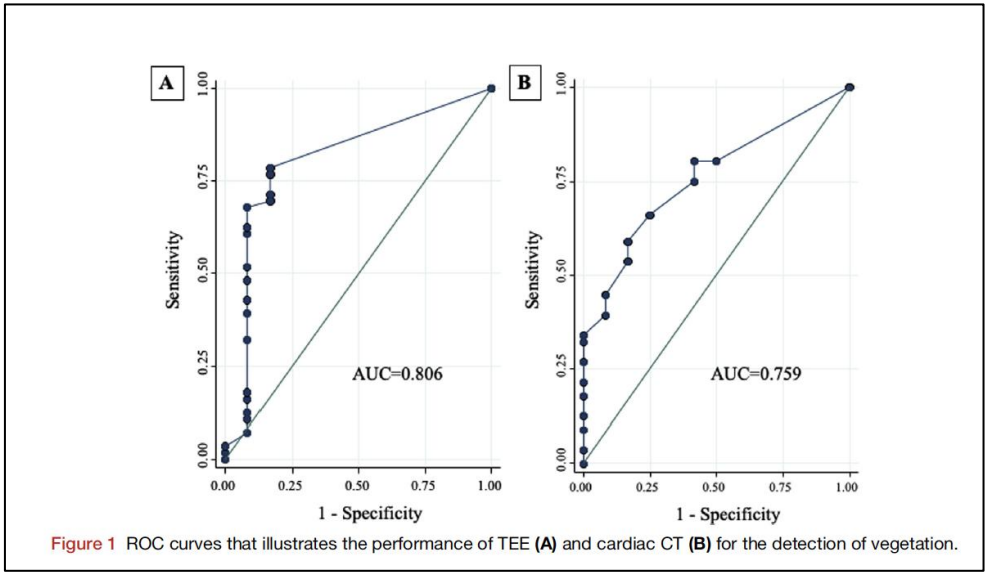


Figure 1 ROC curves that illustrates the performance of TEE **(A)** and cardiac CT **(B)** for the detection of vegetation.

HIGHLIGHTS

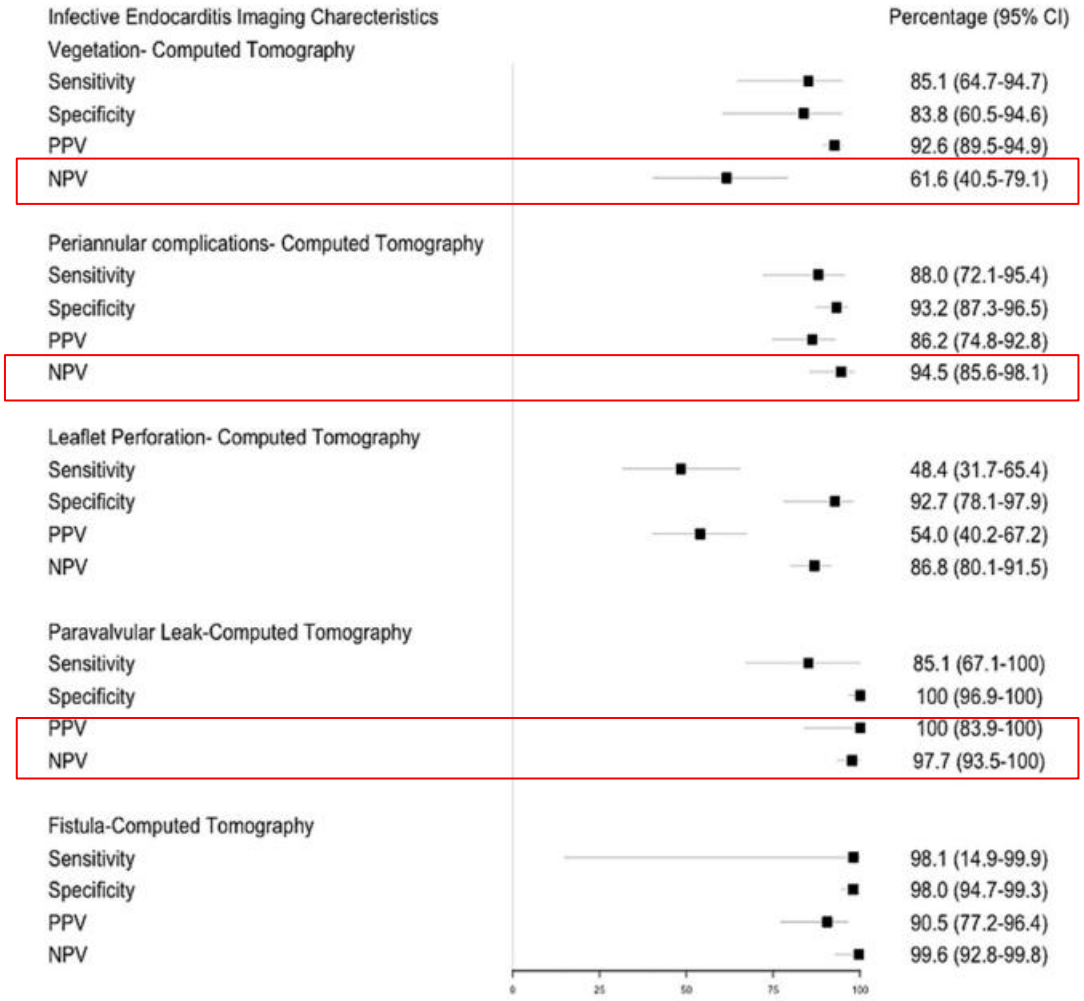
- TEE performed better than CT for detection of valvular IE-related lesions.
- TEE and CT were similar in the detection of paravalvular IE-related lesions.
- CT may be useful when TEE is equivocal or not feasible in left-side IE.

CT > TEE pour pseudo-anévrismes

Sifaoui et al. Journal of the American Society of Echocardiography 2020

Scanner cardiaque multicoupe

Diagnostic performance of cardiac computed tomography versus transesophageal echocardiography in infective endocarditis: A contemporary comparative meta-analysis



V. Jain et al. Journal of Cardiovascular Computed Tomography 15 (2021)

Rôle de l’imagerie en dehors de l’échographie cardiaque

Diagnostic de l’atteinte cardiaque = critère majeur

Diagnostic des atteintes extra cardiaques = critère mineur

Place de l'IRM cérébrale

Figure 2. Infarcts and microhemorrhages.

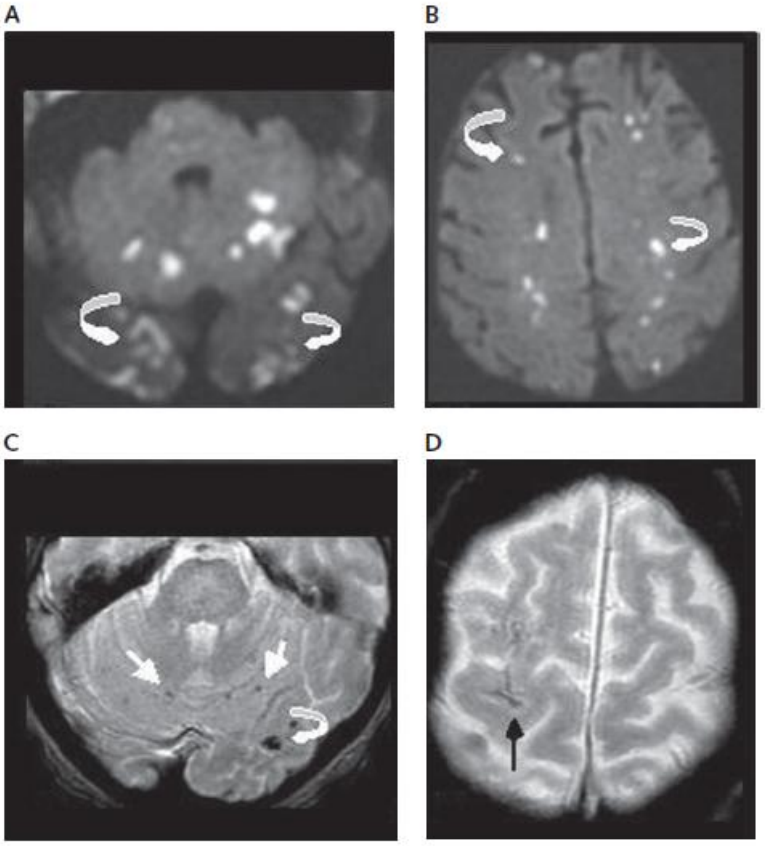


Table 3. Effect of Systematic MRI on Infective Endocarditis Diagnosis*

Diagnosis After MRI	Diagnosis Before MRI†		
	Definite (n = 77)	Possible (n = 50)	Excluded (n = 3)
Definite (n = 91 [101])	77	14 [24]	–
Possible (n = 39 [29])	–	36 [26]	3
Excluded (n = 0)	–	–	0

MRI = magnetic resonance imaging.
* Evaluated through the reclassification of Duke modified criteria in 130 patients. Numbers in square brackets include microhemorrhages as vascular phenomena in the Duke modified classification.
† According to Duke modified classification.

- IRM systématique chez 130 patients suspects d'EI
- 72% valves natives
- 17 cas « reclassés »(sans les micro-saignements)
  - 14 possibles => certaines
  - 3 exclus => possibles

Duval et al. Annals of Internal Medecine 2010

Impact de l'imagerie cérébrale

Clinical Infectious Diseases
MAJOR ARTICLE

Role of Cerebral Imaging on Diagnosis and Management in Patients With Suspected Infective Endocarditis

Matthaios Papadimitriou-Olivgeris,[1] Benoit Guery,[1] Nicoleta Ianculescu,[2] Vincent Dunet,[3] Yosra Messaoudi,[2] Silvia Pistocchi,[3] Piergiorgio Tozzi,[4] Matthias Kirsch,[4] and Pierre Monney[2]

- Hôpital de Lausanne
- Cohorte rétrospective de 190 EI + cohorte prospective de 1259 suspicion d'EI
- IRM 60%, Scanner cérébral 60% (77% avec PDC), les 2 examens 20%

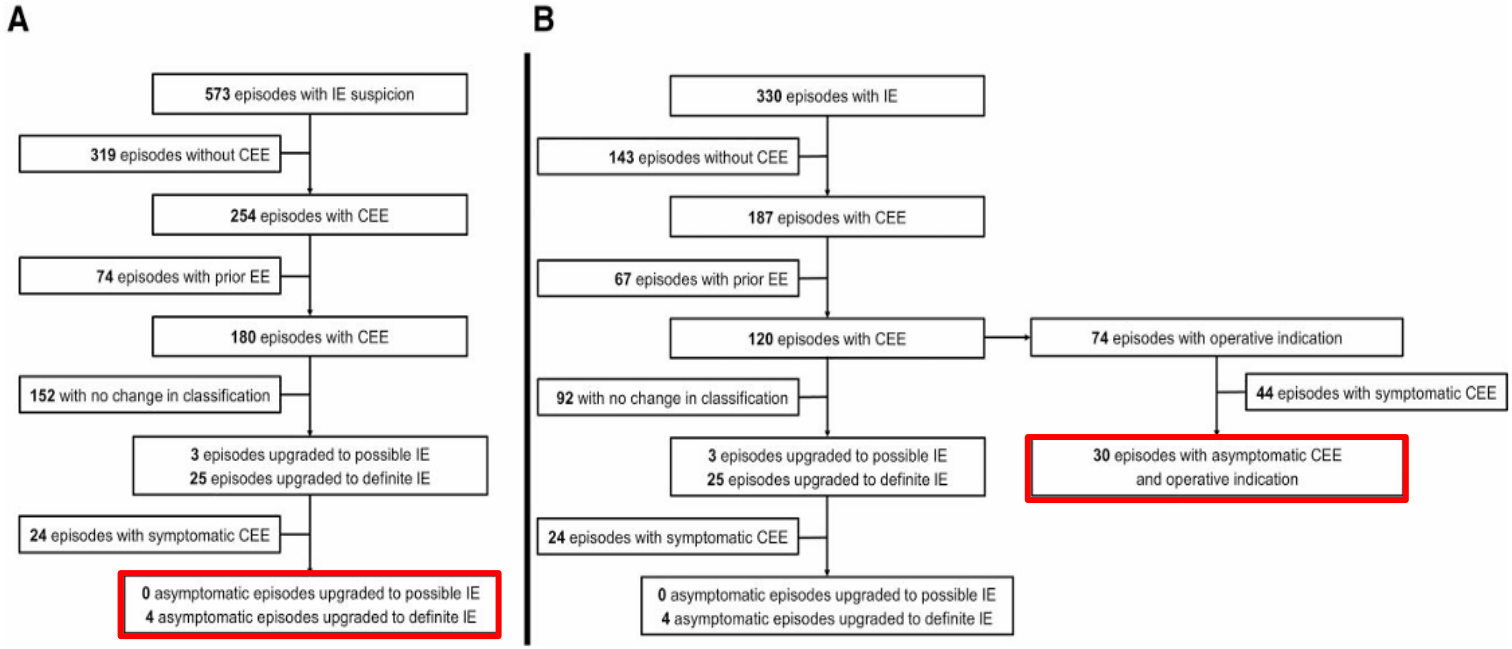


Figure 2. Changes in diagnostic classification management due to cerebral imaging results in patients suspected (*A*) and those with infective endocarditis (*B*). Abbreviations: CEE, cerebral embolic event; Cer-Im, cerebral imaging; EE, embolic event; IE, infective endocarditis.

Papadimitriou-Olivgeris et al. CID 2023

TEP TDM : localisations extra cardiaques

Impact of Systematic Whole-body ^{18}F-Fluorodeoxyglucose PET/CT on the Management of Patients Suspected of Infective Endocarditis: The Prospective Multicenter TEPvENDO Study

Clinical Infectious Diseases

MAJOR ARTICLE

140 patients avec suspicion d'EI

70 valves natives (VN), 70 valves prothétiques (VP)

Diagnostic définitif après 6 mois de suivi

Modification de la classification ESC : impact du TEP sur le diagnostic

- VN 5,7%
- VP 24, 3%

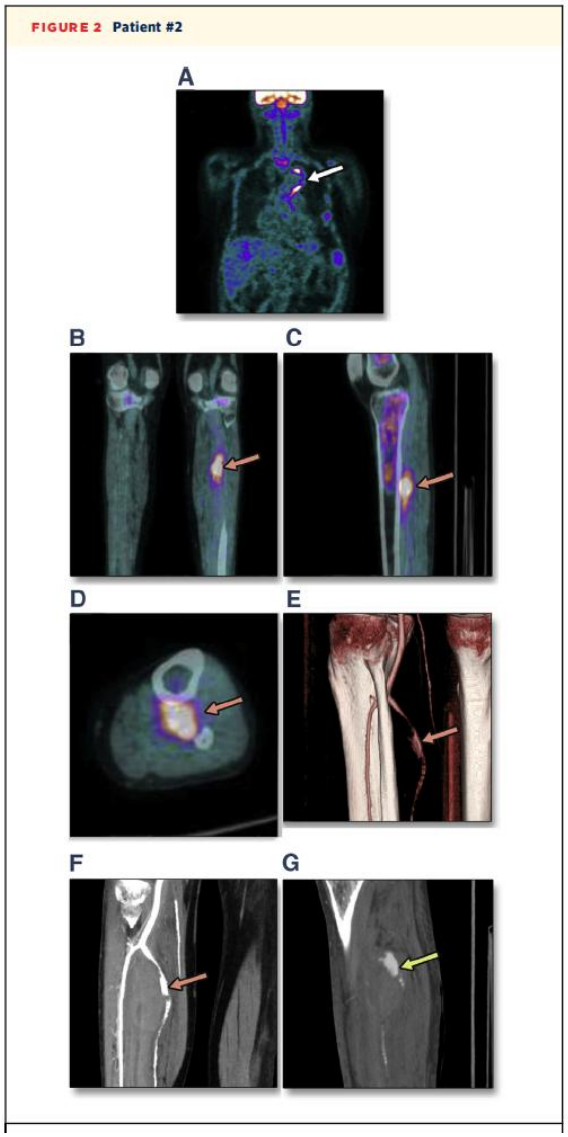
Modification de la prise en charge (ATB ou chir)

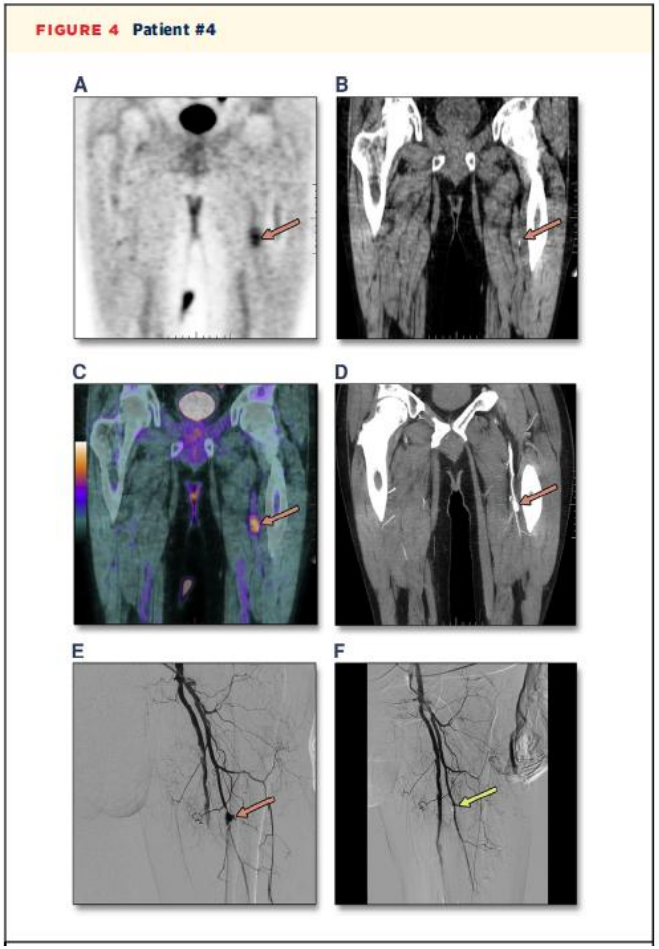
- VN 31,4%
- VP 21,4%

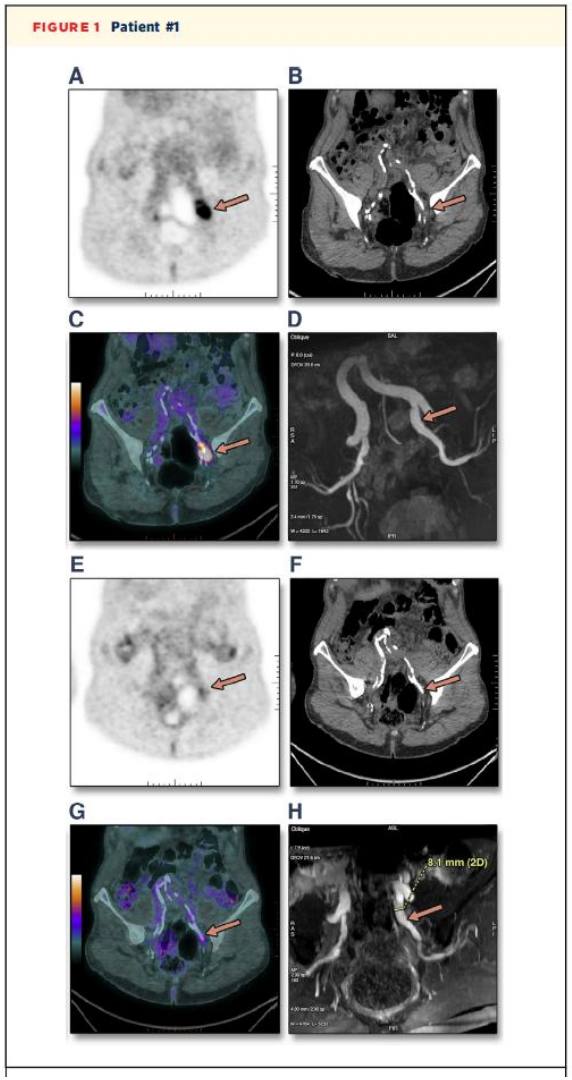
=> Détection et caractérisation des localisations infectieuses extracardiaques

Duval et al. CID 2020

TEP TDM : anévrysmes mycotiques







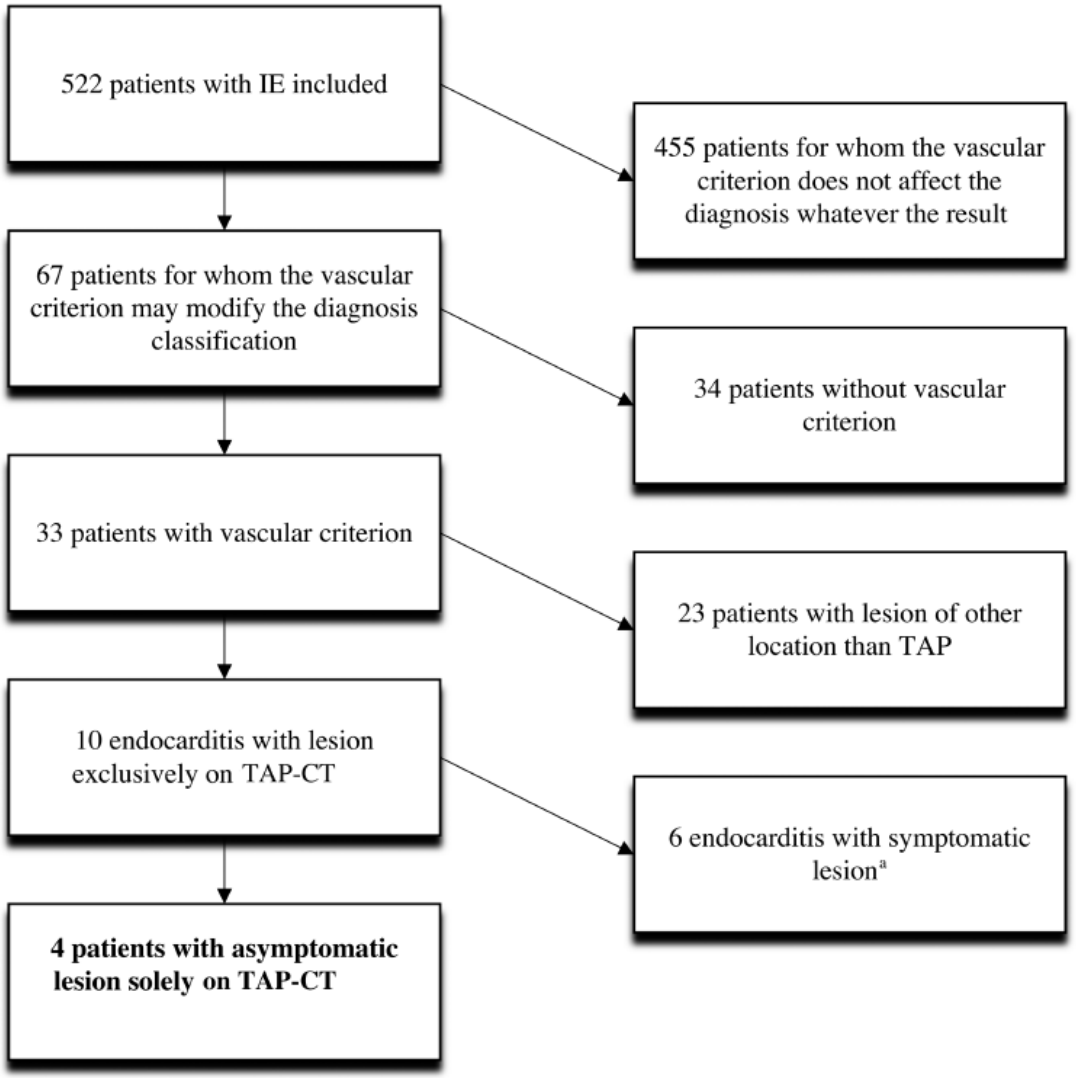
Mikail et al. JACC : Cardiovascular Imaging 2015

Scanner thoraco-abdomino-pelvien

Clinical Infectious Diseases

MAJOR ARTICLE

Modification du diagnostic ?



Lecomte et al. CID 2019

Scanner thoraco-abdomino-pelvien

Modification de la prise en charge ?

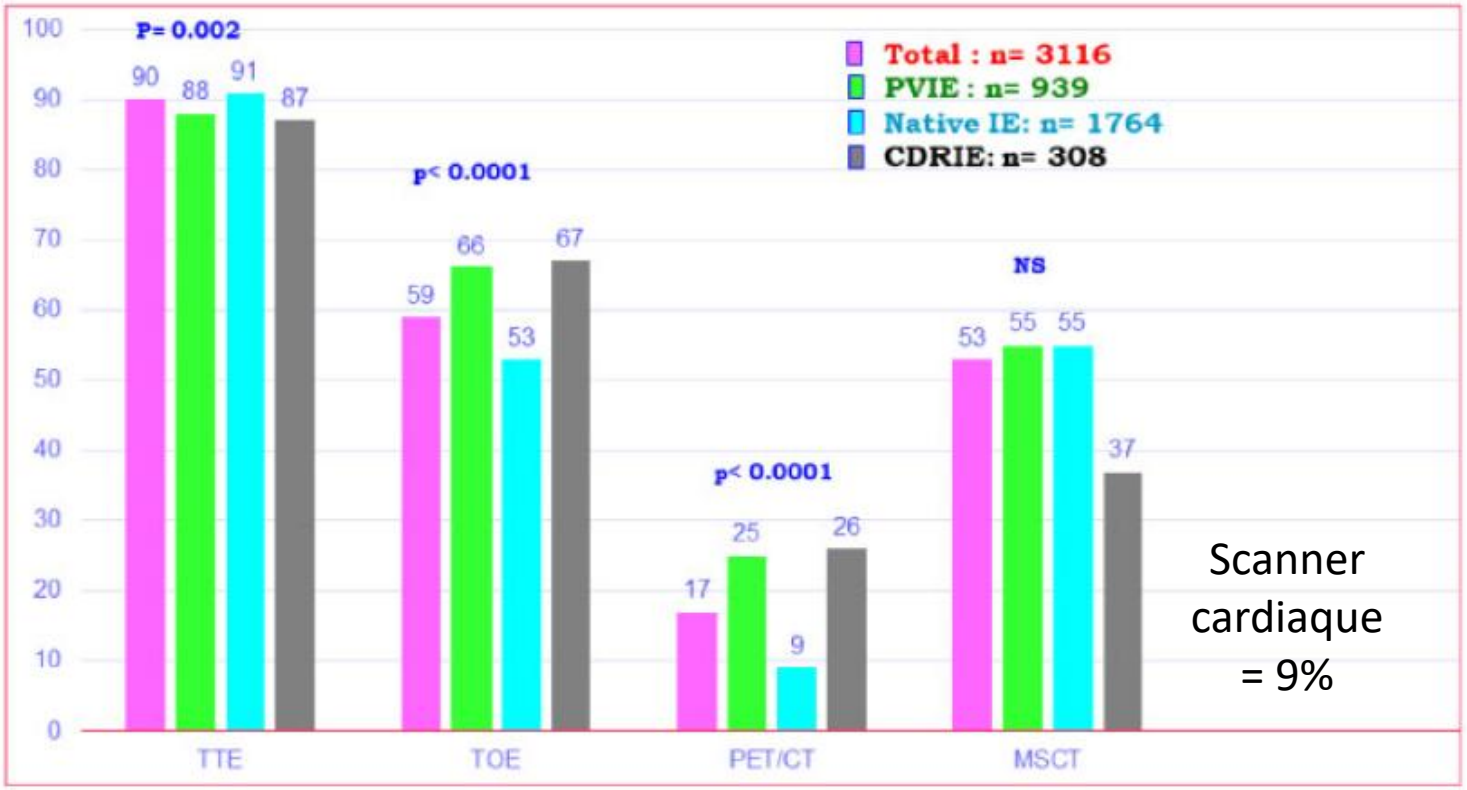
Lesion	Lesion on TAP-CT	Lesion With Modification of Treatment	Asymptomatic Lesion With Modification of the Treatment
Spondylodiscitis	25	23	5
Abscess[a]	254	10	0
Vascular	11	3	2
Pulmonary	39	6	2
Total	325	42	9

IRA chez 78 patients (17%) dans les 5 jours suivant le scanner

Lecomte et al. CID 2019

En pratique ? Cohorte EURO-ENDO

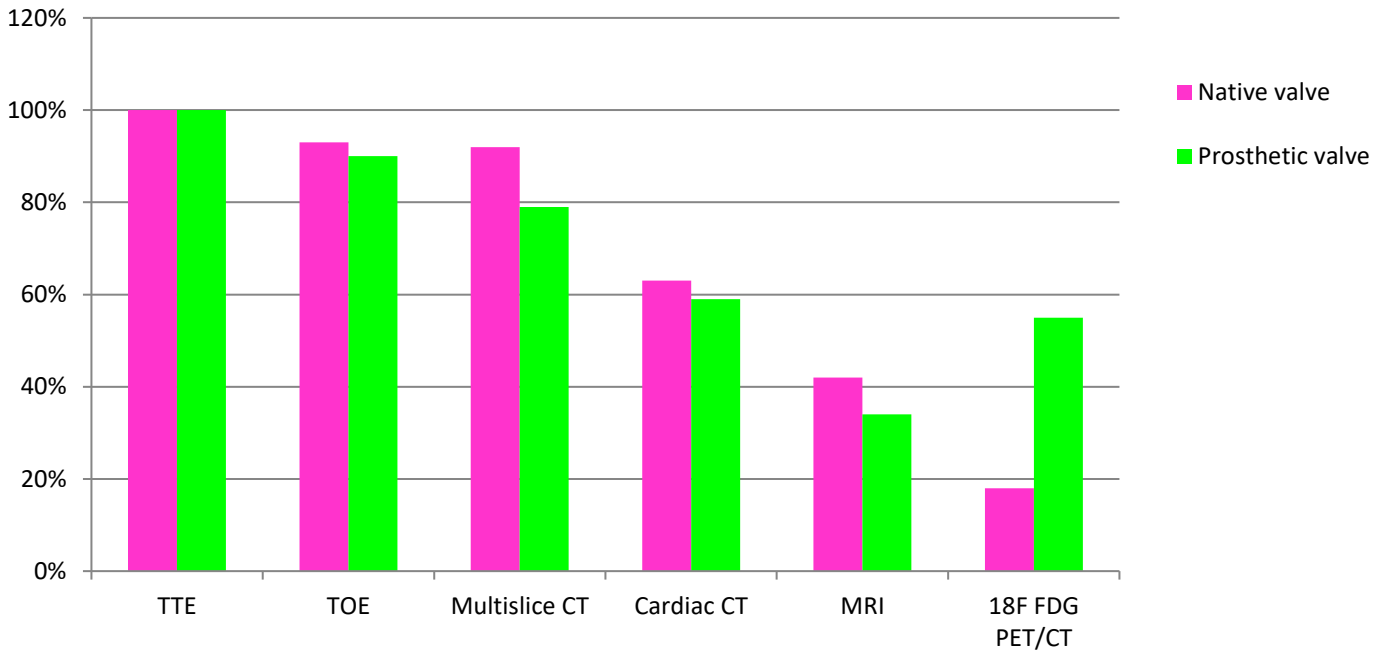
Place de l'imagerie ?



Scanner cardiaque = 9%

Habib G et al, European Heart Journal 2019

En pratique ? Cohorte Mondor



- PET CT was more frequently used in PVIE (55%) VS in NVE (18%),
- PET CT was positive in 37% with a better sensitivity in PVIE (60%)

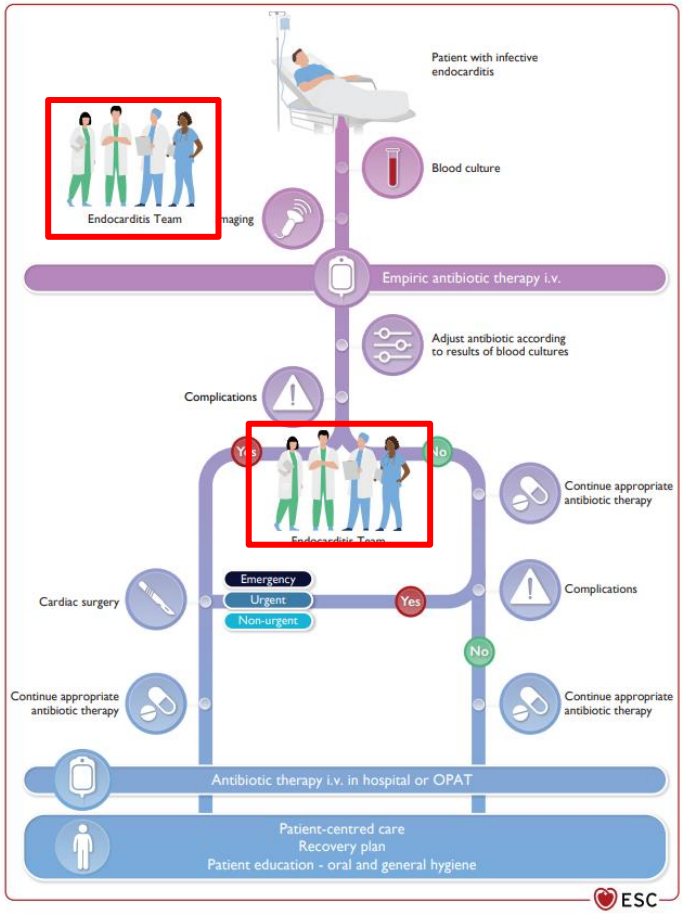
AP-HP.
Hôpitaux universitaires
Henri-Mondor

Imagerie

SOS ENDOCARDITES
APHP- CHU HENRI MONDOR

Endocardites certaines et possibles (N=130)	N	%
ETT	130	100,00%
ETO	117	90,00%
Coronarographie	10	7,69%
IRM cérébrale	41	31,54%
TDM cérébral	102	78,46%
TDM TAP + cœur	117	90,00%
^{18}FDG PET-TDM	58	44,62%
• *PET TDM sur prothèse*	*27*	
• *PET TDM native*	*23*	
• *PET CIED*	*8*	

Endocarditis team

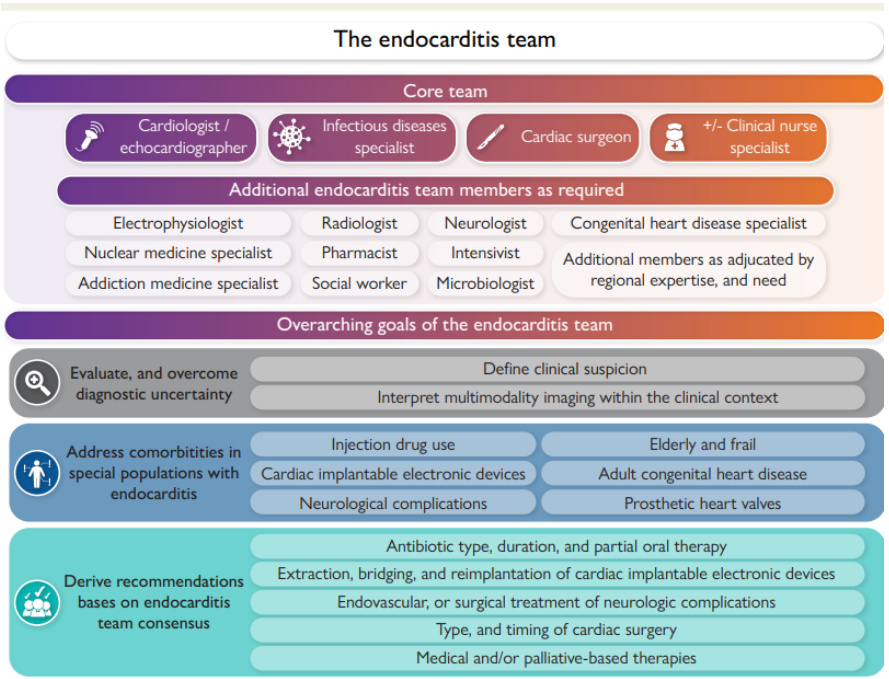


V. Delgado et al. European Heart Journal 2023

ESC European Society of Cardiology
European Heart Journal (2025) **46**, 2275–2288
https://doi.org/10.1093/eurheartj/ehaf219

STATE OF THE ART REVIEW
Valvular heart disease

Infective endocarditis: it takes a team



Lau et al. European Heart Journal 2025

Conclusions

- **Echocardiographie** reste l'examen de référence mais plusieurs techniques d'imagerie alternatives à l'échocardiographie

- **TEP scanner**
  - Intérêt diagnostic largement validé sur **valves prothétiques**
  - Sur valves natives intérêt potentiel pour la recherche des **localisations secondaires**, intérêt sur la prise en charge ?
  - Profil de la fixation > délais de la chirurgie

- Scanner cardiaque
  - Complément de l'échocardiographie ou quand ETO impossible
  - Moins performant sur les végétations mais intérêt sur les **lésions péri-valvulaires**
  - Associé au scanner TAP systématiquement ?

- IRM Cérébrale :
  - **Intérêt diagnostic** validé pour la recherche de localisations cérébrales asymptomatiques
  - Intérêt dans la prise en charge thérapeutique à définir

- Situations souvent complexes

- Imagerie multi modale et équipe multidisciplinaire : « Endocarditis team »