JFMN

29 mai 2015

Actualités TEP-IRM en cardiologie

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UniversityHospital Zurich

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COI Disclosure:
Institutional research contract with GE Healthcare

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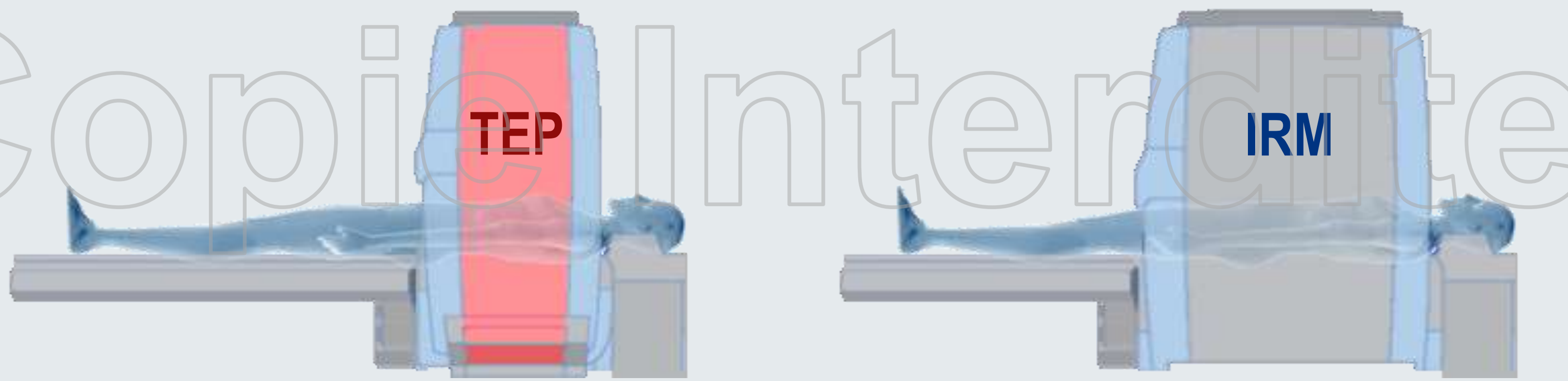
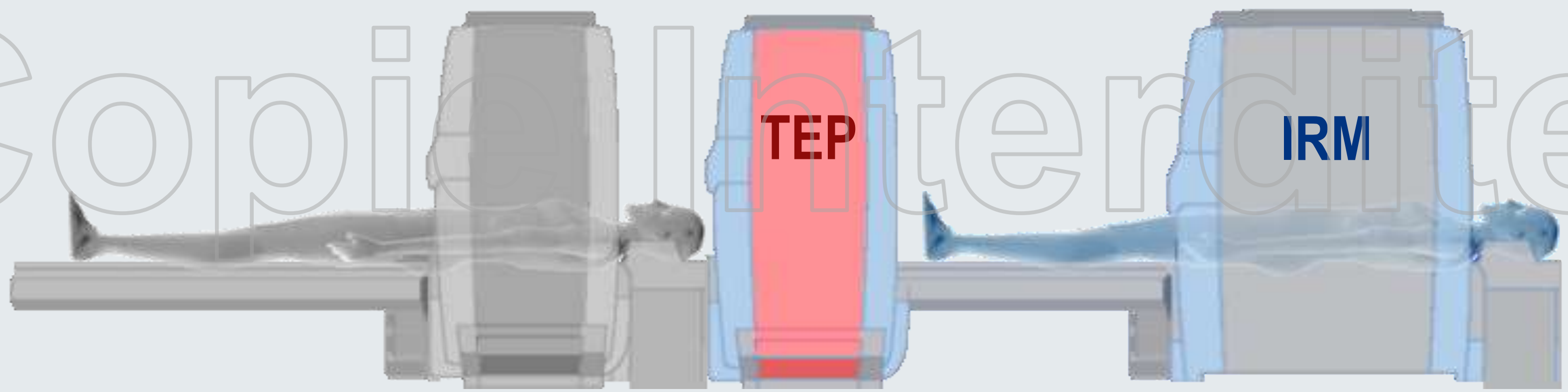
Volume 22, Number 2 / April, 2015

Examen hybride TEP-IRM



Séparés

Examen hybride TEP-IRM



Séparés ➡ Co-planaires

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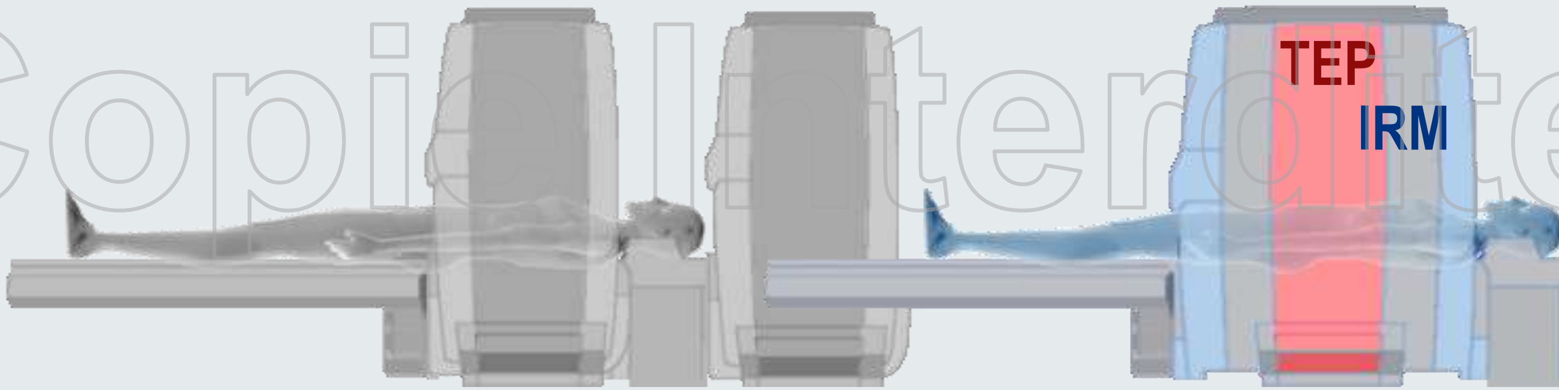
Remerciements à M. Wissmeyer

HUG Hôpitaux Universitaires de Genève

Examen hybride TEP-IRM



Séparés ➡ Co-planaires ➡ Intégrés

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Remerciements à M. Wissmeyer

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SIGNA PET/MR
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Table 1. Avantages et limitations des différentes modalités d'imagerie cardiovasculaire

	TEP	TDM	IRM
Avantages	Haute sensibilité des traceurs pour l'imagerie moléculaire Correction d'atténuation intégrée Quantification de la perfusion myocardique dans la maladie coronarienne et la maladie microvasculaire Evaluation de la viabilité Evaluation de l'inflammation	Haute résolution spatiale Imagerie détaillée des vaisseaux coronaires et de l'anatomie Quantification des calcifications coronariennes Durée d'examen plus courte de l'IRM Employé chez les patients avec des appareils métalliques implantés Généralement disponible	Haute résolution spatiale et temporelle Excellent contraste des tissus mous Evaluation des cicatrices par RTG (LGE) Evaluation de l'anatomie et de la fonction Evaluation de la perfusion myocardique Potentiel d'imagerie moléculaire Pas de radiation ionisante
Désavantages	Manque d'informations anatomiques détaillées Exposition aux radiations Pas généralement disponible Manque de large disponibilité des traceurs Coûteux	Exposition aux radiations Contraste contre-indiqué lors d'insuffisance rénale Risque de néphropathie due au contraste Limité chez les patients avec arythmie ou fréquence cardiaque élevée Données fonctionnelles seulement par acquisition rétrospective	Contre-indication pour certains appareils implantés Gadolinium contre-indiqué lors d'insuffisance rénale Claustrophobie du patient Requiert la coopération du patient Examen relativement long Coûteux

Examen hybride TEP-IRM

- Original motivation
  - To improve PET spatial resolution by reducing the range of positron travel within a magnetic field

    B. E. Hammer et al., "Use of a magnetic field to increase the spatial resolution of positron emission tomography," Med. Phys. 21 (1994).

- Motivation has shifted to simultaneous image acquistion
  - Similar acquisition times for MR and PET (~minutes)
  - Real-time MR (e.g., navigator-based planar imaging) can be used to rebin the PET data (4D PET)

- Early challenge: MR-compatible PET detectors
  - A single ring LSO detector within the magnetic field
  - Coupled to position-sensitive PMTs placed outside the field
  - Long (3-4 m) fiber optic coupling (Simon Cherry, UCLA)

    K. Farahani et al., "Contemporaneous positron emission tomography and MR imaging at 1.5 T," J. Magn. Reson. Imaging 9 (1999).

Modified from Siewerdsen 2010, Toronto

A-t-on vraiment besoin d'un TEP/IRM hybride?

Med. Phys. 34 (5), May 2007

Simultaneous PET/MR will replace PET/CT as the molecular multimodality imaging platform of choice

Habib Zaidi, Ph.D.
Division of Nuclear Medicine, Geneva University Hospital, CH-1211 Geneva 4, Switzerland

Osama Mawlawi, Ph.D.
Department of Imaging Physics, The University of Texas M. D. Anderson Cancer Center, Houston, Texas 77030

Colin G. Orton, Ph.D., Moderator

(Received 30 March 2007; accepted for publication 30 March 2007; published 17 April 2007)

Zaidi

Mawlawi

Advantages of PET-MR

Simultaneous; therefore identical physiological conditions
Faster than sequential scanning; no motion
Better soft-tissue contrast resolution
No radiation dose (MR), supporting sequential studies, pediatrics, etc.
MR can be used with a variety of contrast agents for functional imaging
MRS can provide biochemical content matched to metabolism (PET)
Increased functionality: MR, fMR, MRS, and PET

Disadvantages

Expensive
Slow
Difficult to derive attenuation coefficents for PET attenuation correction
Diagnostic utility for whole-body imaging not clear

Modified from Siewerdsen 2010, Toronto

Eur J Nucl Med Mol Imaging (2010) 37:980–990
DOI 10.1007/s00259-009-1378-4

SPECIAL CONTRIBUTION

Integrating imaging modalities: what makes sense from a workflow perspective?

Gustav K. von Schulthess · Cyrill Burger

Integrated imaging in the form of PET/CT has virtually replaced PET alone, and integrated SPECT/CT is replacing SPECT in many institutions. Recently, there has been a surging interest in PET/MR and some experimental systems are available. In principle any combination of cross-sectional imaging devices into an integrated system is of interest. However, the added value of the integrated system depends on several factors. The following factors support imaging system integration:

1. The devices which are combined in an integrated system complement each other technically and/or clinically.
2. The inherent match of the acquired images has substantial advantages over software fusion of images acquired on separate devices.
3. The clinical workflow is improved by system integration.
4. The integrated system has financial advantages over separate systems, i.e. it is more cost-effective.

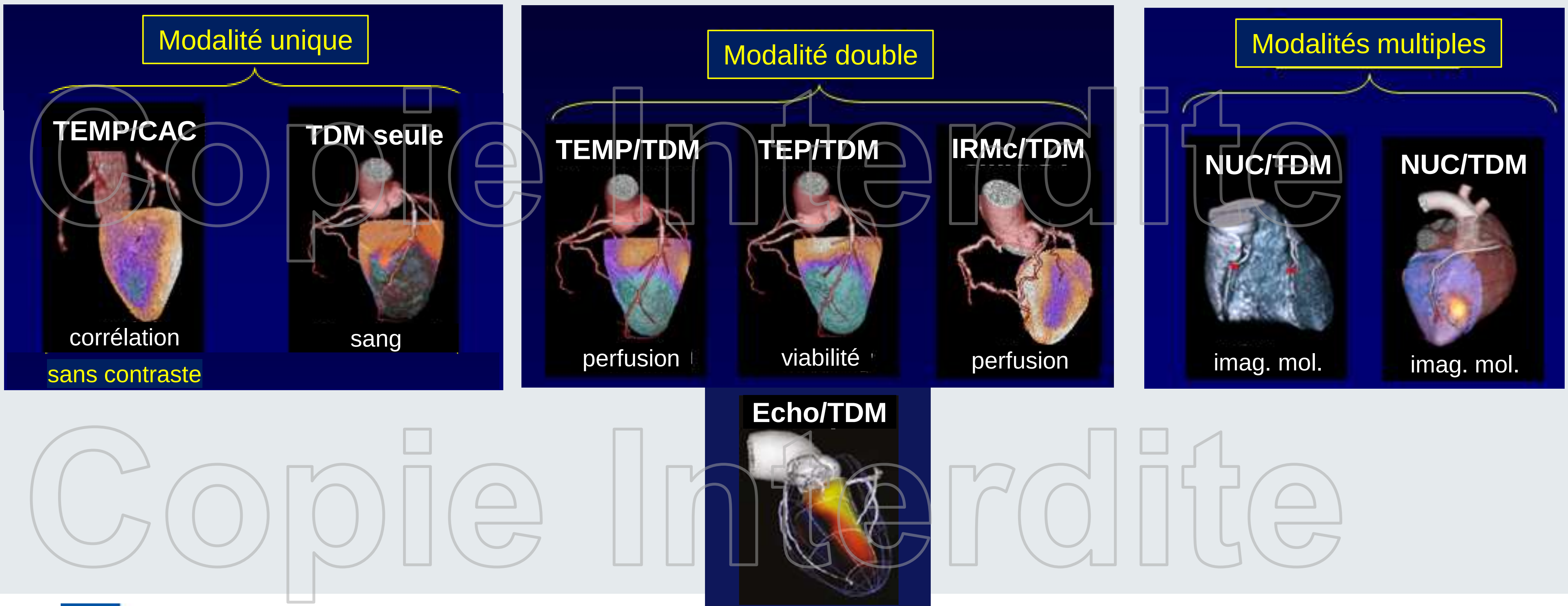
Table 2 Cost assumptions for the analysed cross-sectional imaging systems in euros

Amortization and interest									
Depreciation time of equipment	Years	8							
Depreciation time of building	Years	20							
Annual interest rate		0.05							
Investment costs	PET	SPECT	CT	MR	PET/CT	SPECT/CT	PET/MR Full integrat.	PET/MR Same room	PET(/CT)/MR Different room
Scanner	1,200,000	500,000	1,000,000	1,300,000	1,600,000	1,200,000	2,800,000	2,400,000	2,800,000
Building	1,400,000	1,200,000	1,400,000	1,400,000	1,500,000	1,400,000	1,500,000	1,500,000	2,400,000
Fixed costs									
Scanner amortization	150,000	62,500	125,000	162,500	200,000	150,000	350,000	300,000	350,000
Capital cost	30,000	12,500	25,000	32,500	40,000	30,000	70,000	60,000	70,000
Building amortization	70,000	60,000	70,000	70,000	75,000	70,000	75,000	75,000	120,000
Building capital cost	35,000	30,000	35,000	35,000	37,500	35,000	37,500	37,500	60,000
Service contract	90,000	40,000	110,000	90,000	150,000	130,000	170,000	170,000	170,000
Upgrades	30,000	20,000	30,000	30,000	40,000	40,000	50,000	50,000	50,000
Infrastructural cost	35,000	30,000	35,000	35,000	40,000	40,000	55,000	55,000	55,000
Total fixed costs	440,000	255,000	430,000	455,000	582,500	495,000	807,500	747,500	875,000
Operating hours/year	1,920	1,920	2,400	2,400	1,920	1,920	1,920	1,920	1,920
Total fixed costs per scanning min	3.82	2.21	2.99	3.16 +	5.06	4.30	7.01 >	6.49	7.60

Eur J Nucl Med Mol Imaging (2010) 37:980–990

Imagerie cardiaque intégrée

La combinaison de différentes modalités permet un diagnostic individualisé pour un traitement personnalisé



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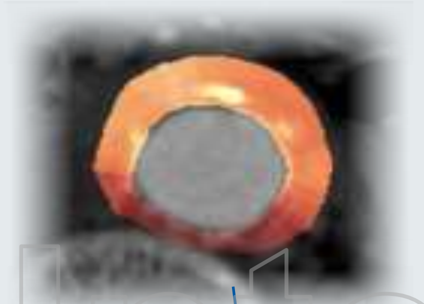
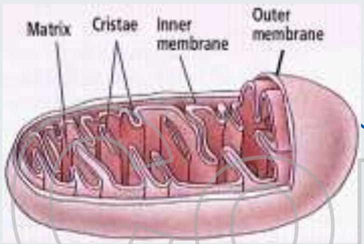
Imagerie cardiaque moléculaire

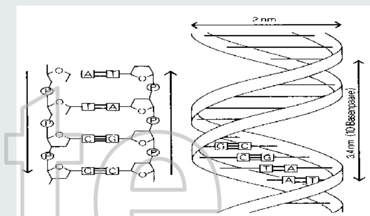
Imagerie de plaque



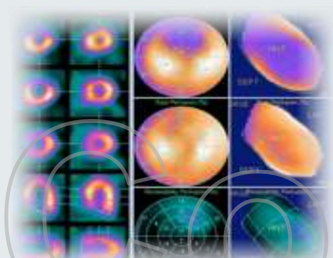
Métabolisme



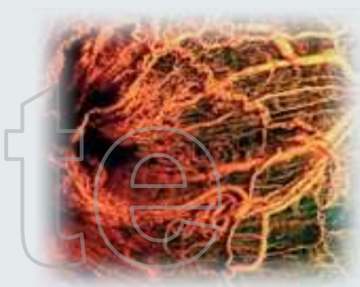
Expression des gènes



Imagerie de perfusion



Angiogenèse



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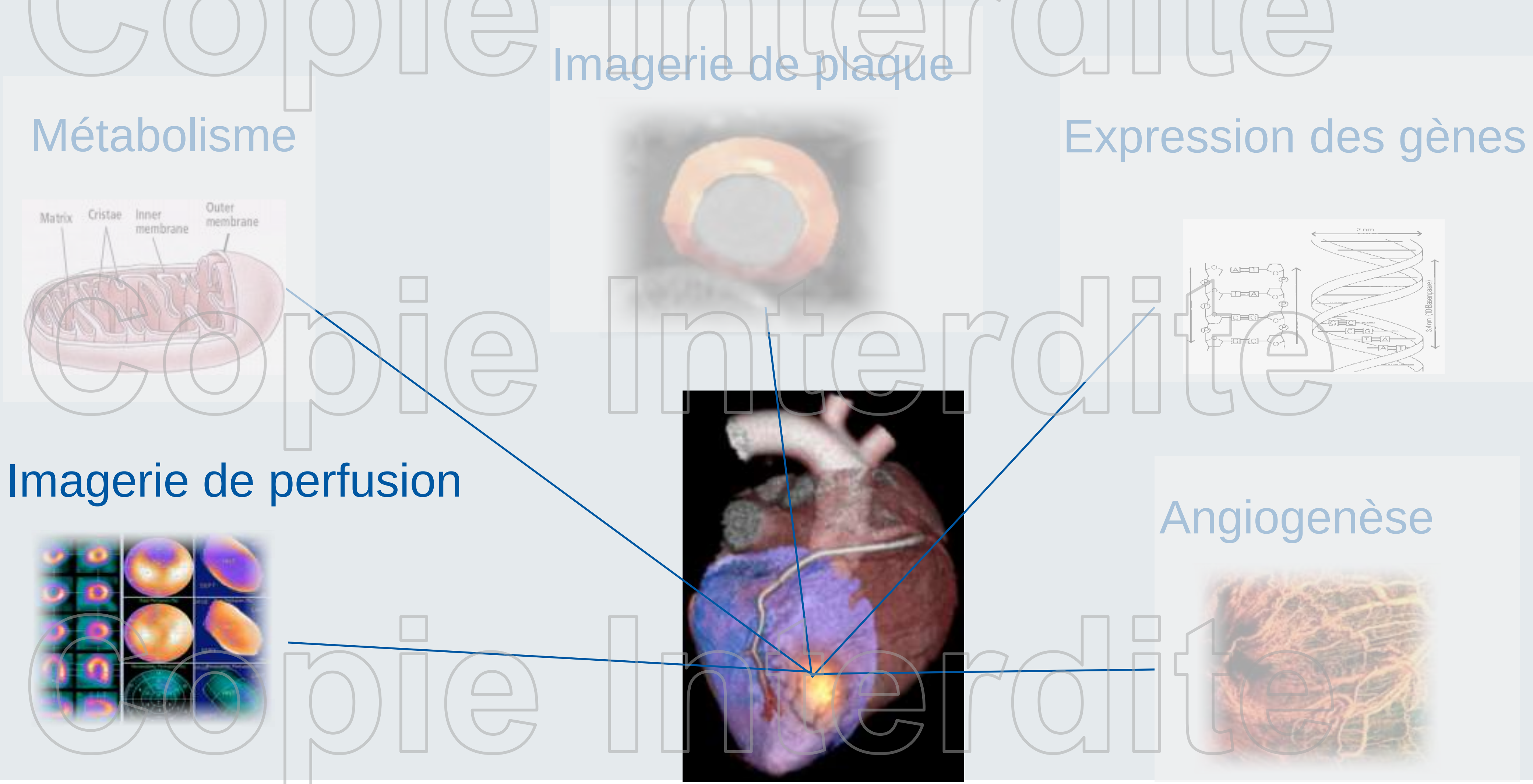
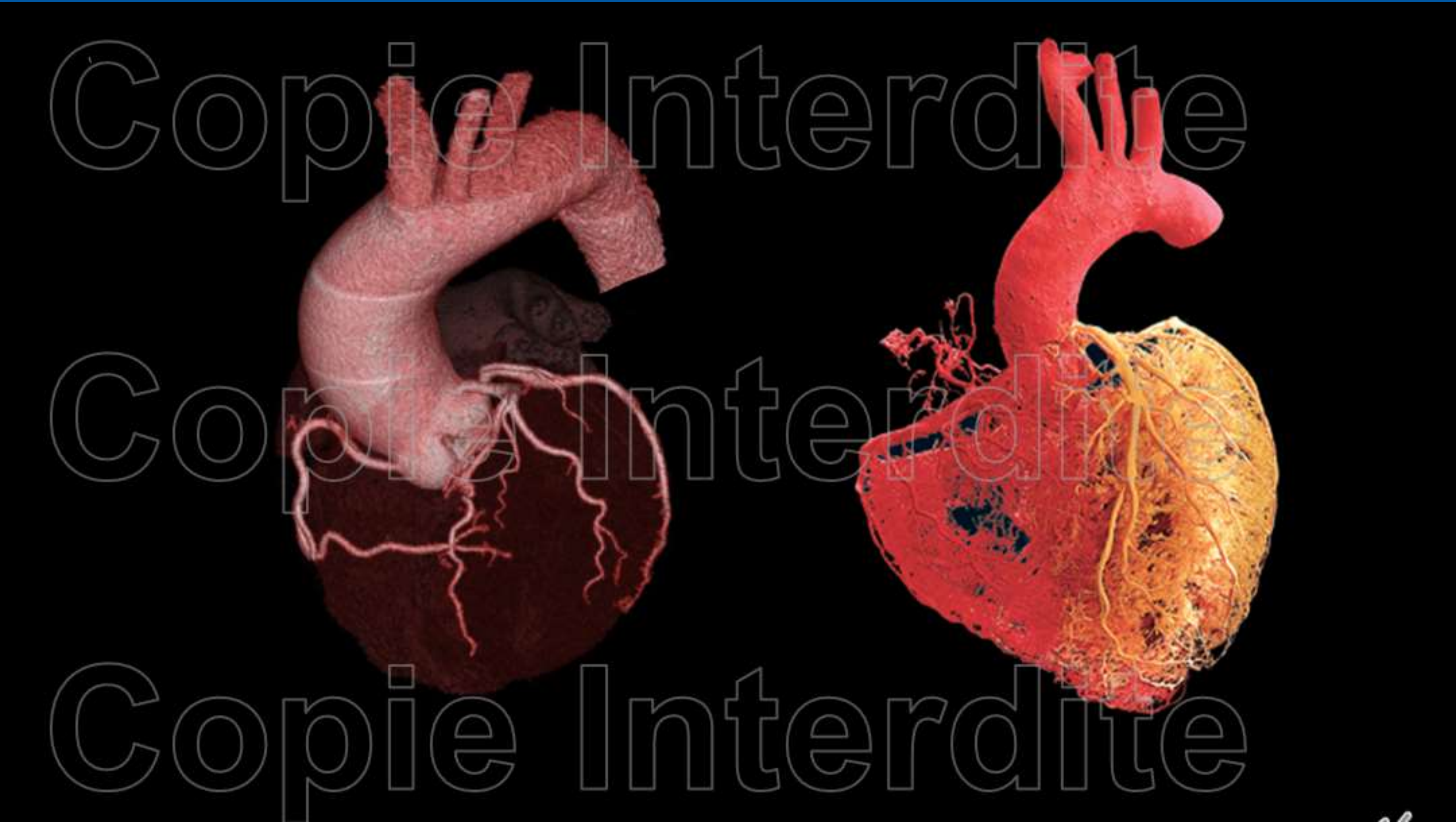
Imagerie cardiaque moléculaire



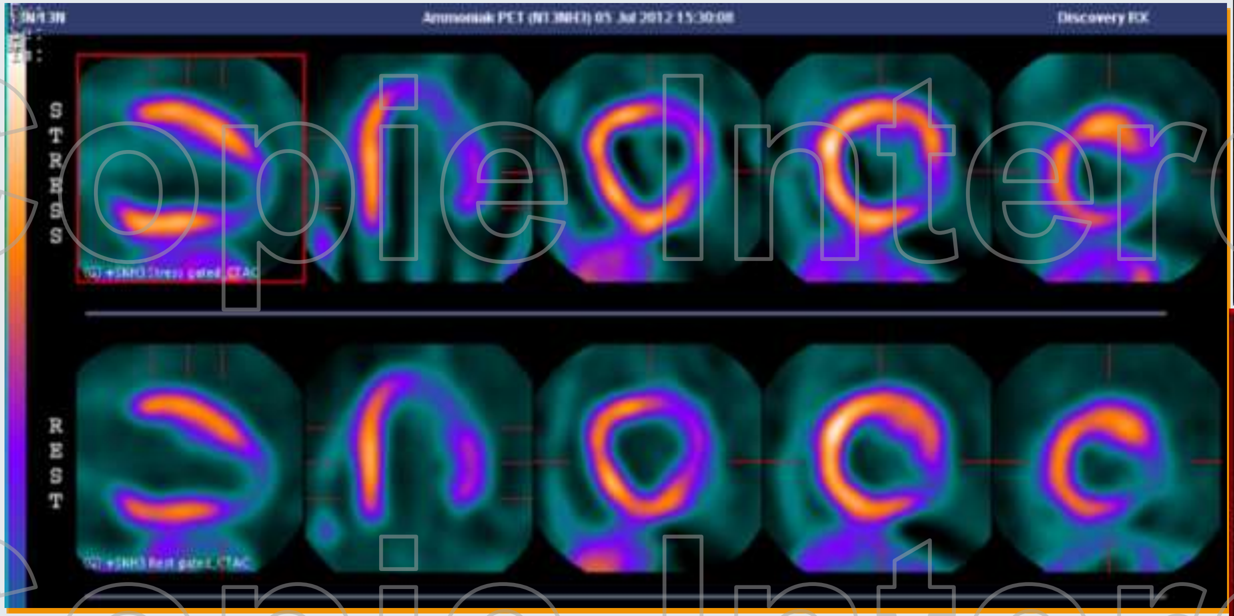


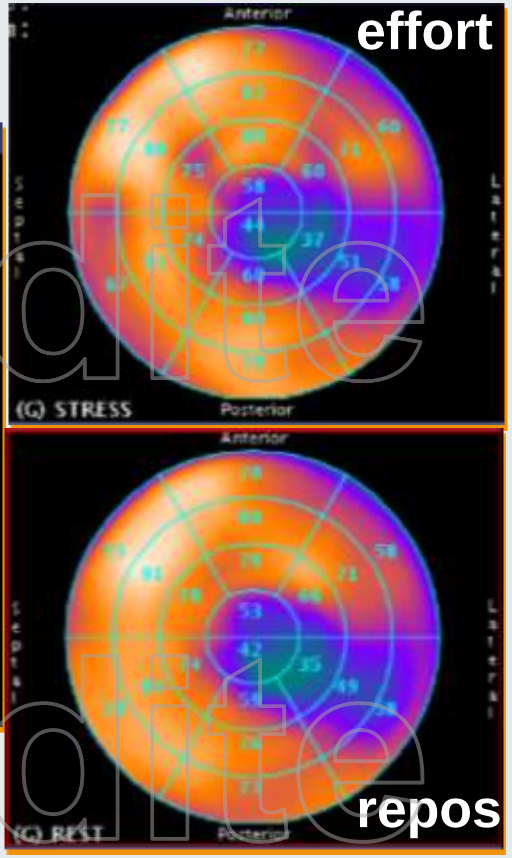
TEP cardiaque

TEP de perfusion au $^{13}N\text{-}NH_3$

effort

repos





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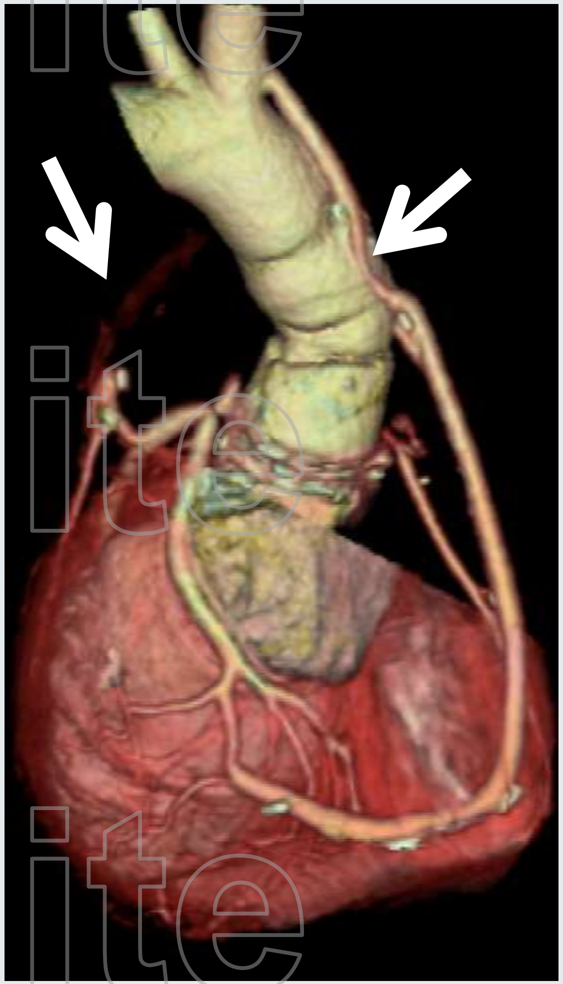
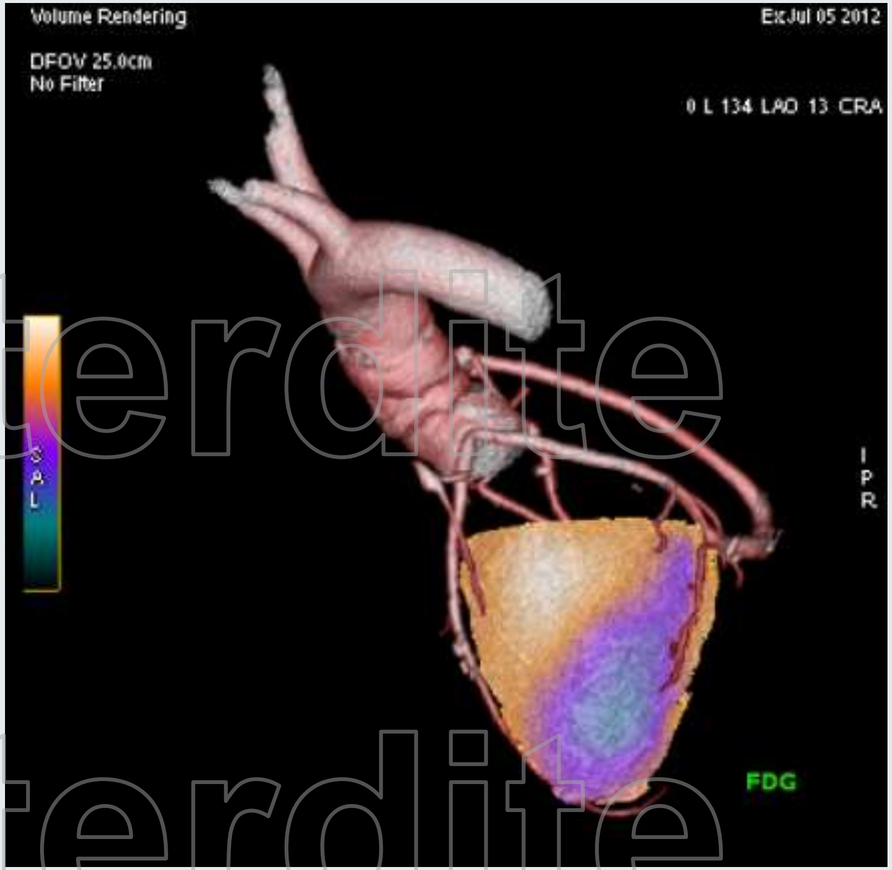


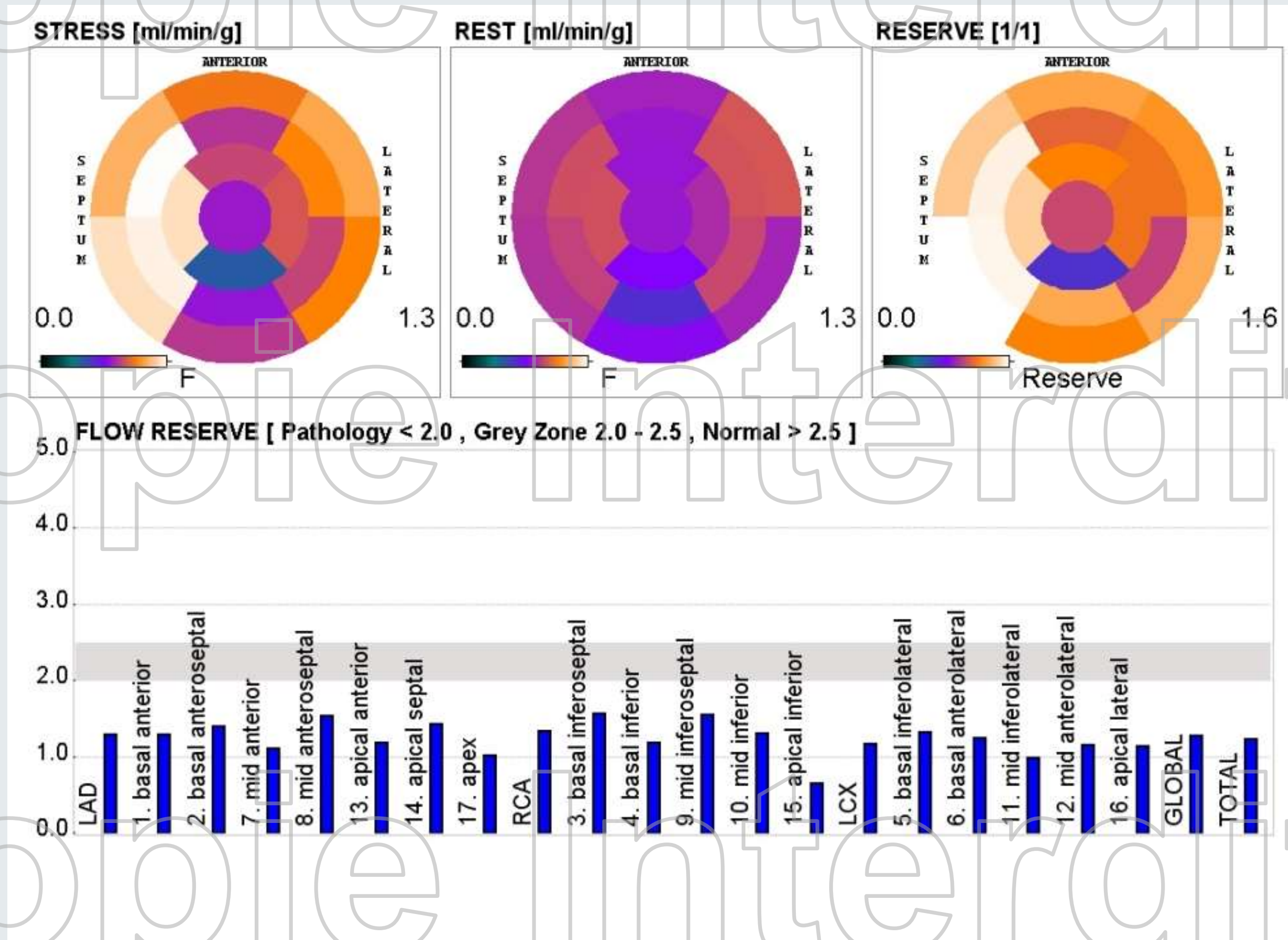
TEP cardiaque

Défaut de perfusion fixe



Pas de viabilité par FDG

TEP cardiaque: réserve de flux coronarien



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Stent à élution 4,0 x 33 mm

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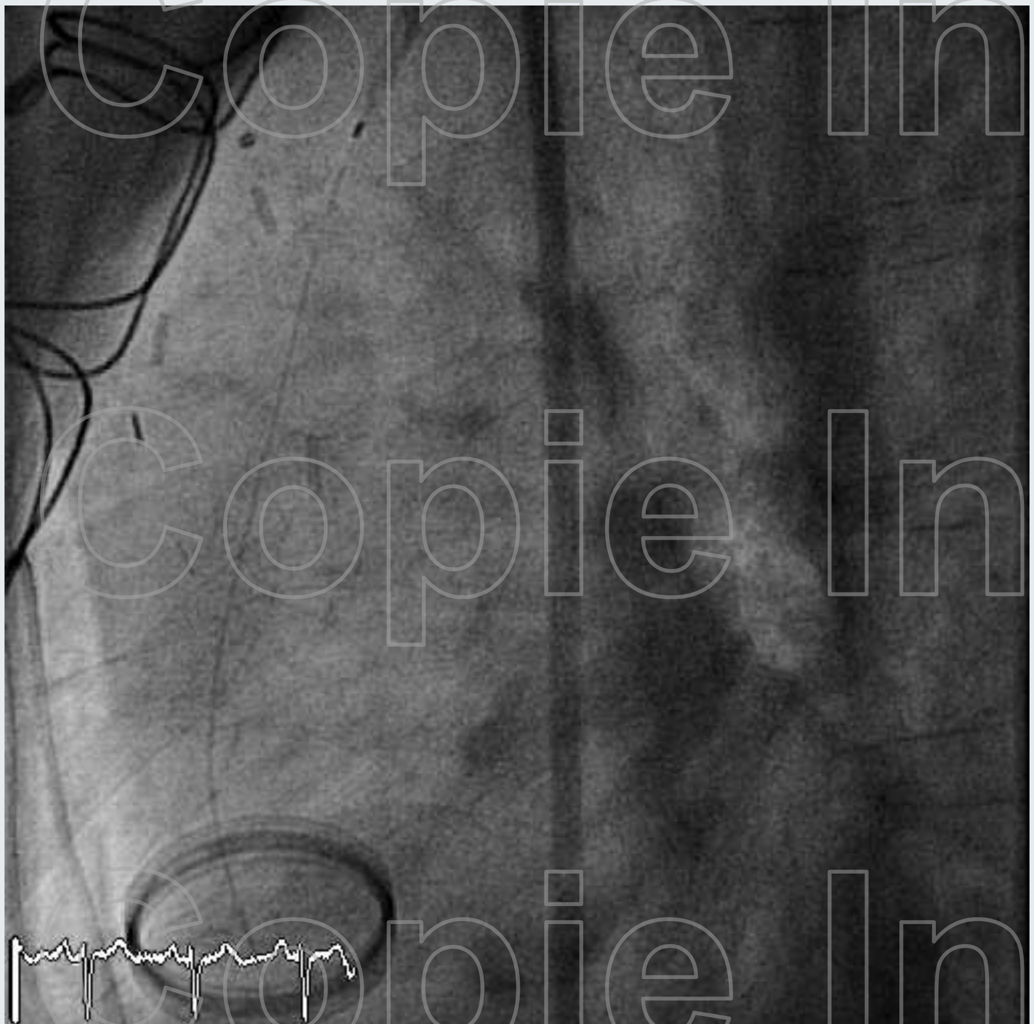

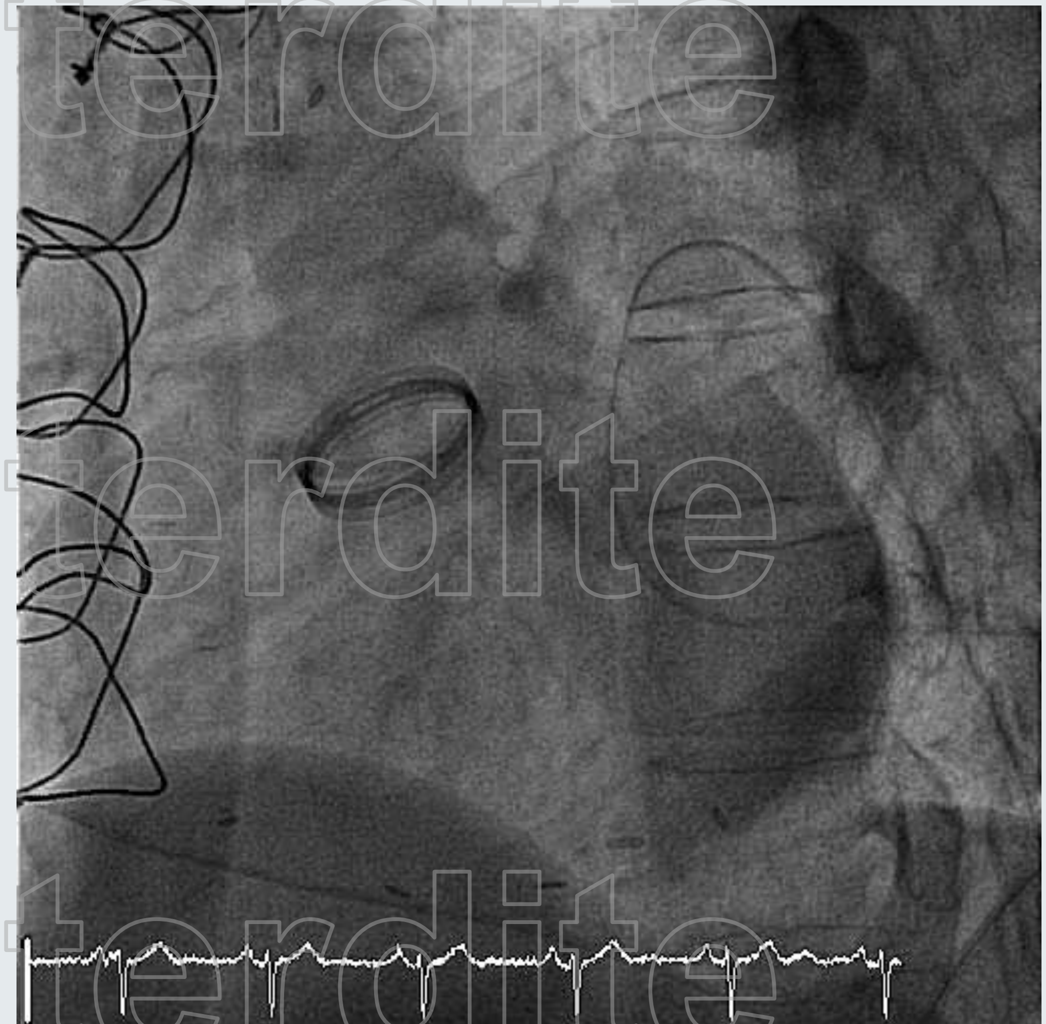

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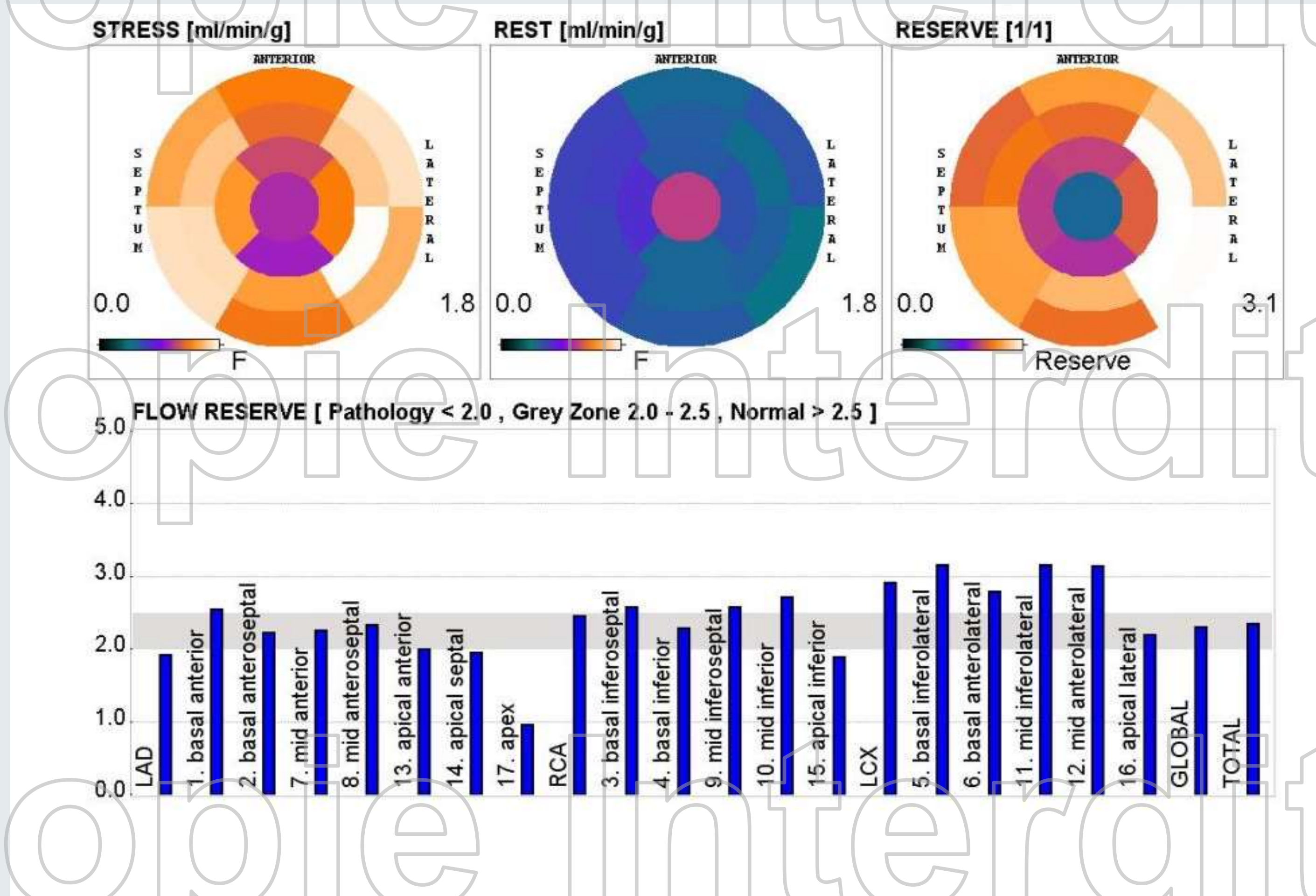
TEP cardiaque: réserve de flux coronarien

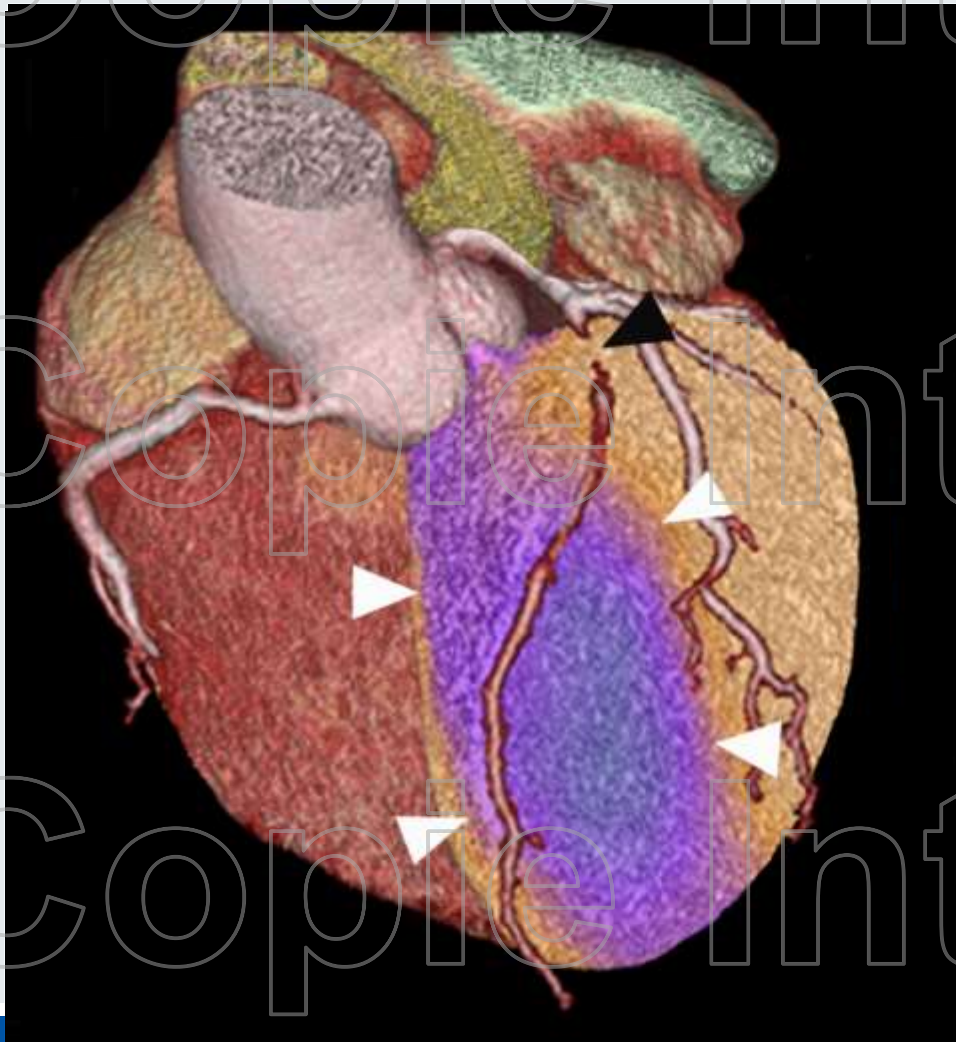


Après

TEMP/TDM

effort uniquement

Angiographie



2,6 mSv

>10 mSv

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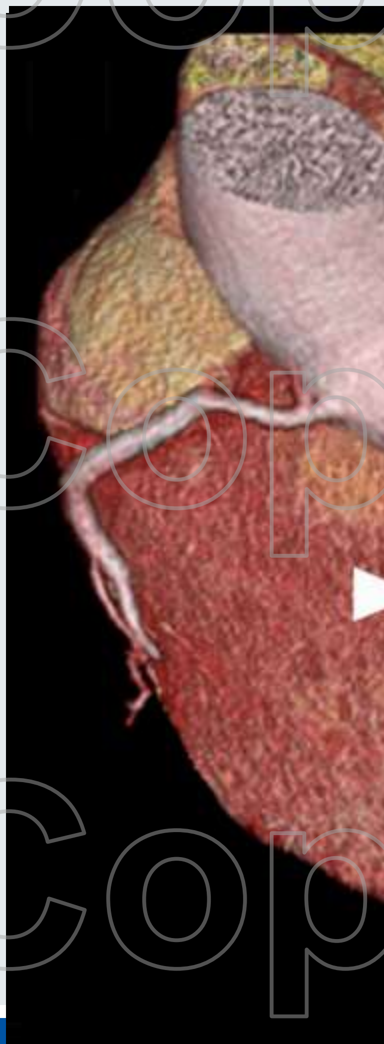
TEMP/T … aphie

effort uniquemen…

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Low-dose computed tomography coronary angiography and myocardial perfusion imaging: cardiac hybrid imaging below 3mSv. See figure legend on page 644.

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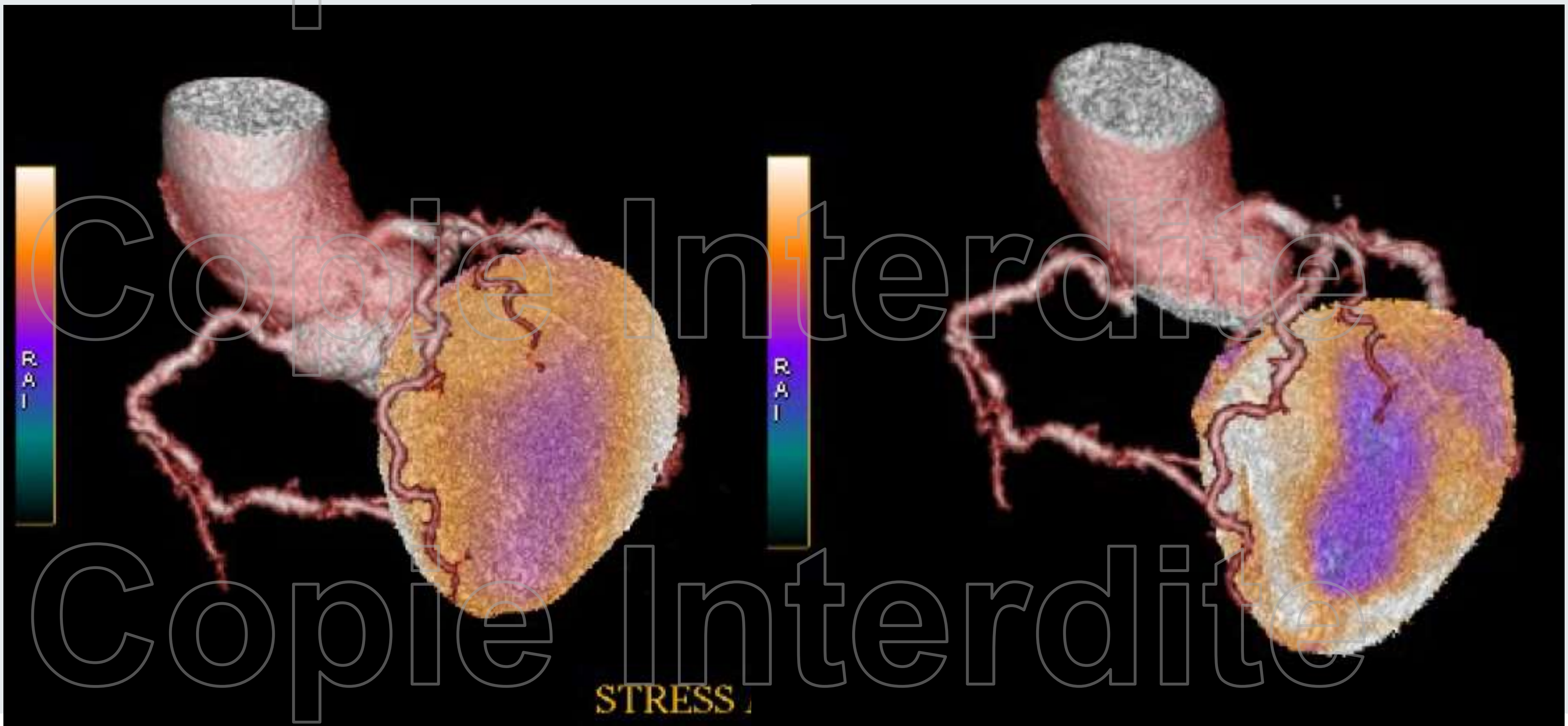
2. … mSv

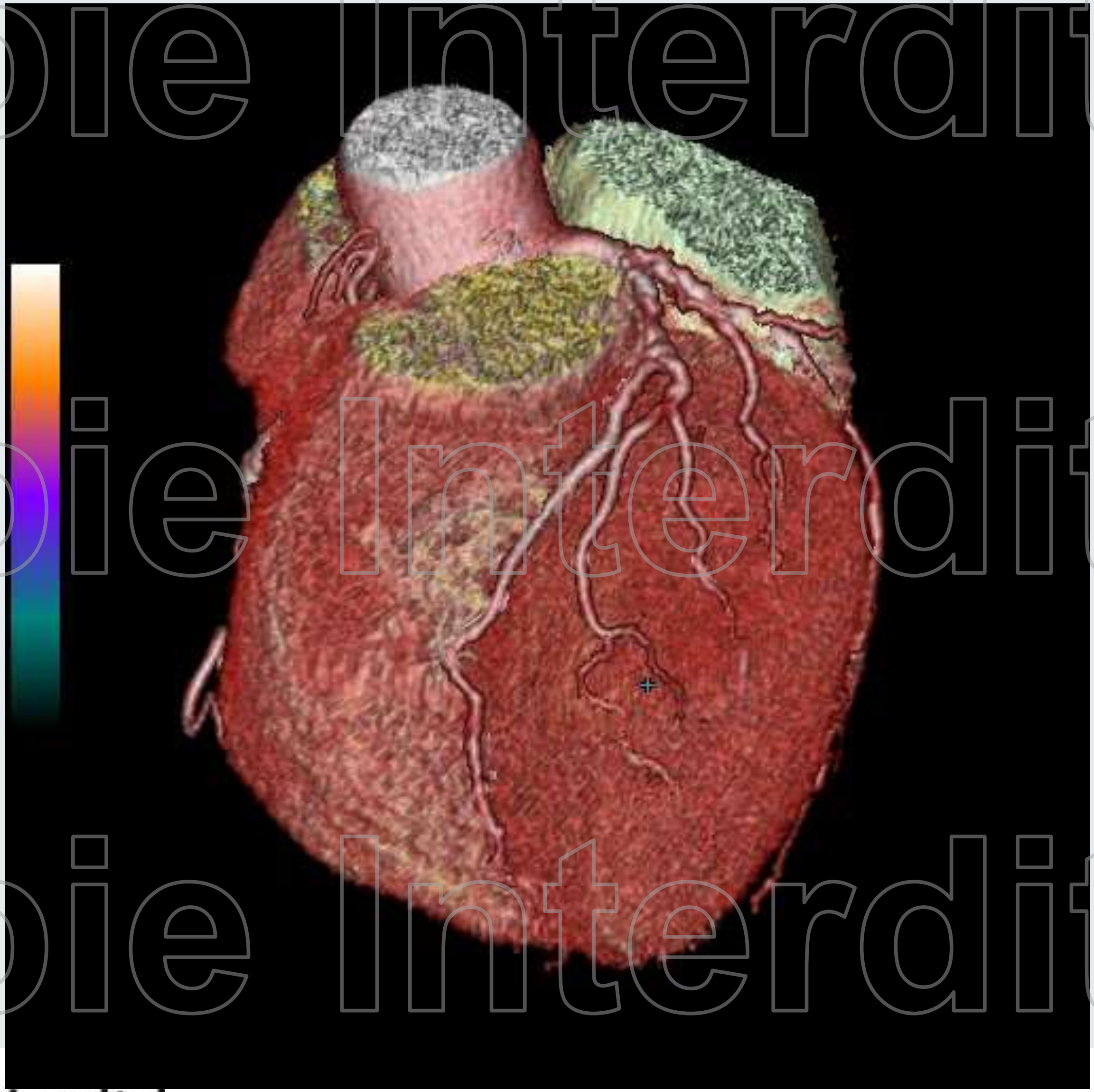
TEMP/TDM d'effort — **IRMc/TDM**

3,5 mSv ⟶ **1 mSv**



Remember: MR is NMR = **Nuclear** Magnetic Resonance

IRMc/TDM



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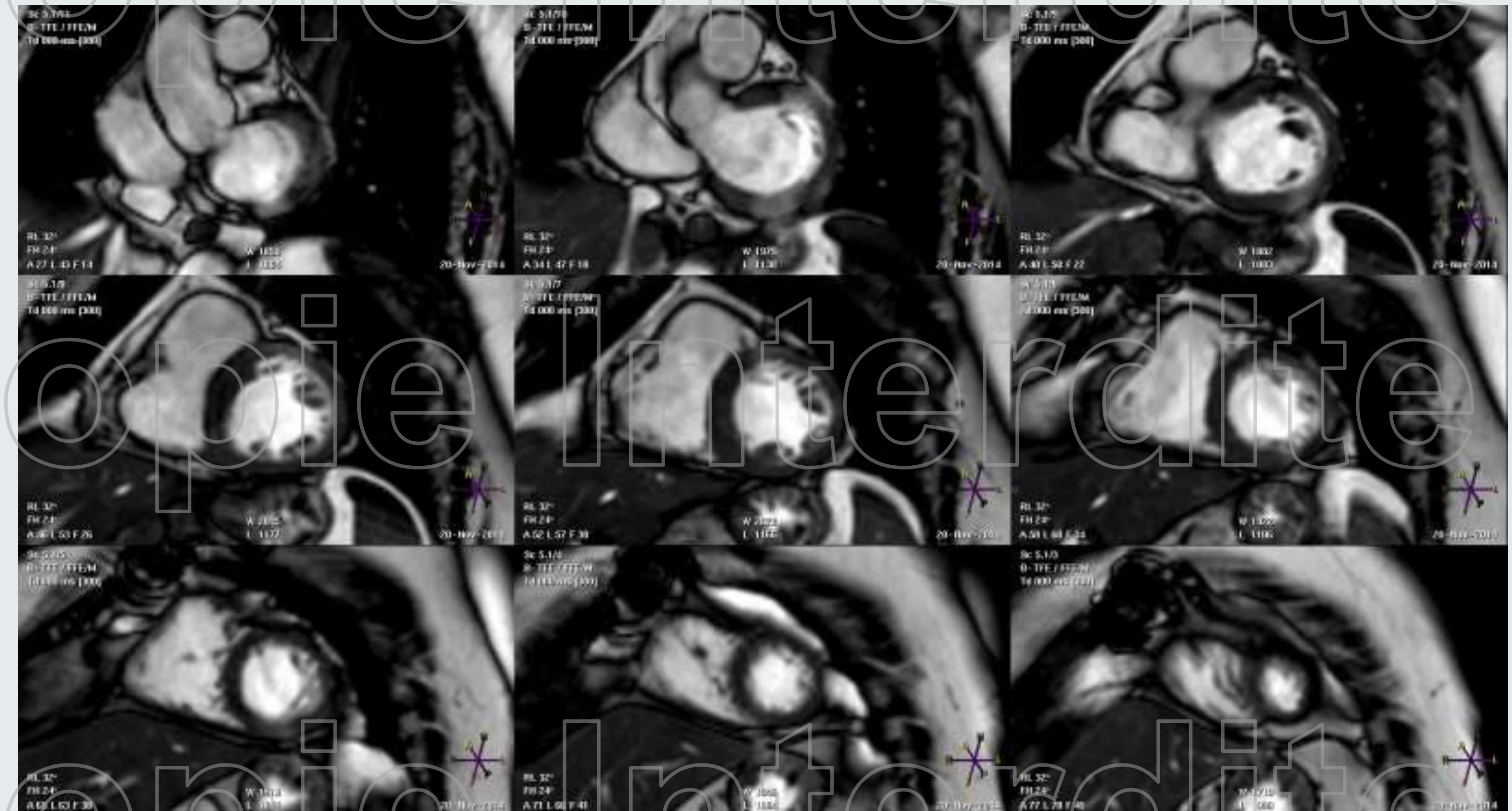
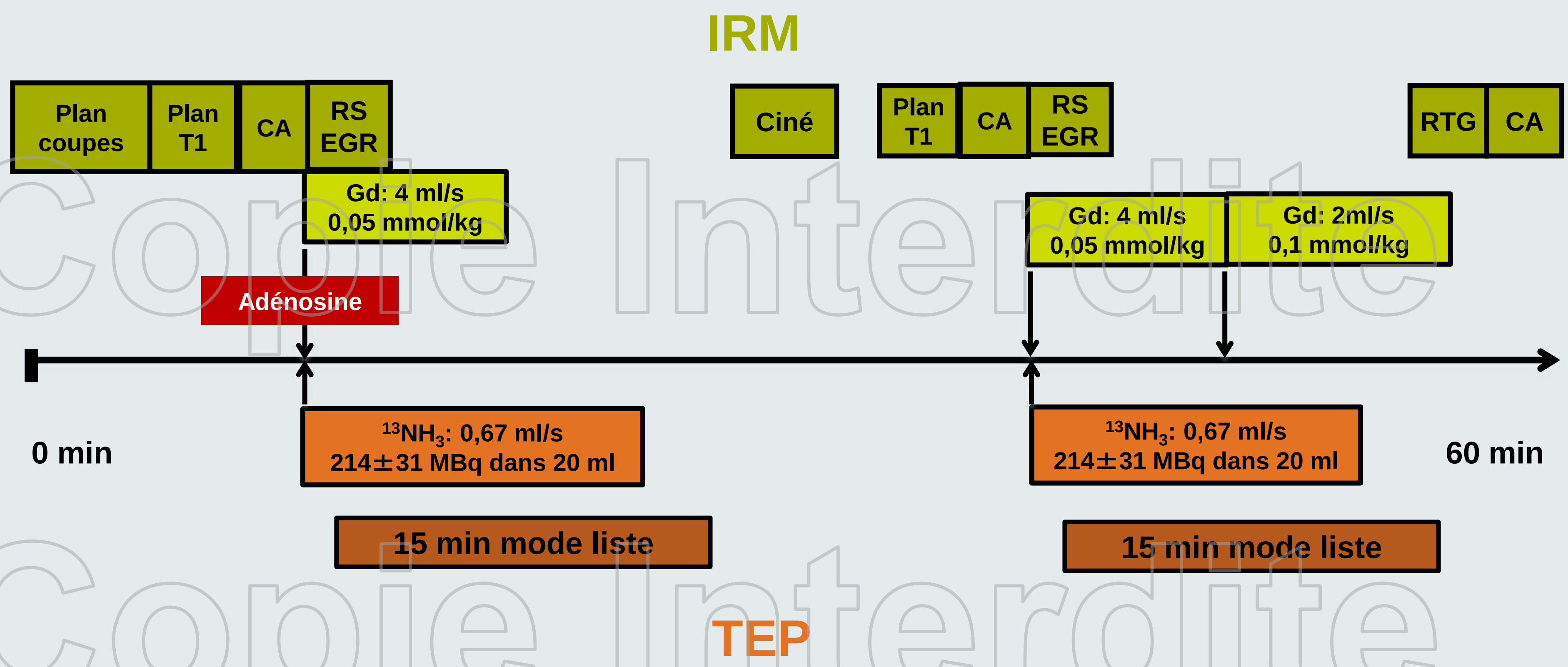
IRM cardiaque



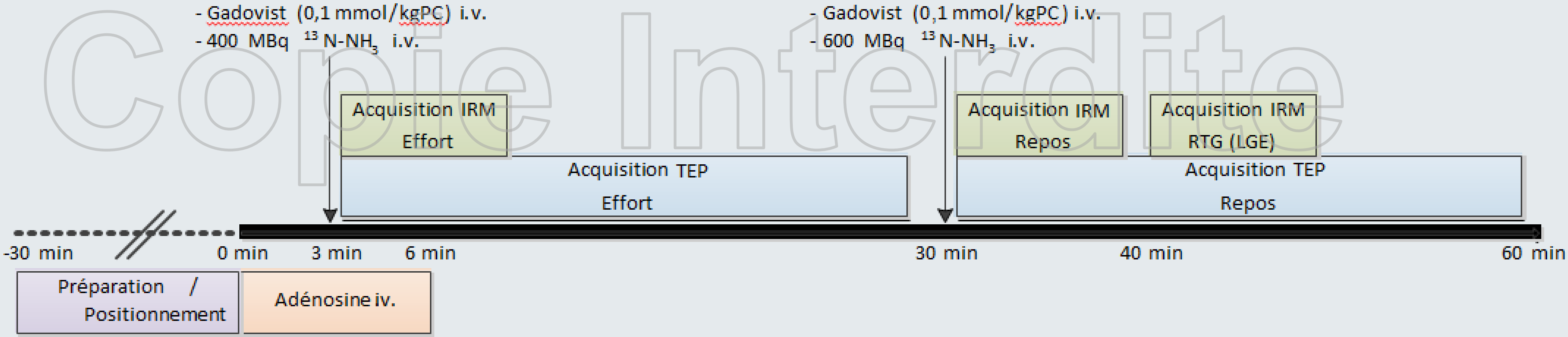
Fonction

Protocole de recherche: hybride TEP/IRM de perfusion myocardique avec co-injection



Zhang, Nekolla, Schwaiger

Protocole de recherche: imagerie cardiaque de Zurich



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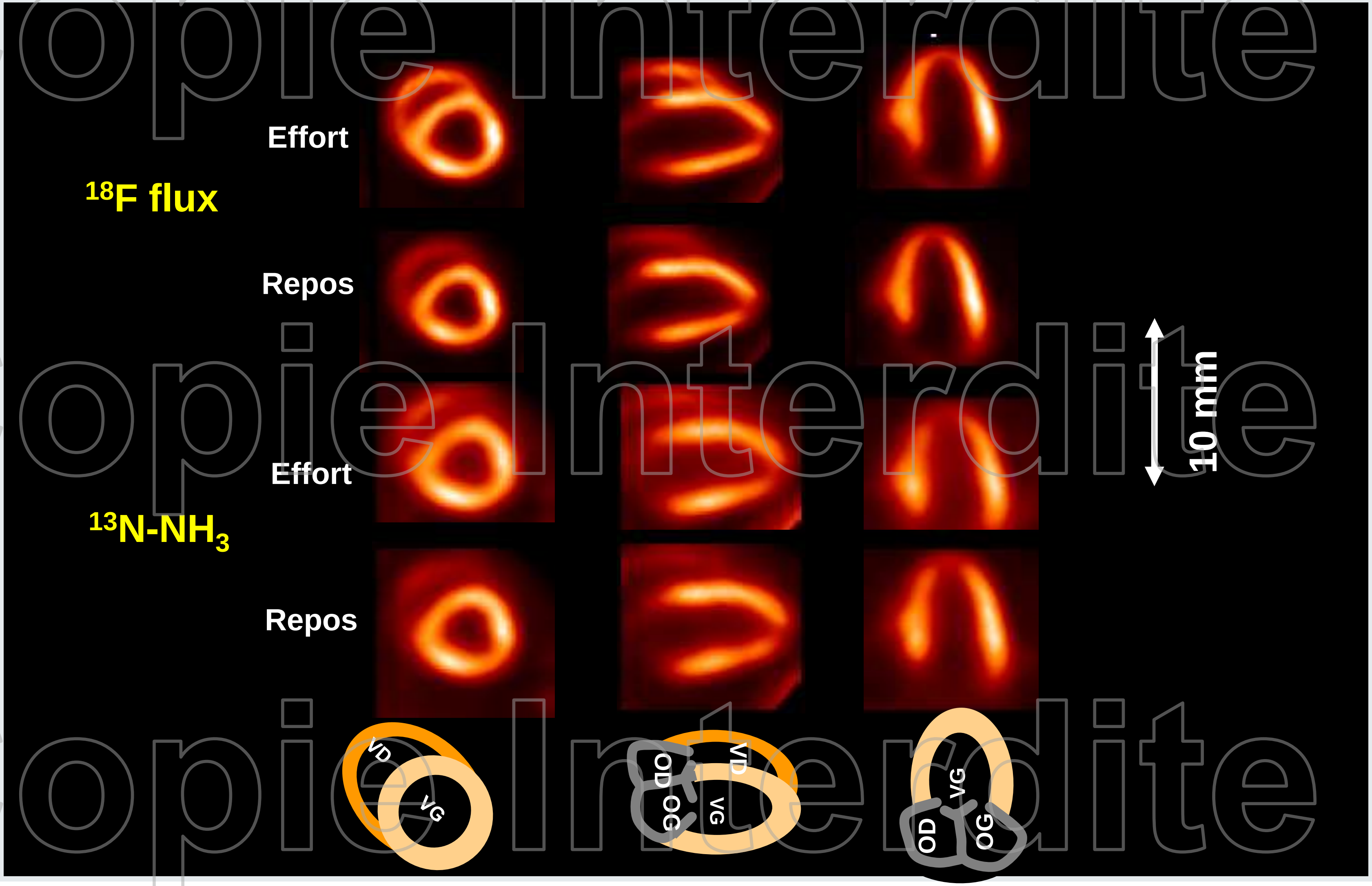
Traceur de flux ^{18}F vs. $^{13}N-NH_3$ (cœur de rat)



Remerciements à M. Wissmeyer

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HUG Hôpitaux Universitaires de Genève

TEP cardiaque

Nouveaux traceurs de flux ^{18}F

^{18}F - Flurpiridaz

REVIEW ARTICLE

Properties of an ideal PET perfusion tracer: New PET tracer cases and data

Jamshid Maddahi, MD, FACC

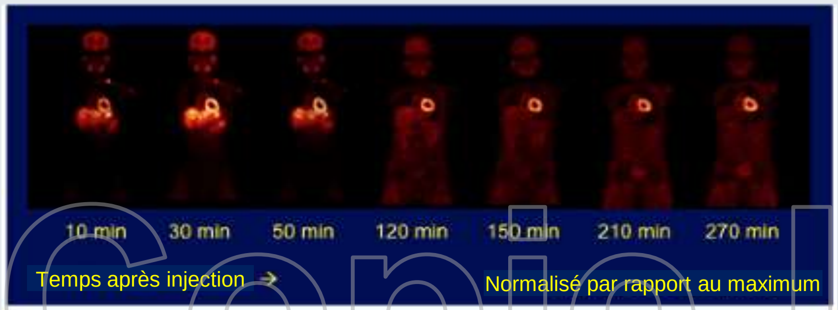
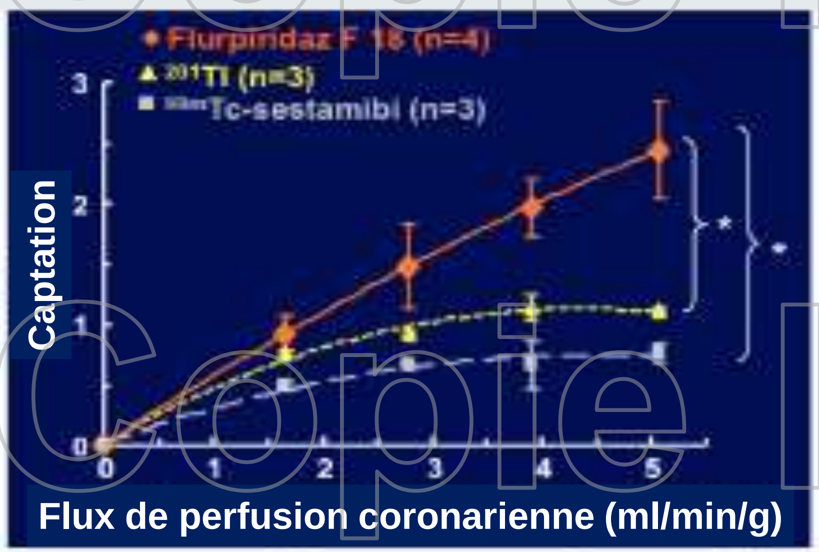


Figure 4. Sequential whole-body images acquired at specified times following injection of flurpiridaz F 18. Used with permission of the Journal of Nuclear Medicine.



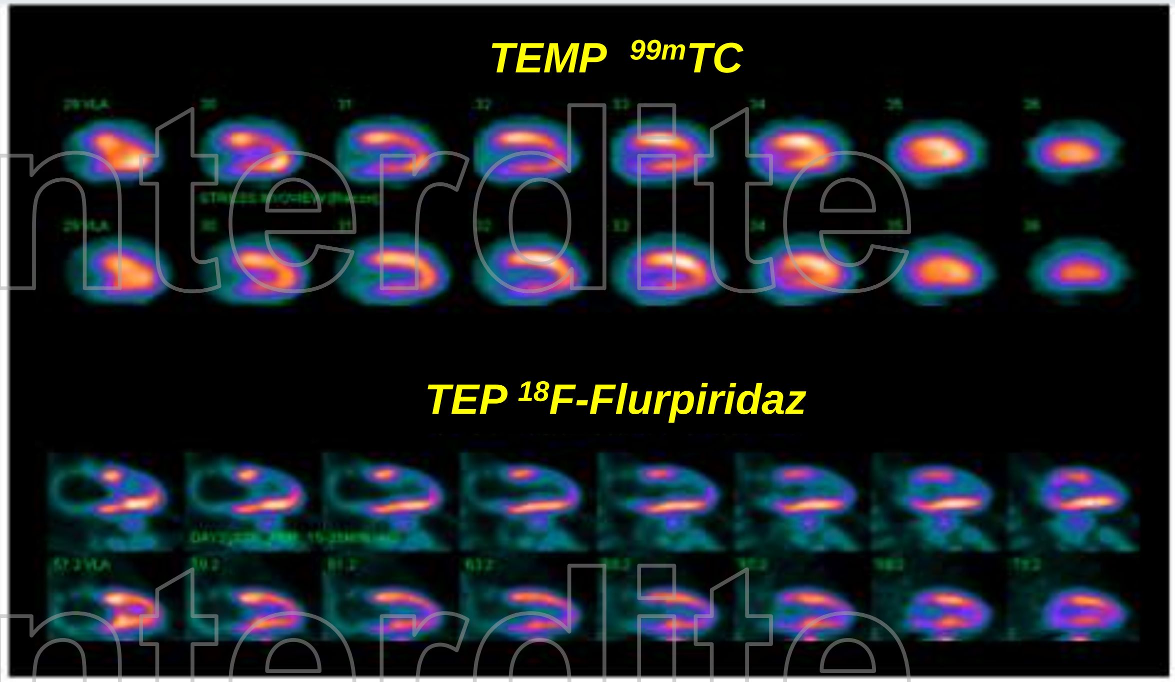


Figure 6. Long-axis stress images acquired in a patient with known coronary artery disease with ^{99m}Tc SPECT (*upper 2 rows*) and flurpiridaz F 18 PET (*lower 2 rows*). Note the higher resolution and more obvious anterior and anteroseptal defects in the PET images. *Tc*, technetium; *SPECT*, single-photon emission computerized tomography; *PET*, positron emission tomography.

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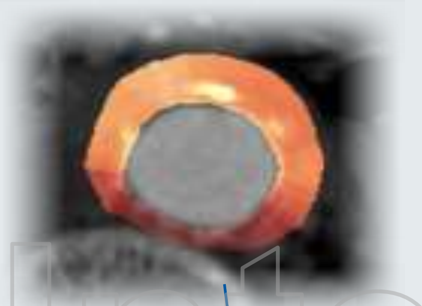
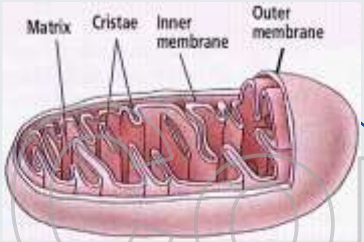
Imagerie cardiaque moléculaire

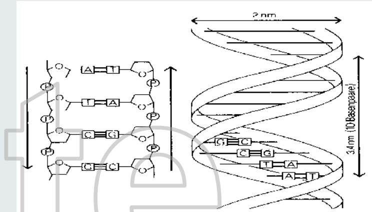
Imagerie de plaque



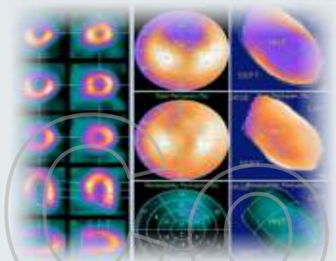
Métabolisme



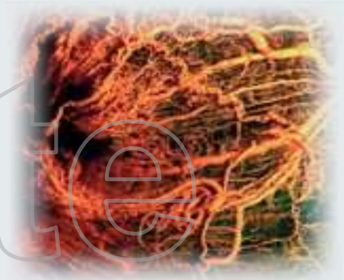
Expression des gènes



Imagerie de perfusion



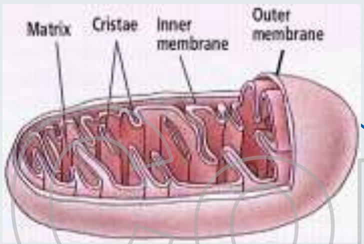
Angiogenèse



Imagerie cardiaque moléculaire

Imagerie de plaque

Métabolisme



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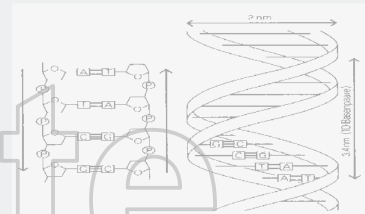
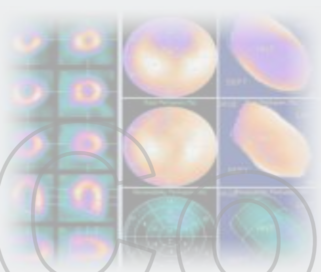


Imagerie de perfusion

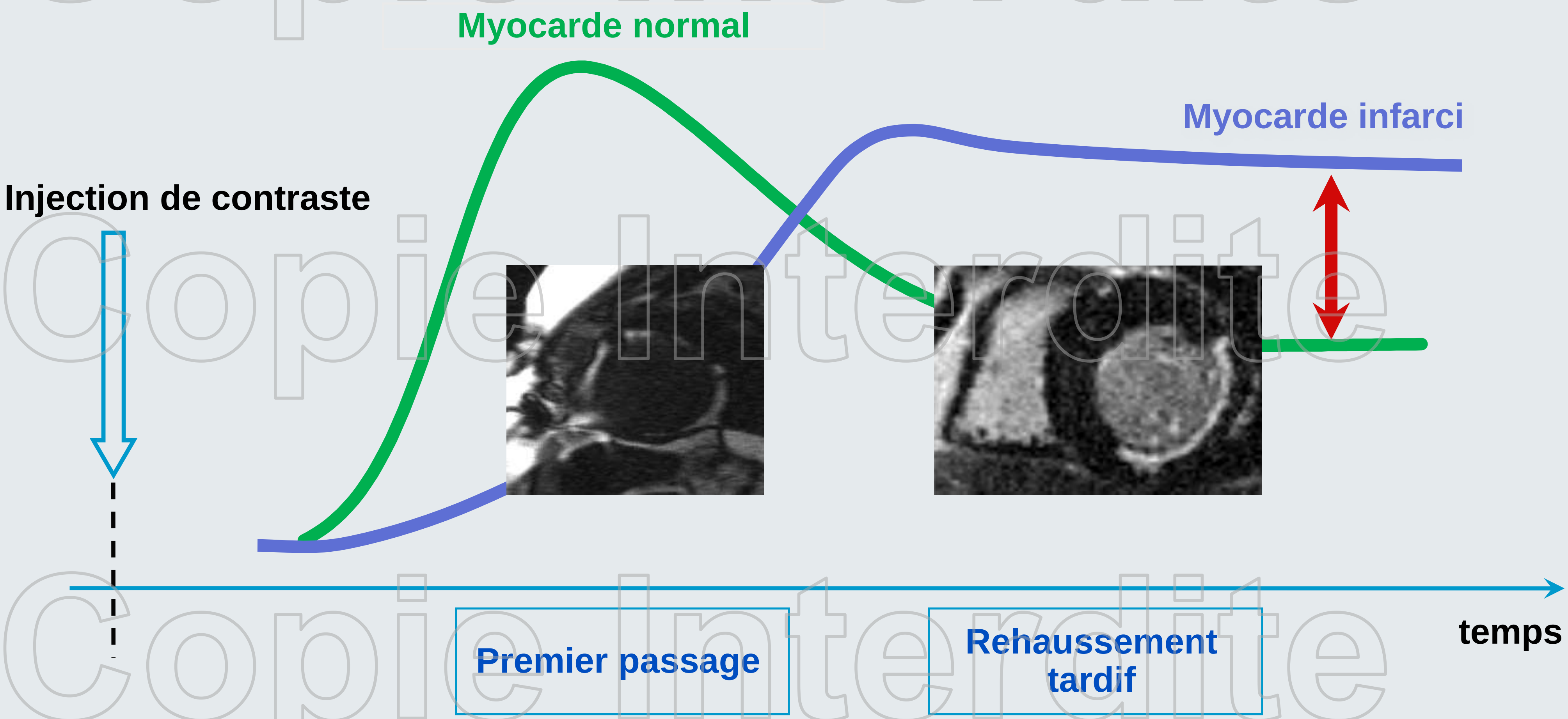


Angiogenèse

Viabilité myocardique

Soutien à la décision clinique

Viabilité myocardique
(rehaussement tardif au gadolinium)



Remerciements à M. Wissmeyer

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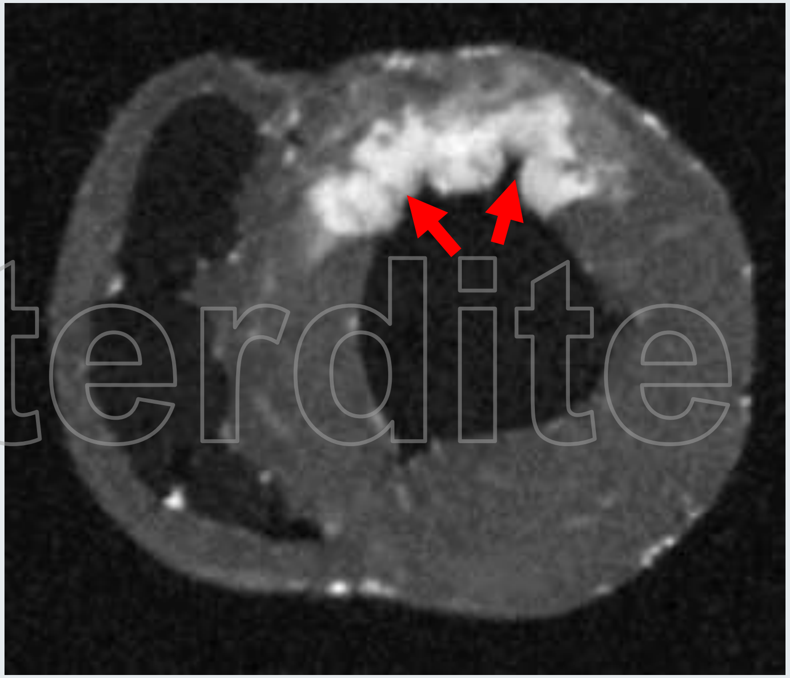
Viabilité myocardique

(rehaussement tardif au gadolinium RTG)

CTT



IRM

Comparaison ex vivo du CTT et de l'IRM au gadolinium pour le myocarde infarci

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Remerciements à Dr. R. Judd, Université du Nord-Ouest, Chicago

Viabilité myocardique

(rehaussement tardif au gadolinium et FDG)

RTG

FUSION

FDG

Le gadolinium et le FDG montrent un résultat concordant

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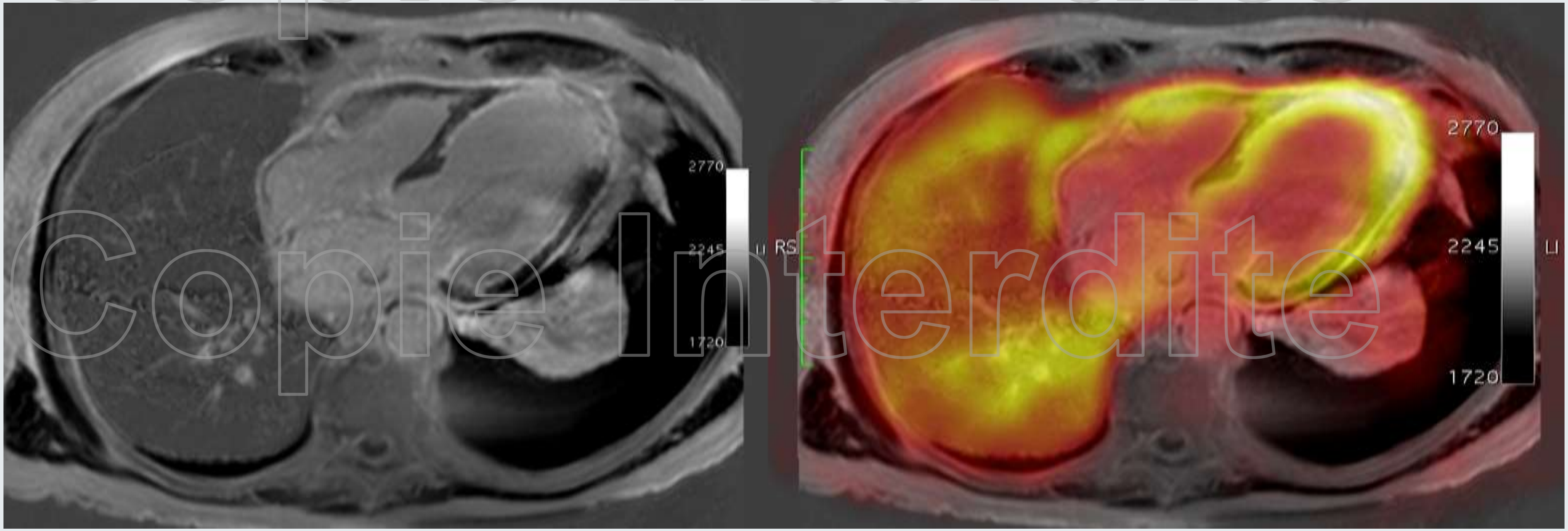
Viabilité cardiaque post-infarctus du myocarde



Le gadolinium et le FDG ne concordent pas

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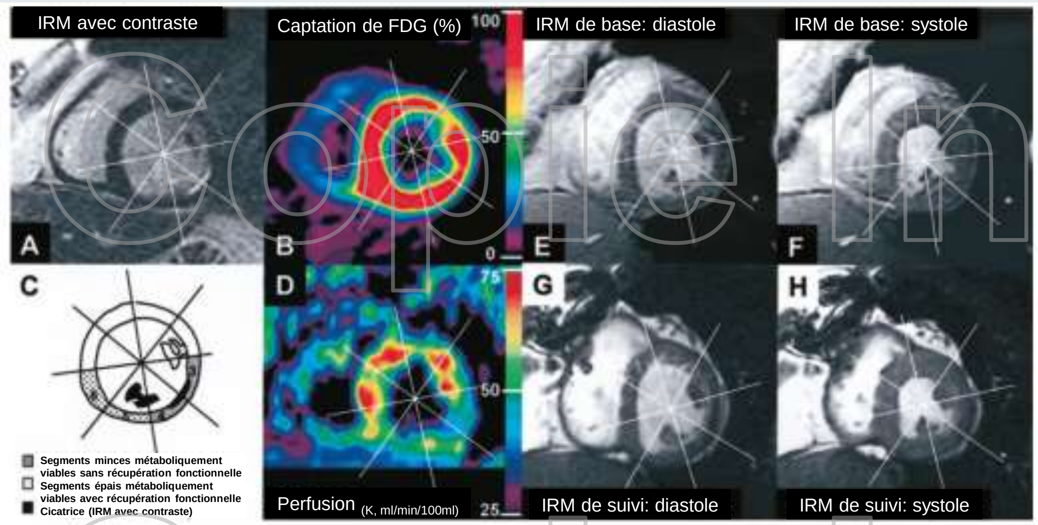
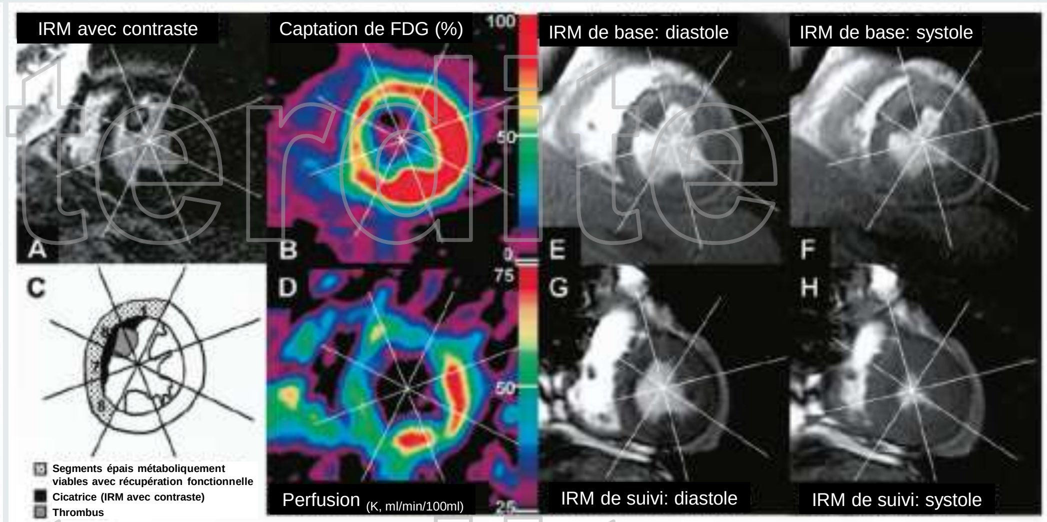
Caractérisation du myocarde dysfonctionnel par TEP et IRM

Relation avec le devenir fonctionnel après revascularisation





Characterization of Dysfunctional Myocardium by Positron Emission Tomography and Magnetic Resonance

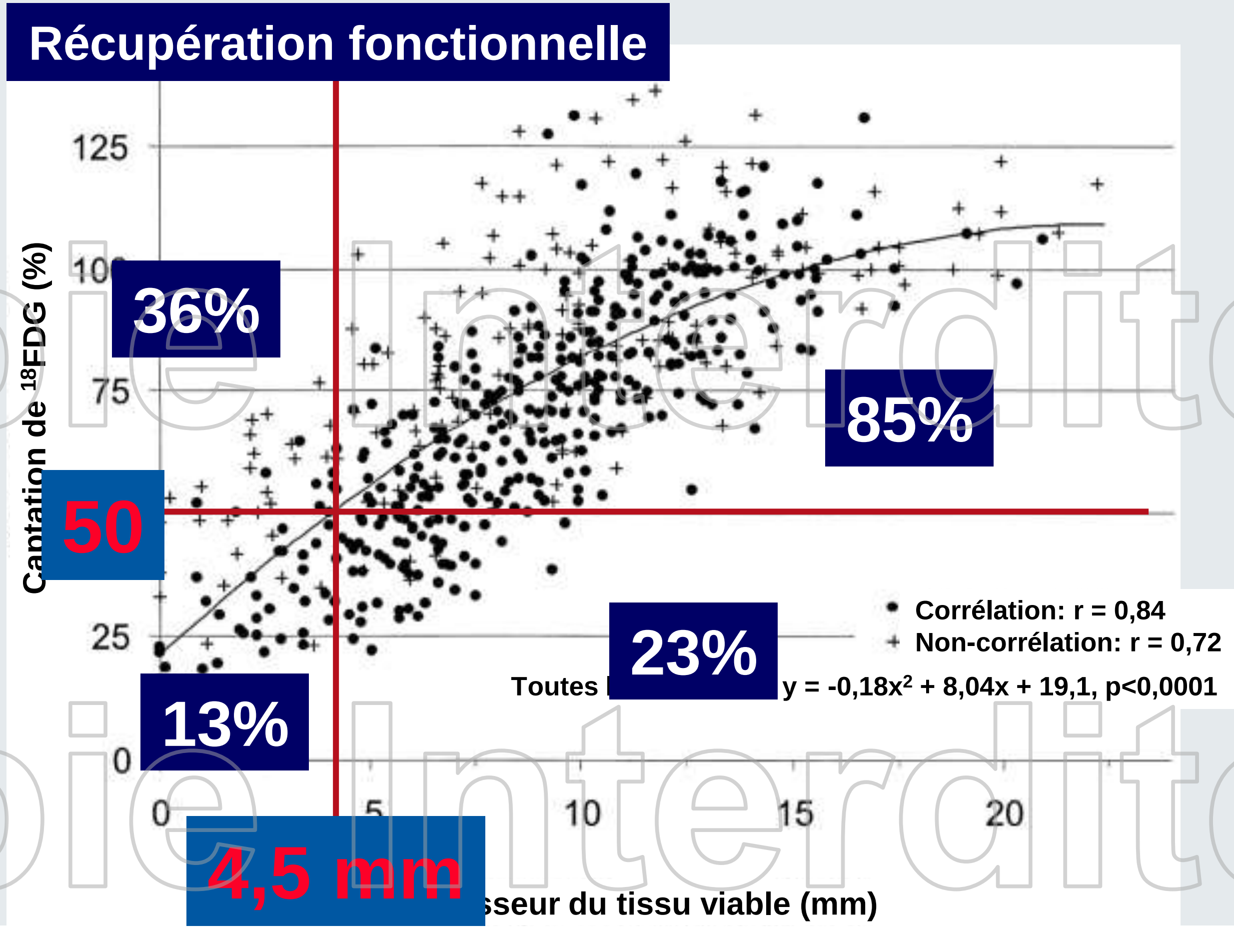
Relation to Functional Outcome After Revascularization

Patrick R. Knuesel, MD; Daniel Nanz, PhD; Christophe Wyss, MD; Martin Buechi, MD;
Philip A. Kaufmann, MD; Gustav K. von Schulthess, MD, PhD;
Thomas F. Lüscher, MD; Juerg Schwitter, MD

Circulation September 2, 2003

UniversityHospital
Zurich

Caractérisation du myocarde dysfonctionnel par TEP et IRM



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Exemple de cas: sarcoïdose ?

Patiente de 69 ans avec
Cardiomyopathie d'origine inconnue.

Echo: FEVG 37%.
Hypertension pulmonaire.

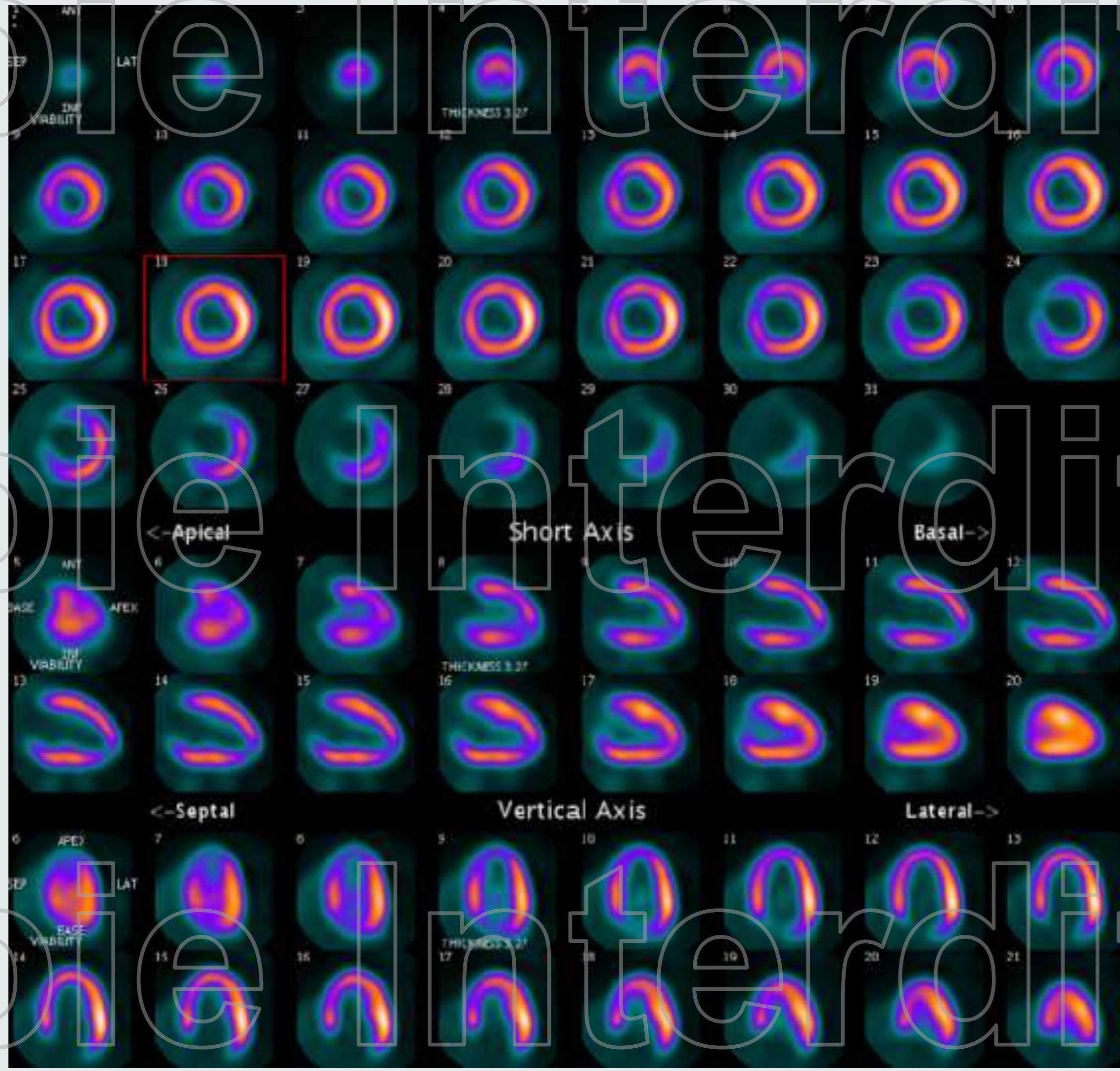
Pas d'antécédent coronarien.

IRMc il y a 3 ans: FEVG 53%.
Fibrose basale inféro-latérale.

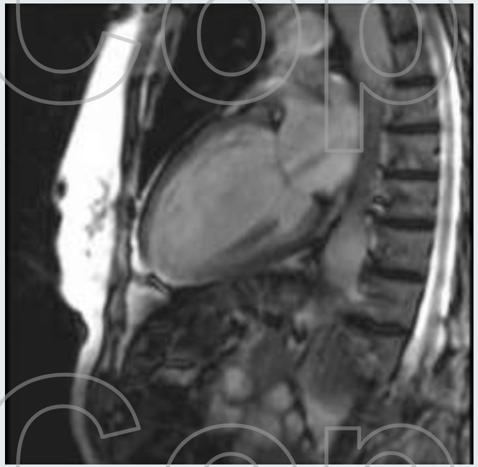
Question: sarcoïdose cardiaque?

Sarcoïdose ?

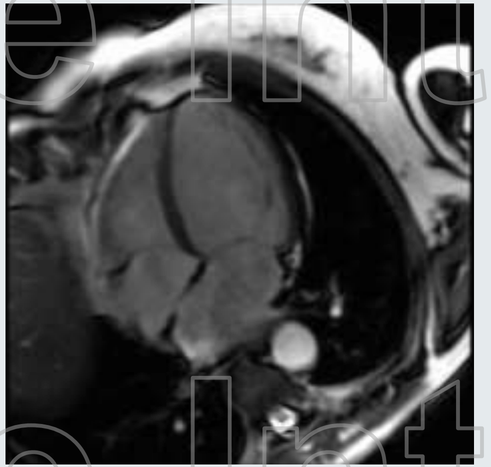
TEP au FDG



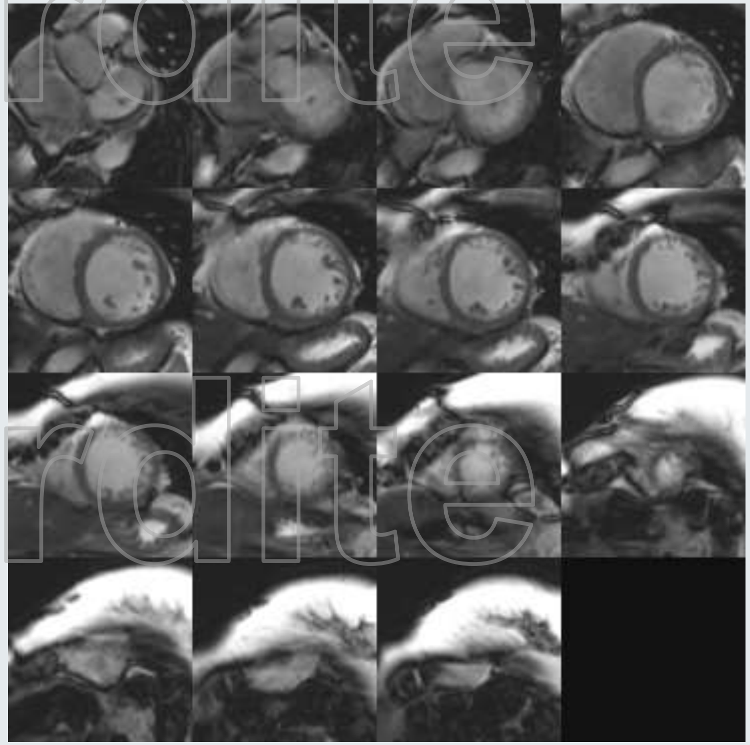
Sarcoïdose ?



IRMc ciné
Vue 2 cavités

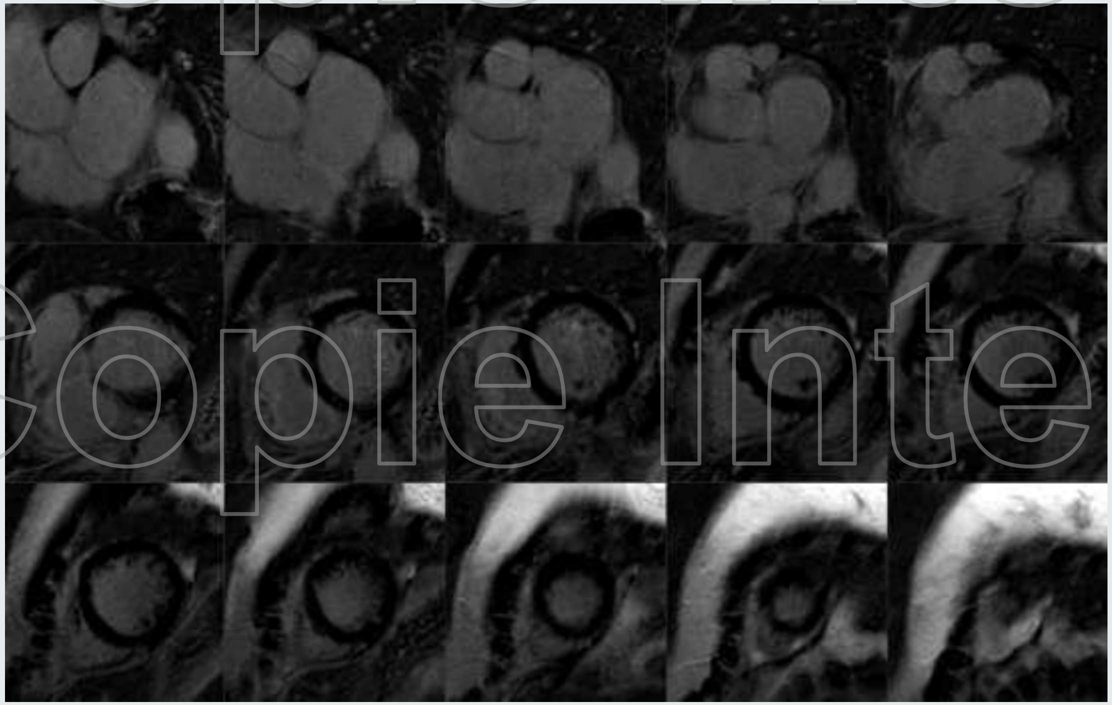


IRMc ciné
Vue 4 cavités

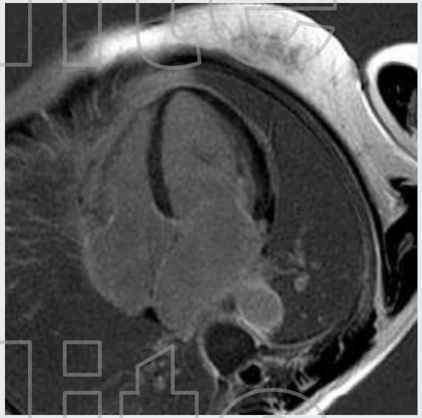


IRMc ciné
Plan transversal

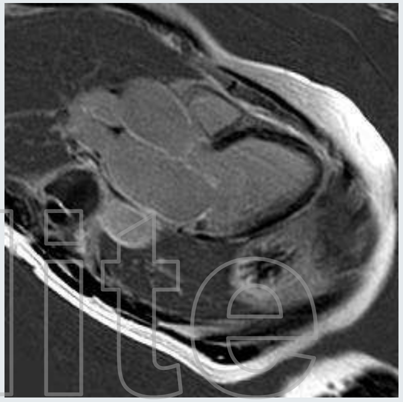
Sarcoïdose ?



RTG plan transversal



RTG
Vue 4 cavités



RTG
Vue 3 cavités

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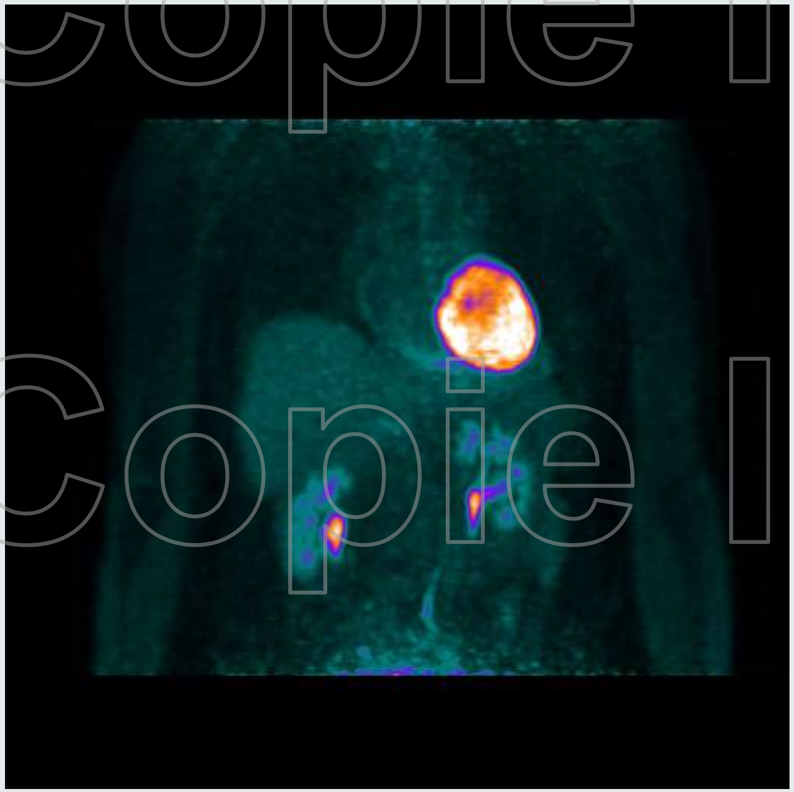
Sarcoïdose ?



TEP au FDG

Fusion TEP/IRM

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Sarcoïdose ?

Conclusion:

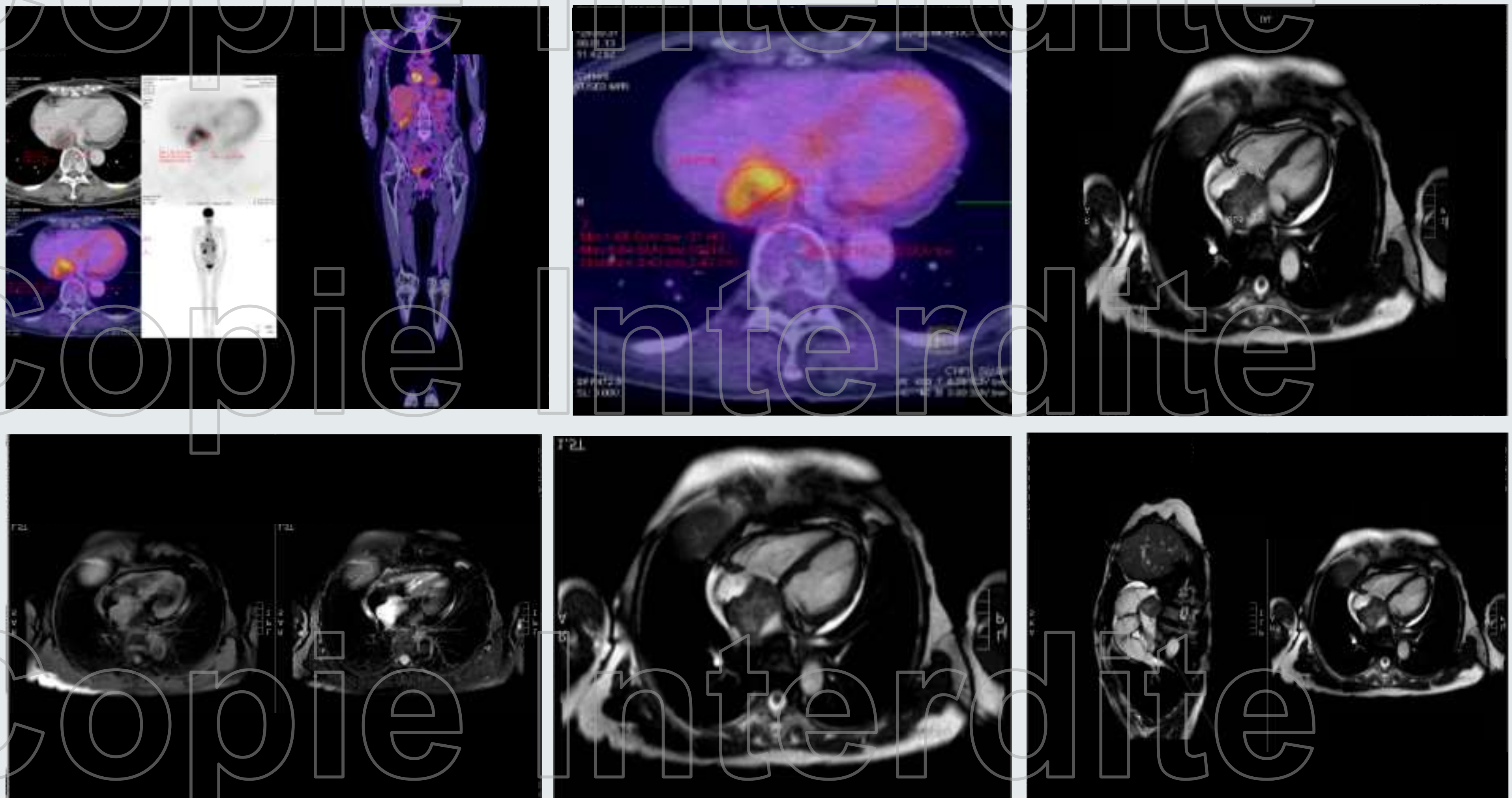
Ventricule gauche dilaté,
FEVG modérément réduite (44%),
hypokinésie diffuse.

Fibrose sous-endocardique inféro-latérale.

Captation diffuse de FDG.

→ Biopsie myocardique recommandée

Tumeurs cardiaques



Tumeurs cardiaques

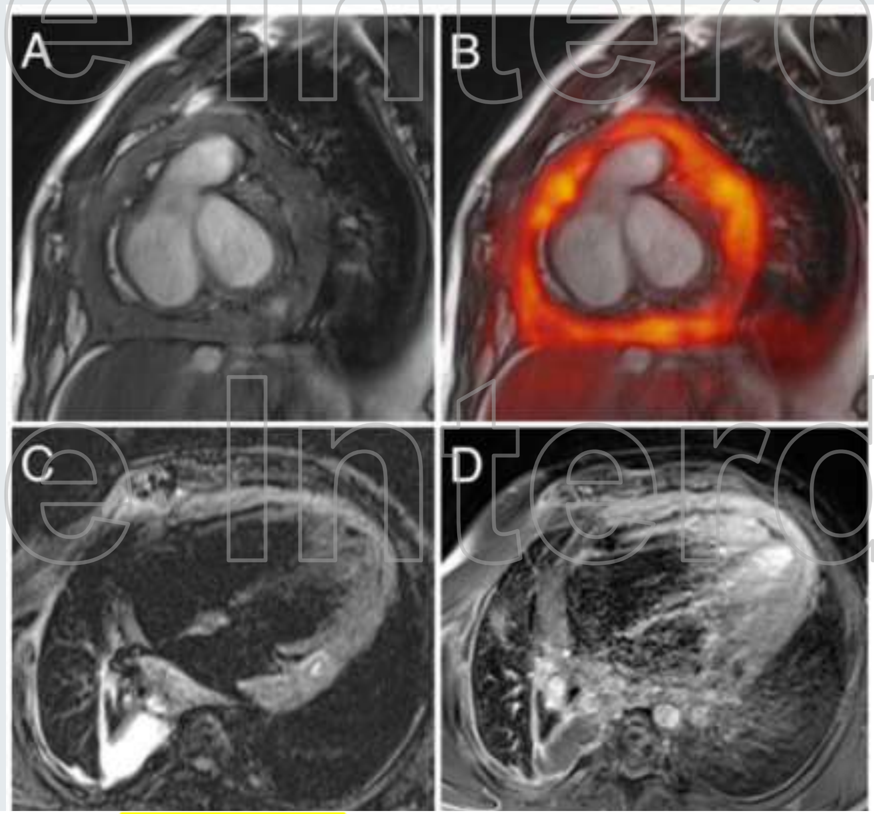
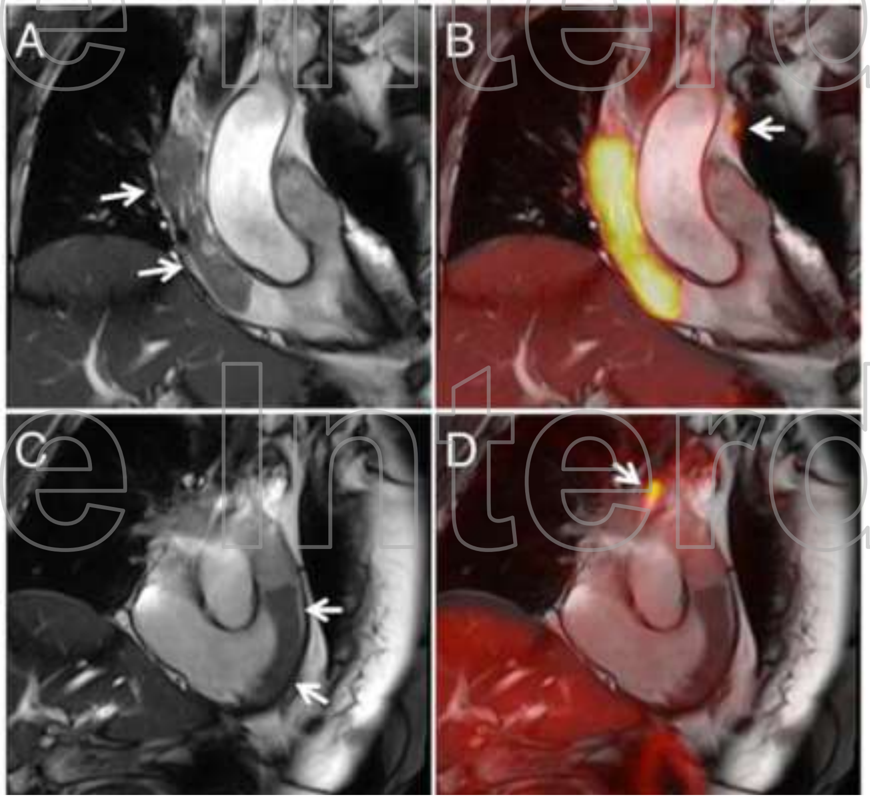


Image IRM (A) d'un patient avec une récidive locale d'un sarcome d'Ewing cardiaque présentant une infiltration péricardique massive avec une capitation intense de FDG (B). Les images en pondération T2 démontrent une hyperintensité des masses tumorales (C) et les images en pondération T1 après contraste indiquent un rehaussement significatif. Cette étude a initialement été publiée dans le JNM (Nensa F et al. Integrated 18F-FDG-PET/MRI in the assessment of cardiac masses: A pilot study. J Nucl Med. 2015;56(2):255-60). © Society of Nuclear Medicine and Molecular Imaging, Inc. [24] Reproduit avec permission.

Tumeurs cardiaques

Cancer du sein

Cancer anal



La première rangée (A et B) présente des images d'une patiente avec un antécédent de cancer du sein et la seconde rangée (C et D) des images d'un patient avec un cancer anal. Chez les deux patients, de larges masses intra-cavitaires ont été initialement découvertes à l'échographie cardiaque. La colonne de gauche (A et C; flèches) montre les images IRM de larges masses tubulaires dans la veine cave supérieure et l'oreillette droite (A) ainsi que dans la chambre de chasse du ventricule droit (C). La colonne de droite (B et D) présente la fusion des images d'IRM et TEP, démontrant clairement une captation de FDG comme preuve de malignité chez la patiente avec un cancer du sein (B) et une masse bénigne (pas de captation de FDG dans la masse de la chambre de chasse) chez le patient avec un cancer anal. Cependant, l'inspection approfondie des images de TEP a révélé des métastases dans les ganglions lymphatiques des deux patients (B et D ; flèches). Cette étude a

UniversityHospital Zurich

Nensa et al. JNM 2015

CONCLUSIONS

- L'imagerie multi-modalités fournit des outils très attractifs pour la recherche translationelle.
- L'examen hybride TEP/IRM peut corréler les résultats diagnostiques des deux modalités et réduire l'incertitude.
- L'analyse quantitative des données apportera un raffinement supplémentaire aux paramètres déjà établis (FRC (CRF), VCS (SUV) etc.).
- L'imagerie moléculaire représente une opportunité d'évaluer des cibles thérapeutiques importantes, telles que la stabilité de la plaque coronarienne et le remodelage ventriculaire.
- De nombreux traceurs moléculaires sont en cours de développement, mais nécessitent l'approbation des autorités et une validation clinique.
- La TEP/IRM a un grand potentiel pour les applications cardiaques, mais a besoin d'être exploré plus en profondeur.

EDITOR'S PAGE

Cardiac PET/MR: Big footprint—small step?

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INTRODUCTION

There is probably no technical invention which has changed more within the medical world than the discovery of the x-rays by Wilhelm Conrad Röntgen in 1895 who explicitly never filed a patent in order to facilitate the widespread availability of his invention. His discovery was indeed groundbreaking, and modern medicine is unthinkable without x-rays. Although most of the many developments in the field of imaging appear to be of modest importance compared to Röntgens invention, modern imaging seems unthinkable without the tremendous developments of the last decades. While the future of Radiology seems to be in molecular imaging based on novel tracers, the present is unimaginable without the past technical evolution which was characterized by brilliant engineers who have breathlessly shortened the time spans needed for closing technological gaps defined by an equally breathless medical community. As the footprints got bigger with the devices growing from simple gamma cameras to SPECT, PET, and finally hybrid scanners, the steps in medical imaging achieved by these advancements were of variable size. The concept of PET/CT was born in the early 1990s,[1] but only in 2001 the first commercial clinical PET/CT system was announced and shortly thereafter installed in our institution. For oncology imaging, the advent of PET/CT represented a breakthrough, causing PET alone to vanish in thin air. For cardiac imaging, the 4-slice technique available at that time in the integrated CT did not allow more than testing the feasibility of a modern concept for cardiac hybrid PET/CT imaging.[2] Before the question whether SPECT or rather PET may represent the future of nuclear myocardial perfusion imaging was ever answered, another development has entered the clinical arena—the hybrid PET/MR scanner. Comparable to PET/CT, the way from concept to realization was long and from a technical point of view, the integration of PET into an MR was a formidable challenge with three main problems which had to be solved: First, the photomultipliers used in the classic PET scanners do not work in an environment with strong magnetic fields. A strategy to overcome this was the installation of a sequential system with PET/CT or PET scanner and an MR scanner adjacent or in two separate rooms,[3] joined by a table system resulting in large installation footprints. The most advanced PET/MR devices combine the PET and MR components physically in one scanner with a single gantry[4] which required major MR hardware rearrangements to make room for the PET and development of modern PET detectors less sensitive to the MR scanner's magnetic fields. Fully integrated systems result in smaller footprints and allow for the simultaneous acquisition of PET and MR data.

Second, surface coils needed to get best MR image quality can cause unwanted attenuation interfering with the gamma rays from PET. Finally, MR data, unlike those acquired by CT, are not readily usable for attenuation correction. Different strategies to address attenuation correction have been suggested including template- or atlas-based methods, or approaches using MR image segmentation and PET emission. Thus, tremendous intellectual efforts have been done for achieving a big technical progress which has raised high hopes for substantial steps of progress in medical imaging.

Similar to PET/CT, the main applications have been suggested for non-cardiac imaging, although cardiac applications are vividly discussed. A PubMed search with the terms "cardiac PET MR or myocardial PET MR" revealed 274 articles on January 23, 2015. A quick look reveals that much less than 10% of these articles really deal with integrated cardiac PET/MR imaging. While numerous review articles describe the great potential and the bright future perspectives of cardiac PET/MR with an important clinical role, no studies are

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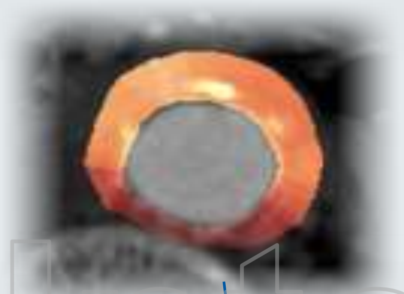
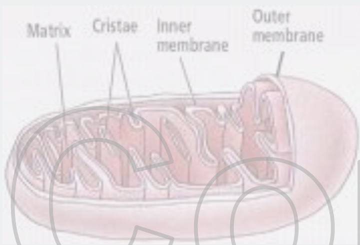
Imagerie cardiaque moléculaire

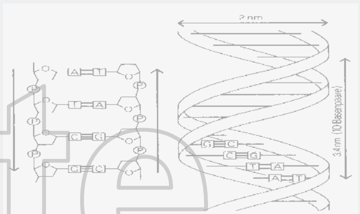
Imagerie de plaque



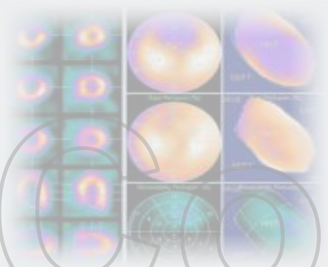
Métabolisme



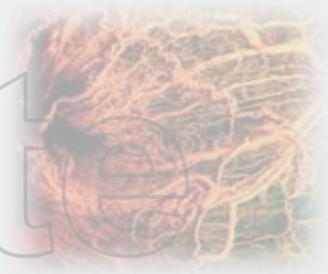
Expression des gènes



Imagerie de perfusion

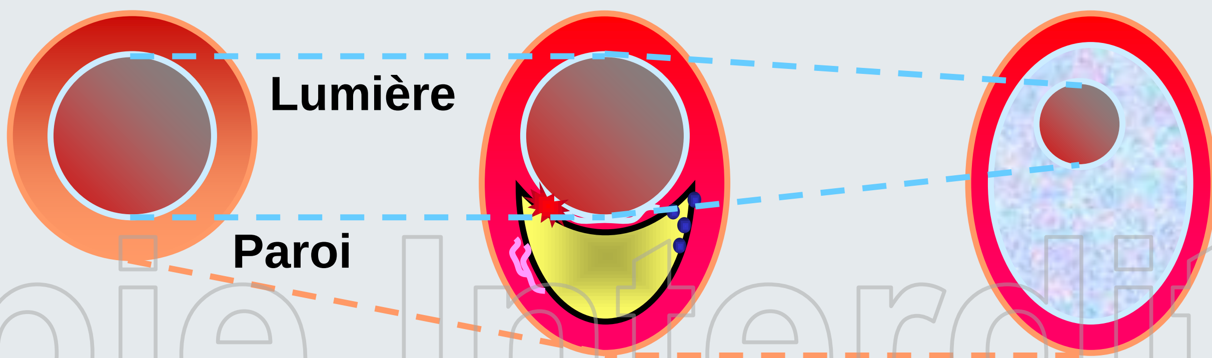


Angiogenèse



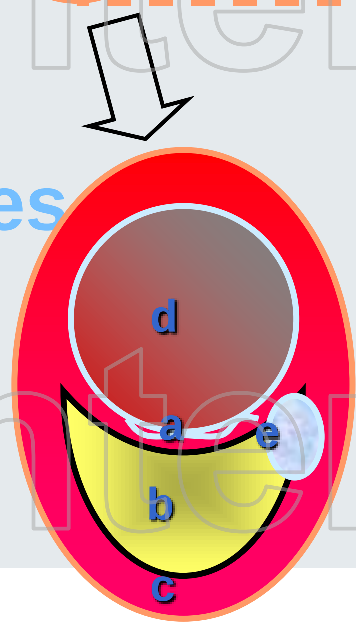
Athérosclérose et structure vasculaire

Normale **Remodelée** **Sténotique**



Plaque vulnérable

Marqueurs morphologiques



a. Capsule fibreuse mince
b. Volumineux noyau lipidique
c. Remodelage vasculaire
d. Sténose de la lumière
e. Calcifications

IRM
TDM
USIV
TCO

Remerciements à M. Wissmeyer

UniversityHospital Zurich

HUG Hôpitaux Universitaires de Genève

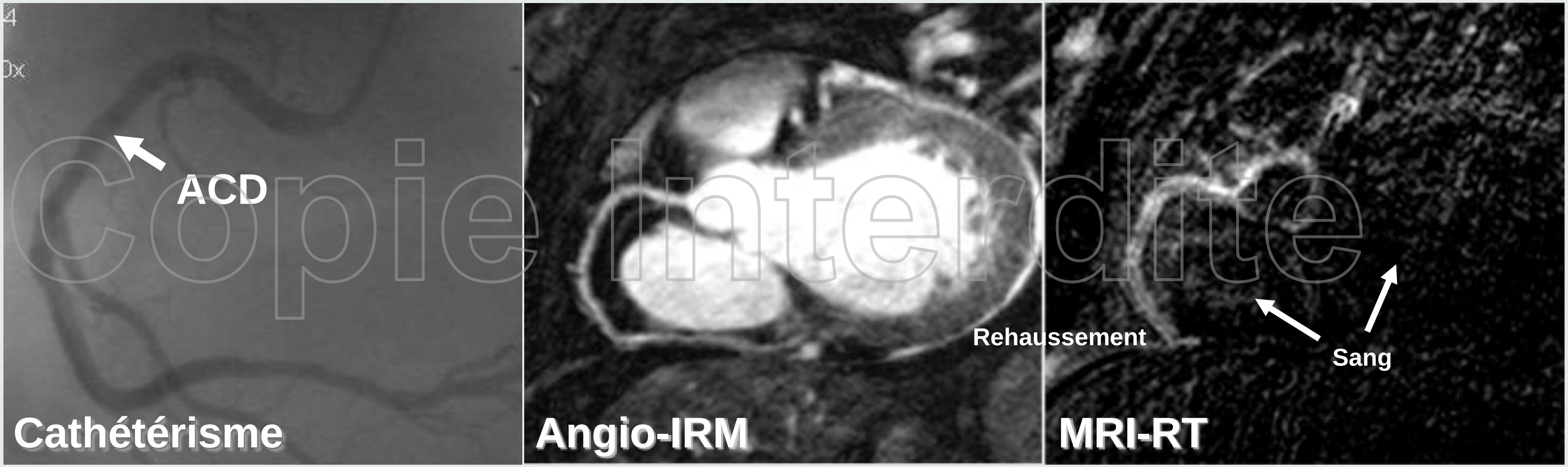
Imagerie de la paroi vasculaire au Gd-DTPA (IRM)

PCR = <0,5 ml/dl   Pas de maladie coronarienne

UniversityHospital Zurich

Botnar et al, TUM

Imagerie de la paroi vasculaire au Gd-DTPA (IRM)

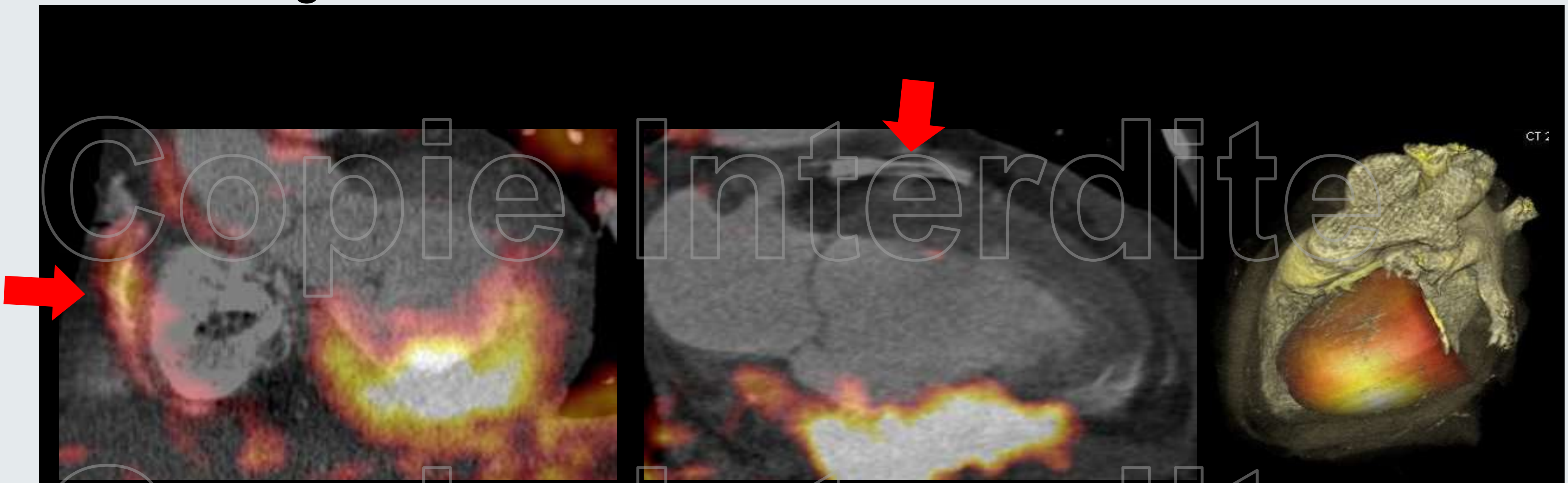


PCR = 1,3 ml/dl

10 jours post-infarctus

TEP/TDM au ^{18}F-FDG de l'artère responsable d'un infarctus inferieur du myocarde

Occlusion aiguë de l'ACD, antécédent de stent sur l'IVA

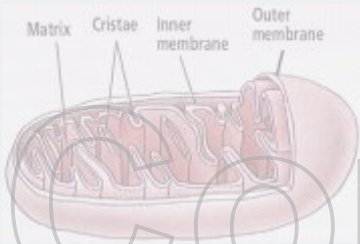


Captation myocardique supprimée par une diète pauvre en hydrates de carbones et riche en graisse

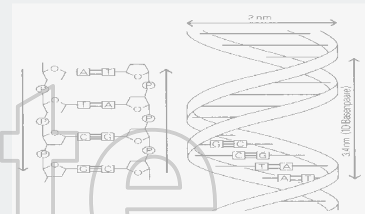
Imagerie cardiaque moléculaire

Imagerie de plaque

Métabolisme



Expression des gènes



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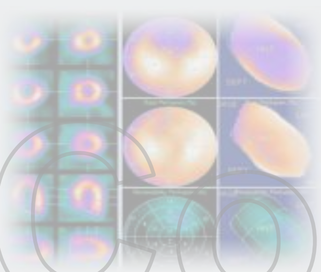
Imagerie de perfusion



Angiogenèse

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Imagerie de la réparation myocardique

Lésion myocardique ischémique

↓

Angiogenèse, collagène

↓

Activation cellulaire (Endo,Fibrobl.)

Expression de l'intégrine $\alpha_v\beta_3$

↓

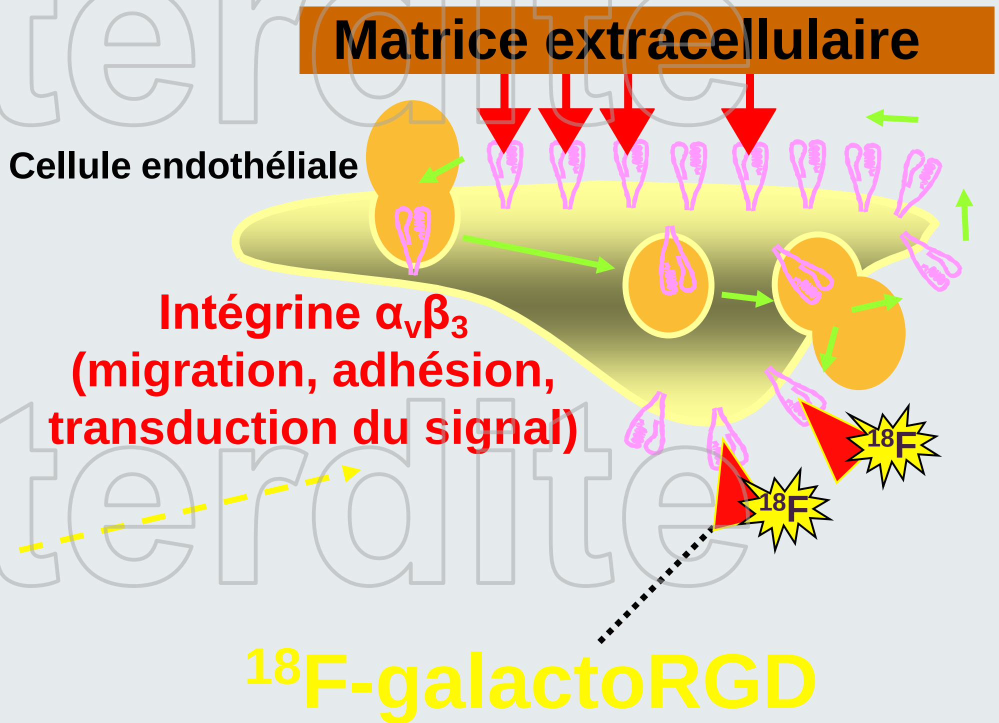
Néovaisseaux, formation de collagène

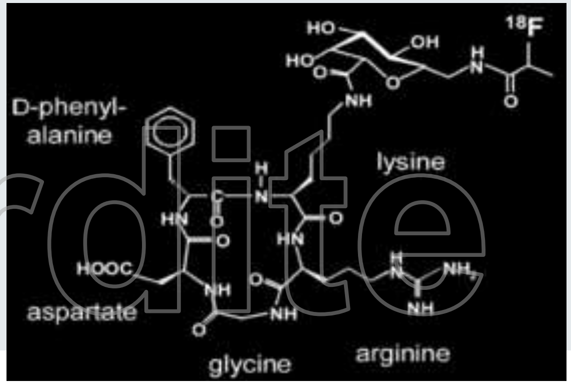
↓

Flux sanguin, réparation tissulaire

↓

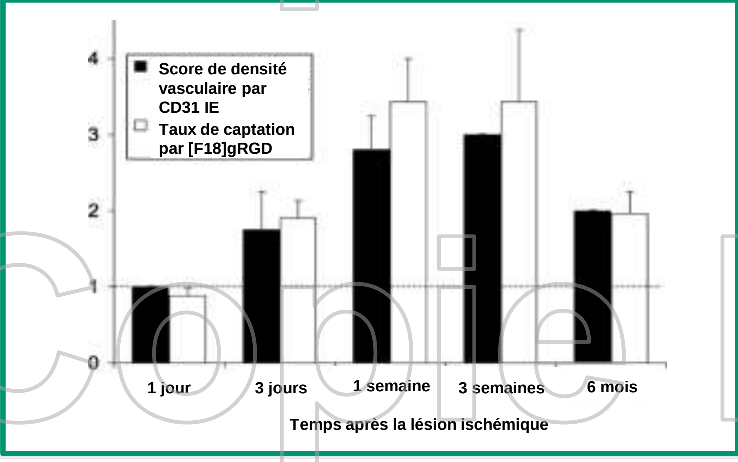
Récupération fonctionnelle, remodelage

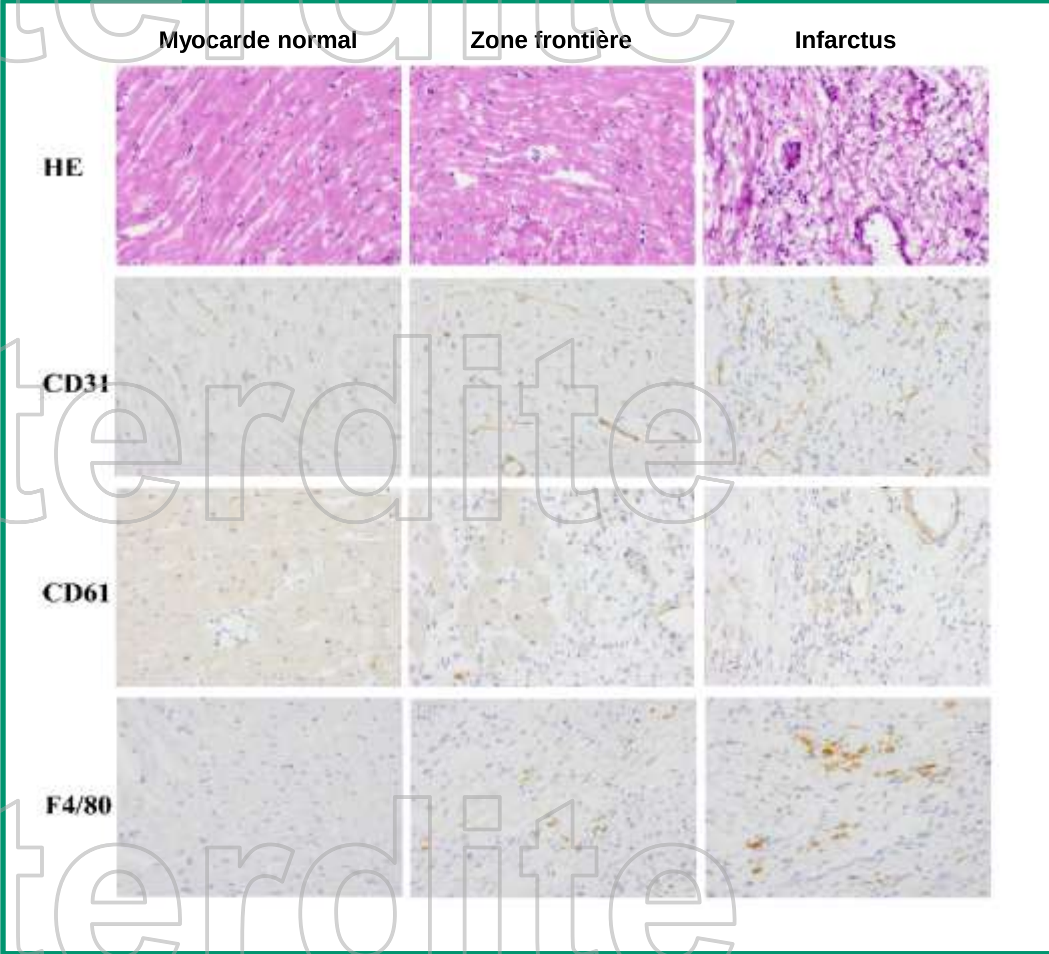




Imagerie de la réparation myocardique

- Ligature permanente de l'ACG induit un infarctus
- Angiogenèse maximale 1 semaine après l'infarctus et correspond au RGD
- Infarctus et zone frontière positifs pour néovaisseaux (CD31), macrophages (F4/80) et béta-3 intégrine (CD61)
- Beta-3 co-localise avec les cellules endothéliales (voir Rudelius, SNM Poster No. 1781 and Gao et al EJNMMI 2012;39:683-92)





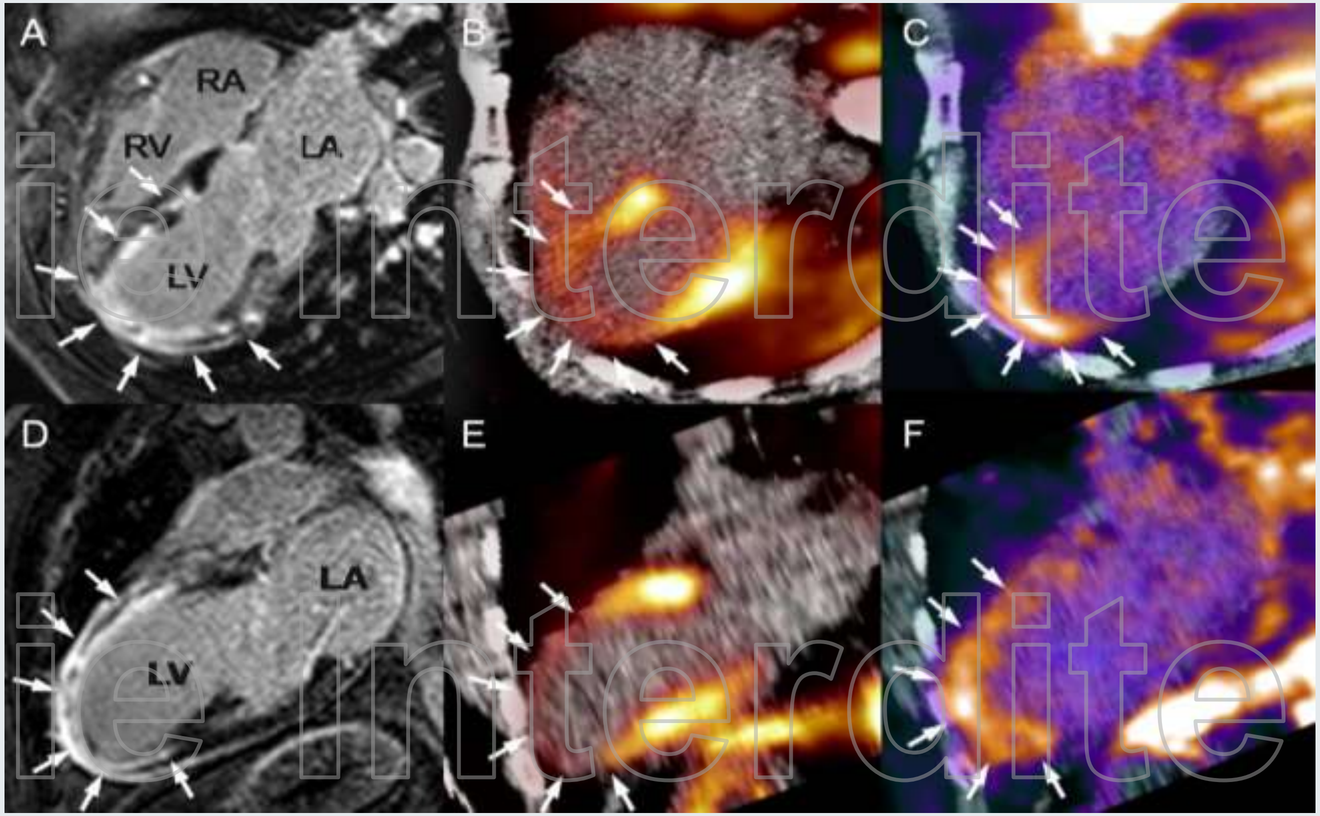
Higuchi et al Cardiovascular Research 2008;78:395–403

Expression de l'intégrine comme marqueur de l'angiogenèse post-infarctus du myocarde

IRM-RT ^{13}N-ammoniac ^{18}F-gRGD

Vue des 4 cavités

Vue des 2 cavités



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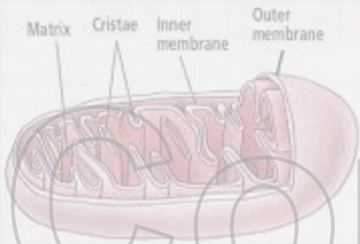
Sharif et al JNM 2012

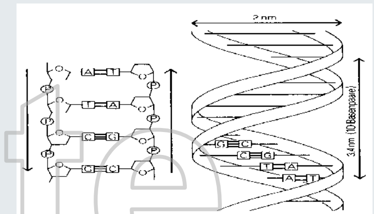
Imagerie cardiaque moléculaire

Métabolisme

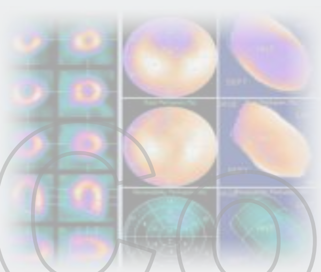


Imagerie de plaque

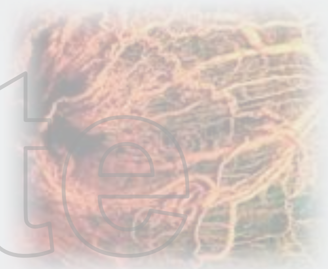
Expression des gènes



Imagerie de perfusion

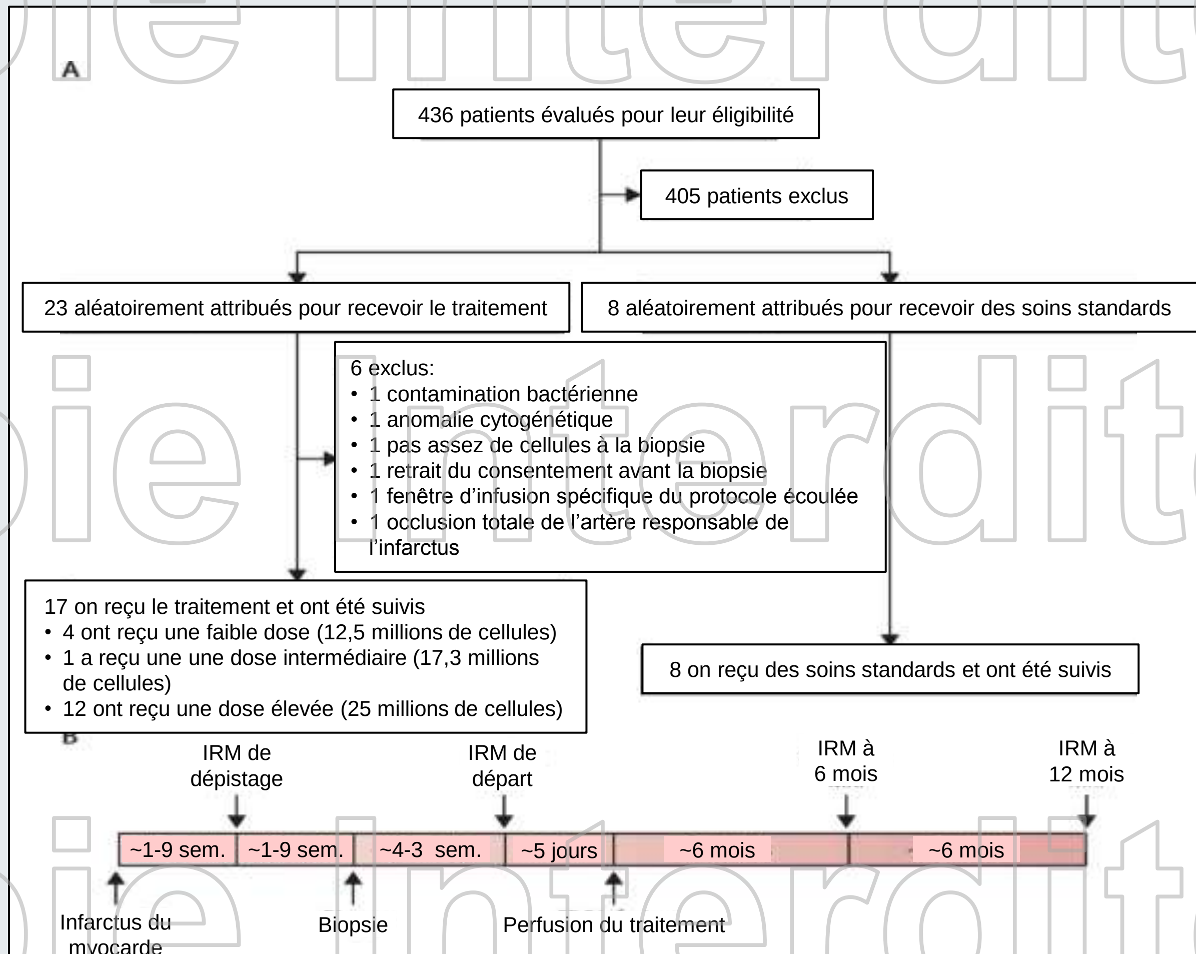


Angiogenèse



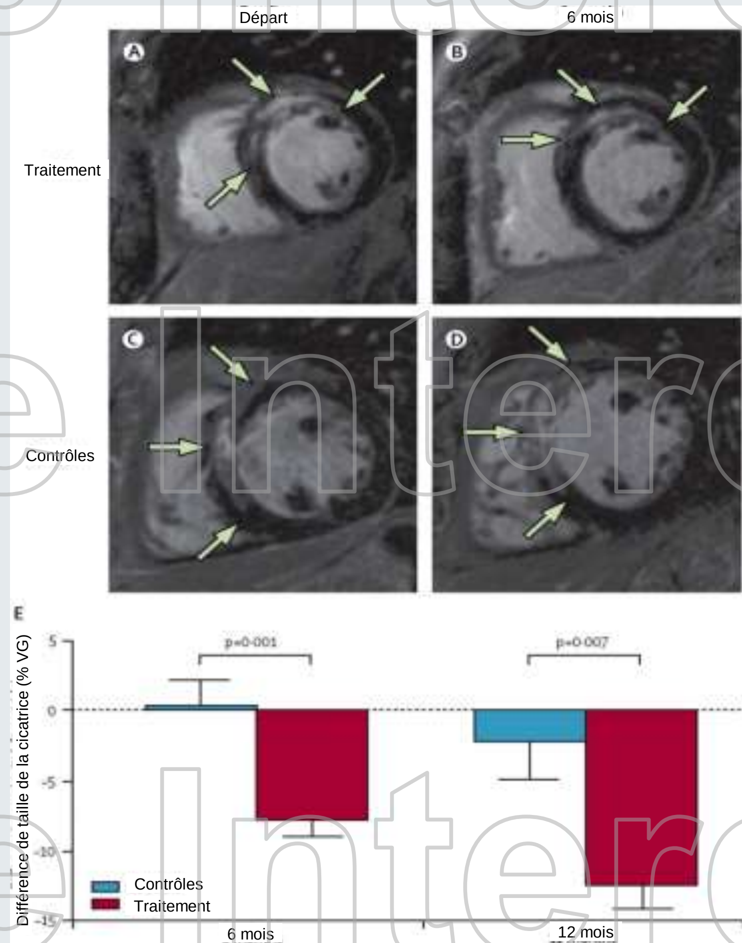
Étude de Phase I CADUCEUS

Transplantation cellulaire intra-coronaire dérivée de cardiosphères

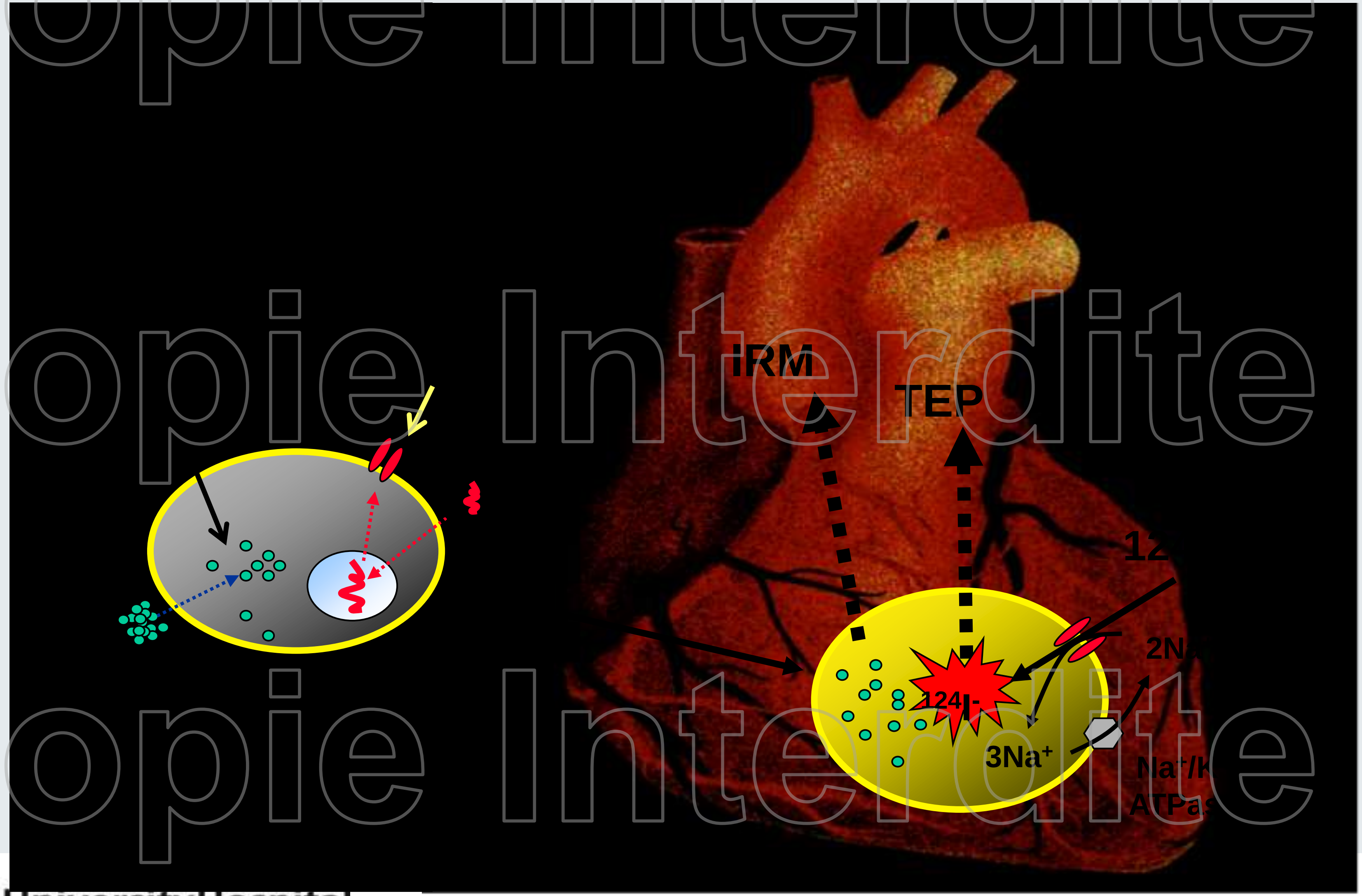


Étude de Phase I CADUCEUS

Transplantation cellulaire intra-coronaire dérivée de cardiosphères



Imagerie de transplantation cellulaire



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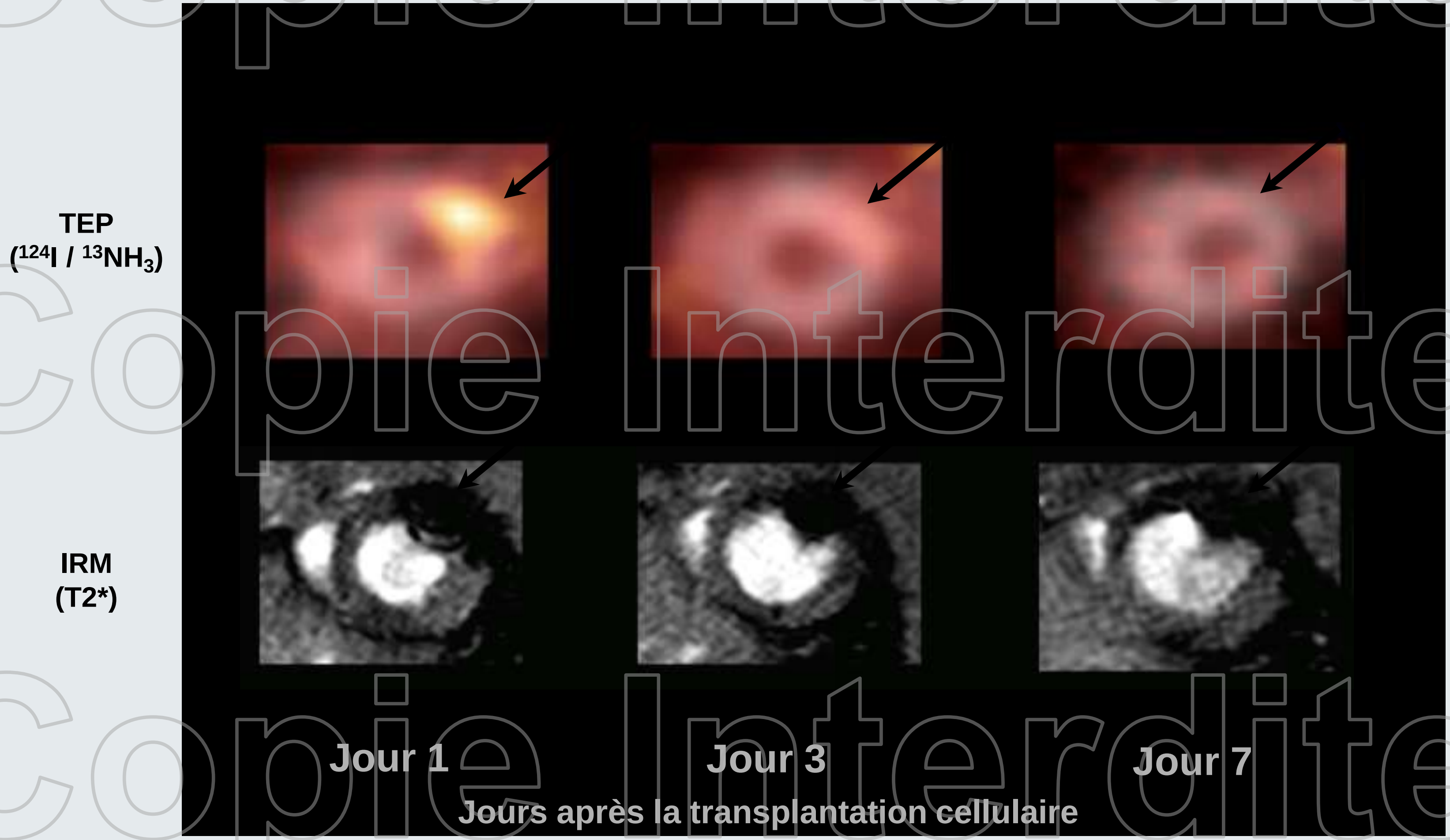
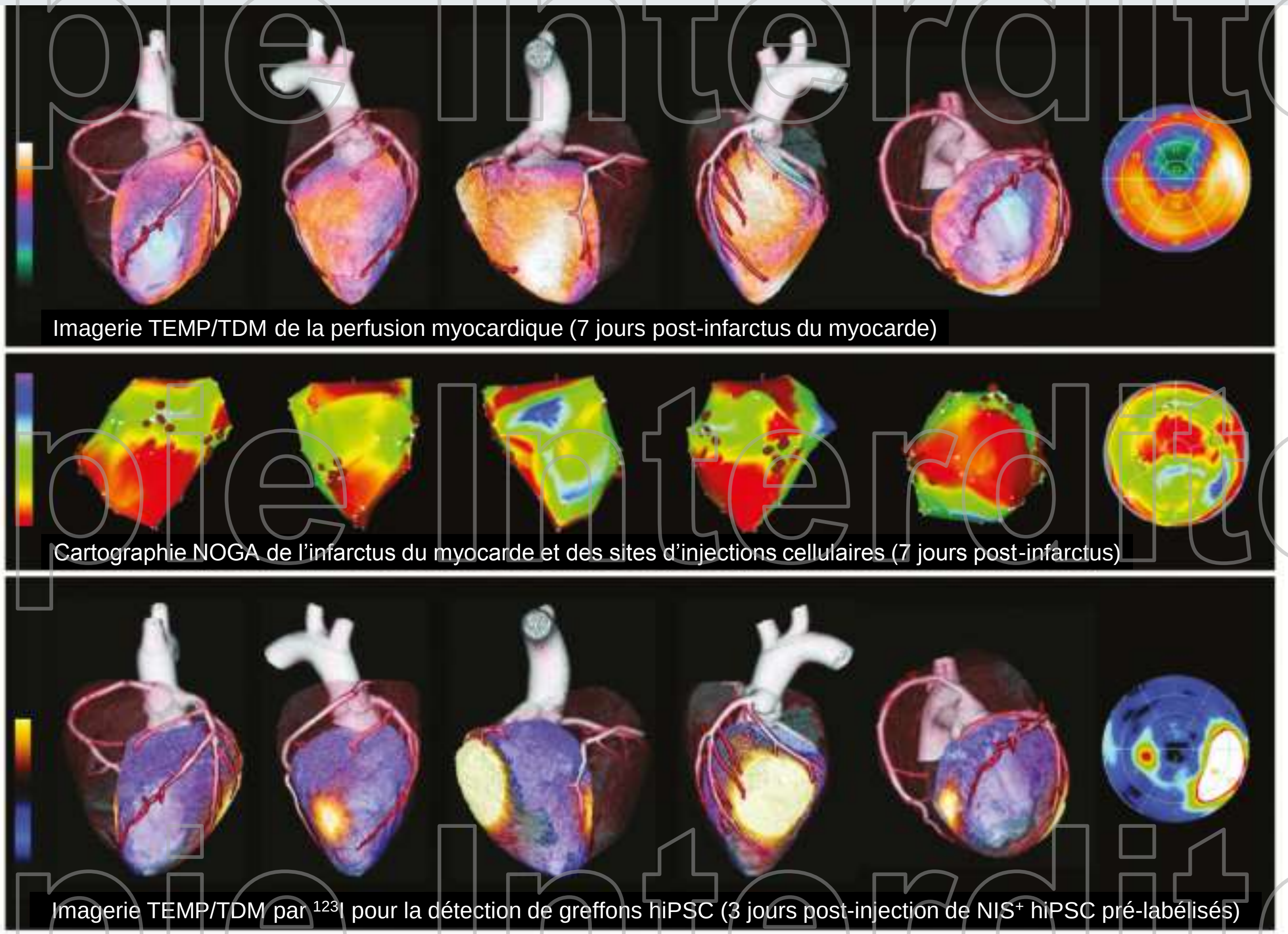
Suivi de la thérapie cellulaire par l'imagerie d'un gène-témoin





Transplantation and Tracking of Human-Induced Pluripotent Stem Cells in a Pig Model of Myocardial Infarction

Assessment of Cell Survival, Engraftment, and Distribution by Hybrid Single Photon Emission Computed Tomography/Computed Tomography of Sodium Iodide Symporter Transgene Expression

UniversityHospital Zurich

Circulation is available at http://circ.ahajournals.org DOI: 10.1161/CIRCULATIONAHA.111.087684

Nuclear meets friends

At eye level?

Friends?