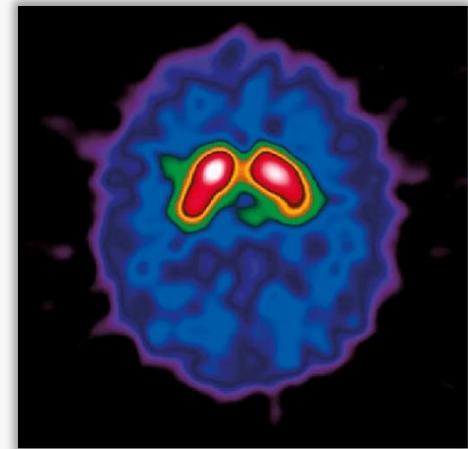


MASTER PhyMed

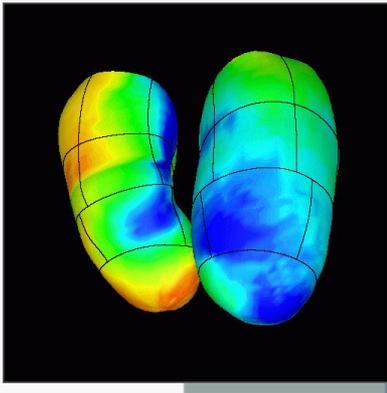
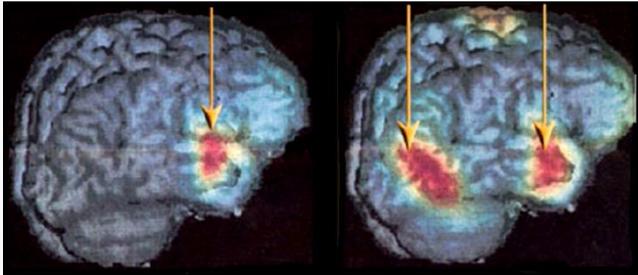
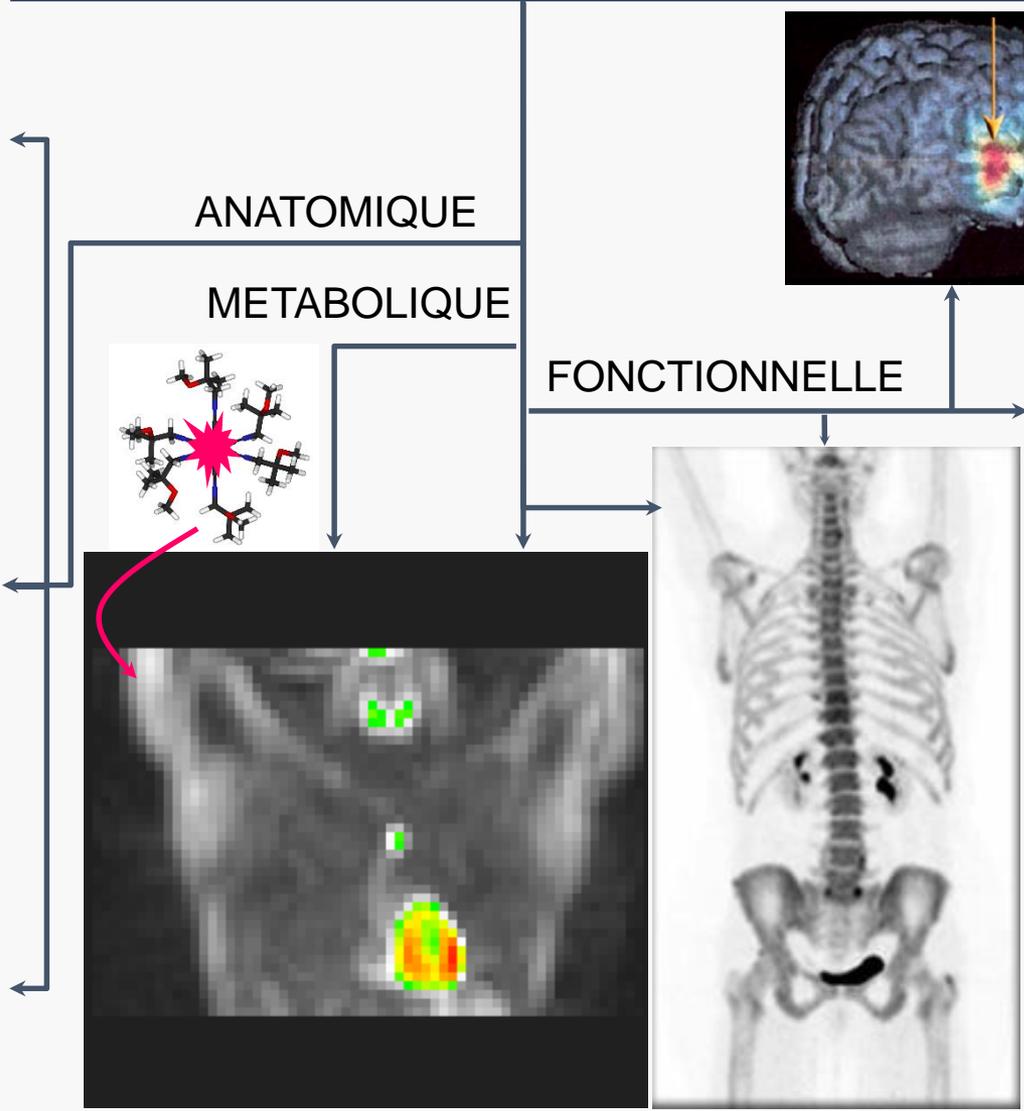
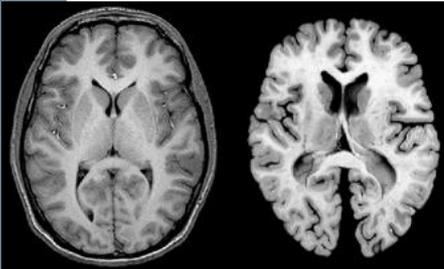
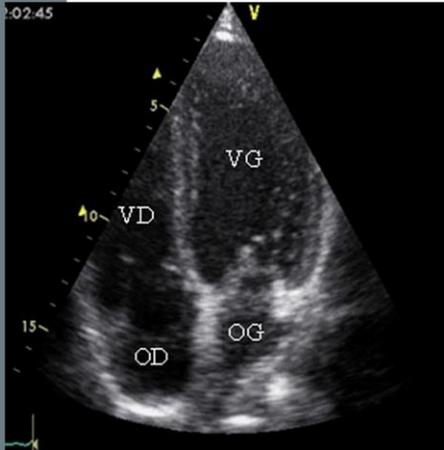
GMPH308 - Physique de l'imagerie médicale

IMAGERIE METABOLIQUE & MOLECULAIRE



Fayçal Ben Bouallègue
faycal.ben-bouallegue@umontpellier.fr
<http://scinti.edu.umontpellier.fr>

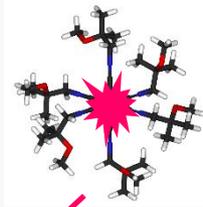
Imagerie médicale



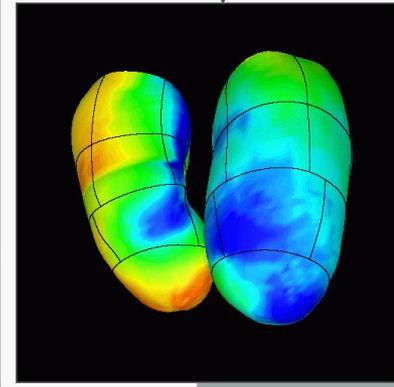
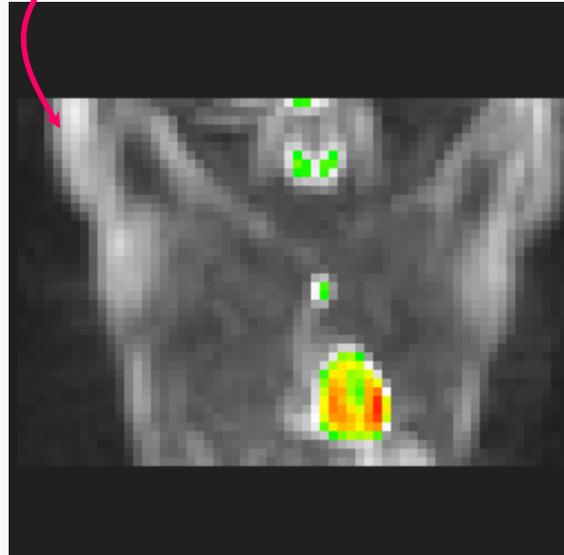
Médecine Nucléaire

Utilisation de **marqueurs radioactifs** pour **tracer** le devenir d'un **vecteur** (atome, molécule, cellule) dans un but **diagnostique**

IMAGERIE
DIAGNOSTIQUE
METABOLIQUE



IMAGERIE DIAGNOSTIQUE FONCTIONNELLE



Médecine Nucléaire

Utilisation de **marqueurs radioactifs** pour **tracer** le devenir d'un **vecteur** dans un but **diagnostique** ou **thérapeutique**

IMAGERIE
DIAGNOSTIQUE
METABOLIQUE

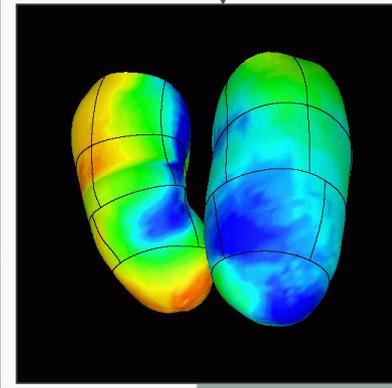
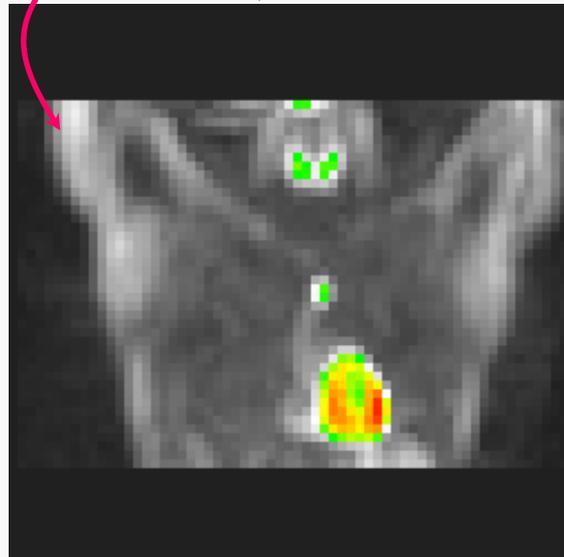


RADIOTHERAPIE INTERNE

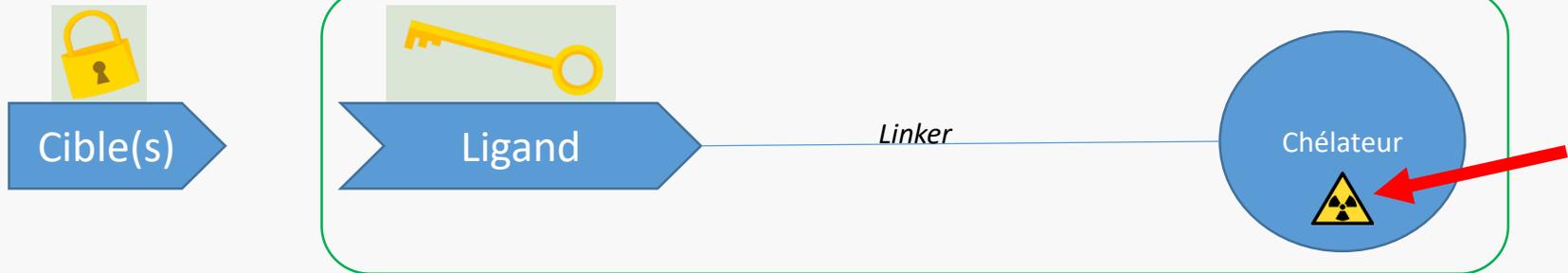
DETECTION PER-OPERATOIRE

DOSAGES RADIOIMMUNOLOGIQUES

IMAGERIE DIAGNOSTIQUE FONCTIONNELLE

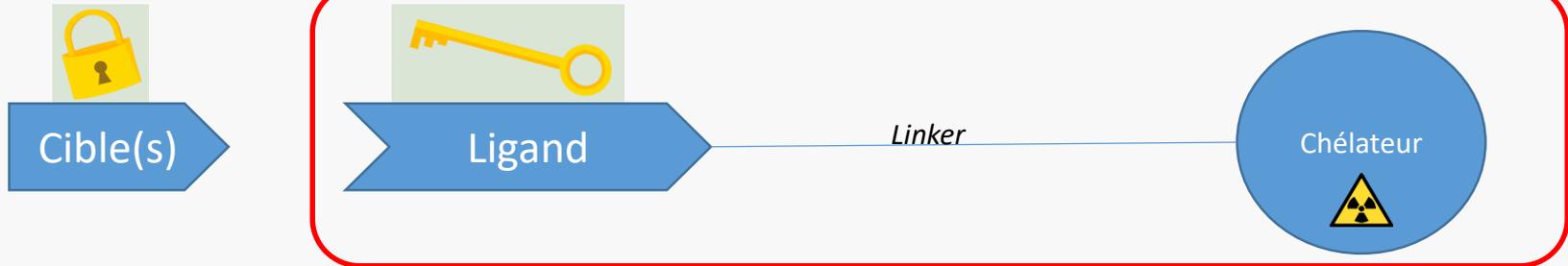


TRACEUR = **marqueur** + vecteur



	ISOTOPE	RADIO PROTECTION	PROPRIETES
DIAGNOSTIC	EMETTEURS DE PHOTONS PENETRANTS PEU DIFFUSES ⇒ β^+ ou γ ⇒ IONISANTS	PEU IRRADIANTS ⇒ T courtes : sec - h ⇒ ISOTOPES ARTIFICIELS	(RENDUS) SPECIFIQUES D'UN METABOLISME ⇒ MARQUAGE
THERAPIE	EMETTEURS DE PARTICULES IRRADIANTES	PARCOURS COURTS ⇒ α ou β ⇒ T assez courtes : jour ⇒ ISOTOPES ARTIFICIELS	(RENDUS) SPECIFIQUES D'UNE PATHOLOGIE ⇒ MARQUAGE

TRACEUR = marqueur + vecteur



- **Simple isotopes radioactifs**

- Diagnostic : $^{99}_{43}\text{Tc}$ $^{201}_{81}\text{Tl}$ $^{123}_{53}\text{I}$ $^{81}_{36}\text{Kr}$ $^{67}_{31}\text{Ga}$ $^{68}_{31}\text{Ga}$ $^{18}_8\text{F}$
- Thérapie : $^{32}_{15}\text{P}$ $^{169}_{68}\text{Er}$ $^{186}_{75}\text{Re}$ $^{90}_{39}\text{Y}$ $^{131}_{53}\text{I}$

- **Molécules**

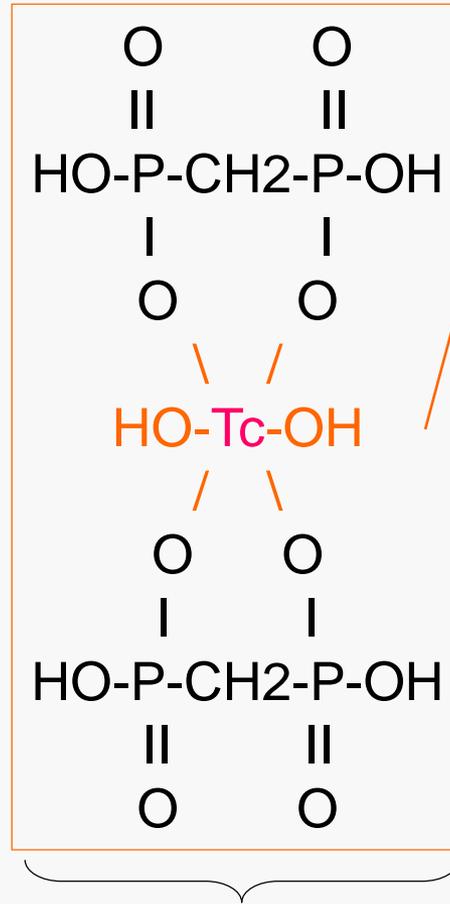
- HMPAO, ECD : **perfusion cérébrale**
- MIBI, TETROFOSMINE / Albumine : **perfusion cœur / poumon**
- MIBG, Cholestérol, Octréotide, FDG : **cancers** (principalement)
- BIPHOSPHONATES : **maladies des os**
- MAG3, DTPA, DMSA : **rein**
- Anticorps monoclonaux, récepteurs mb. : **infection, thérapie**

- **Cellules**

- globules rouges : **fonction cardiaque**
- polynucléaires : **infection**

SCINTIGRAPHIE

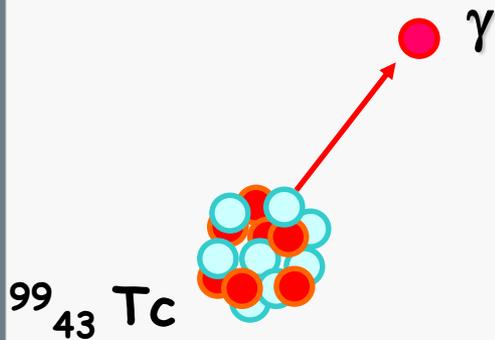
Le **marqueur** est utilisé pour rendre radioactive une molécule vectrice spécifique d'un métabolisme d'intérêt.
La cartographie de radioactivité mesurée est appelée **scintigraphie**



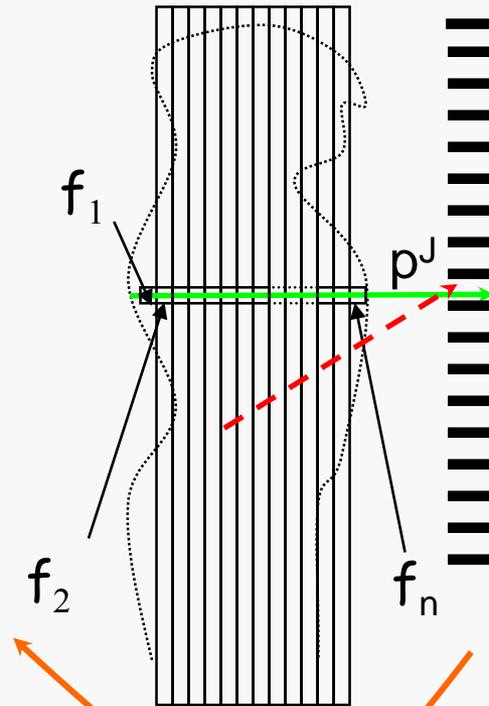
TRACEUR RADIOACTIF



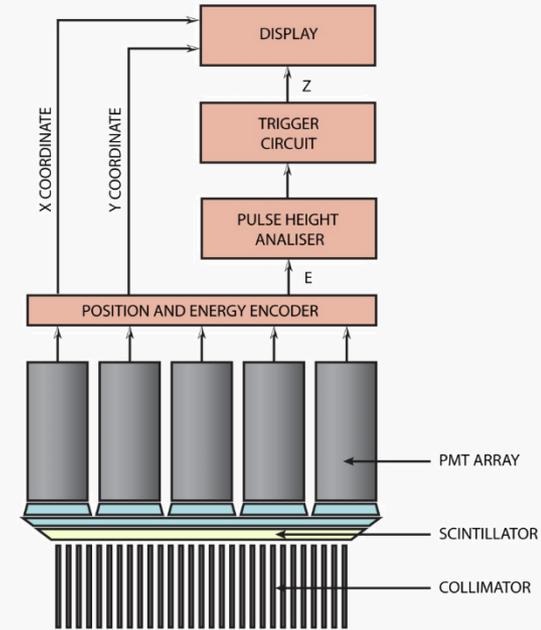
SCINTIGRAPHIE γ (SPECT)



COLLIMATEUR



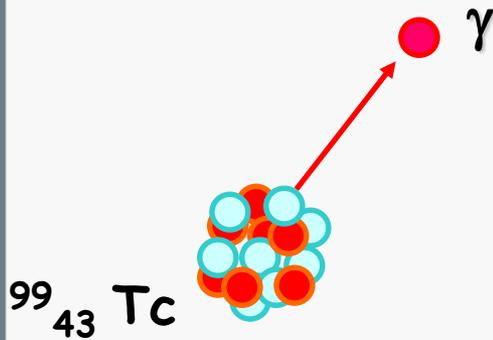
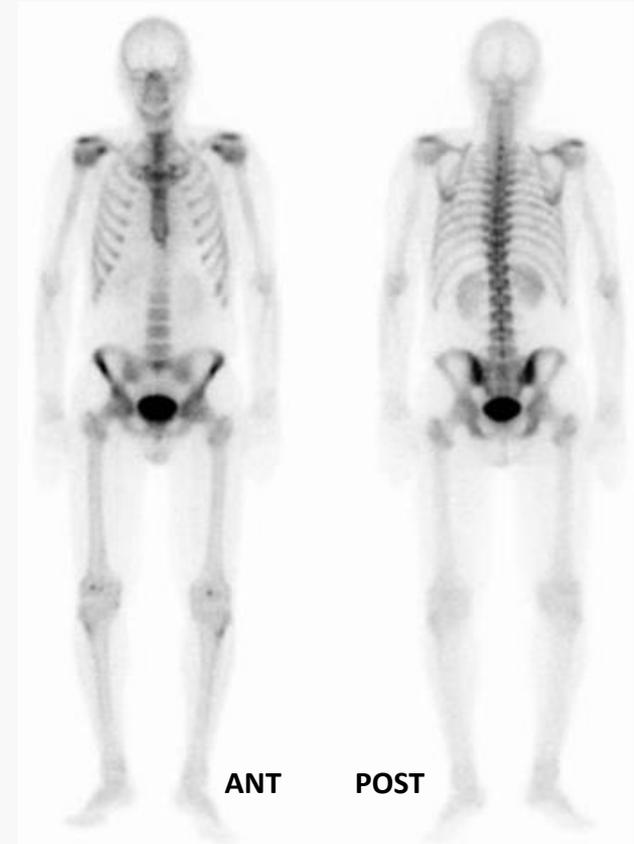
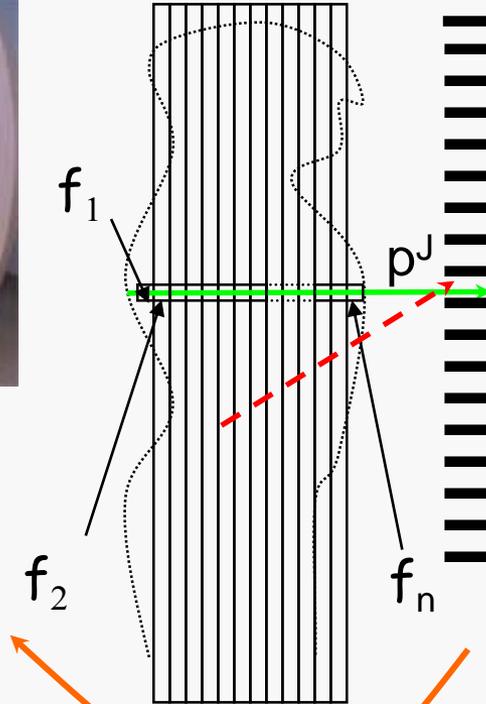
$$p^j = \sum_i R_i^j f_i$$



SCINTIGRAPHIE γ (SPECT)



COLLIMATEUR

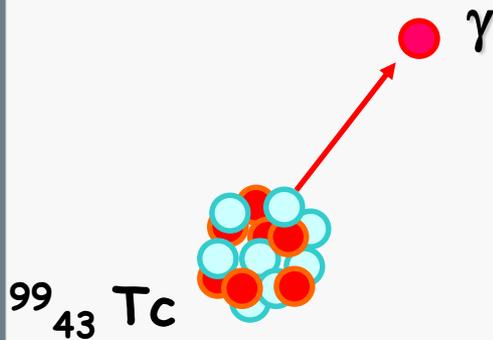
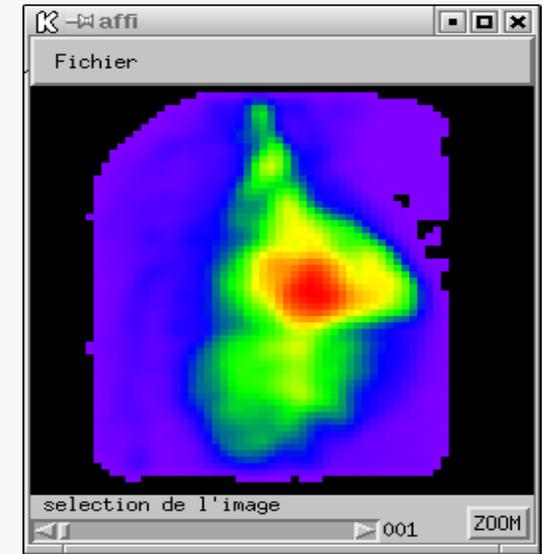
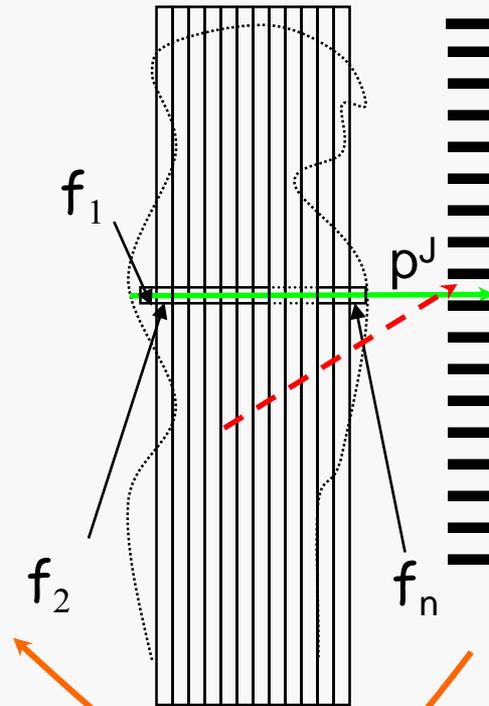


$$p^j = \sum_i R_i^j f_i$$

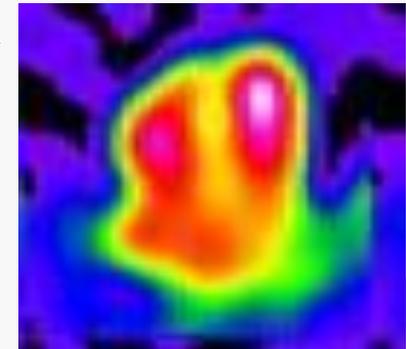
SCINTIGRAPHIE γ (SPECT)



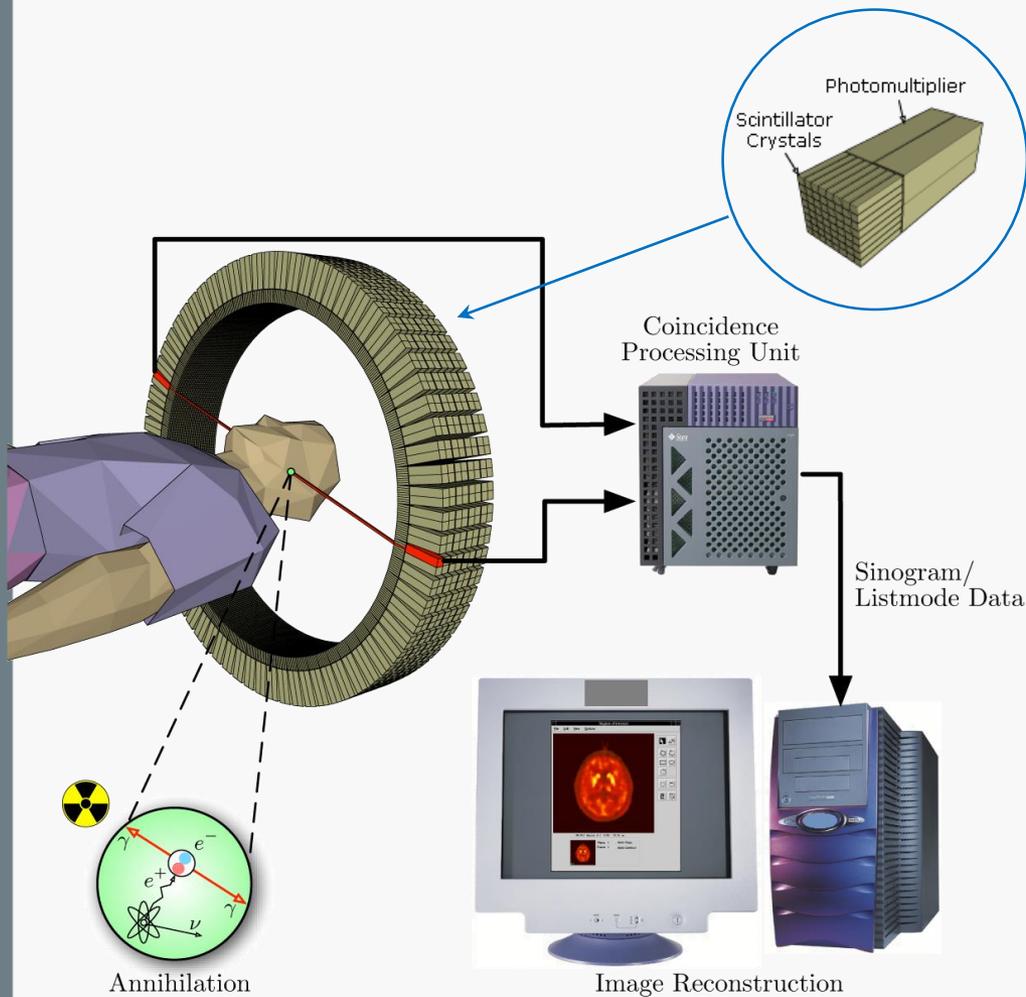
COLLIMATEUR



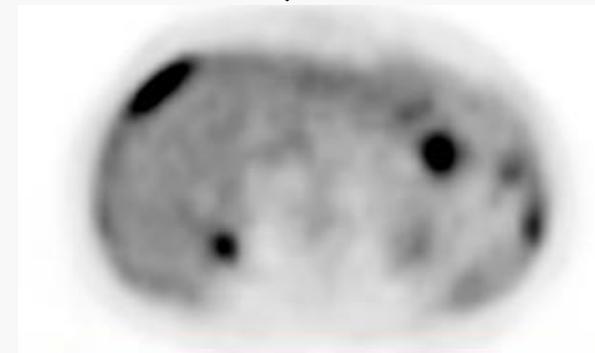
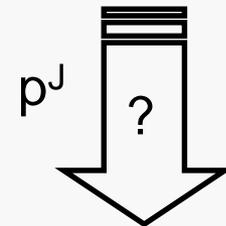
$$p^j = \sum_i R_i^j f_i$$



SCINTIGRAPHIE β^+ (PET)



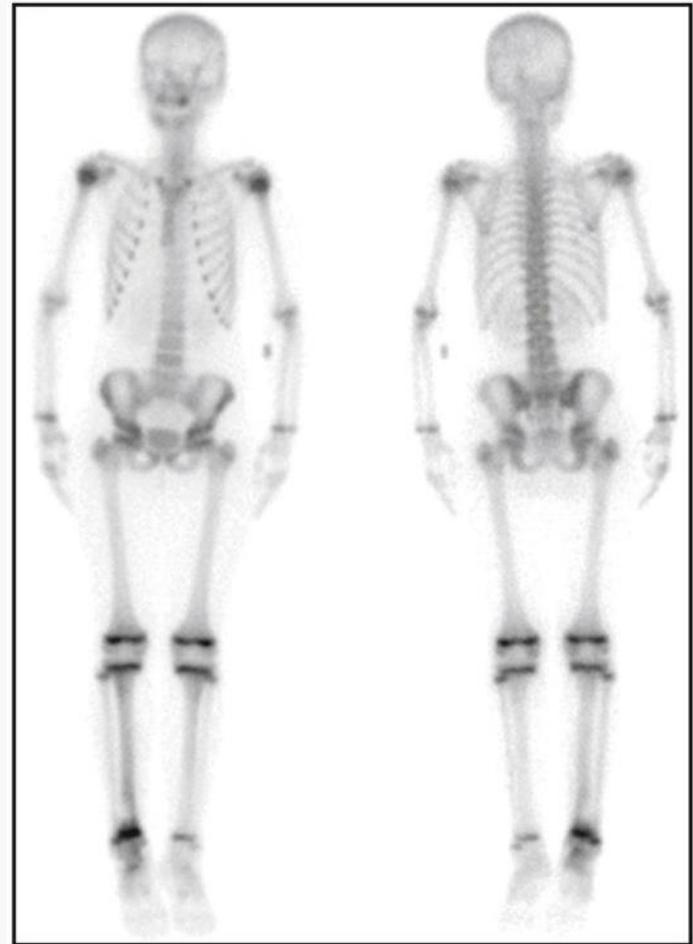
$$p^j = \sum_i R_i^j f_i$$



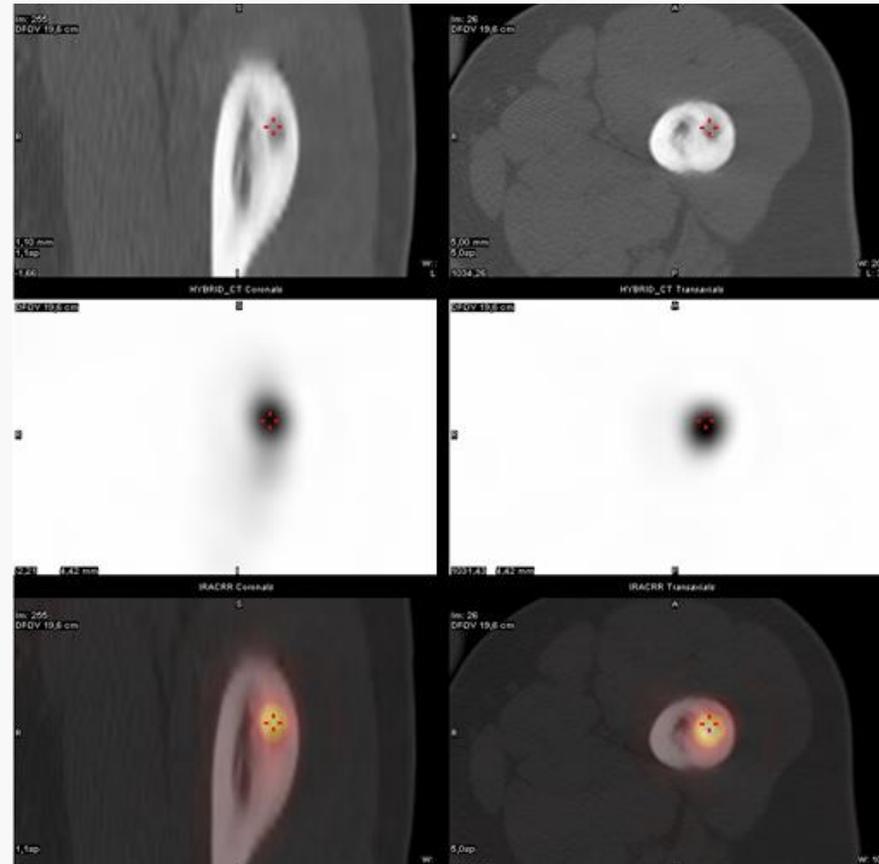
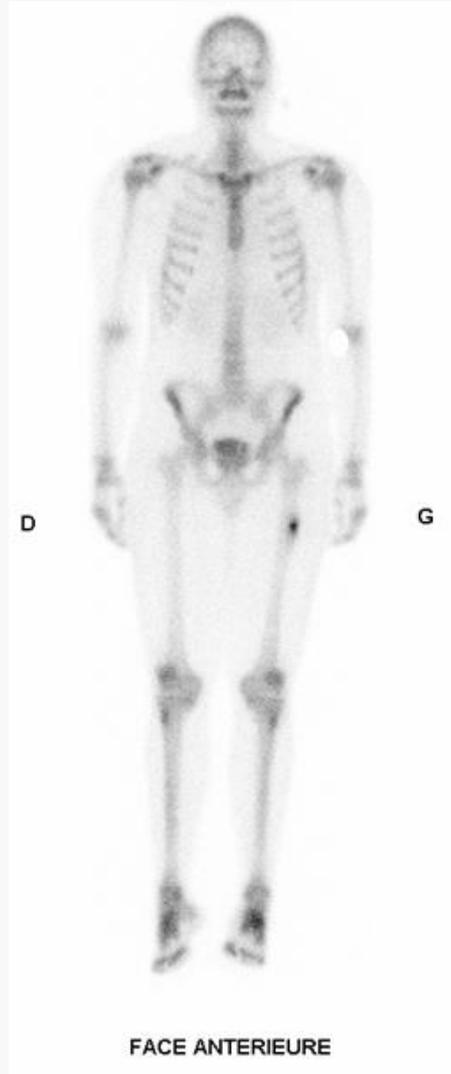
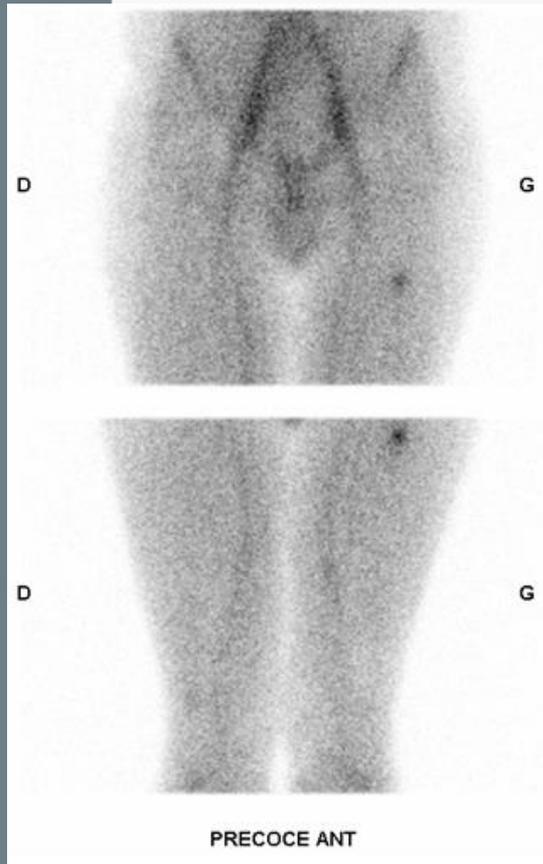
REMODELAGE OSSEUX



BIPHOSPHONATE
mTc 99 - BP



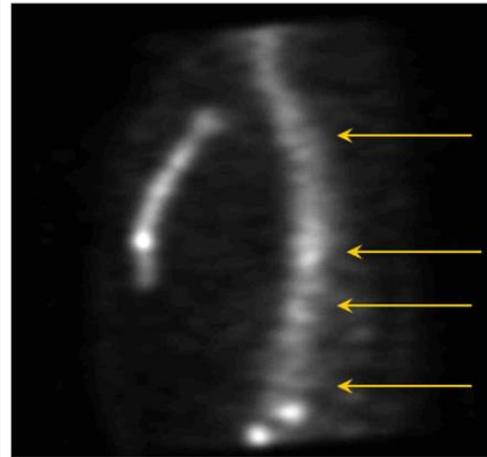
REMODELAGE OSSEUX



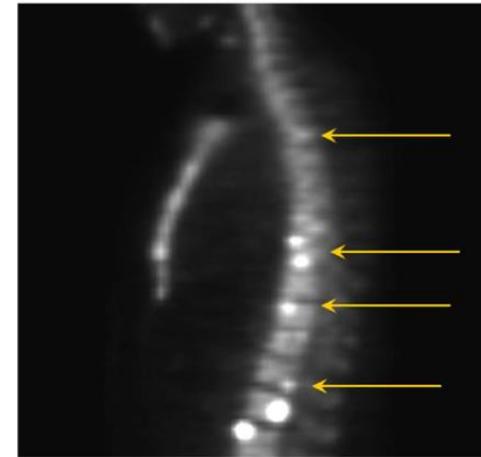
REMODELAGE OSSEUX



F 18 - Na

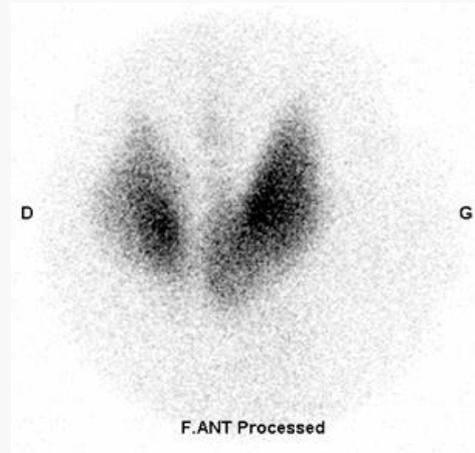
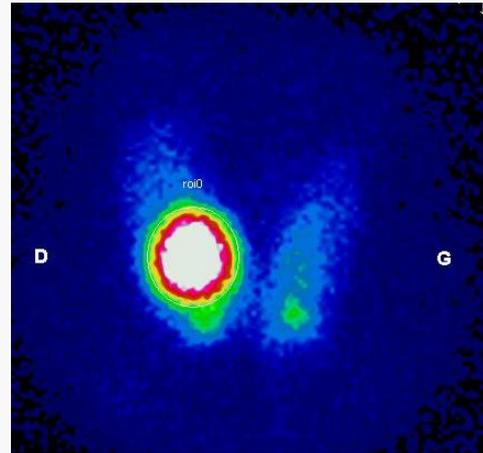
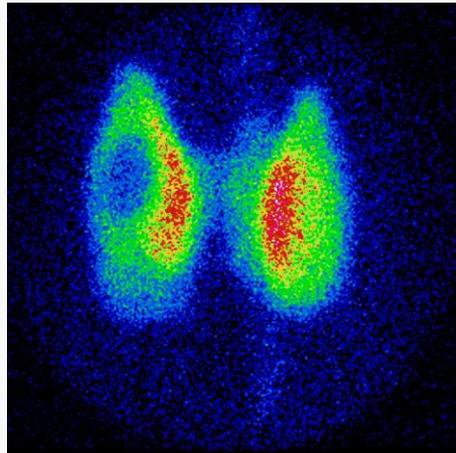
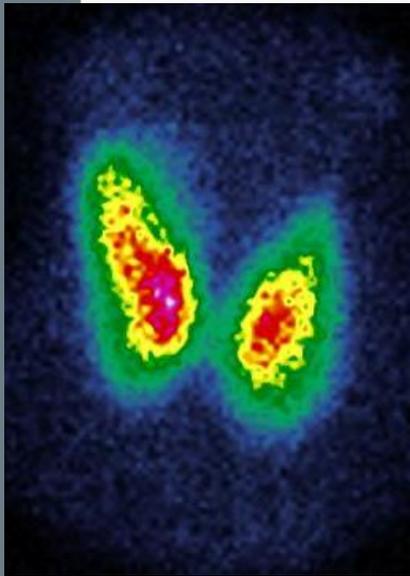


BIPHOSPHONATE
mTc 99 - BP



F 18 - Na

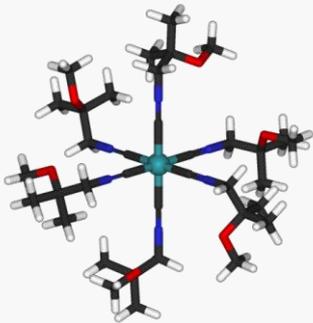
SCINTIGRAPHIE THYROÏDIENNE



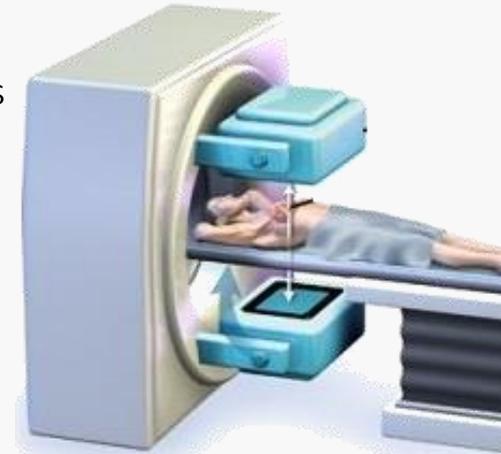
mTc 99 - O₄⁻

Principale indication: bilan des hyperthyroïdies

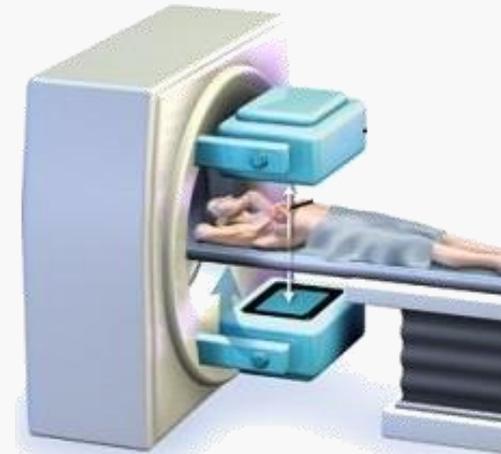
PERFUSION MYOCARDIQUE



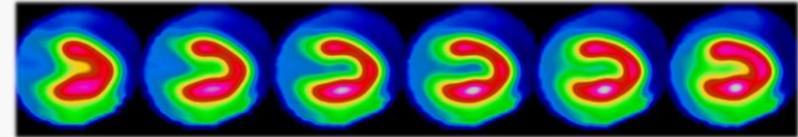
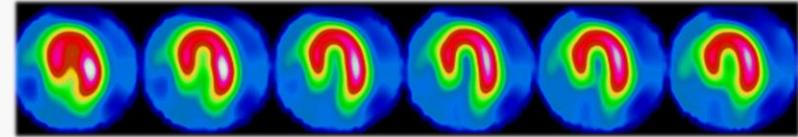
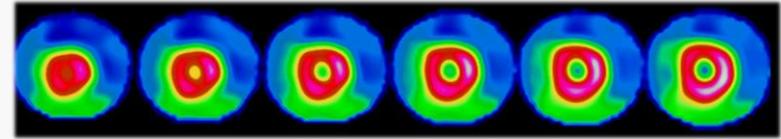
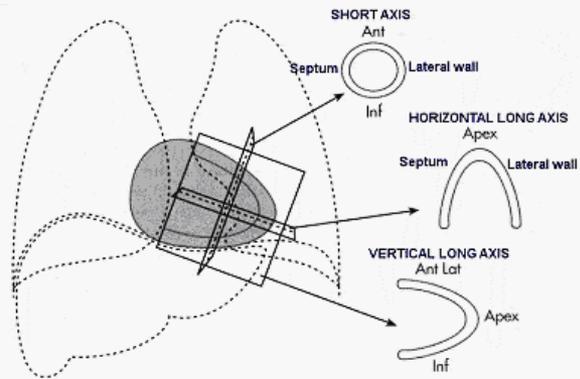
Repos



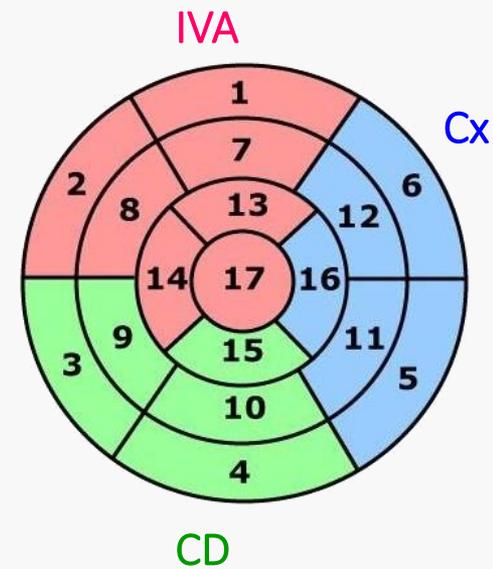
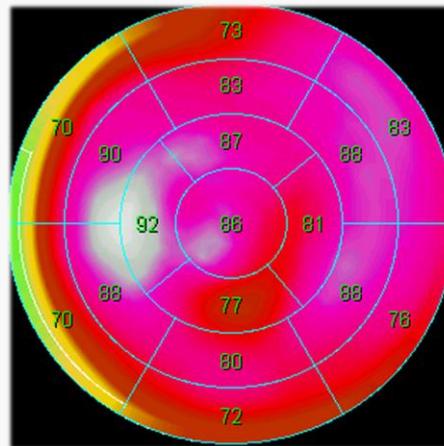
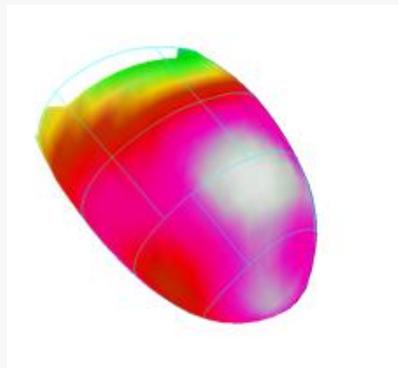
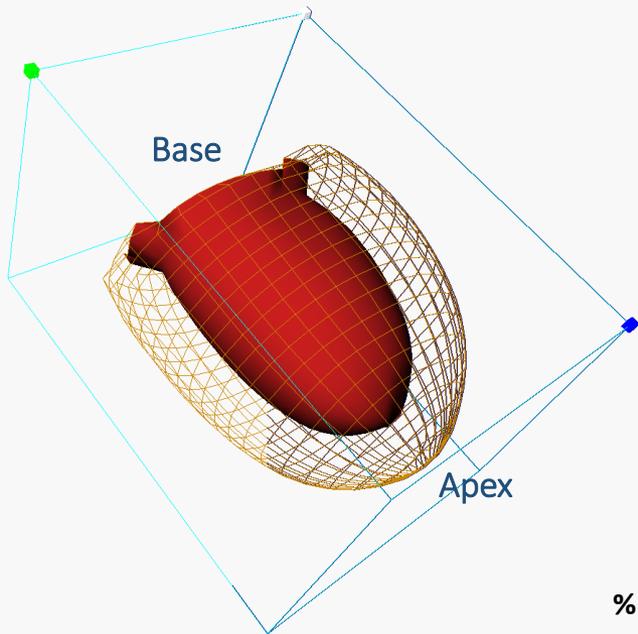
Effort



PERFUSION MYOCARDIQUE

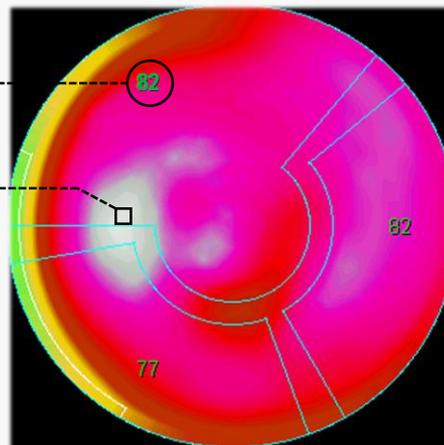


PERFUSION MYOCARDIQUE

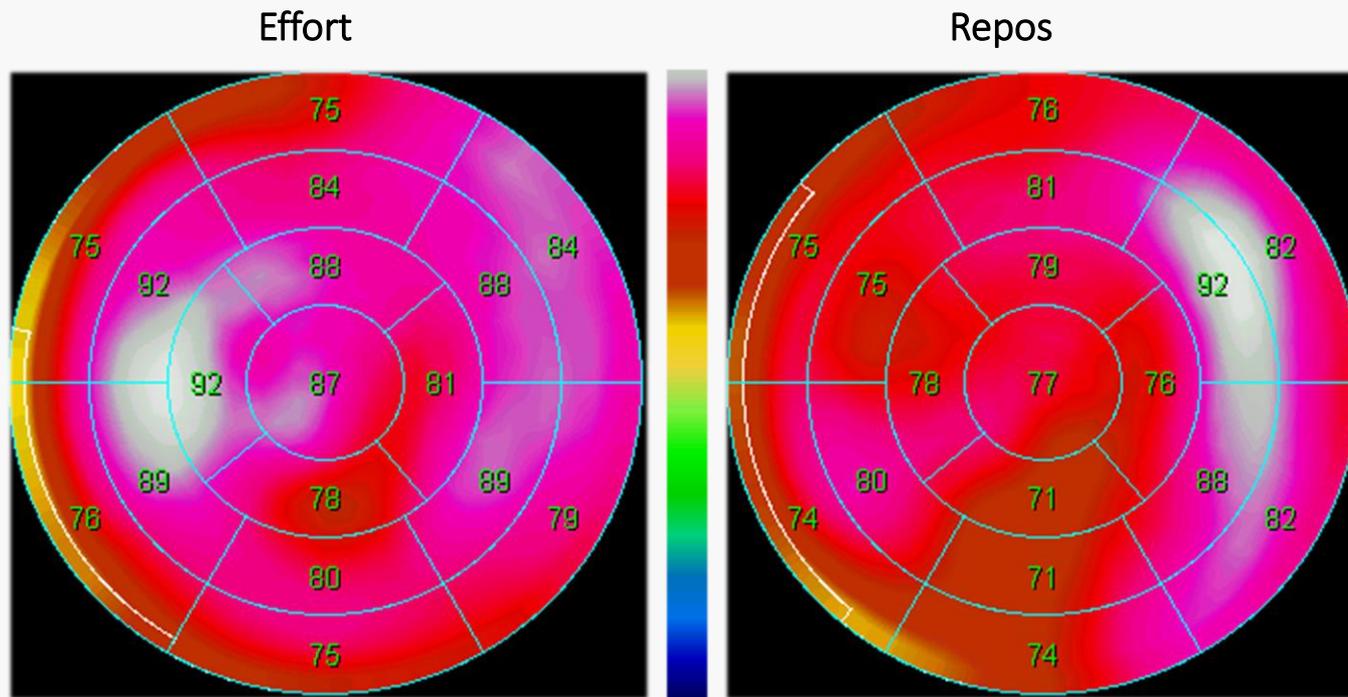


% max

max (100%)

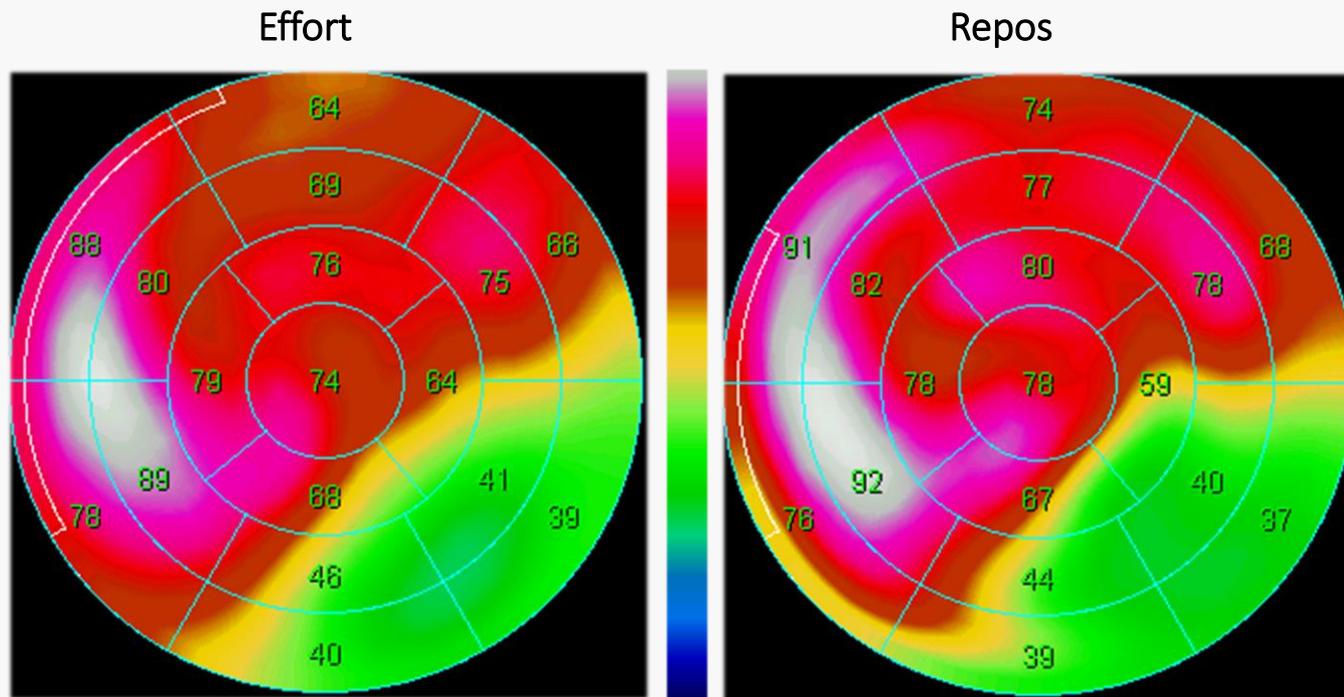


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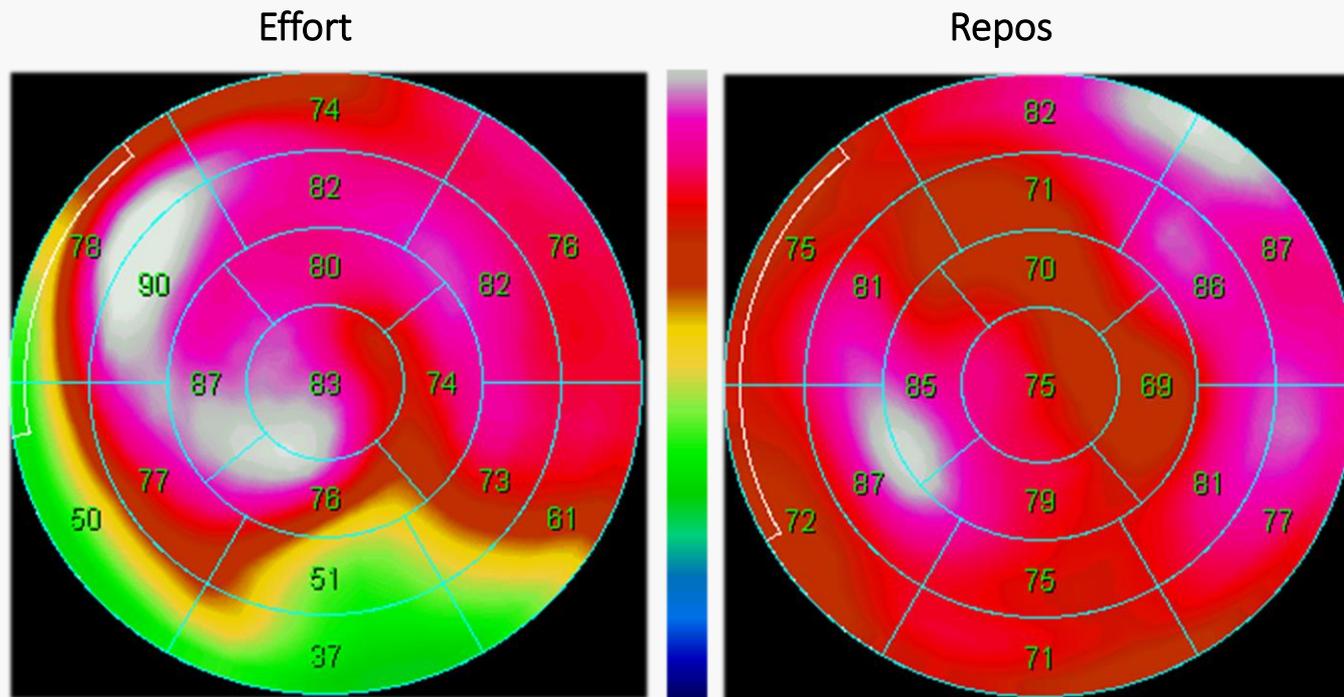
Scintigraphie normale

PERFUSION MYOCARDIQUE



Séquelle d'infarctus

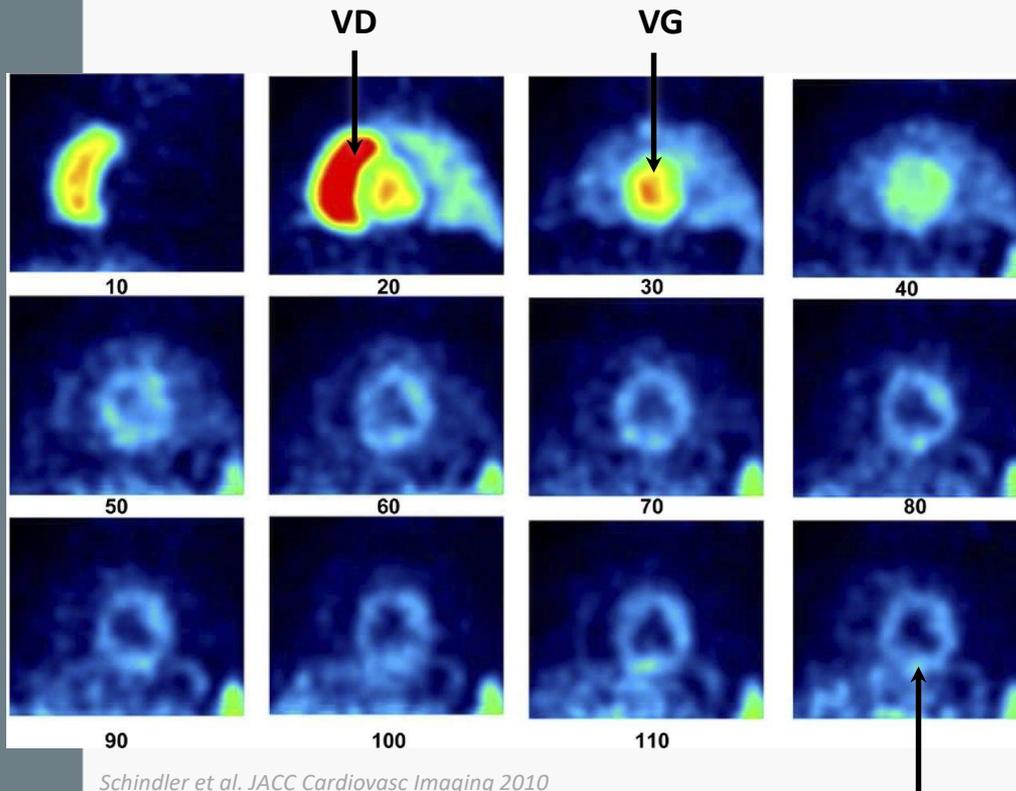
PERFUSION MYOCARDIQUE



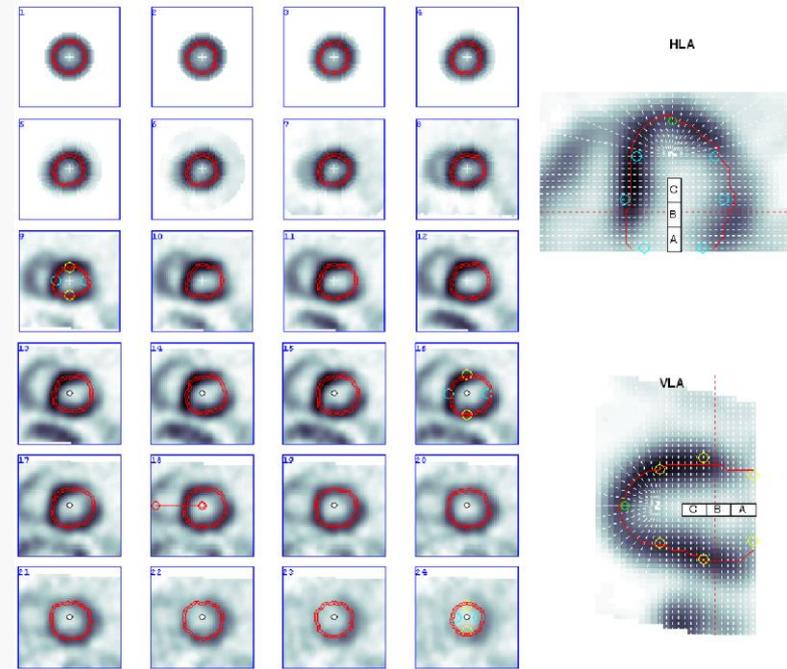
Ischémie myocardique

PERFUSION MYOCARDIQUE

PERFUSION : QUANTIFICATION ABSOLUE

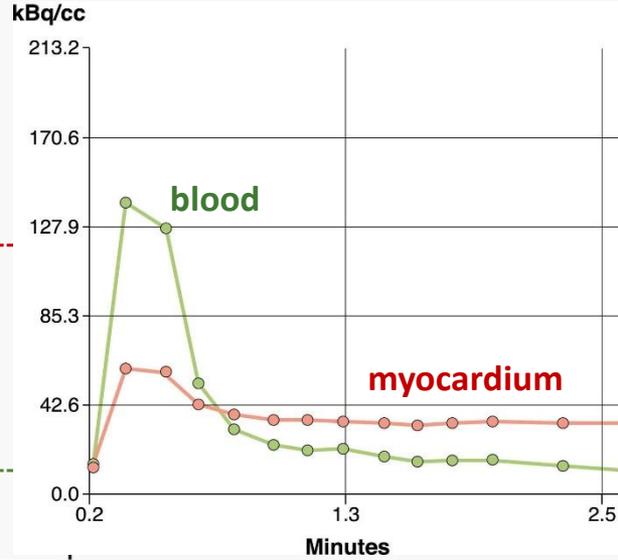
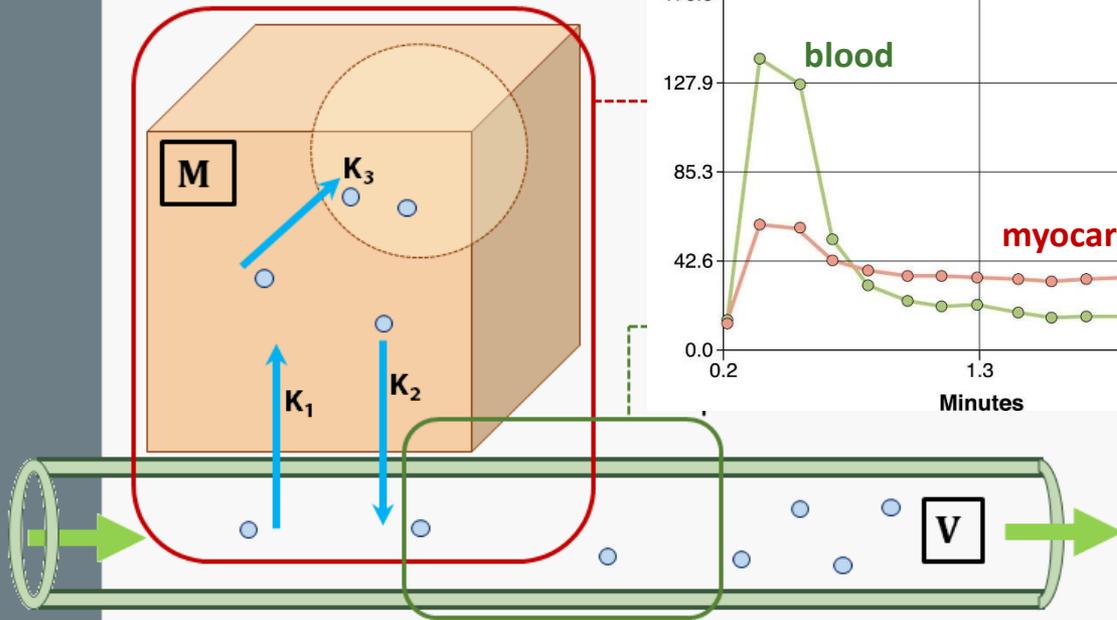


Schindler et al. JACC Cardiovasc Imaging 2010

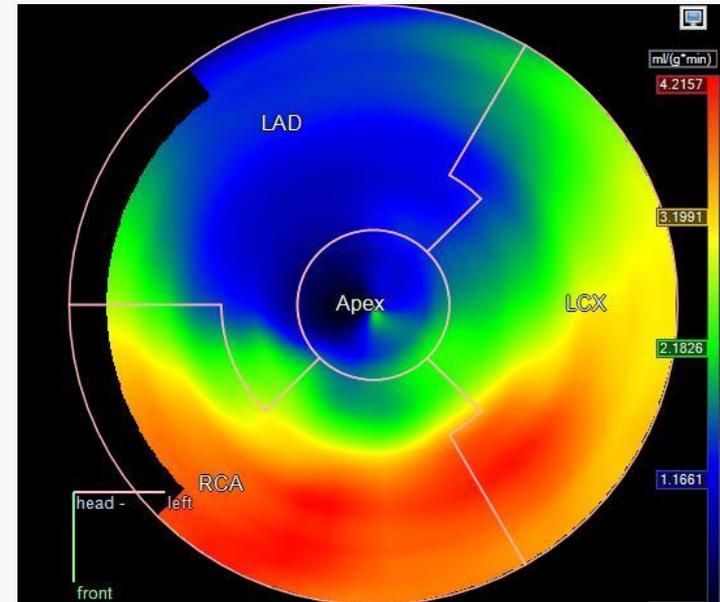
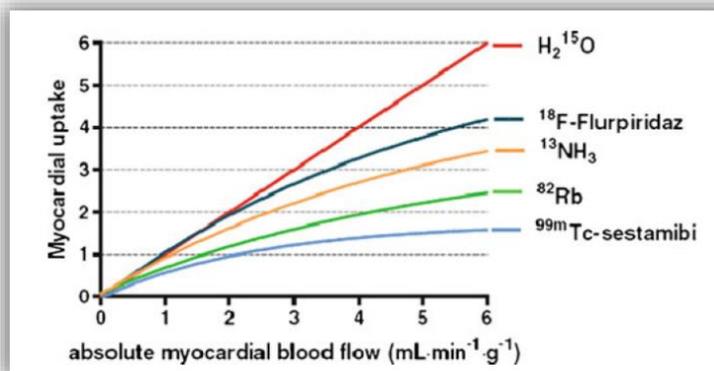


Klein et al. J Nucl Cardiol 2010

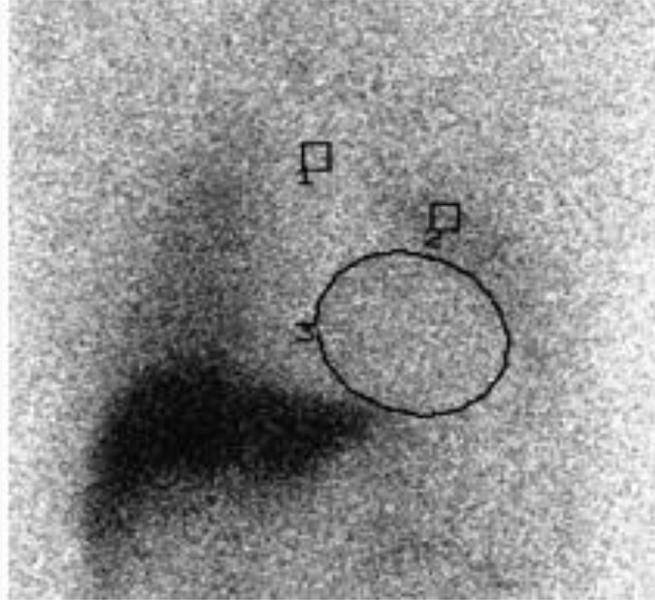
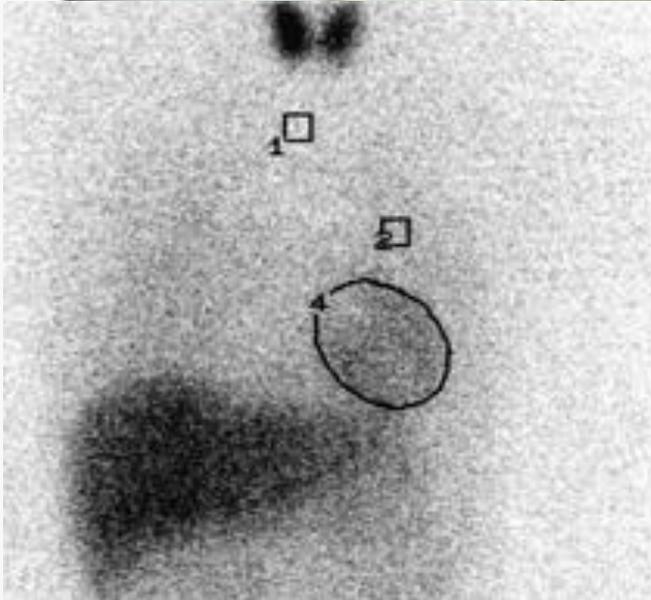
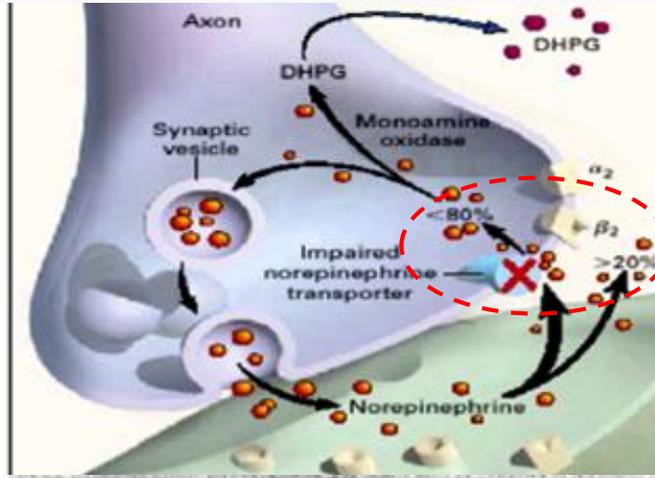
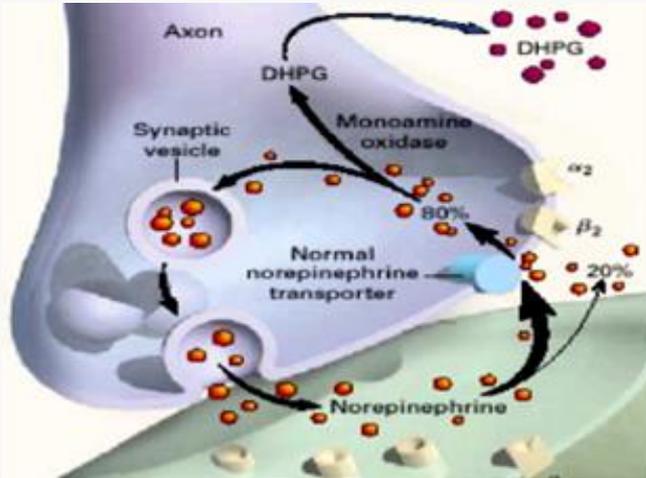
PERFUSION MYOCARDIQU



Schindler et al. JACC Cardiovasc Imaging 2010



INNERVATION MYOCARDIQU



MIBG - I 123

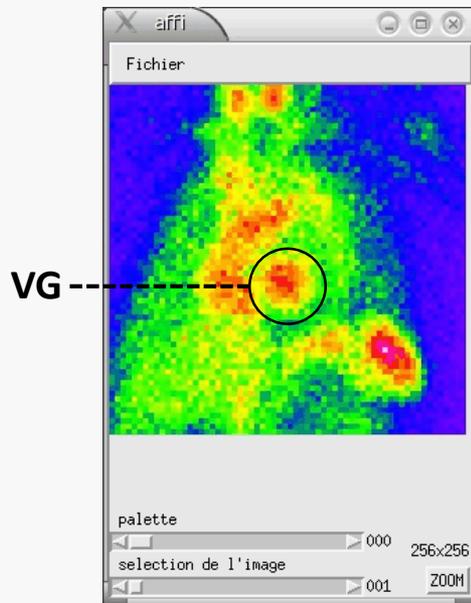
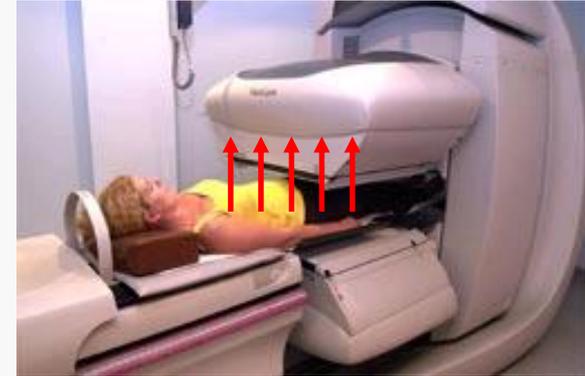
CONTRACTION CARDIAQUE

Tomo-ventriculographie isotopique

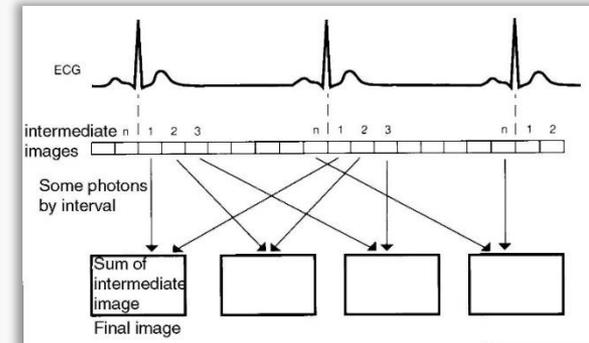
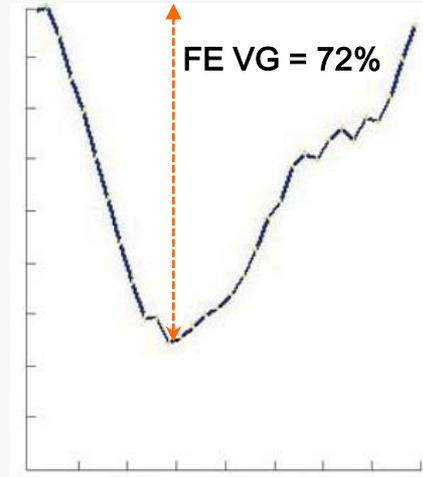
Marquage des GR (^{99m}Tc)

Acquisition **planaire**

Synchronisation ECG



Volume \propto activité



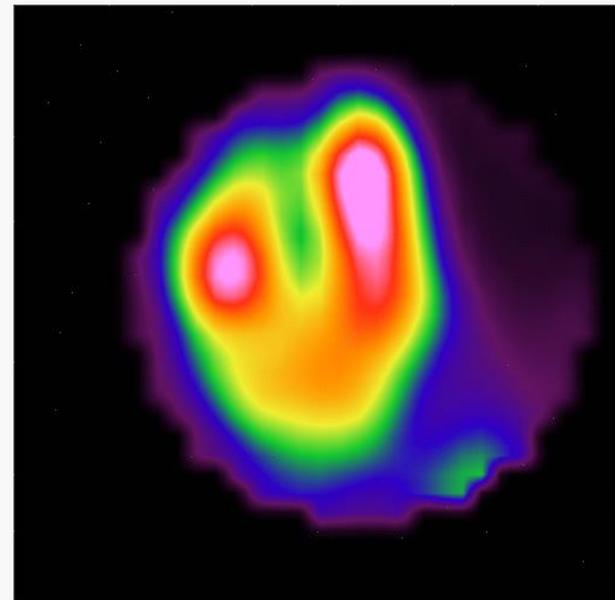
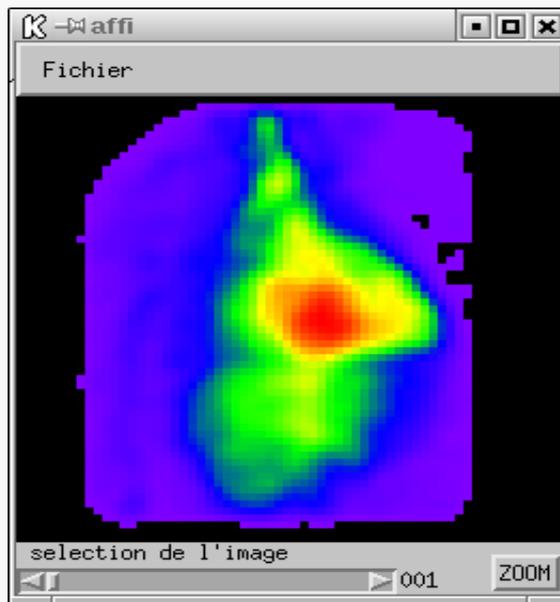
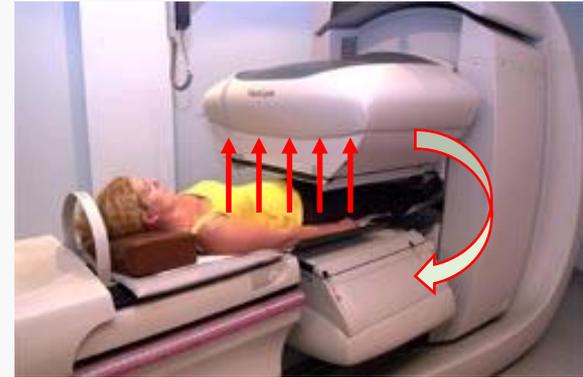
CONTRACTION CARDIAQUE

Tomo-ventriculographie isotopique

Marquage des GR (^{99m}Tc)

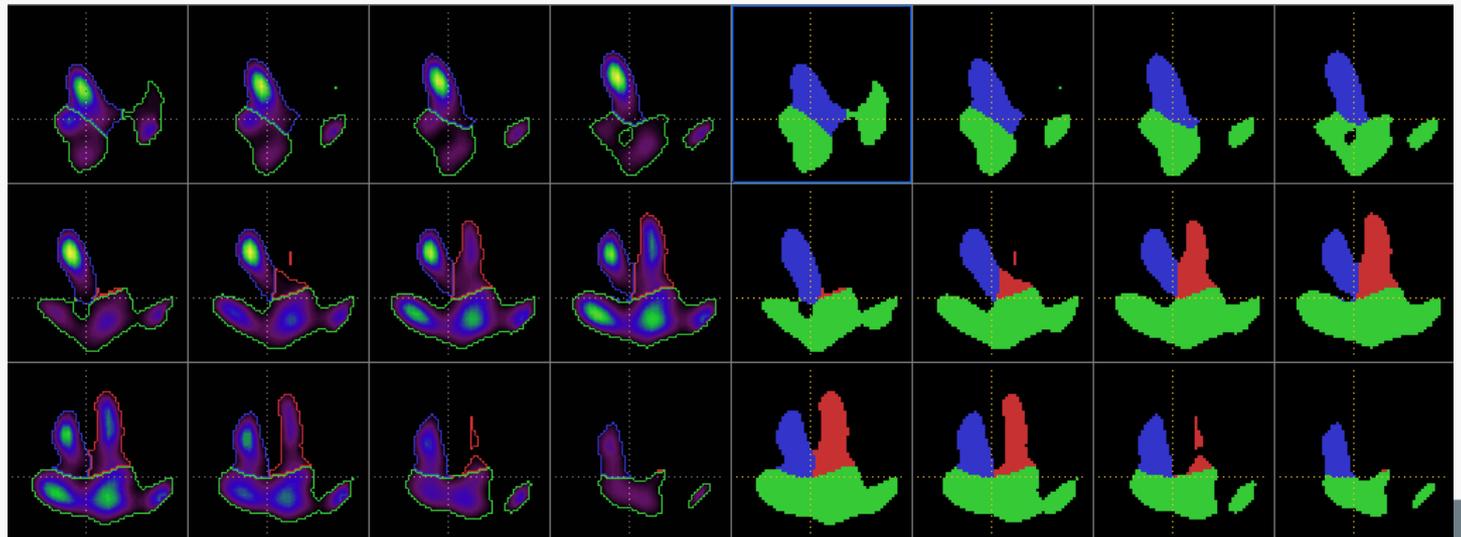
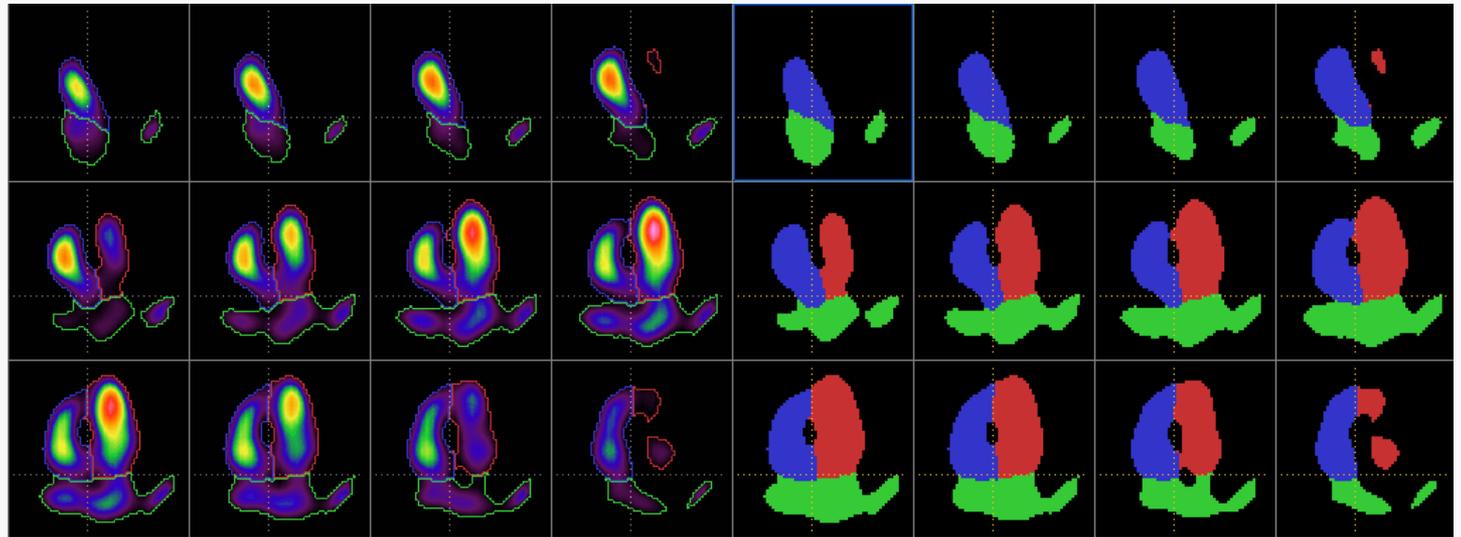
Acquisition **tomographique**

Synchronisation ECG



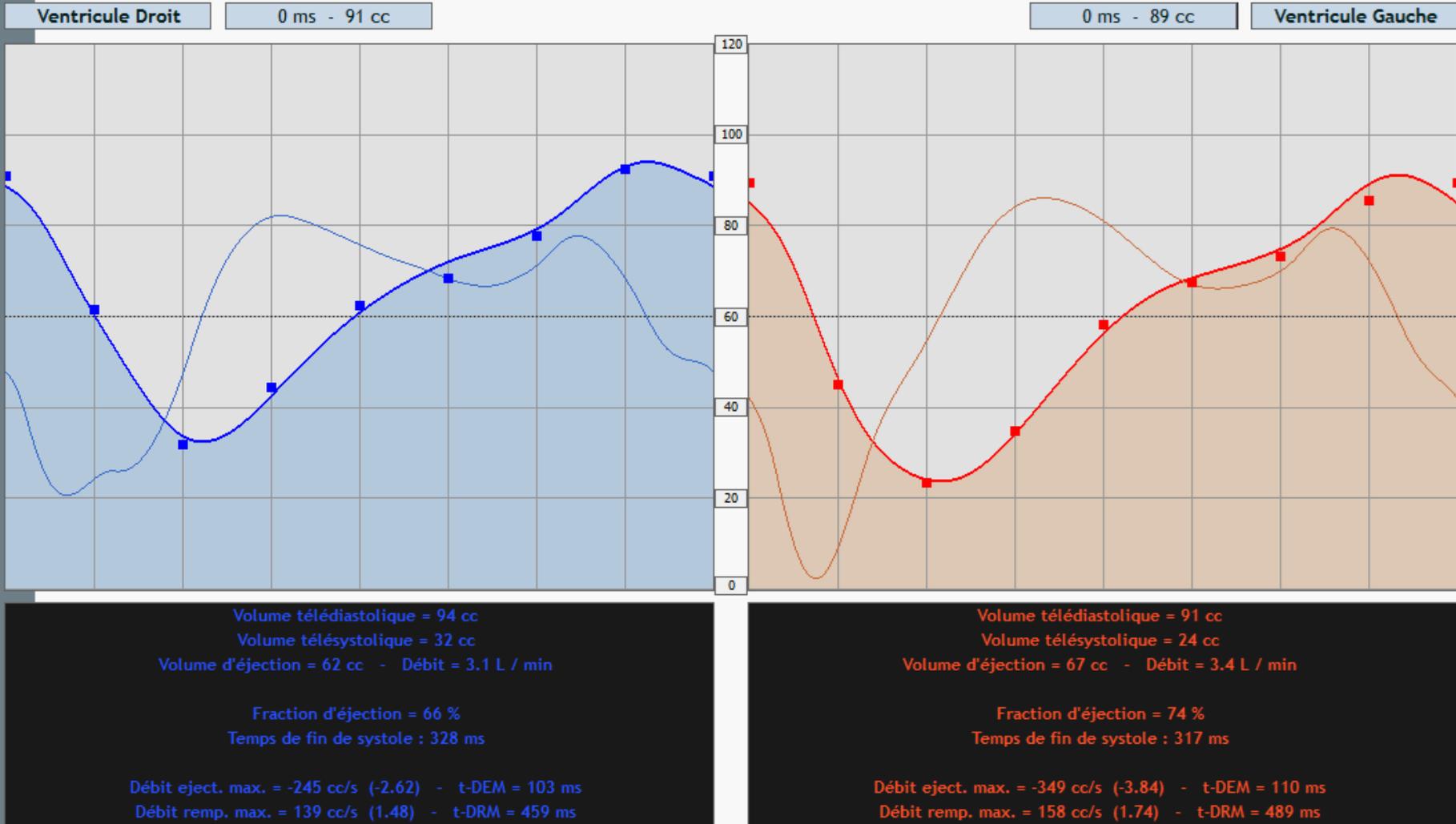
CONTRACTION CARDIAQUE

SEGMENTATION

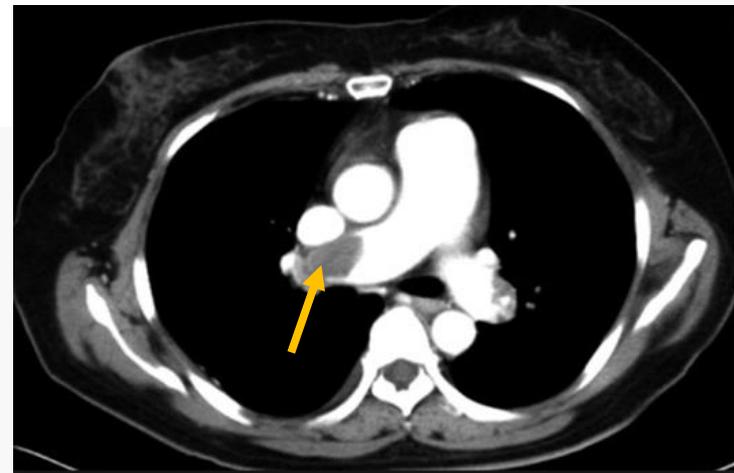
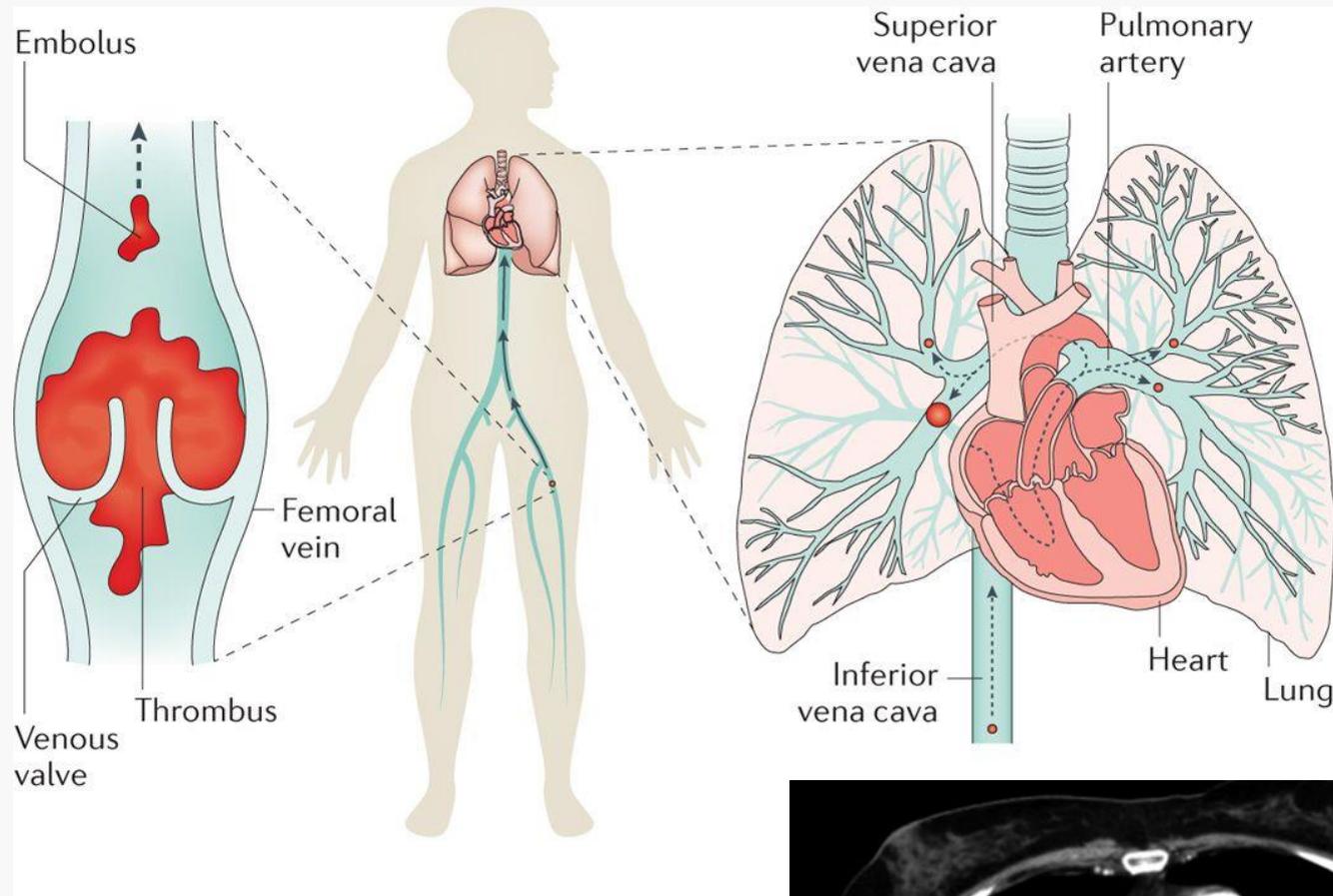


CONTRACTION CARDIAQUE

CINETIQUE GLOBALE

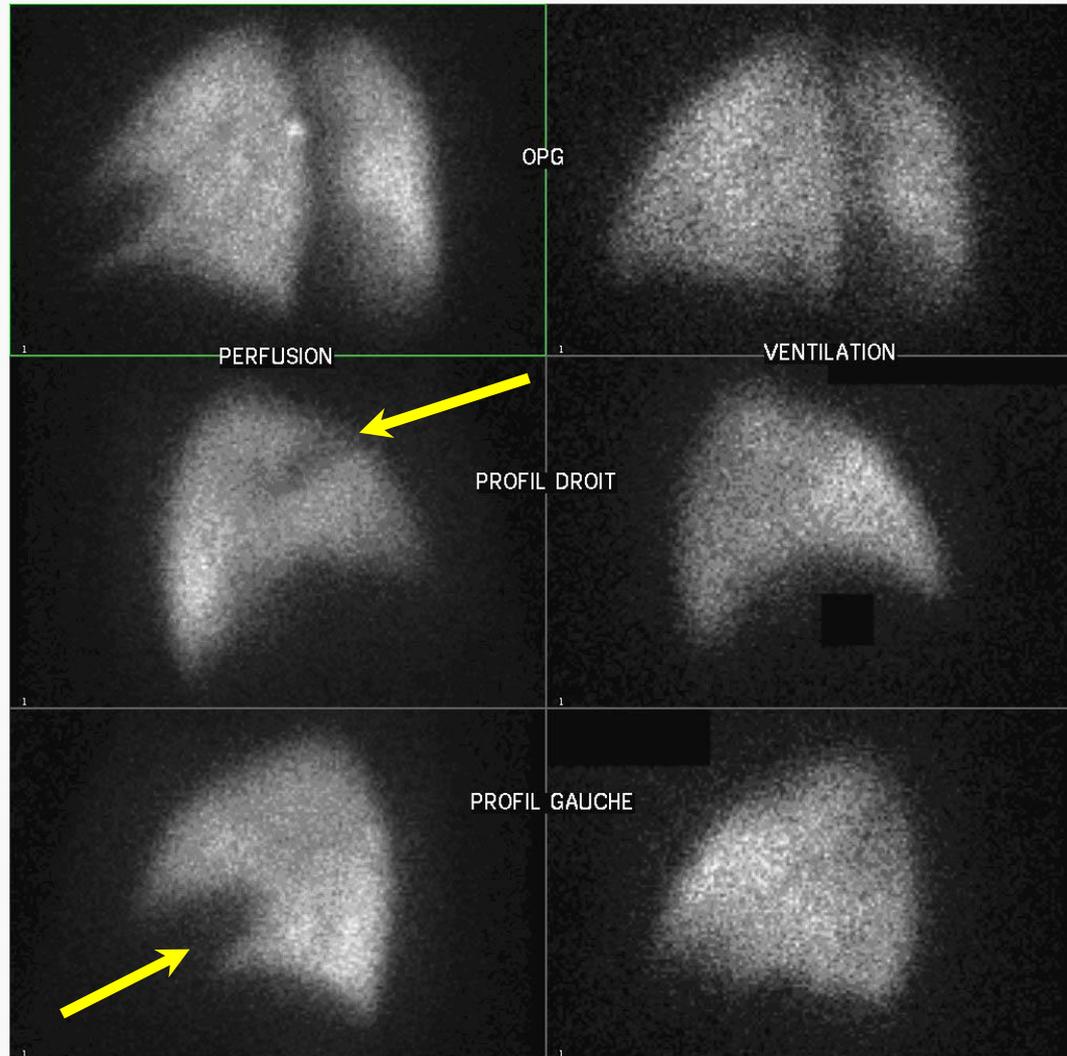


VENTILATION & PERFUSION PULMONAIRES



VENTILATION & PERFUSION PULMONAIRES

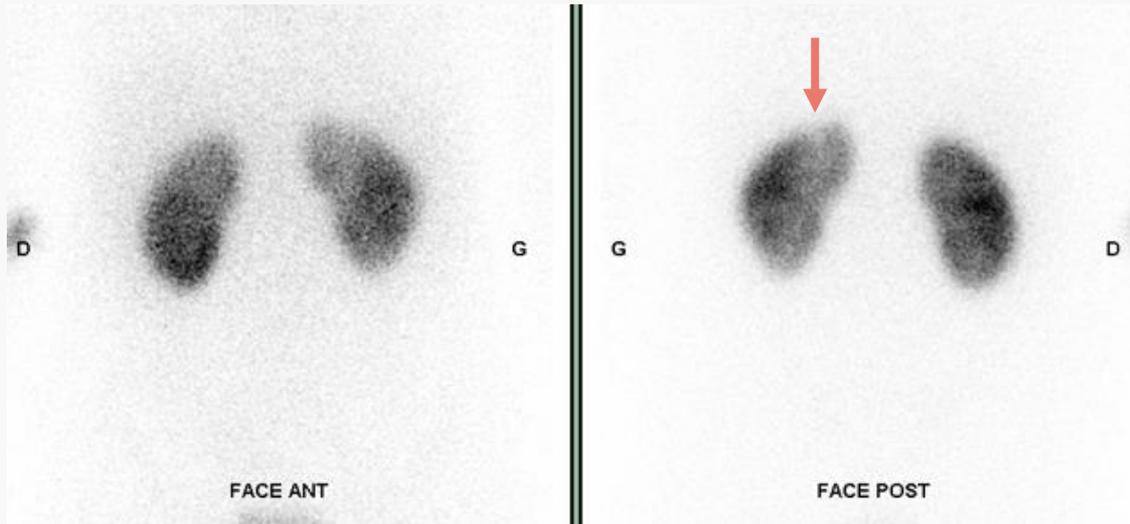
PERF
^{99m}Tc – Albumine



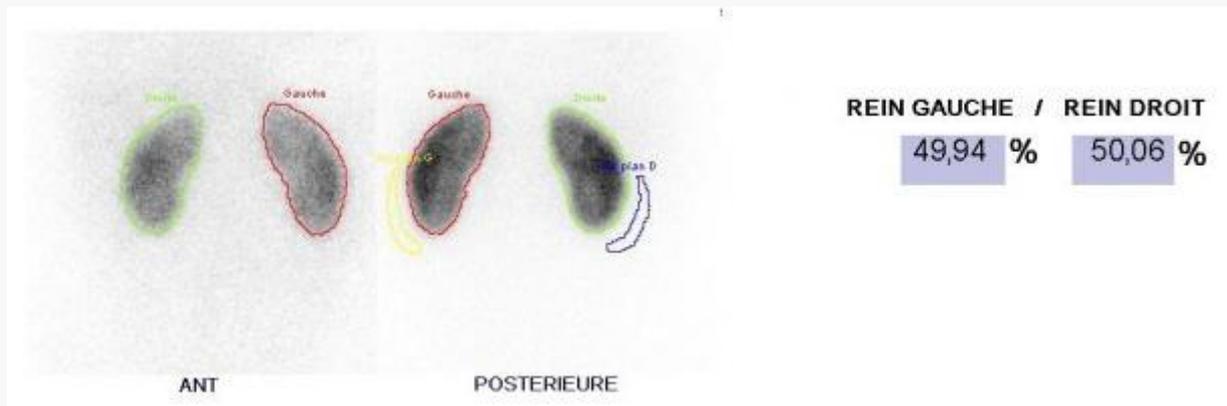
VENT
^{99m}Tc - Aérosol

SCINTIGRAPHIES RENALES

m99Tc-DMSA



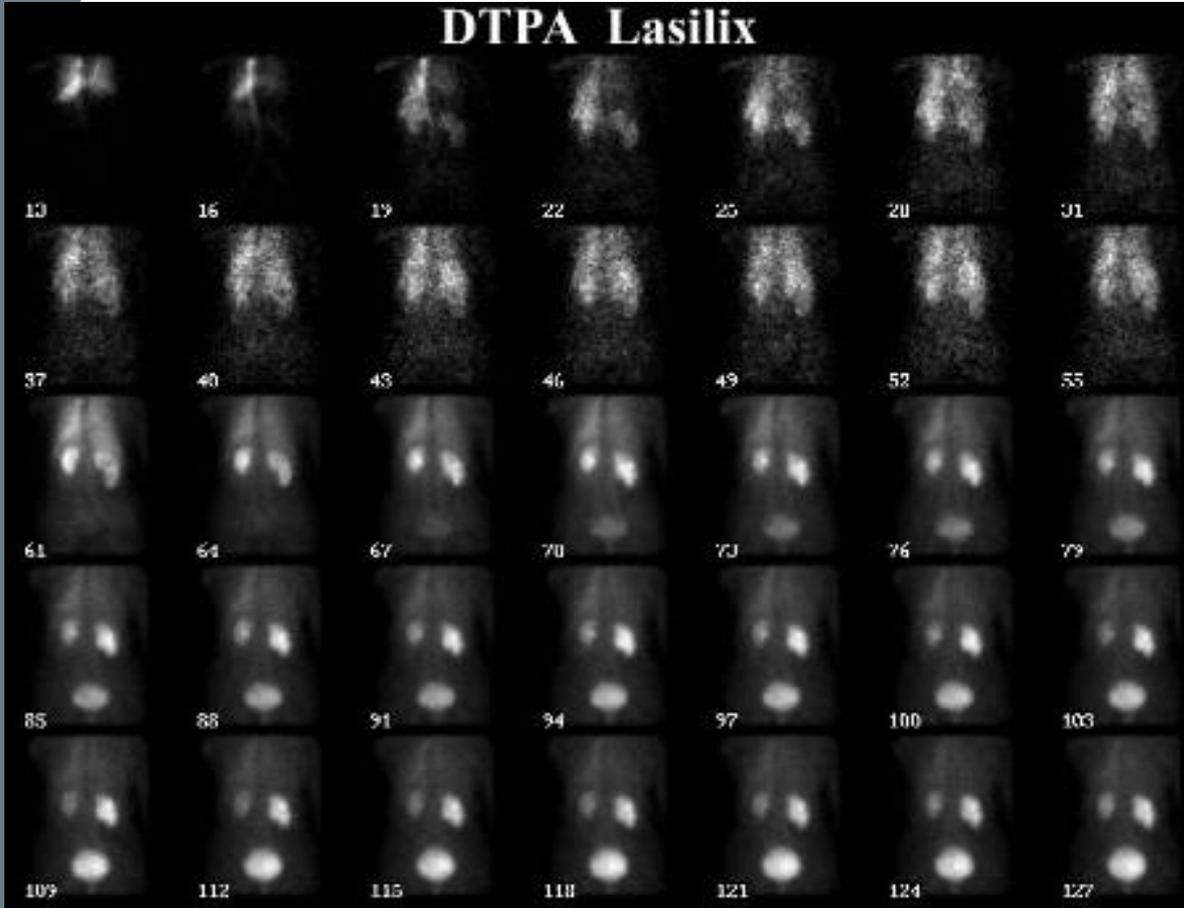
Cicatrice d'infection urinaire



Fonctions relatives

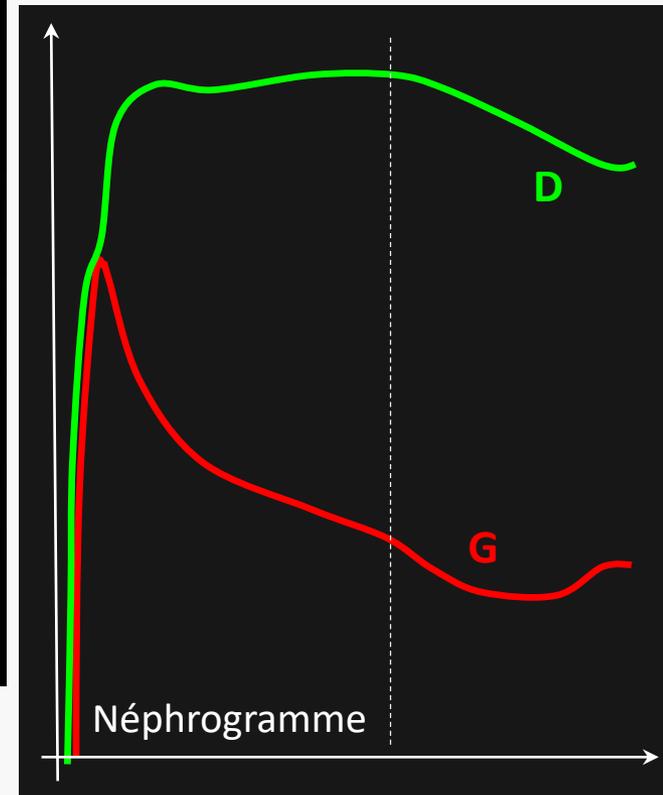
SCINTIGRAPHIES RENALES

DTPA Lasilix



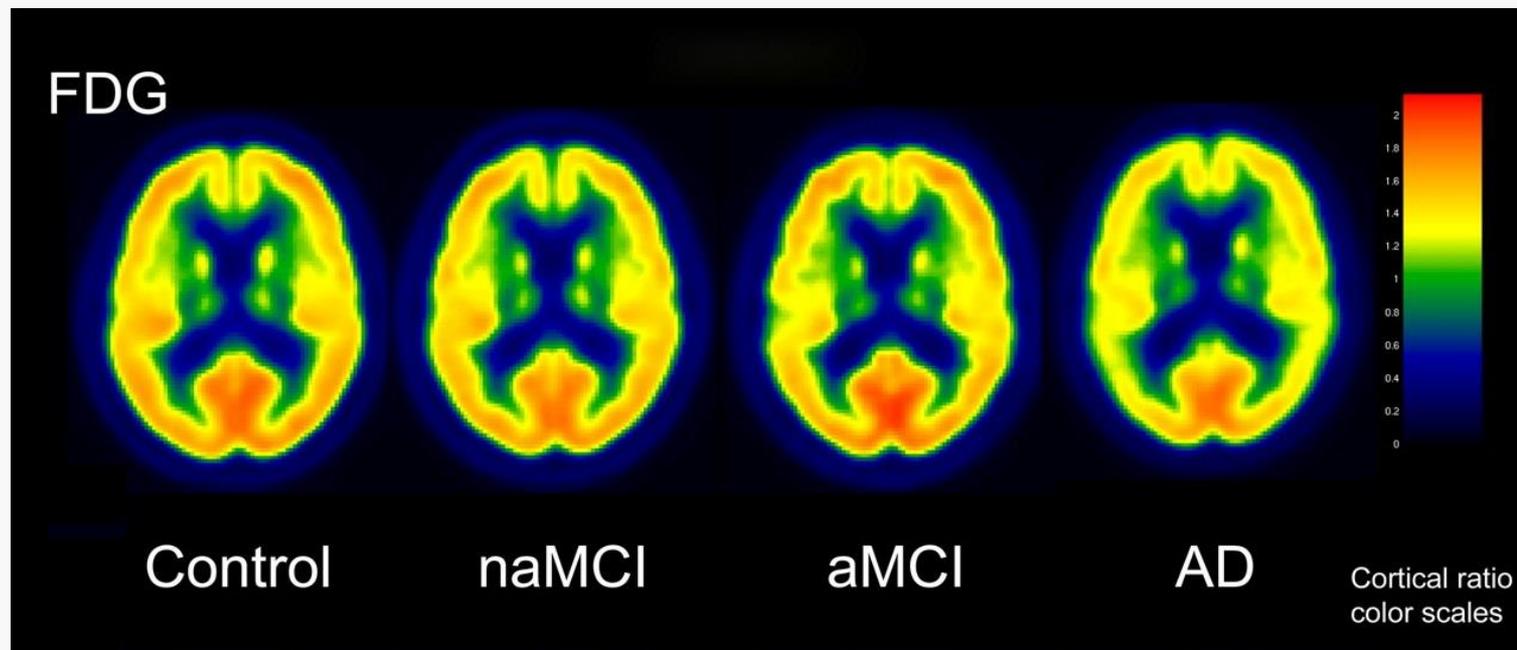
m99Tc-DTPA

Syndrôme de jonction



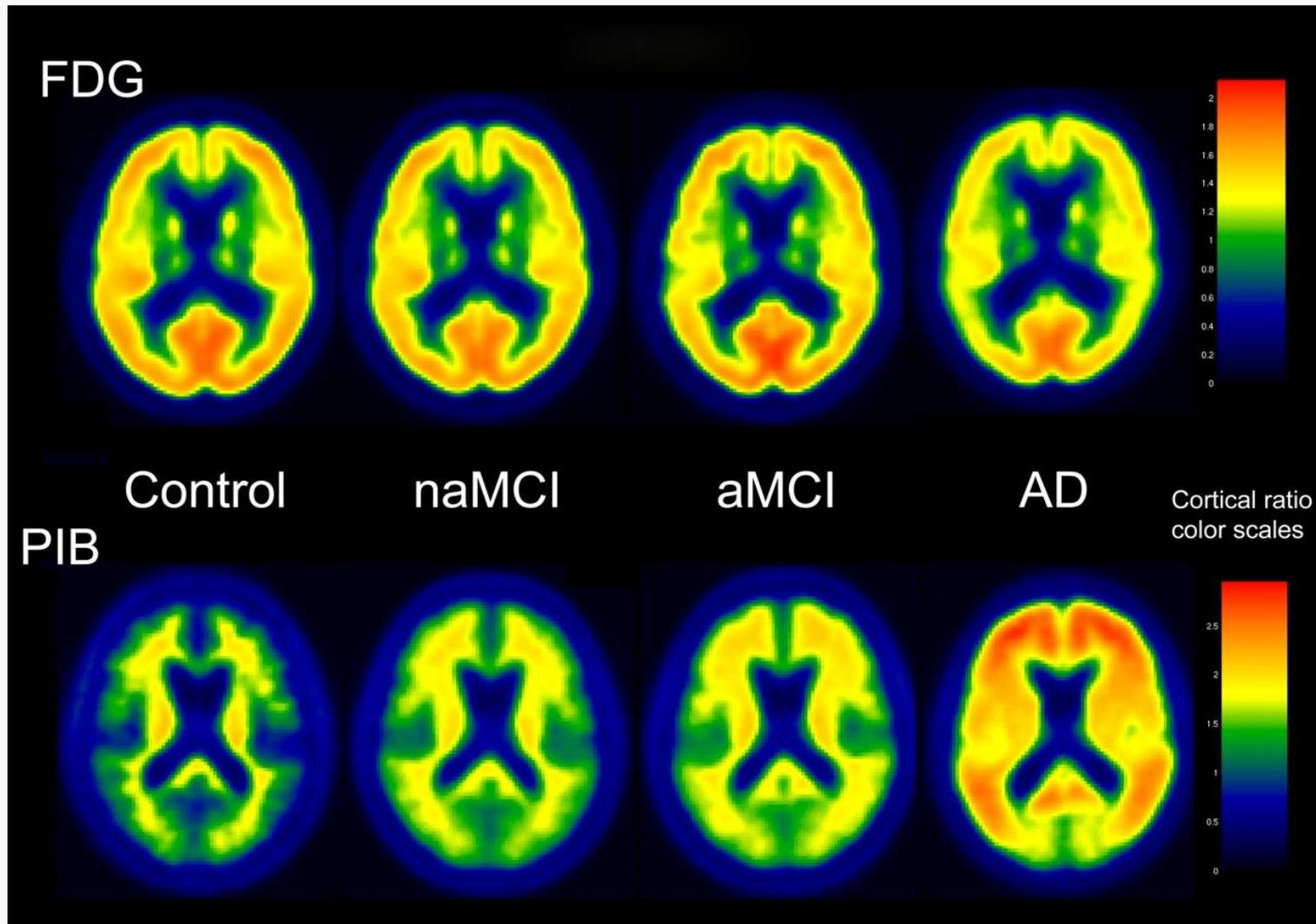
SCINTIGRAPHIES CEREBRALES

Démences



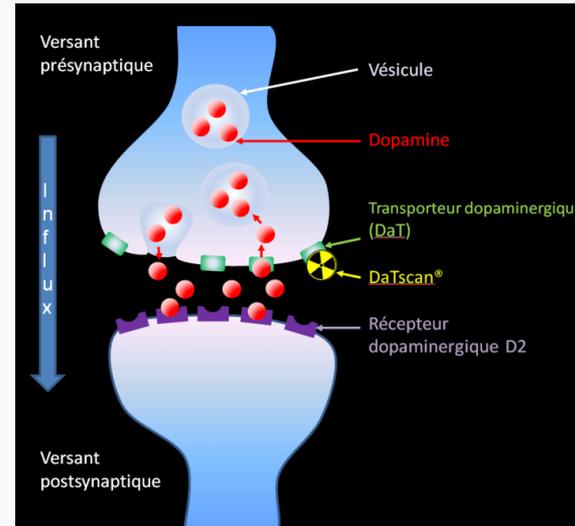
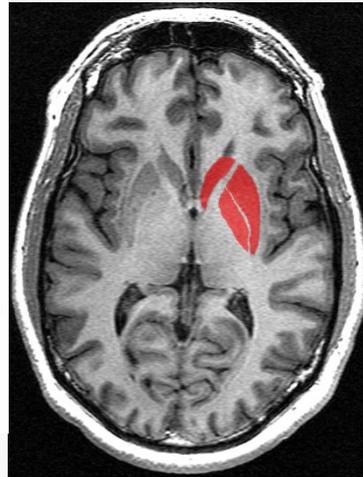
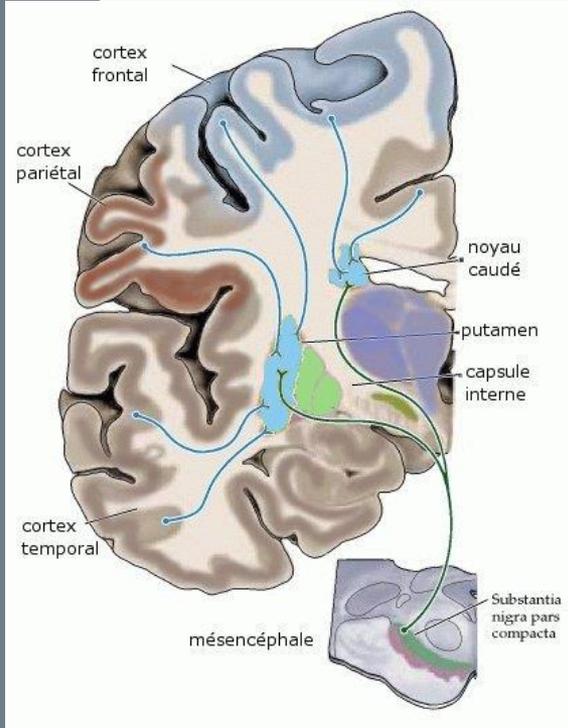
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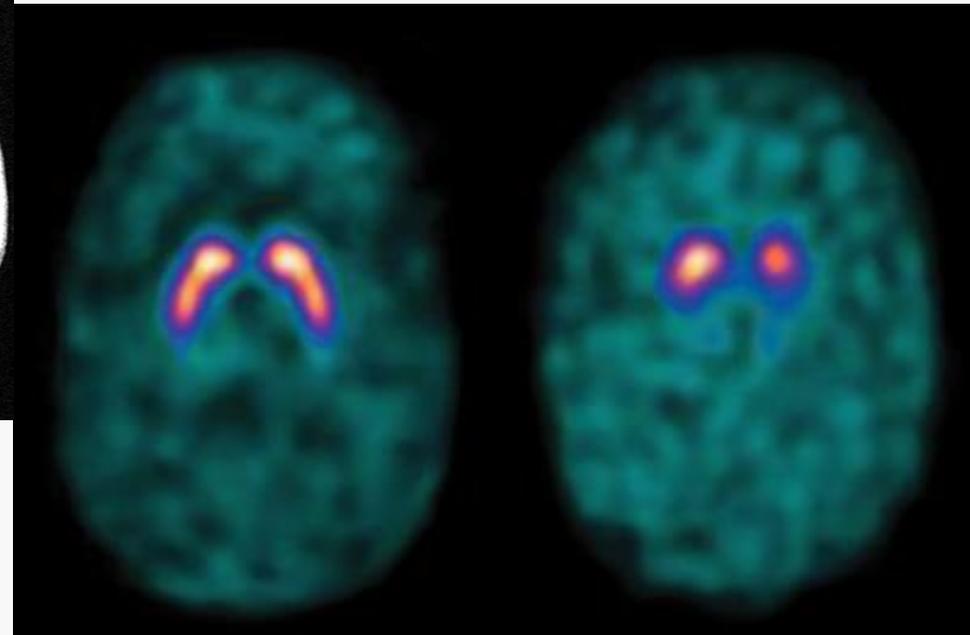


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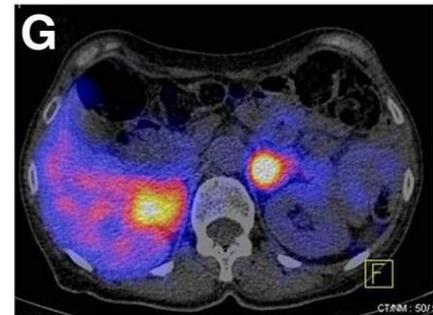
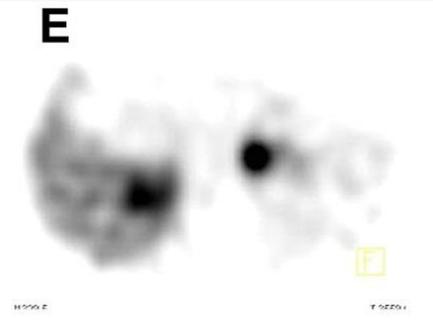
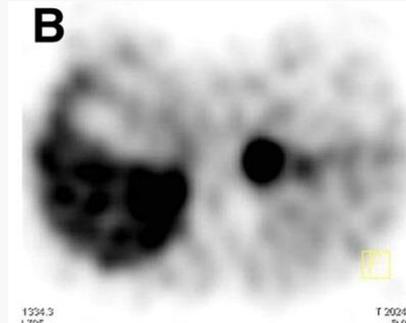
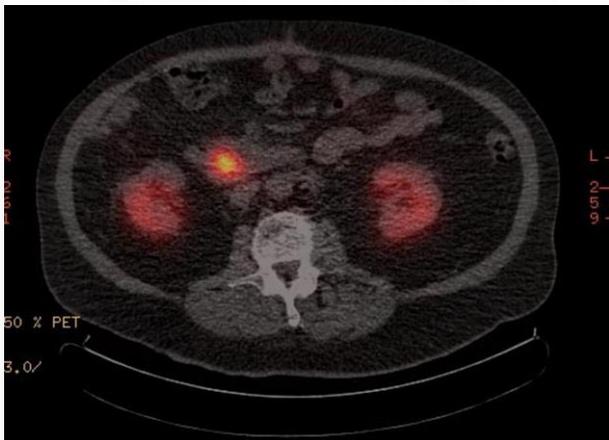
Syndromes PK



123 I - DaTScan



CANCERS



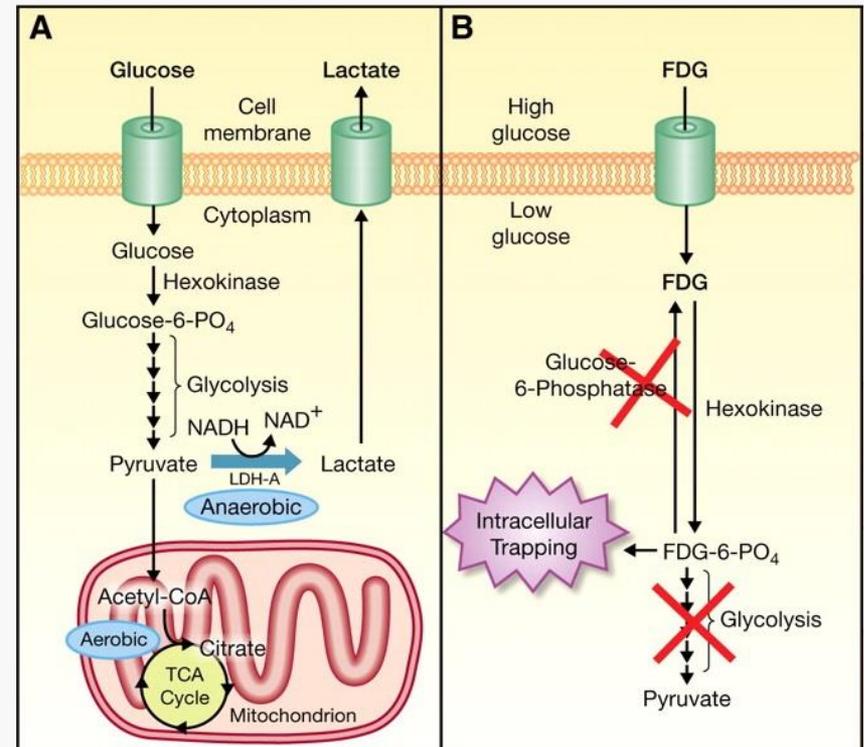
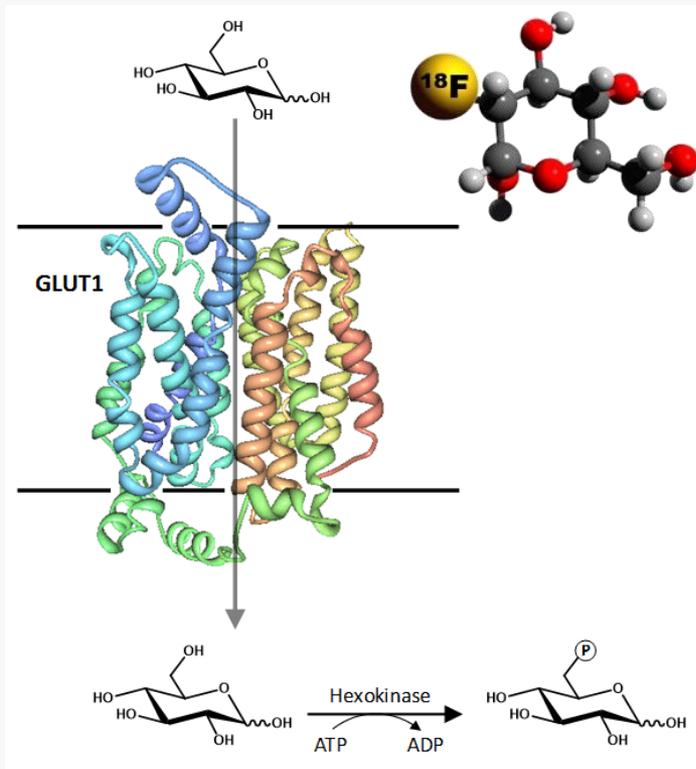
^{123}I - MIBG

OCTREOTIDE - ^{111}In

CANCERS

^{18}F -FDG

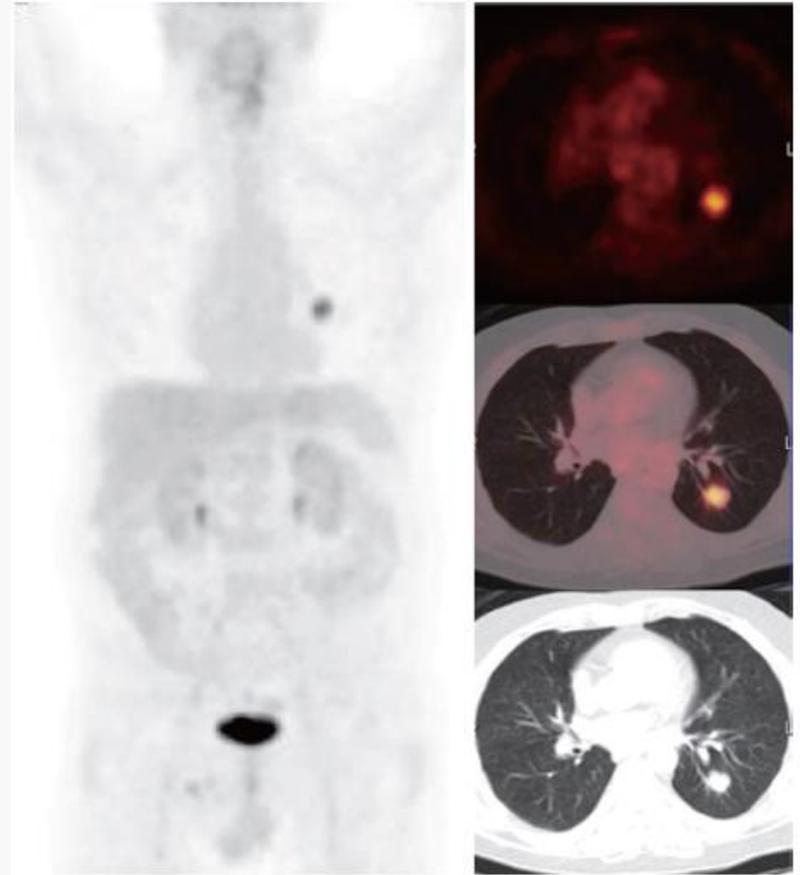
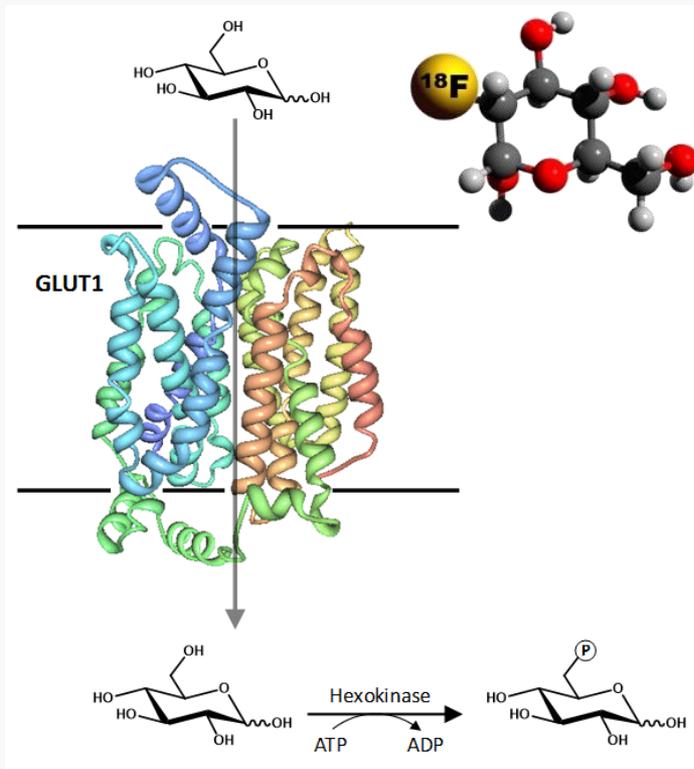
^{18}F FDG : analogue du glucose marqué au ^{18}F



CANCERS

^{18}F –FDG : Poumon

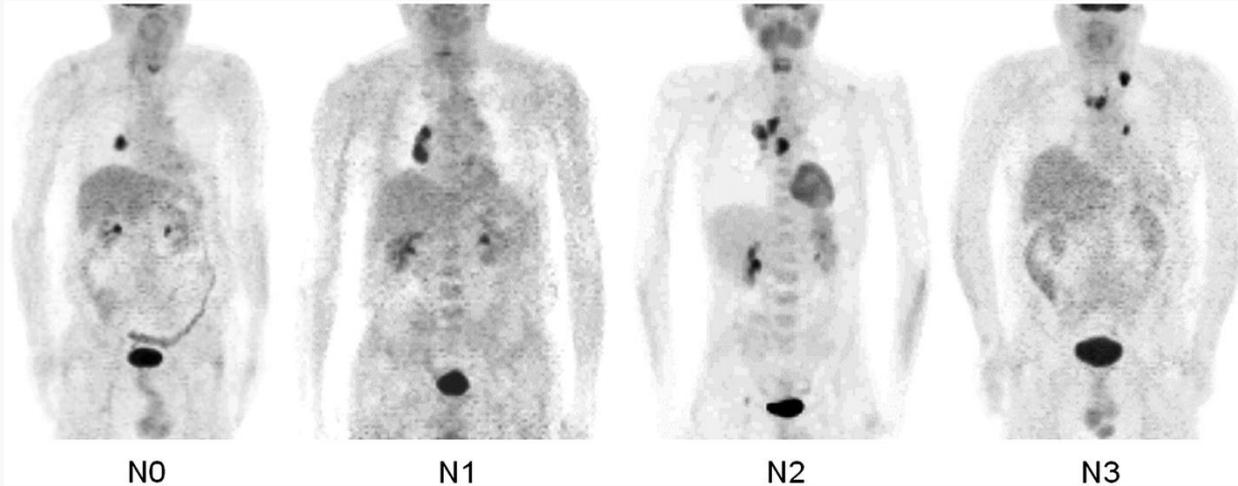
^{18}F FDG : analogue du glucose marqué au ^{18}F



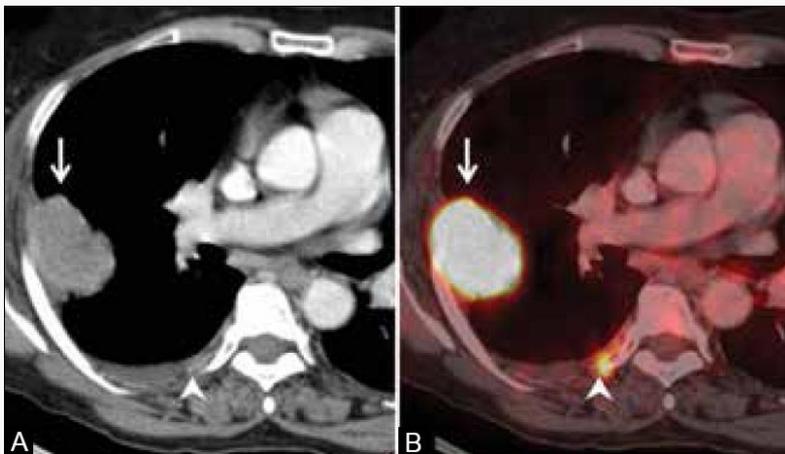
Murmann et al. J Thorac Dis 2014

CANCERS

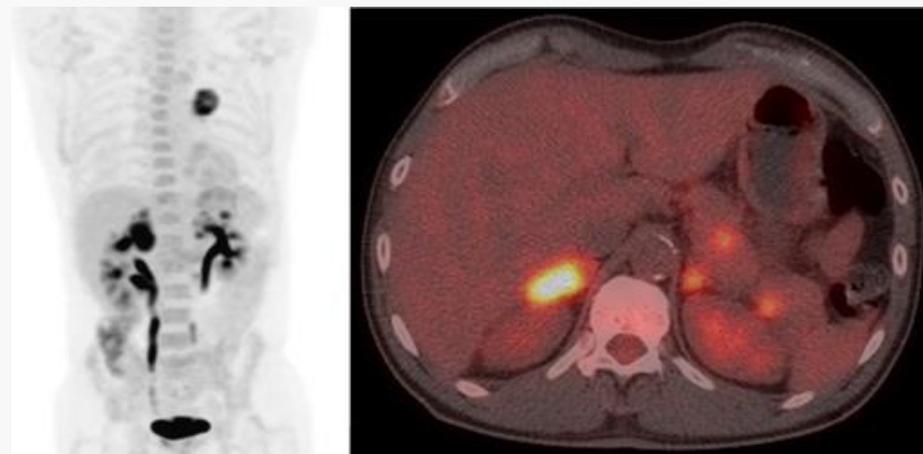
¹⁸F –FDG : Poumon



Hellwig et al. J Nucl Med 2007



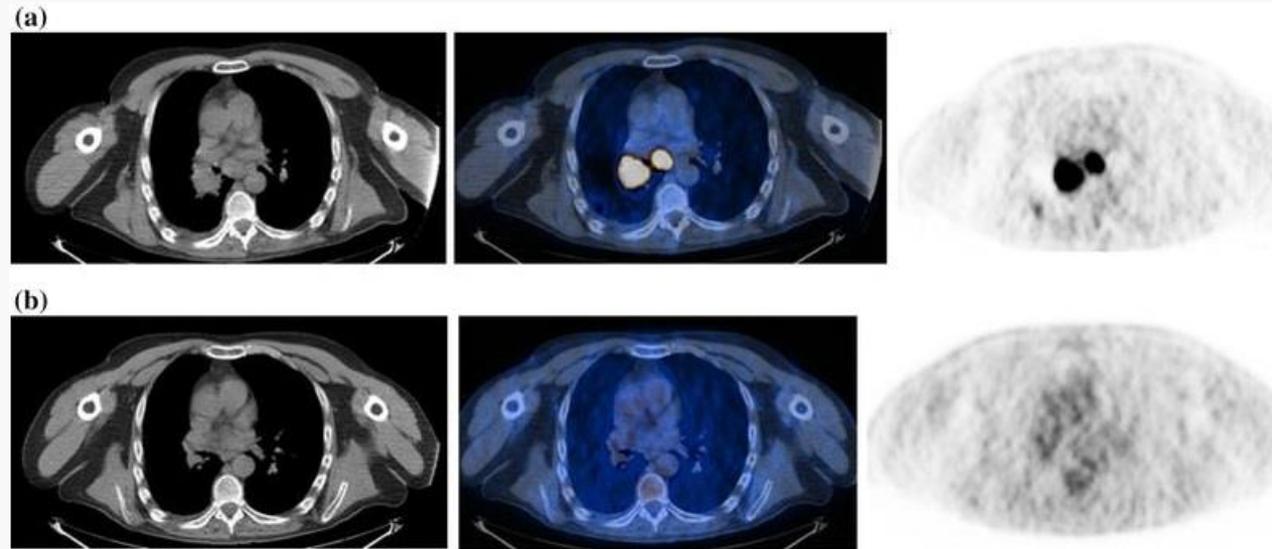
Purandare et al. Indian J Radiol Imaging 2015



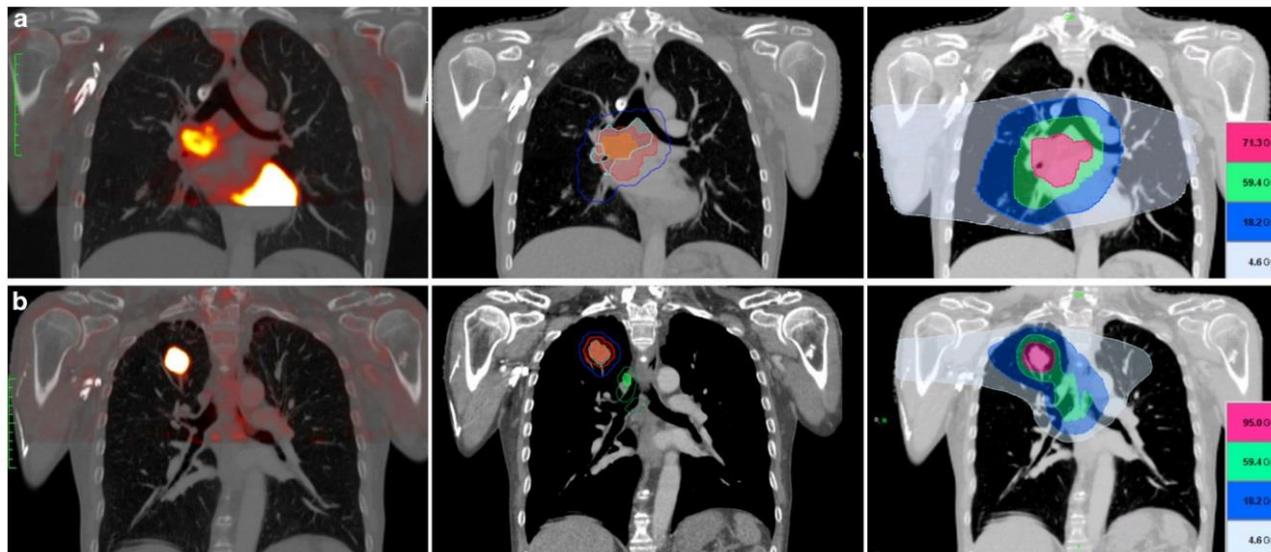
Groheux et al. Diagn Interv Imaging 2016

CANCERS

¹⁸F –FDG : Poumon



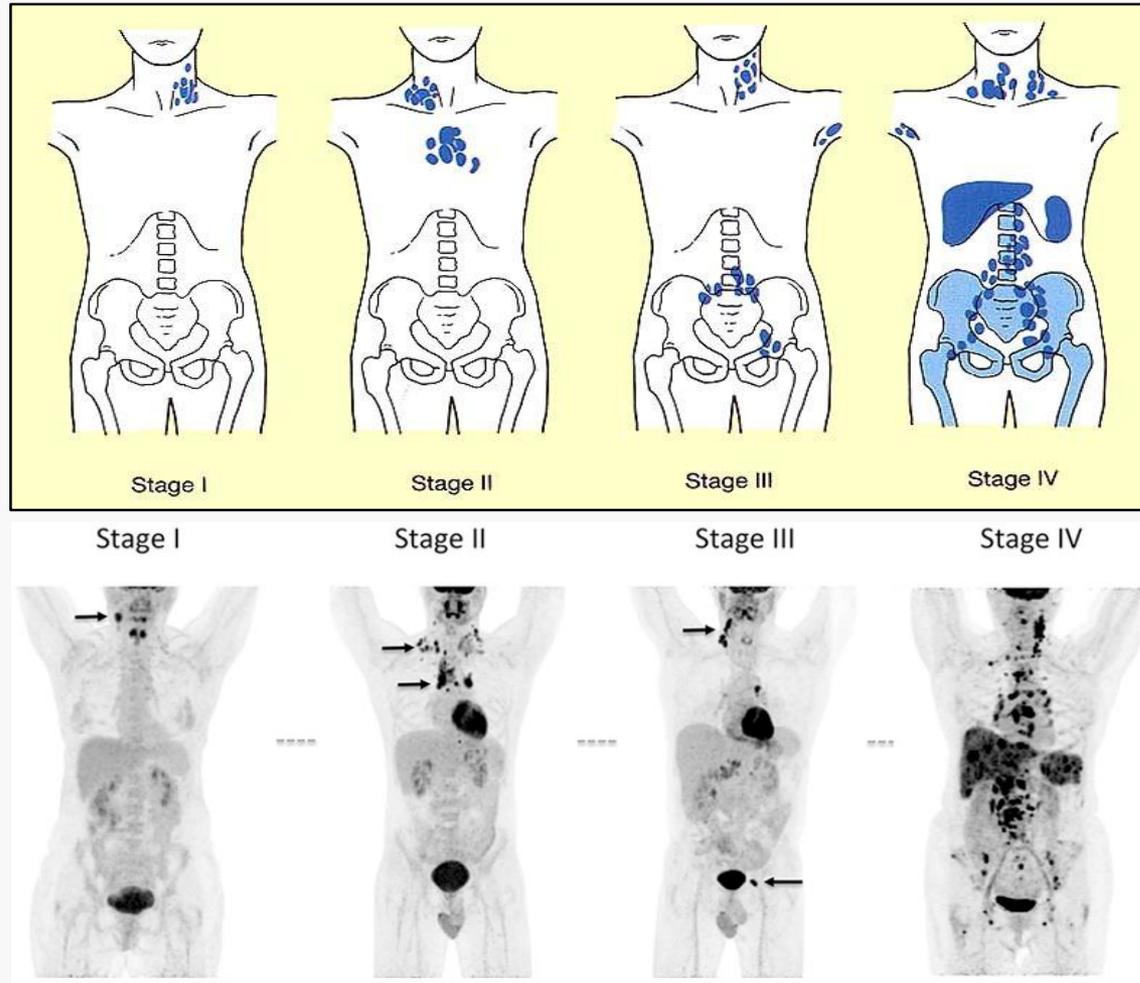
Kremer et al. Ann Nucl Med 2016



Wanet et al. Strahlenther Onkol 2017

CANCERS

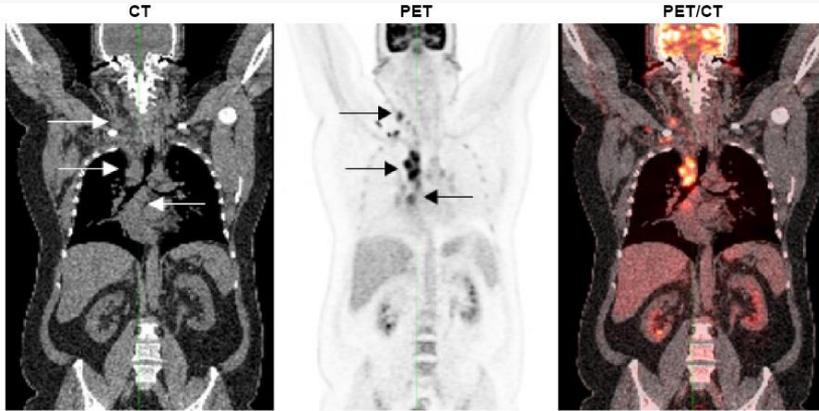
¹⁸F –FDG : Lymphome



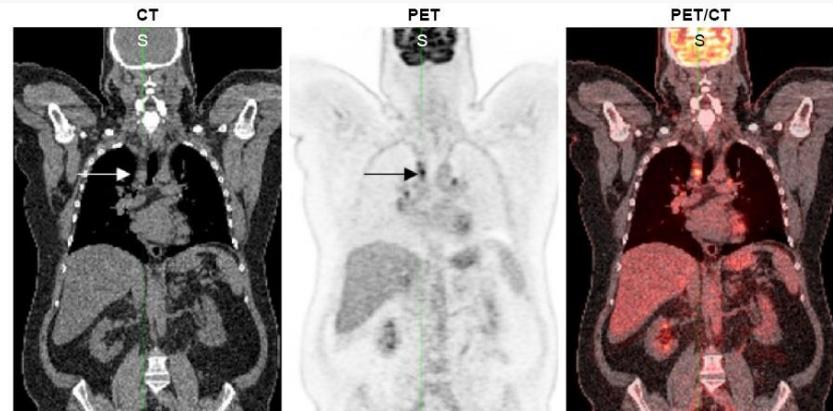
CANCERS

¹⁸F –FDG : Lymphome

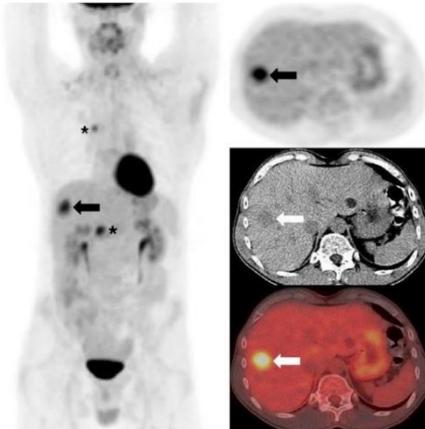
TEP initiale



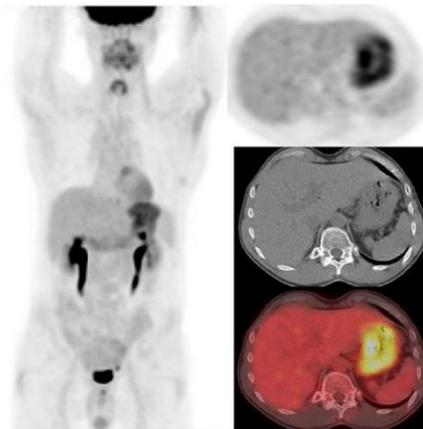
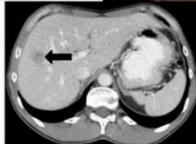
TEP intérim : réponse métabolique partielle



Van Heertum et al. Drug Des Devel Ther 2017



Baseline PET/CT and Contrast-enhanced CT



Restaging PET/CT and Contrast-enhanced CT

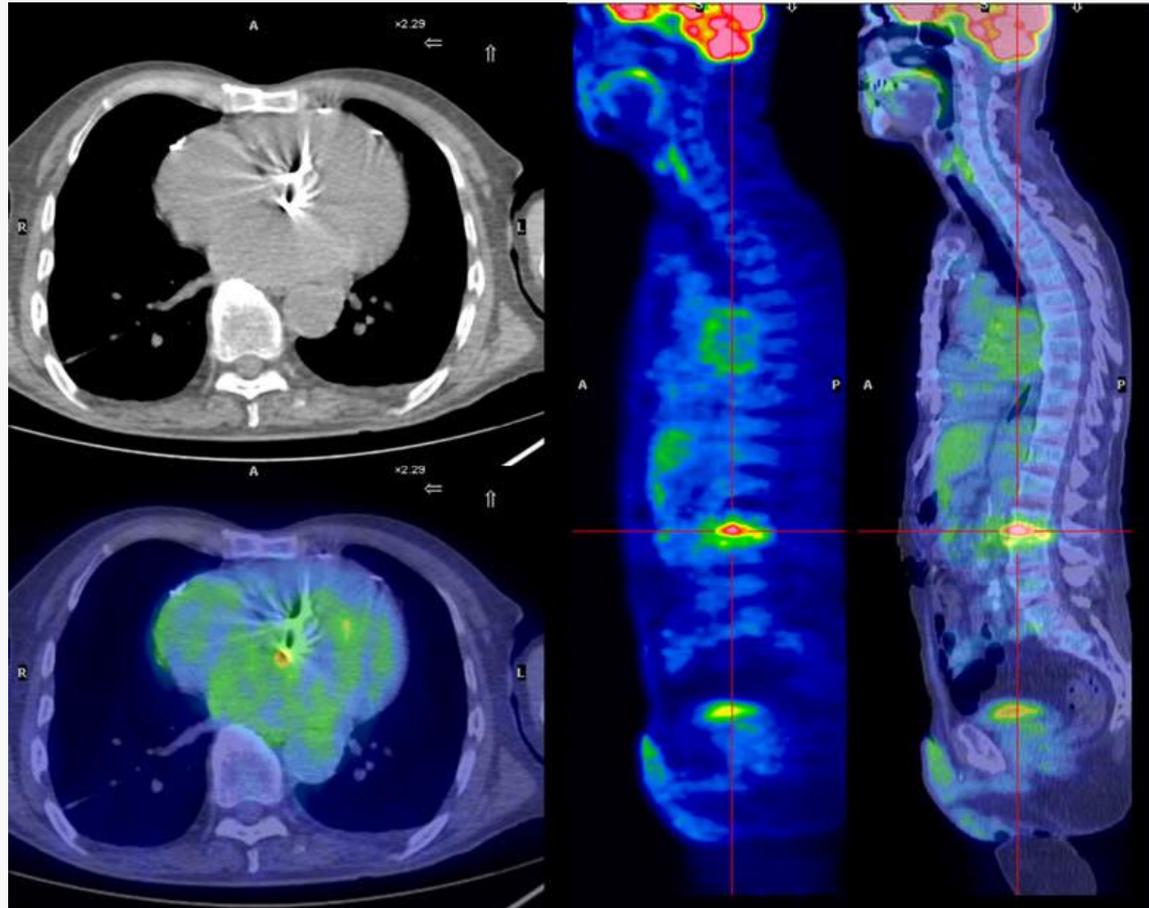


TEP intérim : réponse métabolique complète

Cheson et al. Blood 2016

INFECTIONS

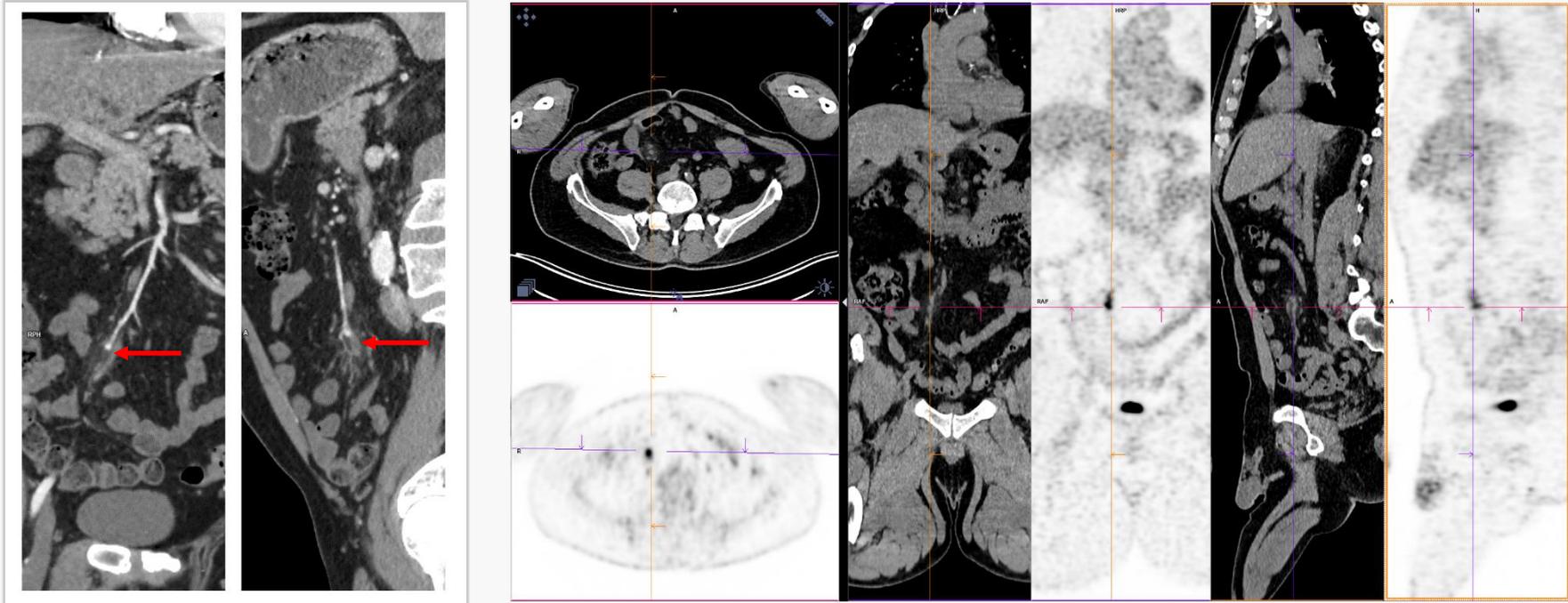
¹⁸F –FDG : Endocardite



Bonfiglioli et al. Eur J Nucl Med Mol Imaging 2013

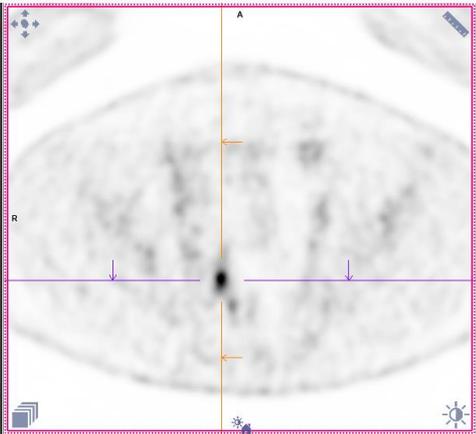
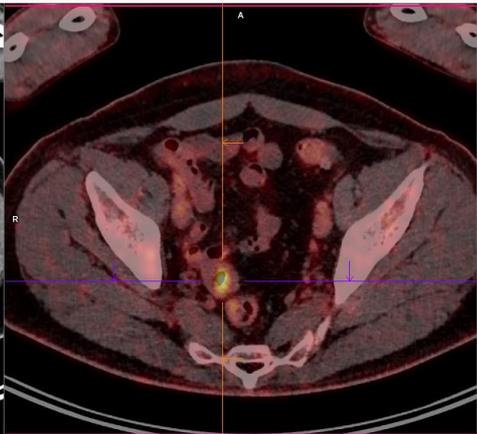
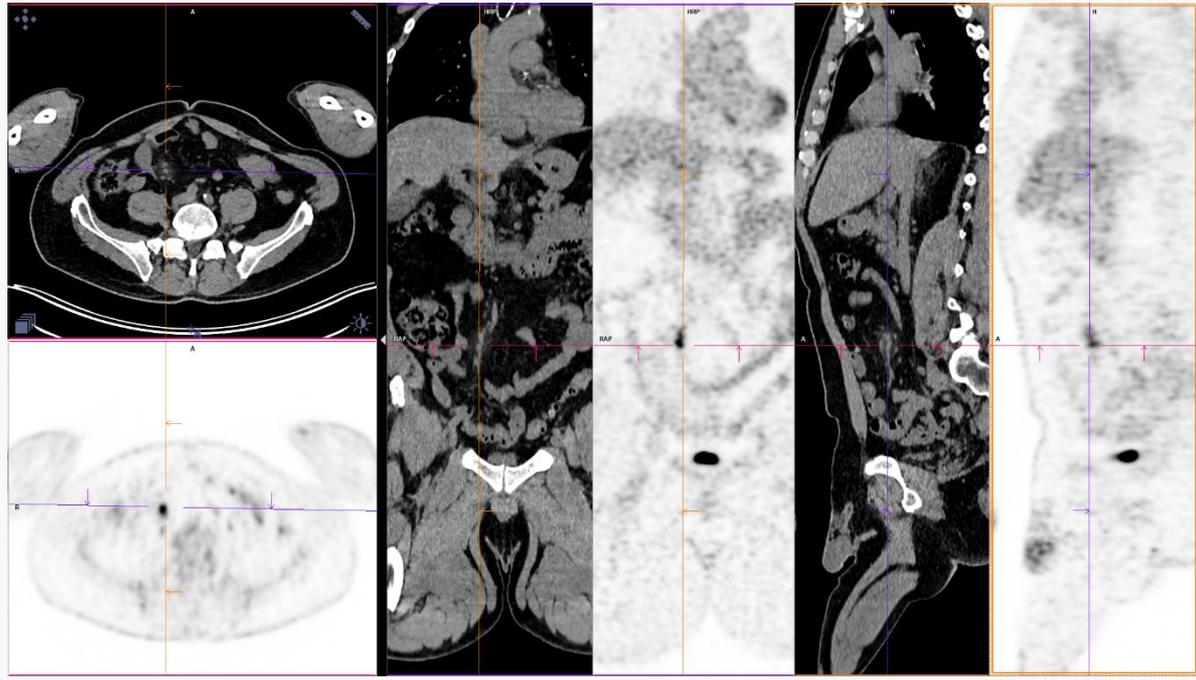
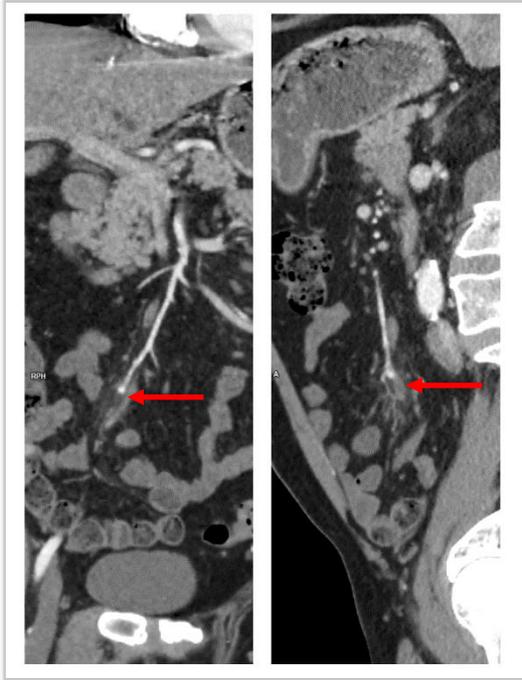
INFECTIONS

¹⁸F –FDG : Endocardite



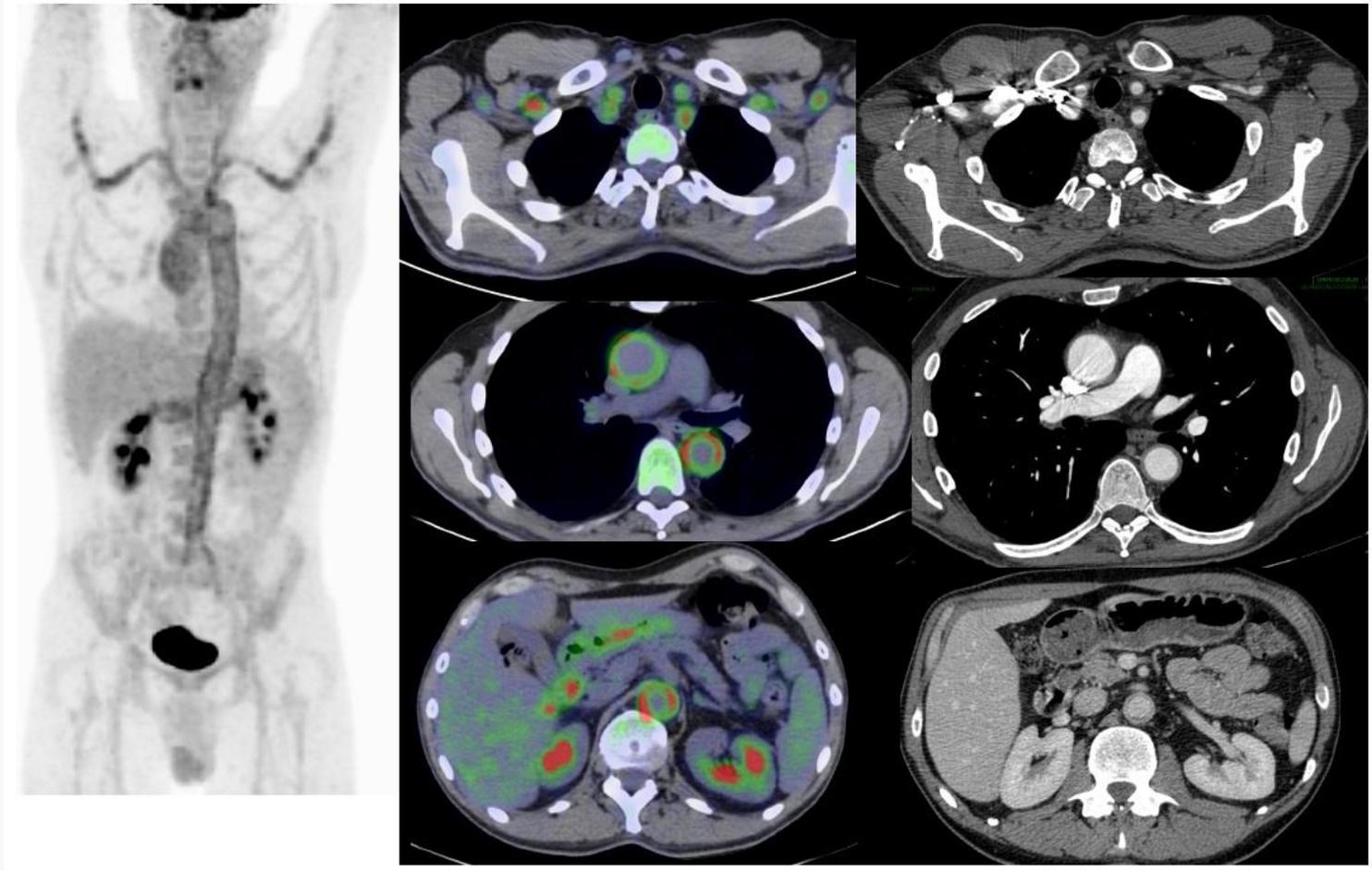
INFECTIONS

¹⁸F –FDG : Endocardite



INFLAMMATION

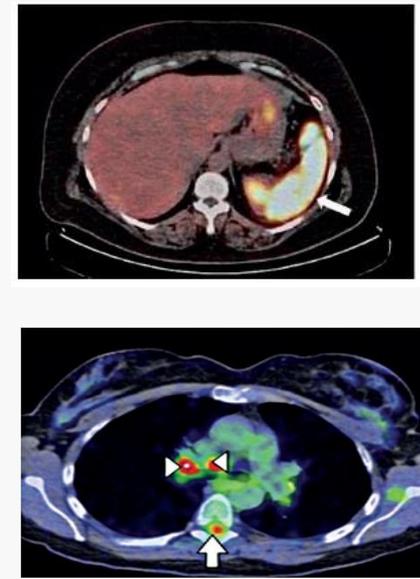
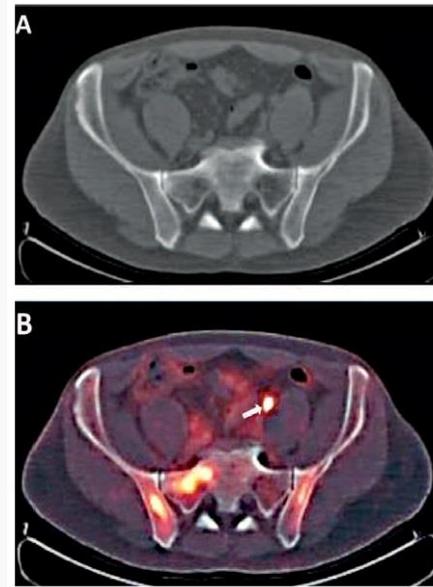
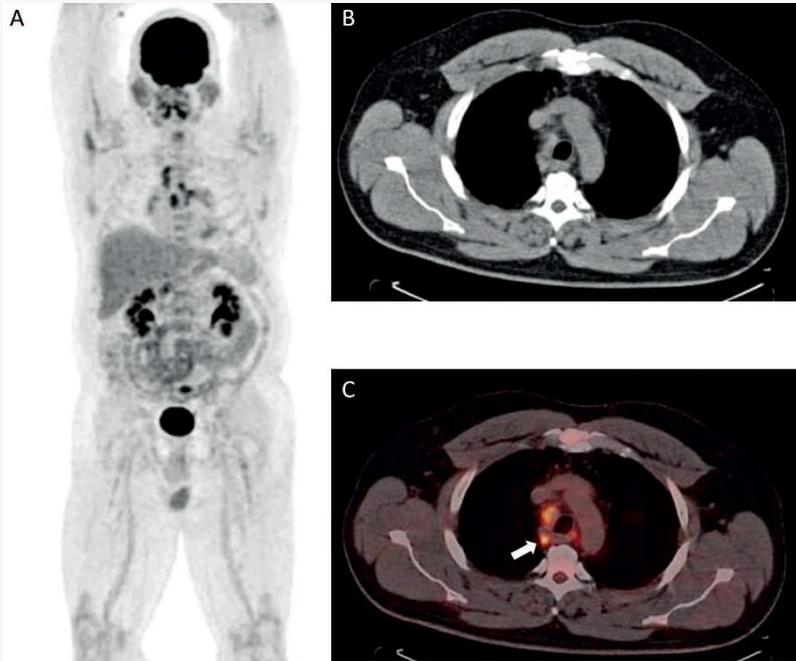
¹⁸F –FDG : **Vascularite**



Besson et al. *Eur J Nucl Med
Mol Imaging* 2011

INFLAMMATION

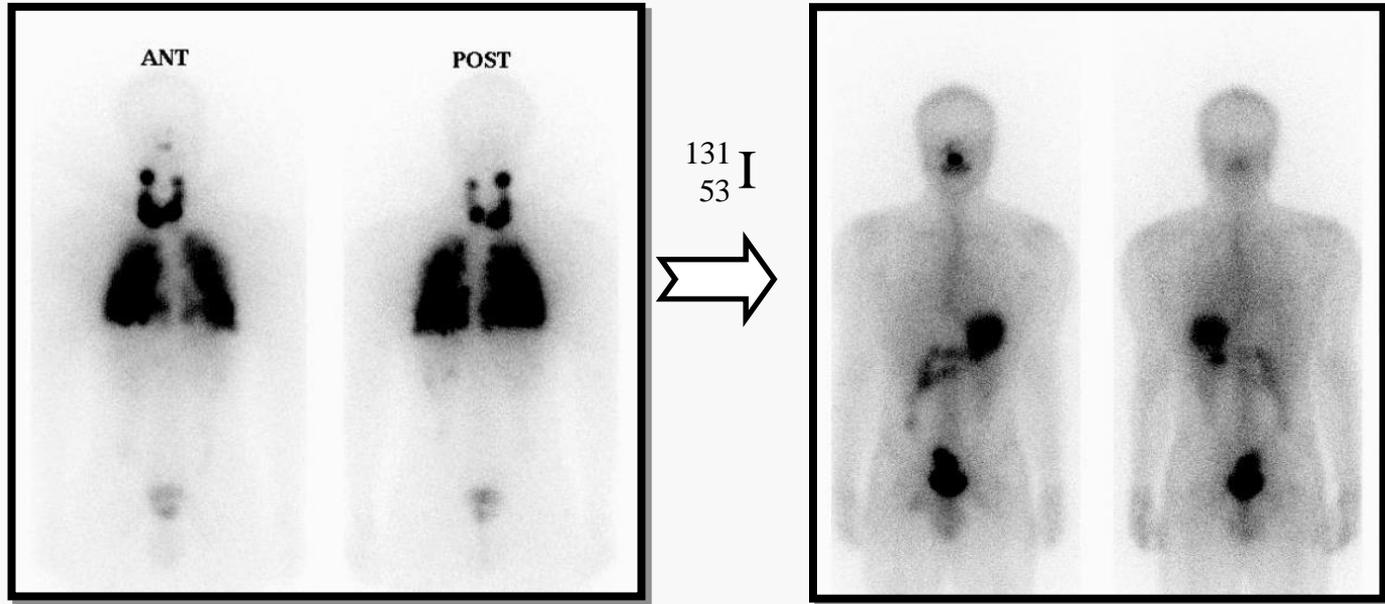
¹⁸F –FDG : Sarcoidose



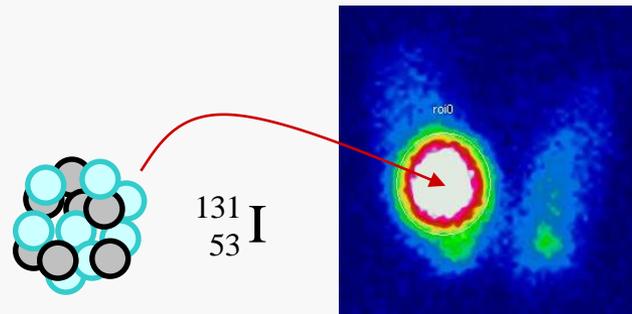
Promteangtrong et al. Hell J Nucl Med 2014

RADIOTHEAPIE METABOLIQUE

❖ Néoplasies thyroïdiennes

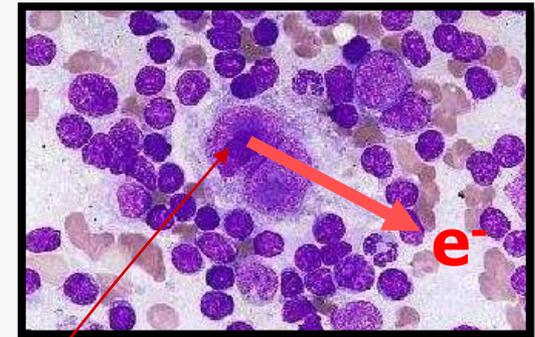
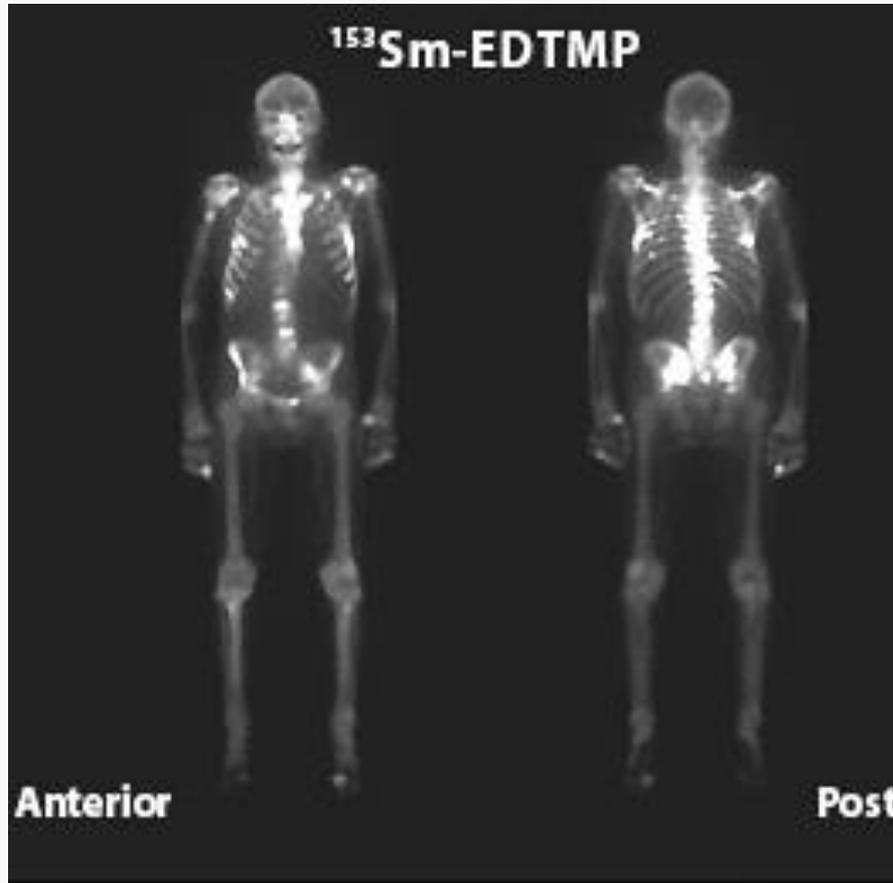


❖ Hyperthyroïdies

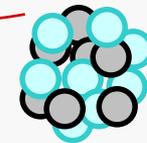


RADIOTHEAPIE METABOLIQUE

❖ Antalgie de métastases osseuses



Ionisations sur quelques mm



$^{153}_{62}\text{Sm}$

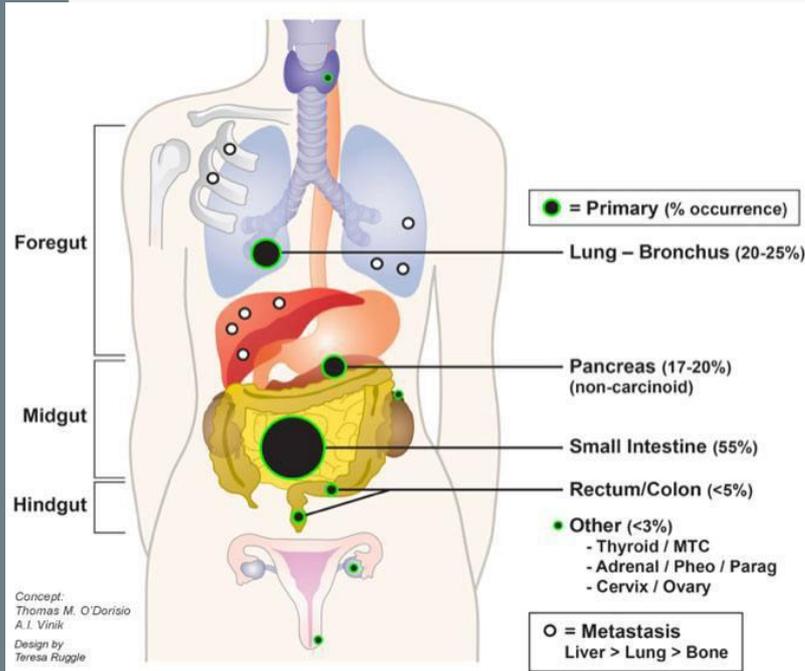


$^{89}_{38}\text{Sr}$

+BP

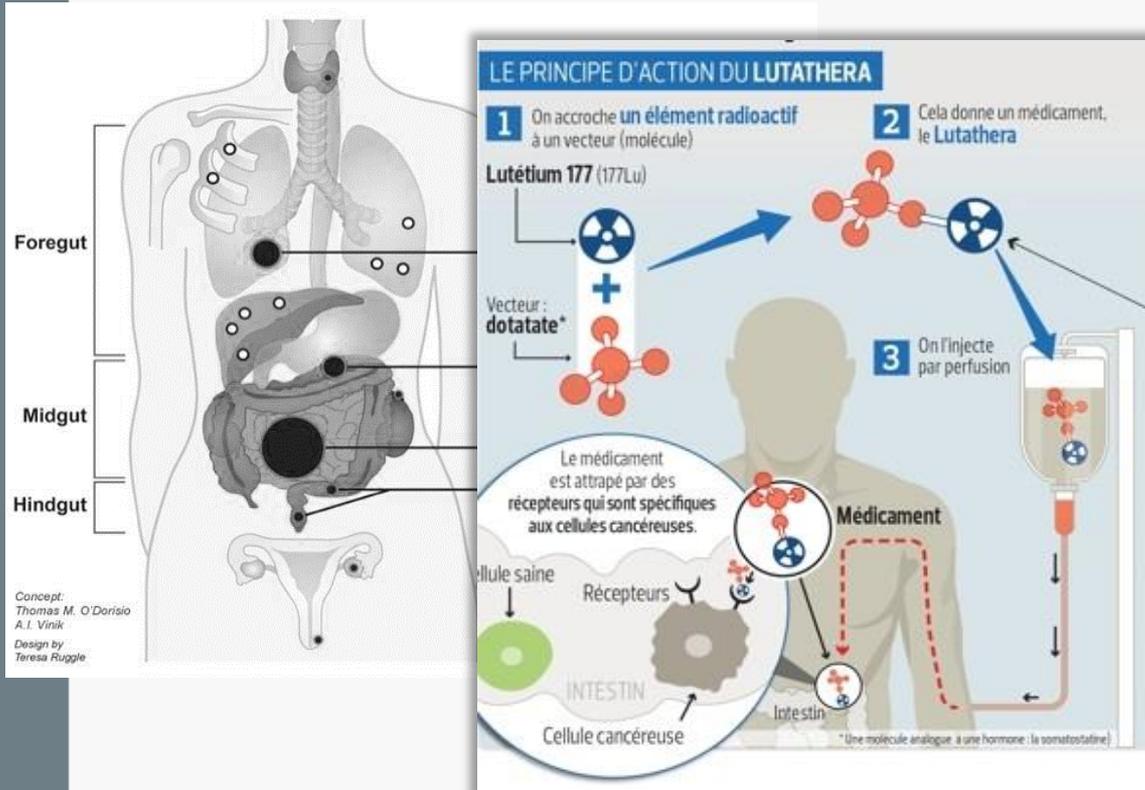
RADIOTHEAPIE METABOLIQUE

❖ Tumeurs neuro-endocrines



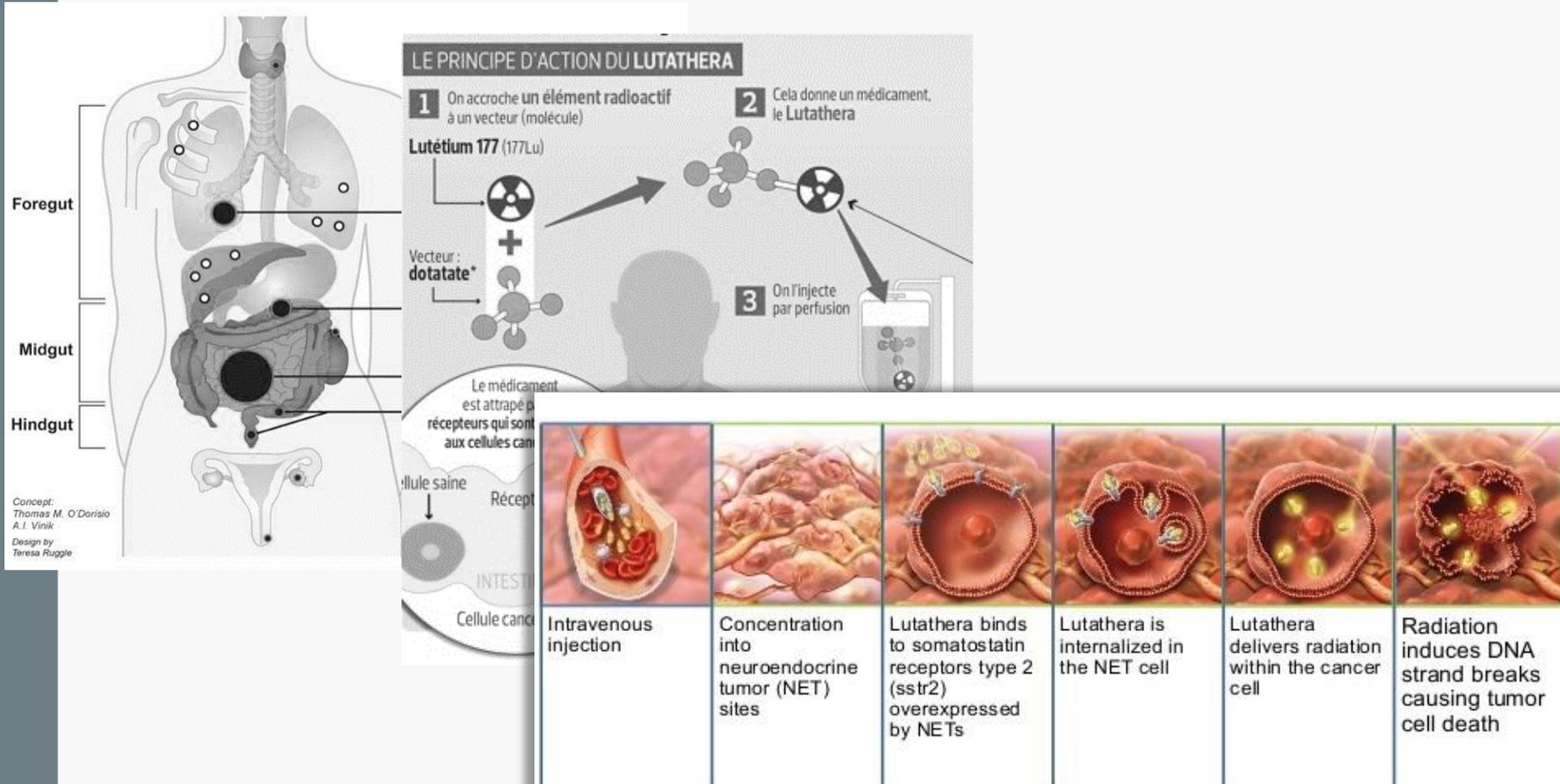
RADIOTHEAPIE METABOLIQUE

❖ Tumeurs neuro-endocrines



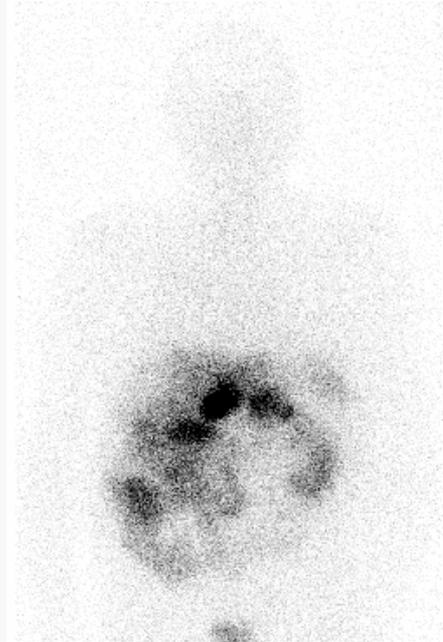
RADIOTHEAPIE METABOLIQUE

❖ Tumeurs neuro-endocrines

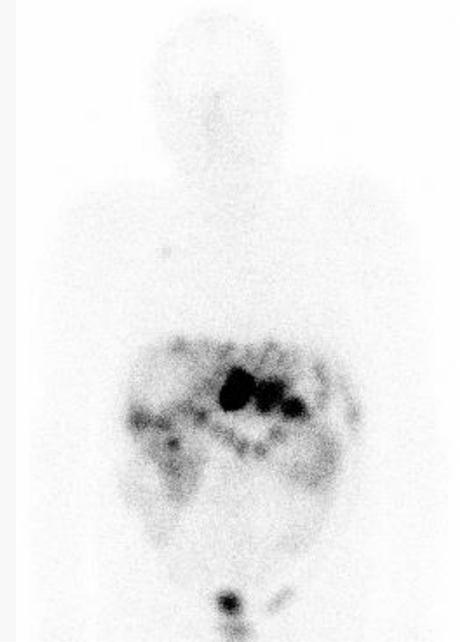
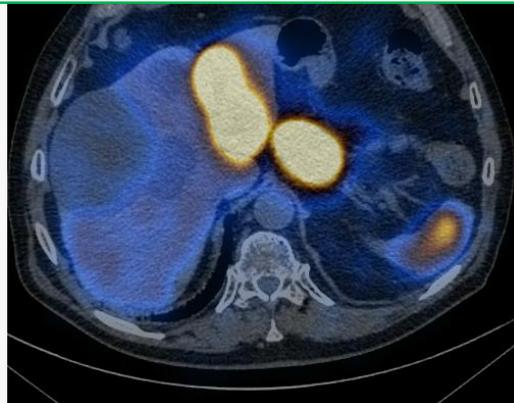


RADIOTHEAPIE METABOLIQUE

Approche
théranostique



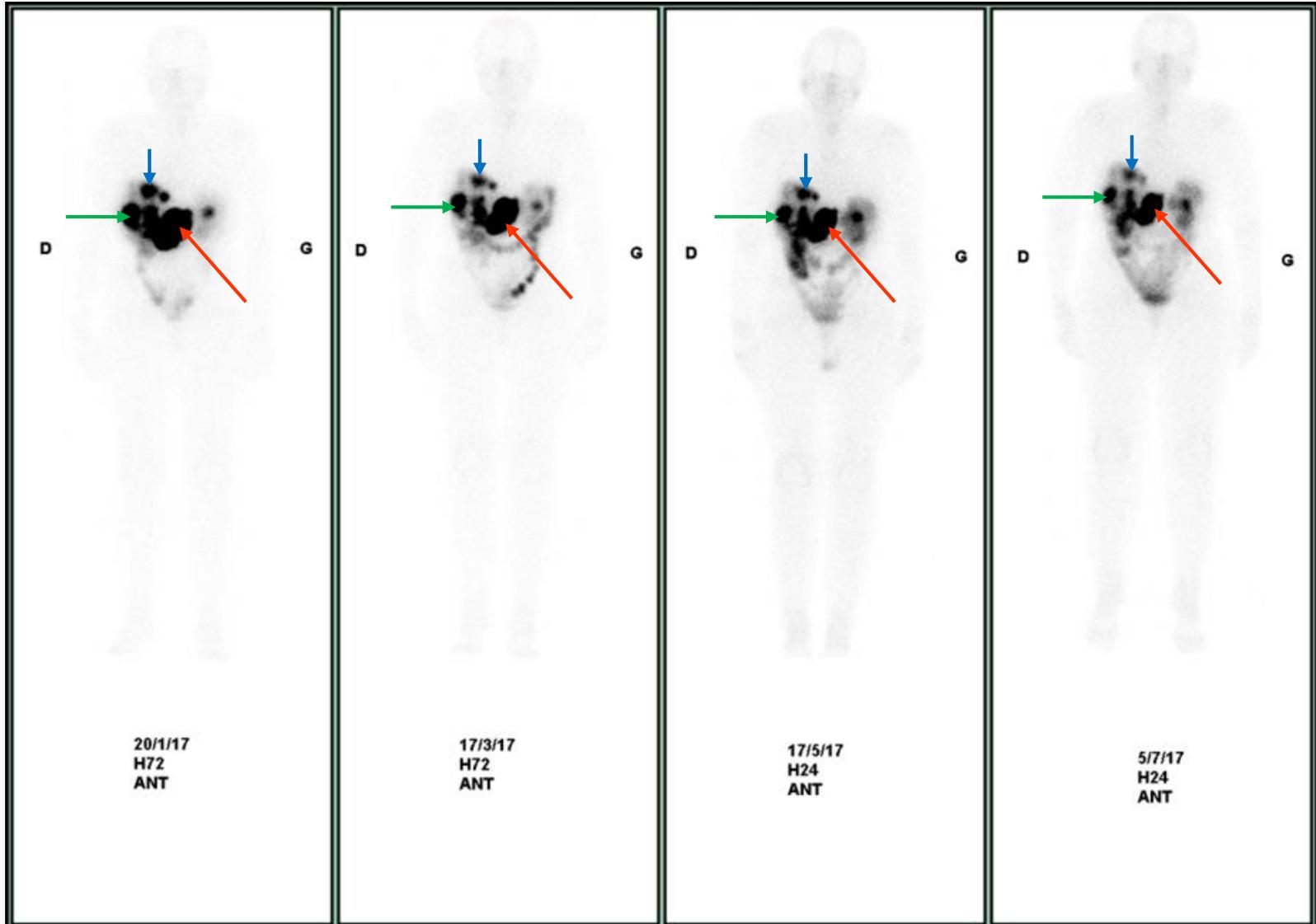
^{111}In -octreotide (Octreoscan®)



^{177}Lu -Dotatate (Lutathera®)



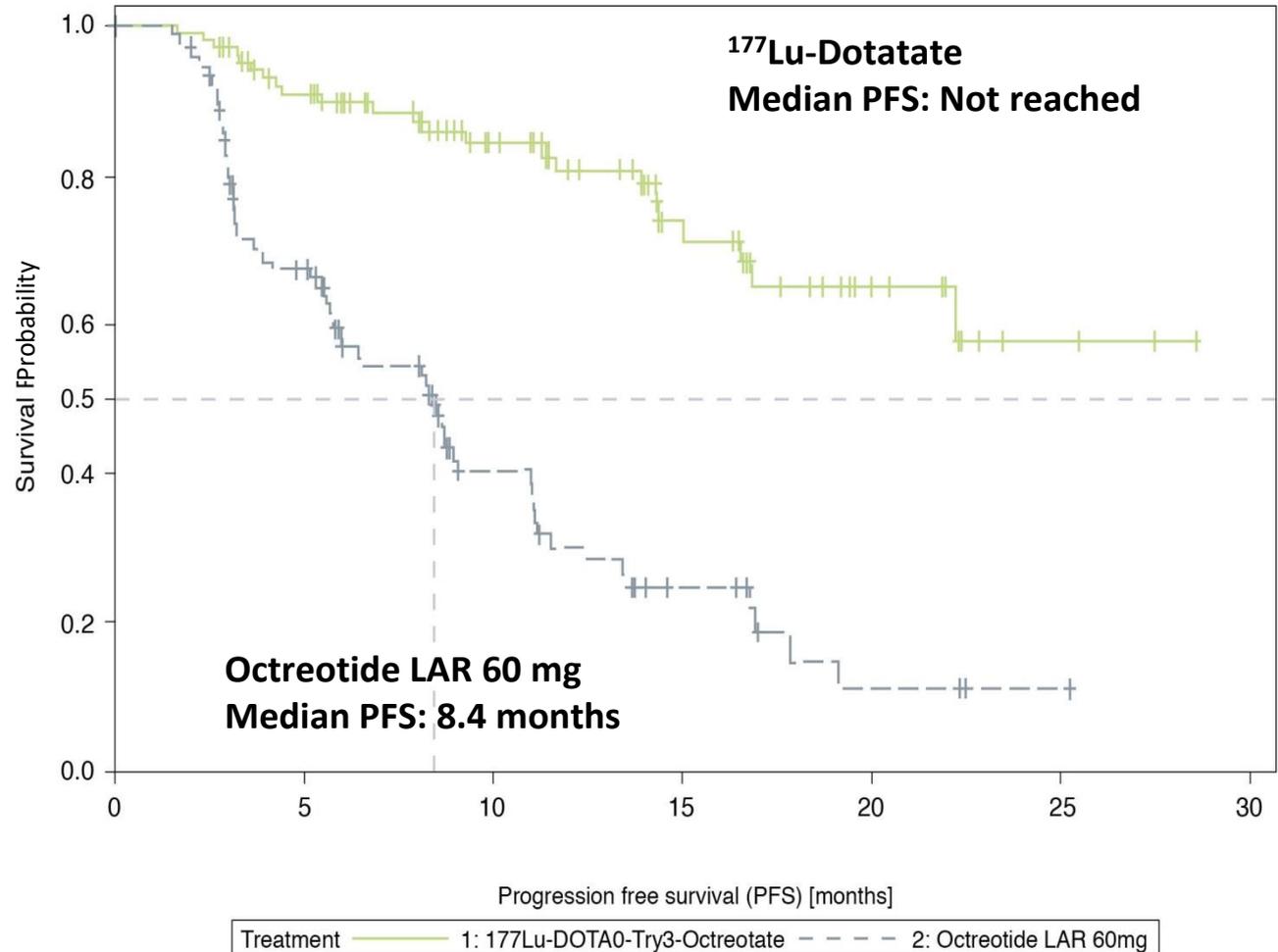
RADIOTHEAPIE METABOLIQUE



RADIOTHEAPIE METABOLIQUE

Survie sans progression

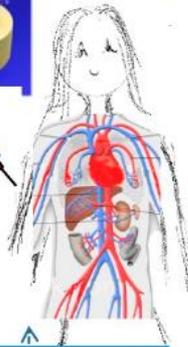
Strosberg J et al.
N Engl J Med 2017



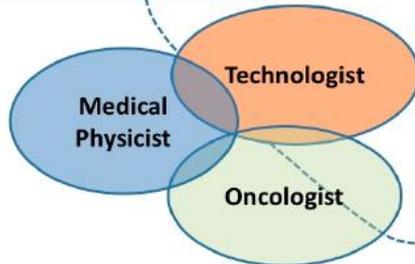
RADIOTHEAPIE METABOLIQUE

DOSIMETRIE

Patient imaging at
3-6 time points

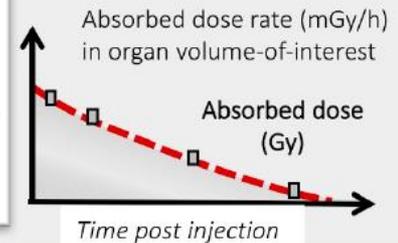
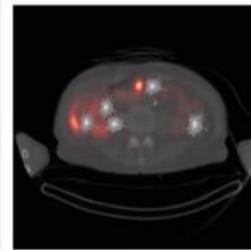
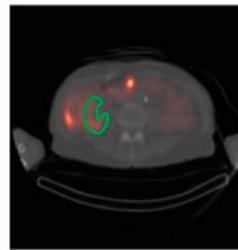


Treatment outcome
Tumor burden and responses
Incidence of clinically-measurable complications on normal organs



Lundadose dosimetry system:

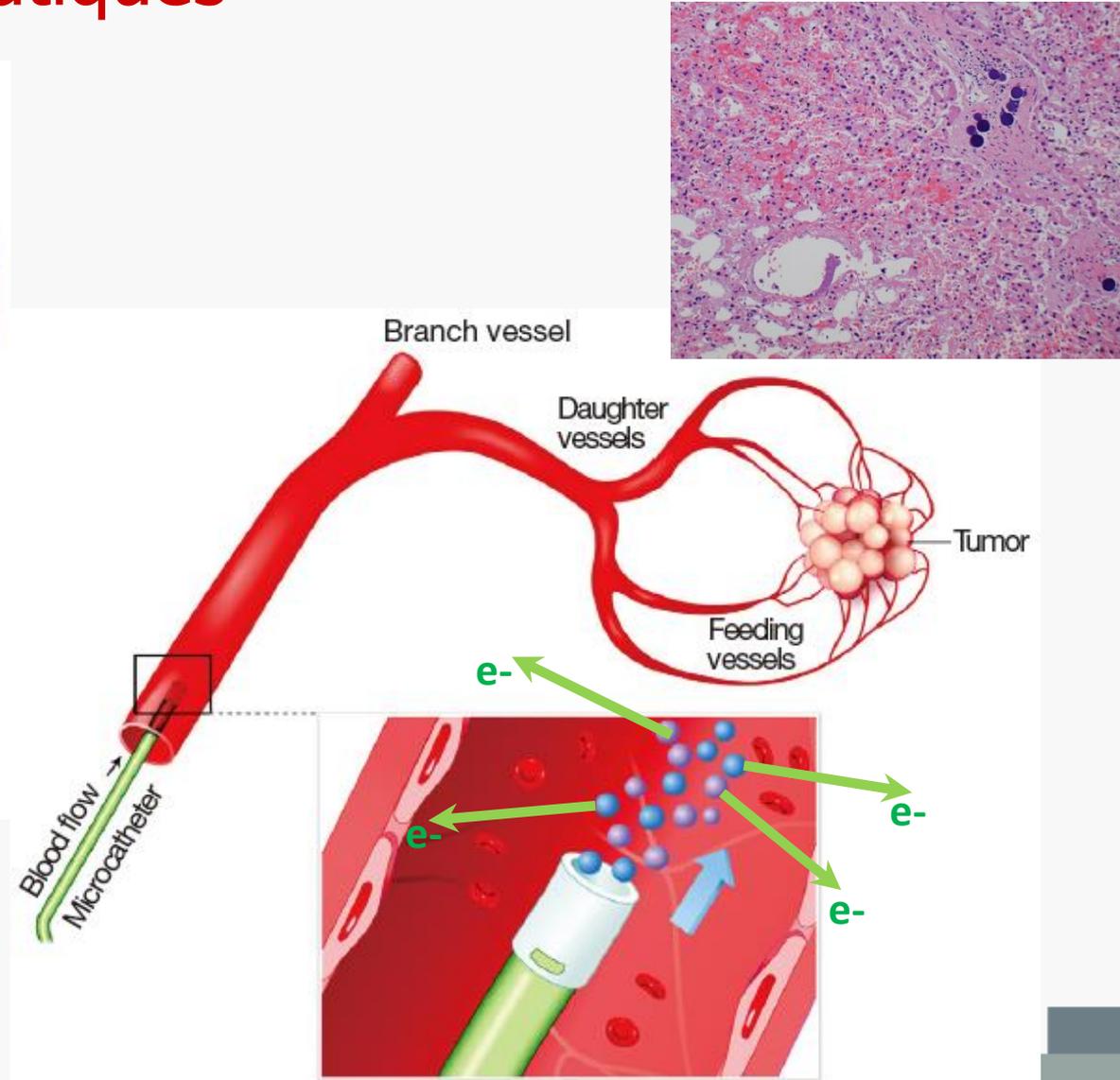
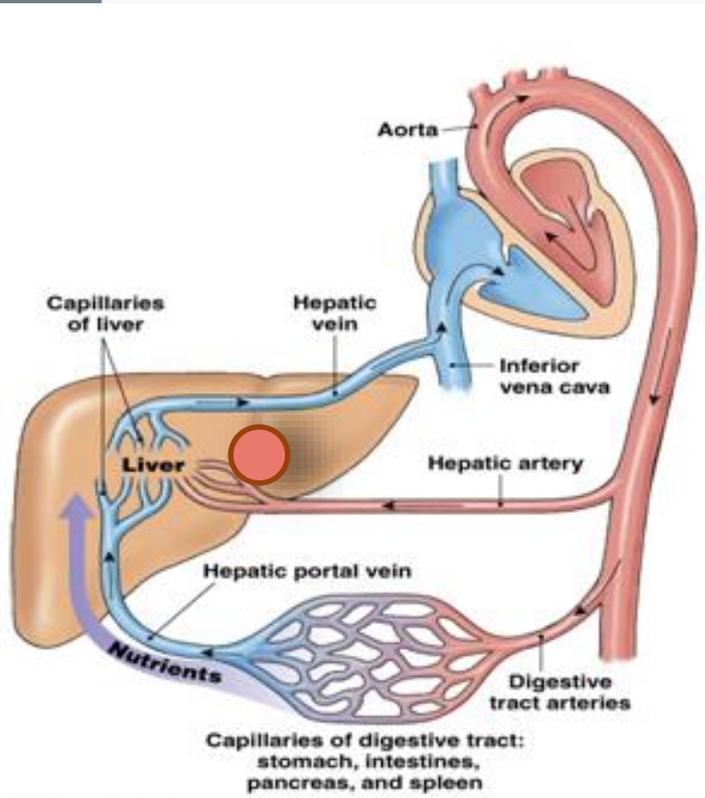
Dosimetric calculations based on **Physics** (corrections for attenuation, scatter and septal penetration of photon irradiation and radiation energy deposition in tissue by Monte Carlo calculation), **Image Analysis** (image segmentation of normal tissues and tumors), and **Pharmacokinetic modeling** (model fitting based on physiological principles)



Radiobiologic models:
Biologically effective dose
Probability of tumor control
Probability of normal tissue complications

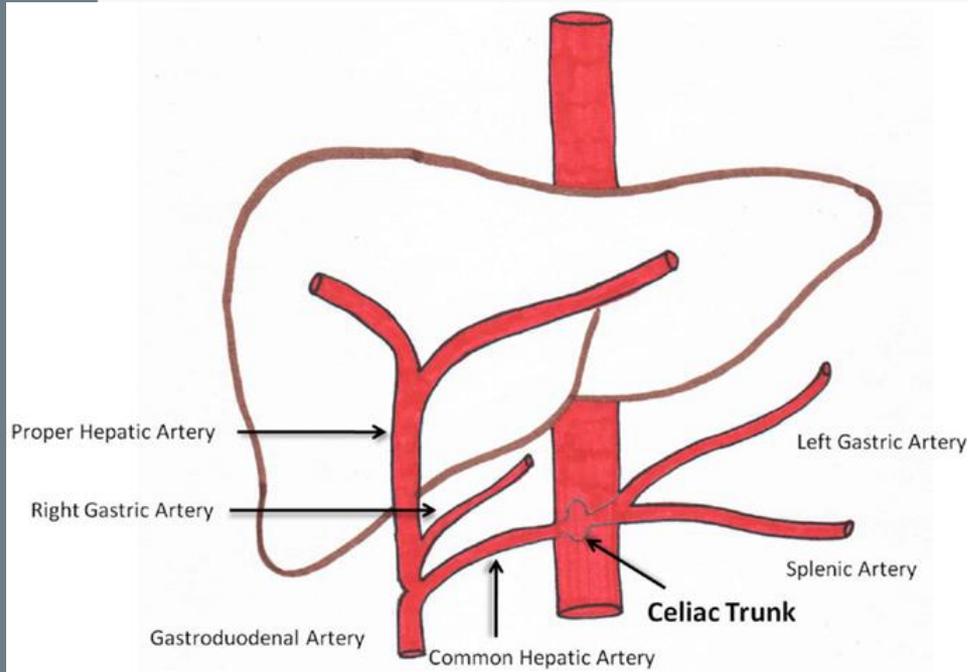
RADIODIAPYCNIE INTERNE SELECTIVE

❖ Tumeurs hépatiques

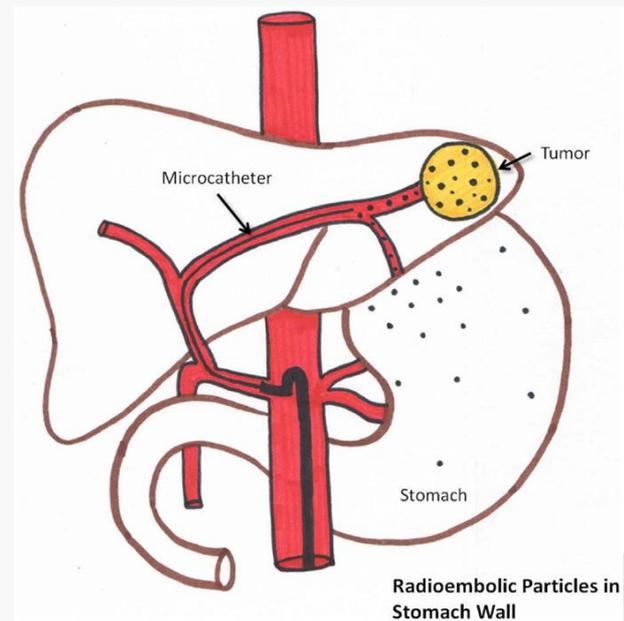
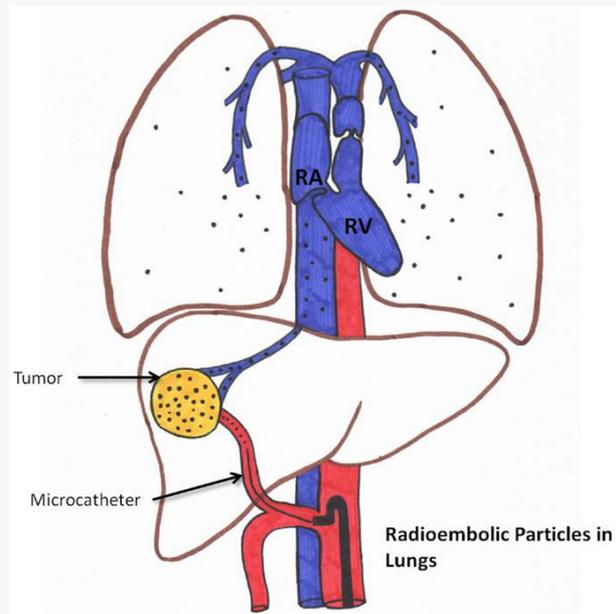
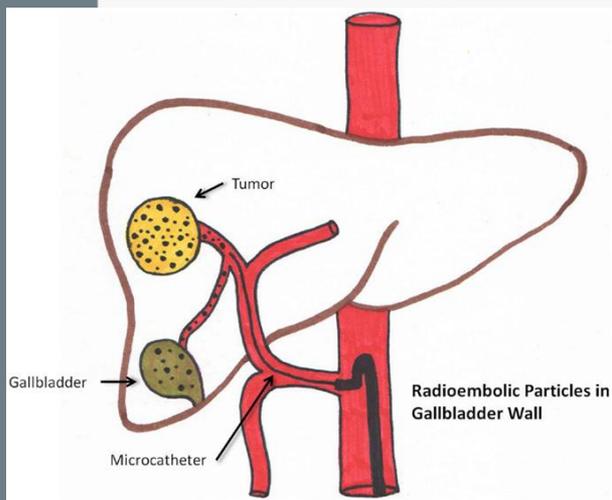


RADIODIAGNOSTIC INTERNE SELECTIVE

❖ Tumeurs hépatiques

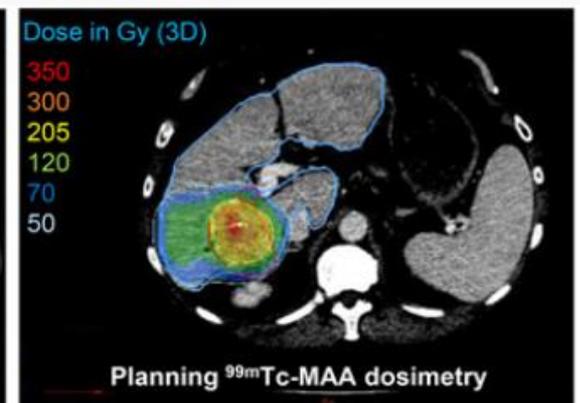
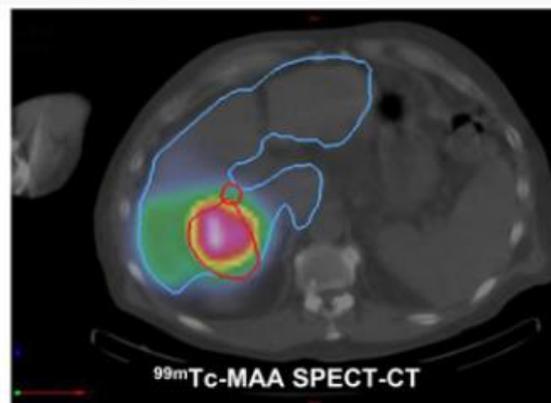
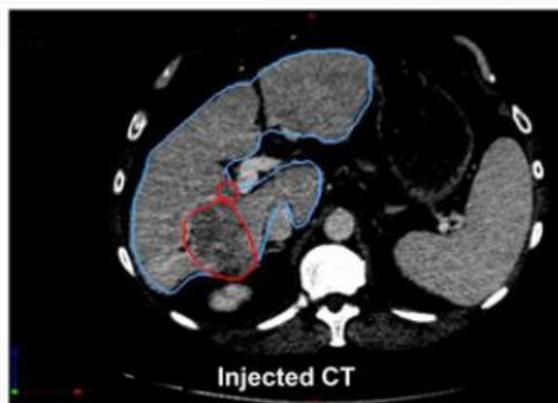
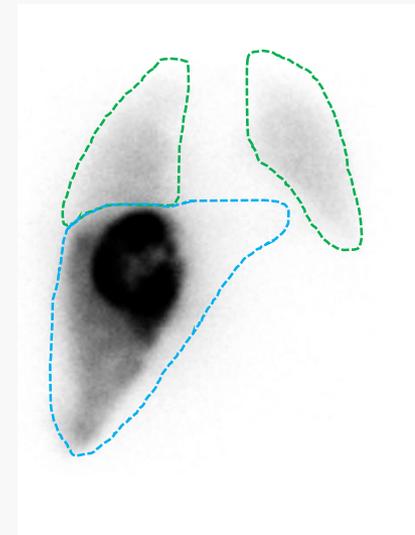
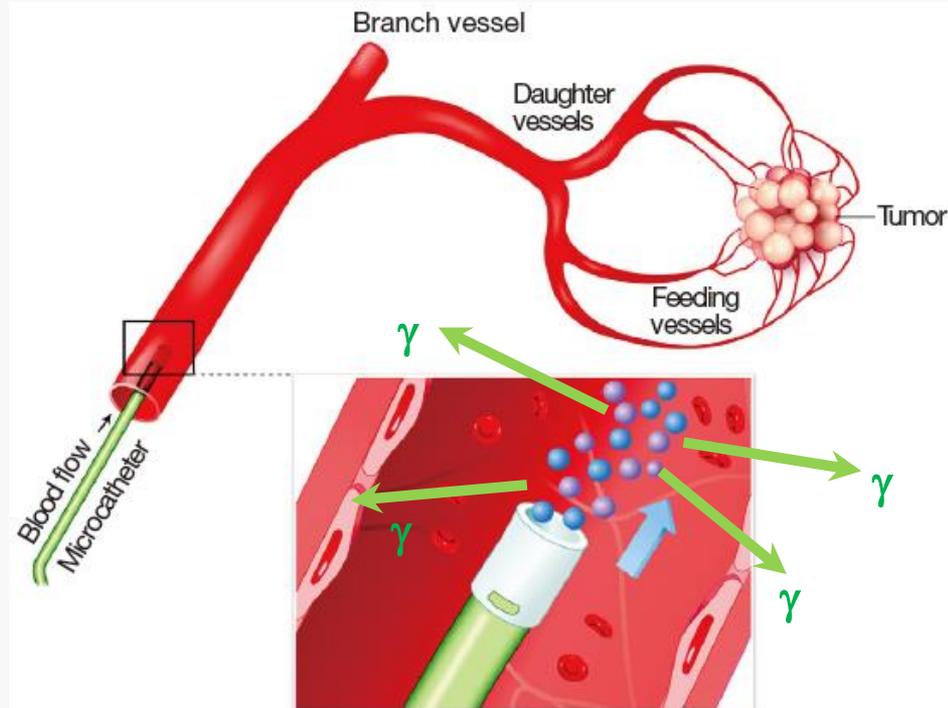


RADIOTHEAPIE INTERNE SELECTIVE



RADIODIAGNOSTIC INTERNAL THERAPY

Workup – étude dosimétrique

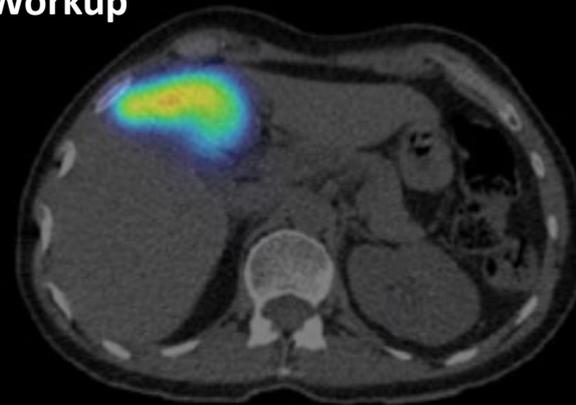


RADIOTHEAPIE INTERNE SELECTIVE

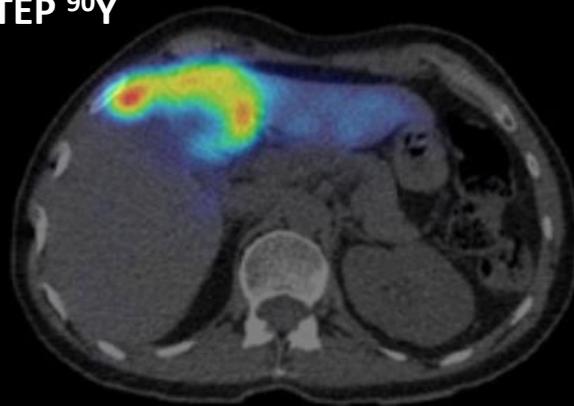
1. TEP FDG



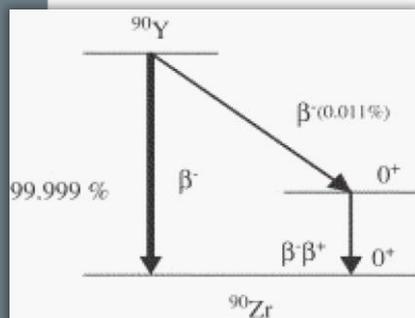
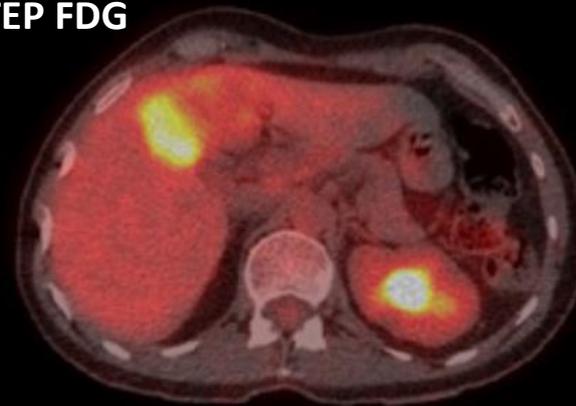
2. Workup



3. TEP ^{90}Y



4. TEP FDG



CONCLUSION

❖ Imagerie fonctionnelle et métabolique :

- ❖ physiologique, **non invasive et peu irradiante**
- ❖ couvrant toutes les spécialités médicales
- ❖ rôle essentiel dans le diagnostic et le traitement
- ❖ impliquant des **équipes multidisciplinaires**
 - paramédicaux, techniciens, médecins, pharmaciens,
 - physiciens, chimistes, informaticiens...

❖ En fort développement :

- ❖ **Recherche : radio-traceurs, protocoles, caméras...**

❖ Économique :

200 centres, 550 médecins en France

+ 5% de patients pris en charge / an

accelerator physics X-ray source physics image reconstruction
detector physics medical doctors

