

Médecine nucléaire

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Physiciens médicaux en médecine nucléaire

Un centre d'excellence, un accès pour tous



introduction

Imagerie médicale: exploration du corps humain: anatomique et fonctionnel

Sondes physiques nécessitant un apport d'énergie

Ondes électromagnétiques dans le spectre visible:

- Vision naturelle; Endoscopie; Microscopie

et en dehors:

- Rayons X pour radiologie (mammo, conventionnel, scanner)
- Radiofréquence (RF) pour IRM
- Gamma en médecine nucléaire

Ondes mécanique dans le spectre onde acoustique haute fréquence: ultrason

introduction

Principe:

Interaction physique avec les tissus, énergie pénétrant les tissus

C'est l'interaction avec le milieu qui génère l'image (interaction rayonnement/matière)

Exception avec médecine nucléaire:

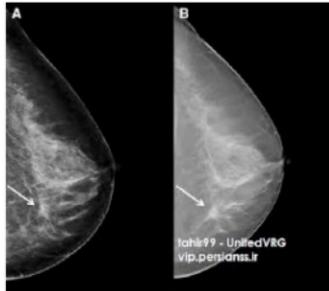
Substance radioactive injecté au patient interactions et c'est l'interaction physiologique avec l'organisme qui génère l'image

Règle générale toute modalité: image est un compromis entre la qualité et le confort/sécurité du patient (quantité d'énergie délivrée) question d'optimisation

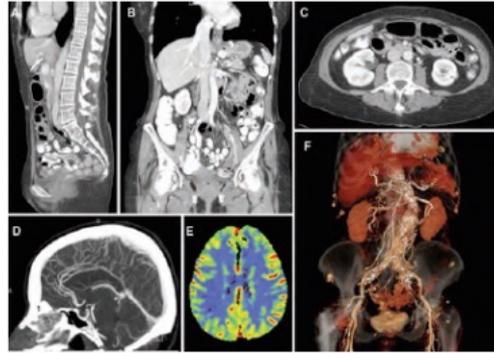
introduction



RX conventionnel



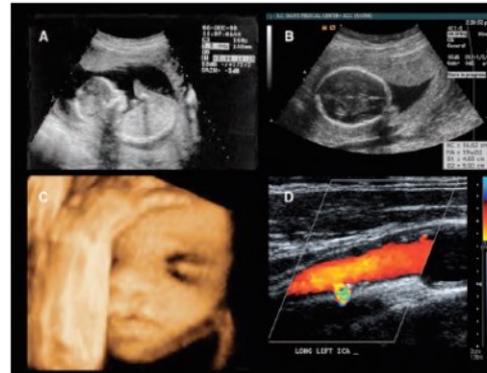
RX mamographie



RX scanner (CT computed tomography)
option produit de contraste

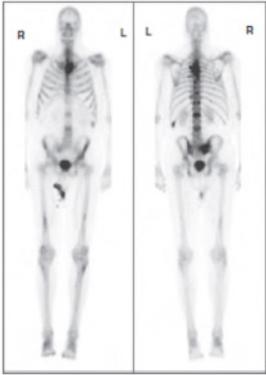


RF MRI (densité protonique des
tissus)

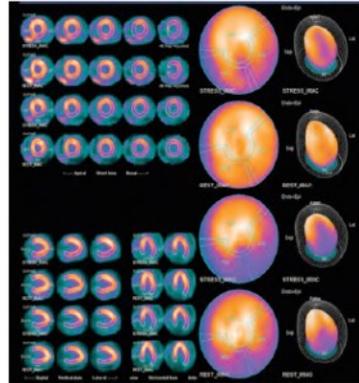


Ultrason option Doppler

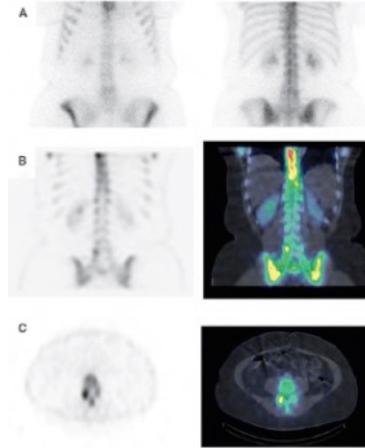
introduction



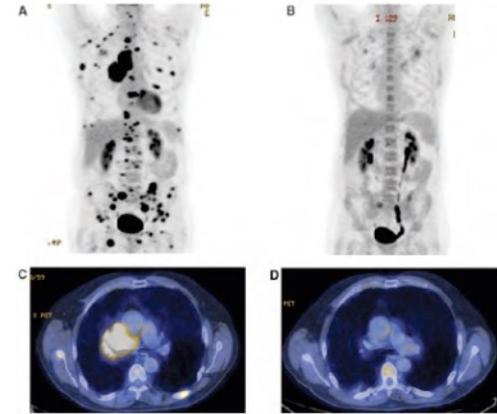
Imagerie planaire
fixations osseuses



Imagerie cardiaque
fonctionnement
musculaire



Hybride SPECT/CT



Hybride PET/CT

Formation de l'image

Contraste:

Propriété intrinsèque des tissus (atténuation numéro atomique, relaxation densité proton)

Densité du tissu, différence aux interfaces signal sonore (impédance acoustique)

Concentration substance radioactive dans le tissu

Résolution spatiale:

Capacité à voir des petits détails

Dépend théoriquement de la longueur d'onde de la sonde

Bruit:

Rapport signal sur bruit

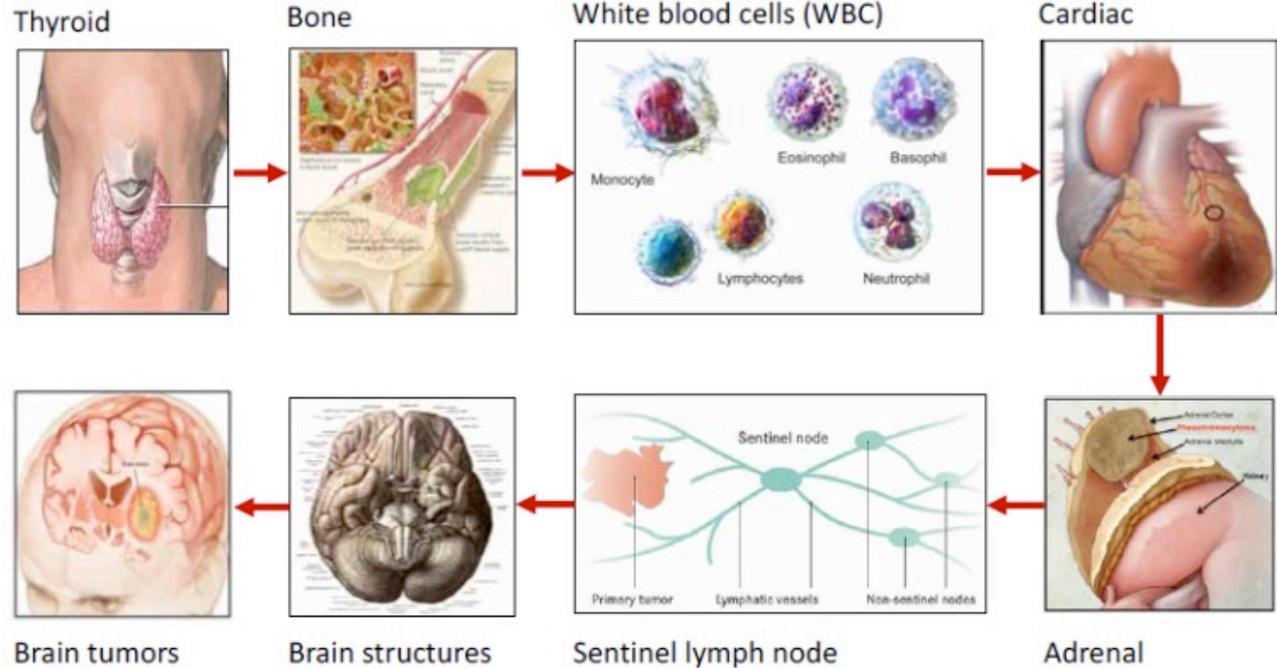
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TABLE 1-1 THE LIMITING SPATIAL RESOLUTIONS OF VARIOUS MEDICAL IMAGING MODALITIES. THE RESOLUTION LEVELS ACHIEVED IN TYPICAL CLINICAL USAGE OF THE MODALITY ARE LISTED

MODALITY	SPATIAL RESOLUTION (mm)	COMMENTS
Screen film radiography	0.08	Limited by focal spot size and detector resolution
Digital radiography	0.17	Limited by size of detector elements and focal spot size
Fluoroscopy	0.125	Limited by detector resolution and focal spot size
Screen film mammography	0.03	Highest resolution modality in radiology, limited by same factors as in screen film radiography
Digital mammography	0.05–0.10	Limited by same factors as digital radiography
Computed tomography	0.3	About ½ mm pixels
Nuclear medicine planar imaging	2.5 (detector face), 5 (10 cm from detector)	Spatial resolution degrades substantially with distance from detector
Single photon emission computed tomography	7	Spatial resolution worst towards the center of cross-sectional image slice
Positron emission tomography	5	Better spatial resolution than the other nuclear imaging modalities
Magnetic resonance imaging	1.0	Resolution can improve at higher magnetic fields
Ultrasound imaging (5 MHz)	0.3	Limited by wavelength of sound

Vue d'ensemble des applications de la médecine nucléaire

Imagerie fonctionnelle



Vue d'ensemble des applications de la médecine nucléaire

L'imagerie nucléaire possède **2 atouts majeurs** :

- I. Celui de posséder une **sensibilité élevée** puisqu'elle donne accès à la quantification de concentrations moléculaires allant jusqu'à 10^{-12} mole/l ;
- II. Celui de bénéficier d'une très **grande variété de molécules** radio marquées.

Parmi les **applications** on retiendra plus particulièrement:

1. la mesure du **métabolisme énergétique** grandement exploitée aujourd'hui en oncologie pour sa sensibilité,
2. la **pharmacocinétique** de molécules d'intérêt
3. **l'expression génique** (nouveau champ d'investigation de l'imagerie très prometteur).

À l'opposé, l'imagerie nucléaire présente **plusieurs limites** :

- I. elle ne fournit **pas de données anatomiques**
- II. possède une **résolution spatiale relativement faible** (quelques millimètres chez l'homme)
- III. son **coût et sa difficulté de mise en œuvre**, en particulier pour la TEP qui nécessite des installations dédiées afin de produire les radioisotopes in situ étant donné la faiblesse de leur période radioactive.

Vue d'ensemble des applications de la médecine nucléaire

Chez l'adulte:

- Cœur
- Poumons
- Système osseux
- Cerveau

Chez l'adulte et l'enfant:

- Cancer
- Rein

Les thérapies:

- traitement à l'iode radioactif (I-131) utilisé pour traiter certaines causes et de cancer de la thyroïde
- certaines formes de lymphome (cancer du système lymphatique)
- troubles sanguins
- métastases tumorales douloureuses aux os
- tumeurs des glandes surrénales chez les adultes et les tumeurs des glandes surrénales / des tissus nerveux chez les enfants

Chez les enfants:

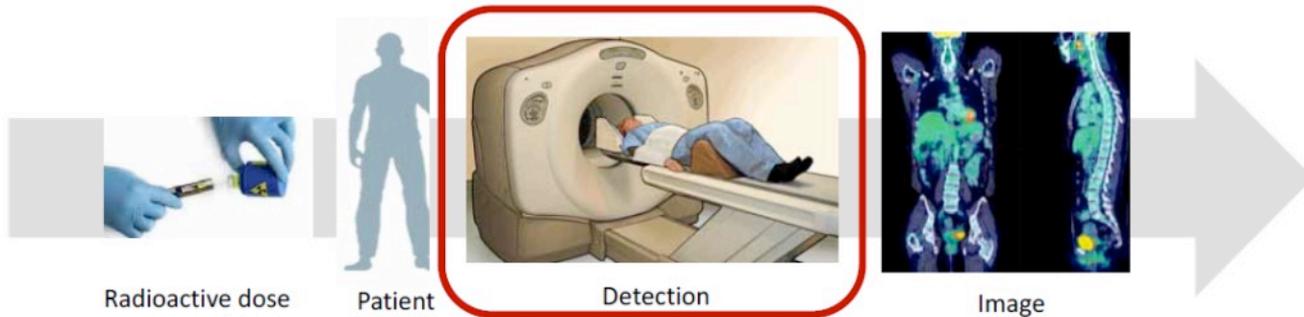
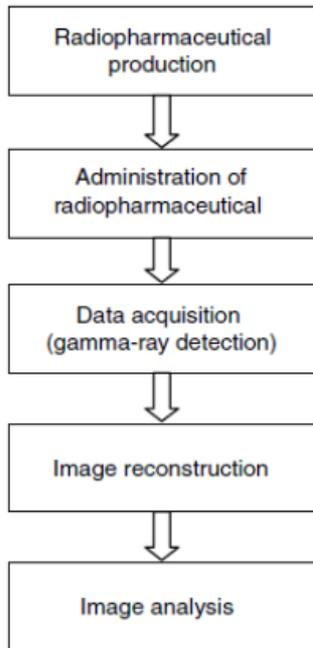
- anomalies de l'œsophage
- ouvertures canaux lacrymaux
- ouverture des shunts ventriculaires dans le cerveau
- cardiopathies congénitales pour les shunts et le flux sanguin pulmonaire

Autres systèmes:

- inflammation ou une fonction anormale de la vésicule biliaire
- fonction thyroïdienne
- vidange de l'estomac
- débit de liquide céphalo-rachidien et les fuites potentielles de liquide céphalorachidien

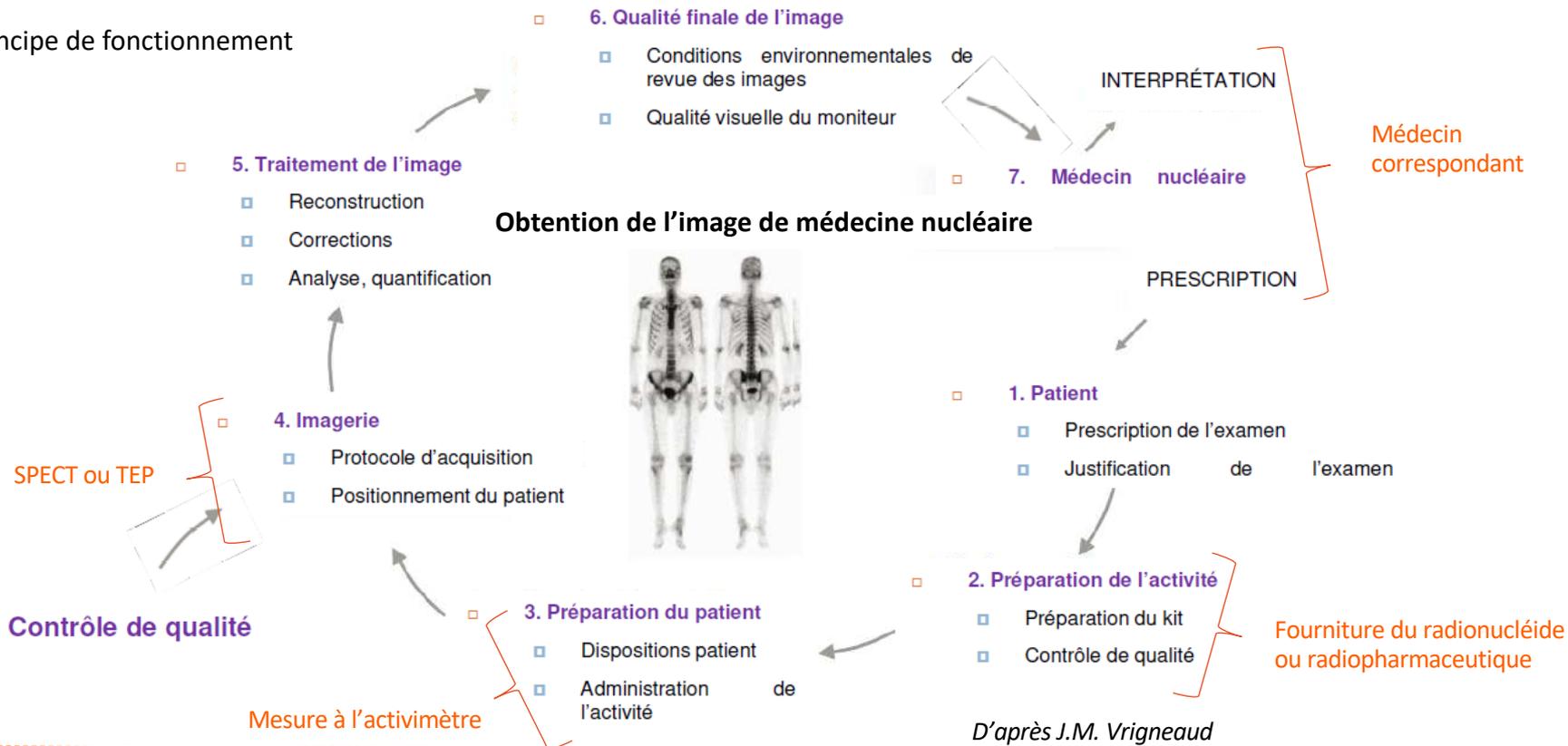
Médecine nucléaire

Principe de fonctionnement



Médecine nucléaire

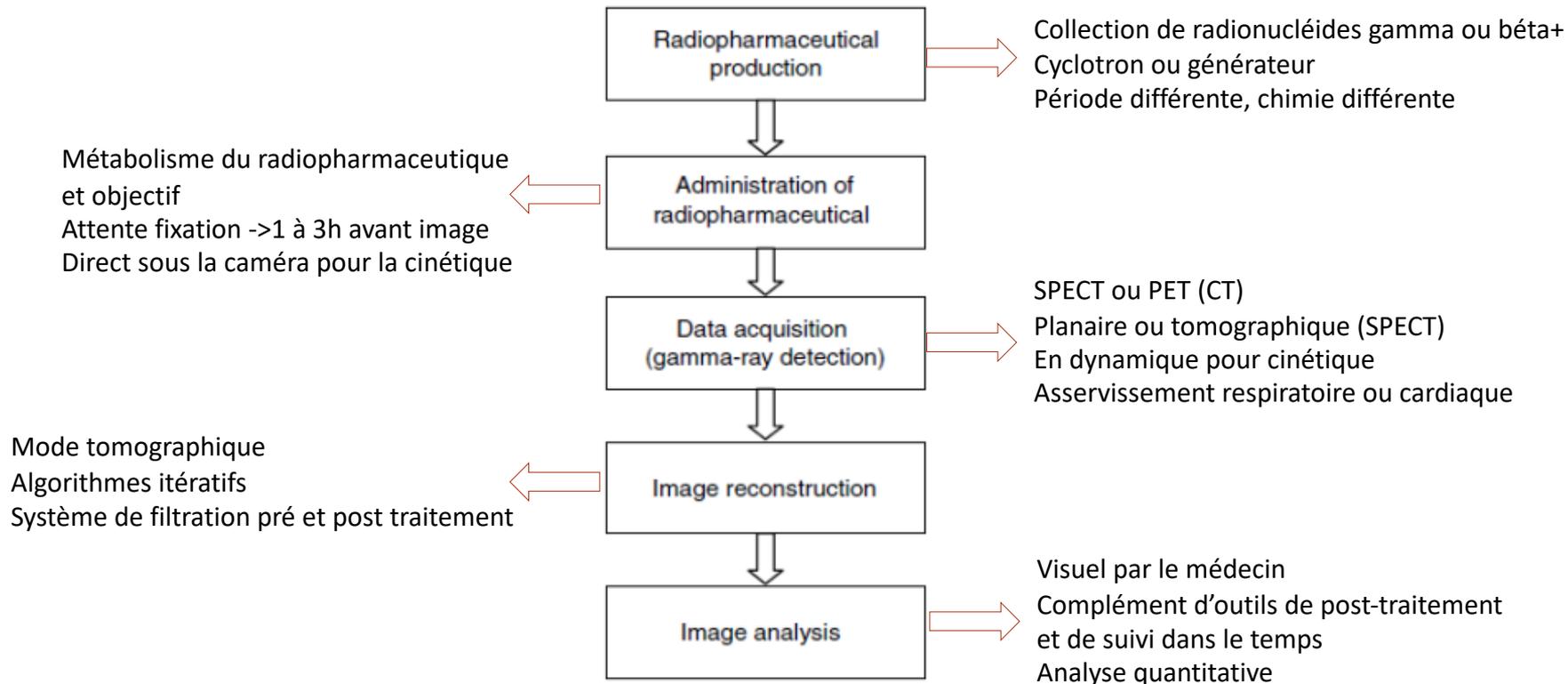
Principe de fonctionnement



D'après J.M. Vrigneaud

Médecine nucléaire

Principe de fonctionnement



Médecine nucléaire

Exemple de radionucléides

Radionuclide	Physical half life	Mode of decay	Modality	Clinical Indication
Iodine (^{123}I)	13.3 h	EC	SPECT	Hyperthyroidism, Parkinson's disease, schizophrenia
Fluorine (^{18}F)	109.77 m	β	PET	Parkinson's disease, schizophrenia
Iodine (^{131}I)	8.02 d	β	SPECT	Hyperthyroidism, neuroblastoma, thyroid cancer, NHL, RIT
Phosphorus (^{32}P)	14.29 d	β	SPECT	Cystic craniopharyngioma, PVNS, polycythemia vera
Strontium (^{89}Sr)	50.57 d	β	SPECT	Painful bone metastasis
Yttrium (^{90}Y)	64.10 h	β	PET/SPECT	Hepatic metastasis, PVNS, RIT, NHL
Tin-177m ($^{177\text{m}}\text{Sn}$)	14.00 d	IT	SPECT	Bone tumor treatment
Samarium (^{153}Sm)	1.93 d	β	SPECT	Painful bone metastasis, synovitis
Erbium (^{169}Er)	9.40 d	β	PET	Synovitis
Rhenium (^{186}Re)	3.78 d	EC β	PET	Painful bone metastasis Painful arthritis
Rhenium (^{188}Re)	16.98 h	β	SPECT	Painful bone metastasis RIT, rheumatoid arthritis
Radium (^{223}Ra)	11.43 d	α	SPECT	Bone metastasis

.....IT; isomeric transition, EC; electron capture, NHL; non-Hodgkin lymphoma, PVNS; pigmented villonodular synovitis, RIT; radioimmunotherapy
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Exemple de radionucléides

TABLE 1 Values of the Half-Life of Some Commonly Used Radioisotopes

Isotope	Half-Life ($t_{1/2}$)
^{11}C	20.4 min
^{13}N	9.96 min
^{15}O	124 s
^{18}F	110 min
^{67}Ga	78.3 h
^{82}Rb	1.25 min
$^{99\text{m}}\text{Tc}$	6.02 h
^{111}In	2.83 days
^{123}I	13.2 h
^{131}I	8.02 days
^{201}Tl	73.1 h

TABLE 2 Clinical PET Radiopharmaceuticals and Their Applications^a

PET Radiopharmaceutical	Application
^{18}F FDG	Characterization, diagnosis, staging, and restaging of many forms of cancer Solitary pulmonary nodule assessment Epilepsy (refractory seizures) Myocardial perfusion or viability assessment
^{82}Rb RbCl	Myocardial perfusion or viability assessment

Médecine nucléaire

Exemple de radionucléides

TABLE 3 Clinical Applications of SPECT and Radiopharmaceuticals Used in These Applications^a

SPECT Radiopharmaceutical	Application
⁶⁷ Ga citrate	Infection or lymphoma detection
¹¹¹ In capromab pentetide	Prostate cancer detection
²⁰¹ Tl TlCl	Myocardial perfusion or viability assessment
^{99m} Tc TlCl	Brain lymphoma detection
^{99m} Tc sestamibi or tetrofosmin	Myocardial perfusion or viability assessment
^{99m} Tc MDP	Metastases or fracture detection
^{99m} Tc HMPAO	Brain perfusion assessment
^{99m} Tc RBCs	Liver hemangioma detection
^{99m} Tc sulfur colloid	Liver/spleen assessment, lymphoscintigraphy
^{99m} Tc sestamibi or tetrofosmin	Parathyroid localization

^a HMPAO, hexamethylpropylene amine oxime; MDP, methylene diphosphonate; RBCs, red blood cells.

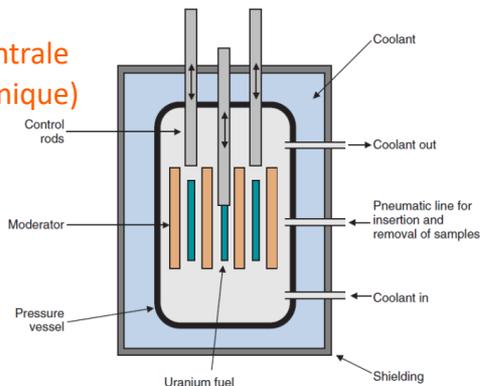
TABLE 4 Clinical Applications of Single-Photon Planar (Projection) Imaging and Radiopharmaceuticals Used in These Applications^a

SPECT Radiopharmaceutical	Application
¹²³ I or ¹³¹ I MIBG	Neuroendocrine tumor detection
¹²³ I NaI	Thyroid function assessment
¹²³ I NaI	Thyroid function assessment
^{99m} Tc RBCs	Gastrointestinal bleed detection
^{99m} Tc sulfur colloid	Sentinel lymph node localization for melanoma and breast cancer
^{99m} Tc DTPA, MAG3	Renal function or obstruction assessment
^{99m} Tc MAA	Lung ventilation assessment
^{99m} Tc DTPA	Lung perfusion assessment
^{99m} Tc RBCs, MUGA	Left ventricular function characterization
¹³³ Xe xenon gas	Lung ventilation assessment

^a MIBG, meta-iodobenzylguanidine; DTPA, diethylenetriamine pentaacetate; MAG3, mercaptoacetyl triglycine; MAA, macroaggregated albumen; MUGA, multiple gated acquisition.

Médecine nucléaire

Environnement de centrale
nucléaire (flux neutronique)



Cyclotron

SOME CYCLOTRON-PRODUCED RADIONUCLIDES USED IN NUCLEAR MEDICINE

Product	Decay Mode	Common Production Reaction	Natural Abundance of Target Isotope* (%)	Energy Threshold (MeV) [†]
¹¹ C	β ⁺ , EC	¹⁴ N(p,α) ¹¹ C	99.6	3.1
		¹⁰ B(d,n) ¹¹ C	19.9	0
¹³ N	β ⁺	¹⁶ O(p,α) ¹³ N	99.8	5.5
		¹² C(d,n) ¹³ N	98.9	0.35
¹⁵ O	β ⁺	¹⁴ N(d,n) ¹⁵ O	99.6	0
		¹⁵ N(p,n) ¹⁵ O	0.37	—
¹⁸ F	β ⁺ , EC	¹⁸ O(p,n) ¹⁸ F	0.20	2.57
		²⁰ Ne(d,α) ¹⁸ F	90.5	0
⁶⁷ Ga	(EC,γ)	⁶⁹ Zn(p,2n) ⁶⁷ Ga	18.8	5.96
¹¹¹ In	(EC,γ)	¹⁰⁹ Ag(α,2n) ¹¹¹ In	48.2	—
		¹¹⁴ Cd(p,n) ¹¹¹ In	12.8	—
¹²³ I	(EC,γ)	¹²² Te(d,n) ¹²³ I	2.6	—
		¹²⁴ Te(p,3n) ¹²³ I	4.8	—
²⁰¹ Tl	(EC,γ)	²⁰¹ Hg(d,2n) ²⁰¹ Tl	13.2	—

*Values from Browne E, Firestone RB: *Table of Radioactive Isotopes*. New York, 1986, John Wiley.¹

[†]Values from Helus F, Colombetti LG: *Radionuclides Production*, Vols I, II. Boca Raton, 1983, CRC Press.⁴ EC, electron capture.

NEUTRON-ACTIVATED RADIONUCLIDES OF IMPORTANCE IN BIOLOGY AND MEDICINE

Radionuclide	Decay Mode	Production Reaction	Natural Abundance of Target Isotope (%) [*]	σ _n (b) [†]
¹⁴ C	β ⁻	¹⁴ N(n,p) ¹⁴ C	99.6	1.81
²⁴ Na	(β ⁻ ,γ)	²³ Na(n,γ) ²⁴ Na	100	0.53
³² P	β ⁻	³¹ P(n,γ) ³² P	100	0.19
		³² S(n,p) ³² P	95.0	0.1
³⁵ S	β ⁻	³⁶ Cl(n,p) ³⁵ S	75.8	0.4
⁴² K	(β ⁻ ,γ)	⁴¹ K(n,γ) ⁴² K	6.7	1.2
⁵¹ Cr	(EC,γ)	⁵⁰ Cr(n,γ) ⁵¹ Cr	4.3	17
⁵⁹ Fe	(β ⁻ ,γ)	⁵⁸ Fe(n,γ) ⁵⁹ Fe	0.3	1.1
⁷⁵ Se	(EC,γ)	⁷⁴ Se(n,γ) ⁷⁵ Se	0.9	30
¹²⁵ I	(EC,γ)	¹²⁴ Xe(n,γ) ¹²⁵ Xe \xrightarrow{EC} ¹²⁵ I	0.1	110
¹³¹ I	(β ⁻ ,γ)	¹³⁰ Te(n,γ) ¹³¹ Te $\xrightarrow{\beta^-}$ ¹³¹ I	33.8	0.24

*Values from Browne E, Firestone RB: *Table of Radioactive Isotopes*. New York, 1986, John Wiley.¹

[†]Thermal neutron capture cross-section, in barns (b) (see "Activation Cross-Sections"). Values from Wang Y: *Handbook of Radioactive Nuclides*. Cleveland, Chemical Rubber Company, 1969.² EC, Electron capture.

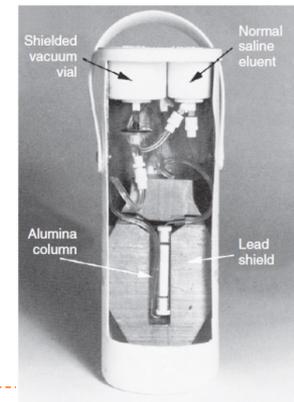
SOME RADIONUCLIDE GENERATORS USED IN NUCLEAR MEDICINE

Daughter*	Decay Mode	T _{1/2}	Parent	T _{1/2}
⁶² Cu	β ⁺ , EC	9.7 min	⁶² Zn	9.3 hr
⁶⁸ Ga	β ⁺ , EC	68 min	⁶⁸ Ge	271 d
⁸² Rb	β ⁺ , EC	1.3 min	⁸² Sr	25 d
^{87m} Sr	IT	2.8 hr	⁸⁷ Y	80 hr
^{99m} Tc	IT	6 hr	⁹⁹ Mo	66 hr
^{113m} In	IT	100 min	¹¹³ Sn	120 d

*Generator product.

EC, electron capture; IT, isomeric transition.

Générateur



Médecine nucléaire

Les vecteurs:
le radionucléide lui-même = analogue chimique

anticorps

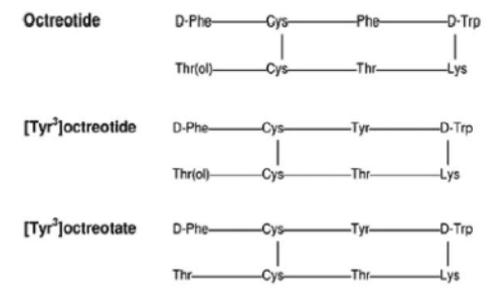
protéines

Table 6.1 Selected examples of protein scaffolds with potential for tumor targeting

Scaffold	Acronym	Randomization size	Example of target proteins	Tumor targeting data	Company reference
Human Fv fragments	Domain antibody dAb	Different loops 12–15 kDa	TNF-alpha, albumin, CD40L	No	GSK/Domantis [36]
Camel Fv fragments	Nanobody cAb	Different loops ca 15 kDa	CEA, TNF-alpha, albumin	Yes	Ablinx [35]
¹²⁵ I-Fa3 Fibronectin	Adnectin	Different loops, 21/94 aa	VEGFR, TNF-alpha, integrin	No	Adnexus [43]
CTLA-4	Evibody	6–9/136 aa	Integrin	No	Evogenix [46]
Apolipoprotein D	Anticalin	Four loops 24/178 aa	CTLA-4 VEGF	No	Pieris/Pasteolab [108]
T-cell receptor	mTCR	Different loops /250 aa	Peptide/MHC complexes	No	Medigene/Avidex [47]
Protein A domain	Affibody molecule	13/58 aa	HER2, EGFR, CD33, TNF-alpha, albumin	Yes	Affibody [57]
Ankyrin repeats	DARPin	7–21 for 1–3 repeats/100–166 (size is 67 + n*33)	HER2, AcrB, caspase-2	Yes	Molecular partners [68]
Ldl receptor domain A	Avimer	Up to 28/40 aa per domain, normally two to three domains (80–120 aa)	Il-6, cMet, CD28	No	Avidia [66]
Mia-23	Microbody/Kaottin	10/23 aa	Mabs, HIV-1 Nef, AMA-1	No	[77]
Fyn Src homology domain 3	Fynomer	12/63 aa	Extra domain B of fibronectin, albumin	Yes	Covagen [89]

Generic name	Trade name	Type/target antigen	Treatment indication	Approval
Unconjugated				
Rituximab	Rituxan	Chi-Anti-CD20	B-cell lymphoma	1997
Trastuzumab	Herceptin	Hum-anti-HER2	Breast	1998
Alemtuzumab	Campath	Hum anti-CD52	CLL	2001
Cetuximab	Erbitux	Chi-anti-	Colorectal Head/neck	2004 2006
Bevacizumab	Avastin	Chi-anti-VEGF	Colorectal	2006
Radioconjugates				
Satamomab pentedide	OncoScint ^a	¹¹¹ In-mur-anti-TAG72	Colorectal Ovarian	1992
Nofetumomab merpentan	Verluma ^a	^{99m} Tc-mur-anti-EGP Fab	Small cell lung cancer	1996
Arcitumomab	CEA-Scan ^a	^{99m} Tc-mur-anti-CEA Fab	Colorectal	1996
Capromab pentedide	ProstaScint	¹¹¹ In-mur-anti-PSMA	Prostate	1996
Ibritumomab tiuxetan	Zevalin	^{99m} Tc-mur-anti-CD20	B-cell lymphoma	2002
Tositumomab	Bexxar	¹³¹ I- mur-anti-CD20	B-cell lymphoma	2003
Drug conjugates				
Gemtuzumab ozogamicin	Mylotard	Hum-antiCD33	AML	2000

peptides



Technologie SPECT

1

Le patient



Fourniture des radionucléides ou
radiopharmaceutiques

Choix du radiopharmaceutique en
fonction de la prescription médicale

Conditionnement du patient →
imagerie immédiate ou après attente
diffusion métabolique



Acquisition des images puis
traitement

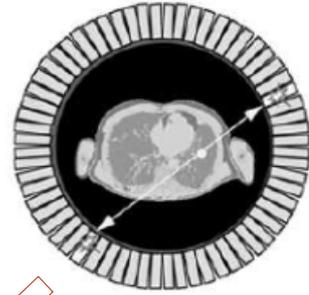
Médecine nucléaire

Principe de fonctionnement

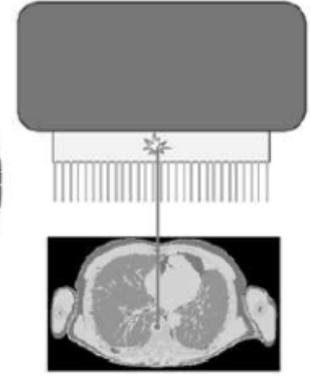


Caméra TEP/CT

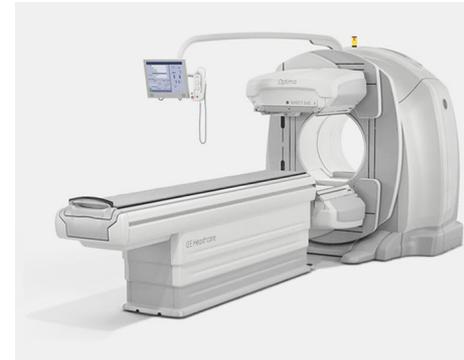
Deux types de système



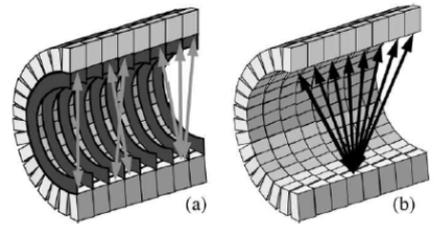
PET



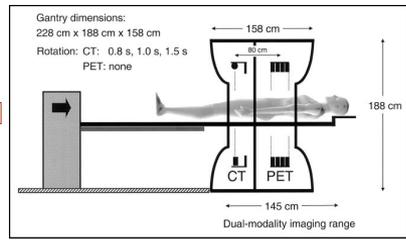
SPECT



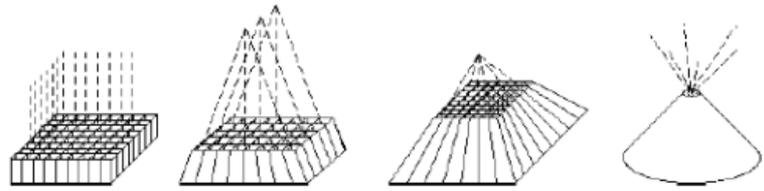
Caméra SPECT/CT



Collimation 2D ou sans 3D



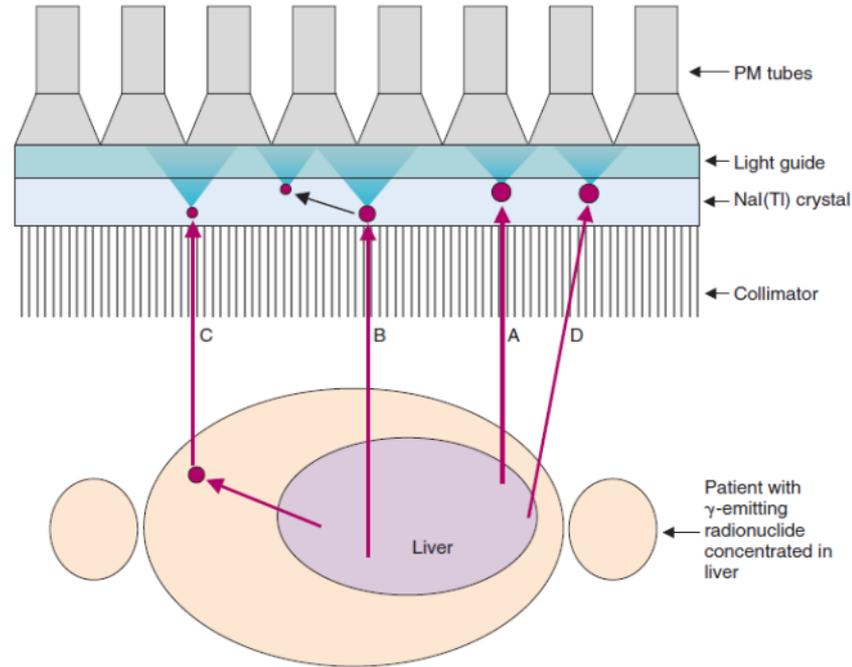
Principe caméra hybride émission/transmission



Jeu de collimateurs adaptés

Technologie SPECT

Principe de fonctionnement

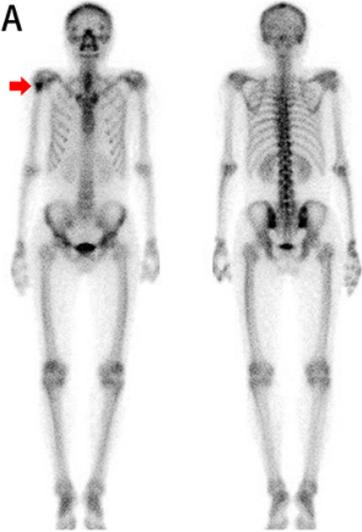


Technologie SPECT

Principe de fonctionnement

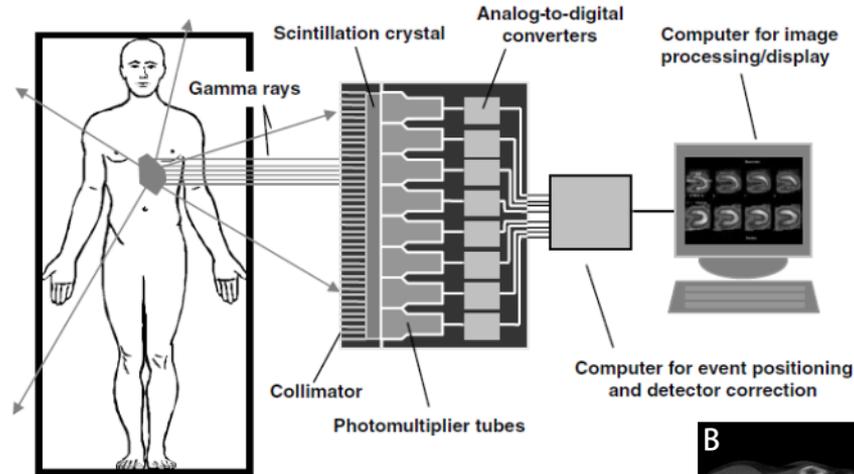
Mode planaire
Balayage du corps entier

A

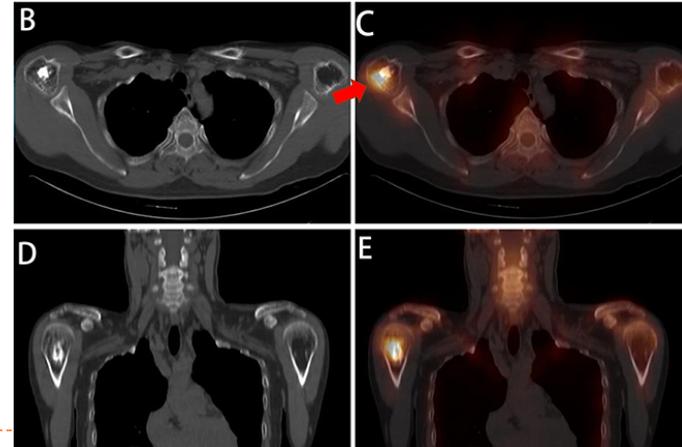


Antérieur

Postérieur



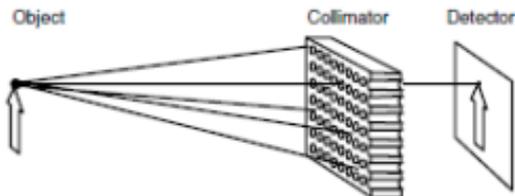
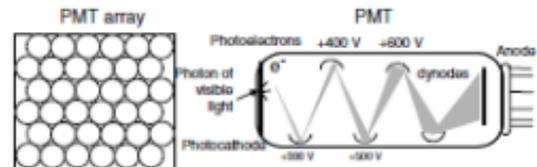
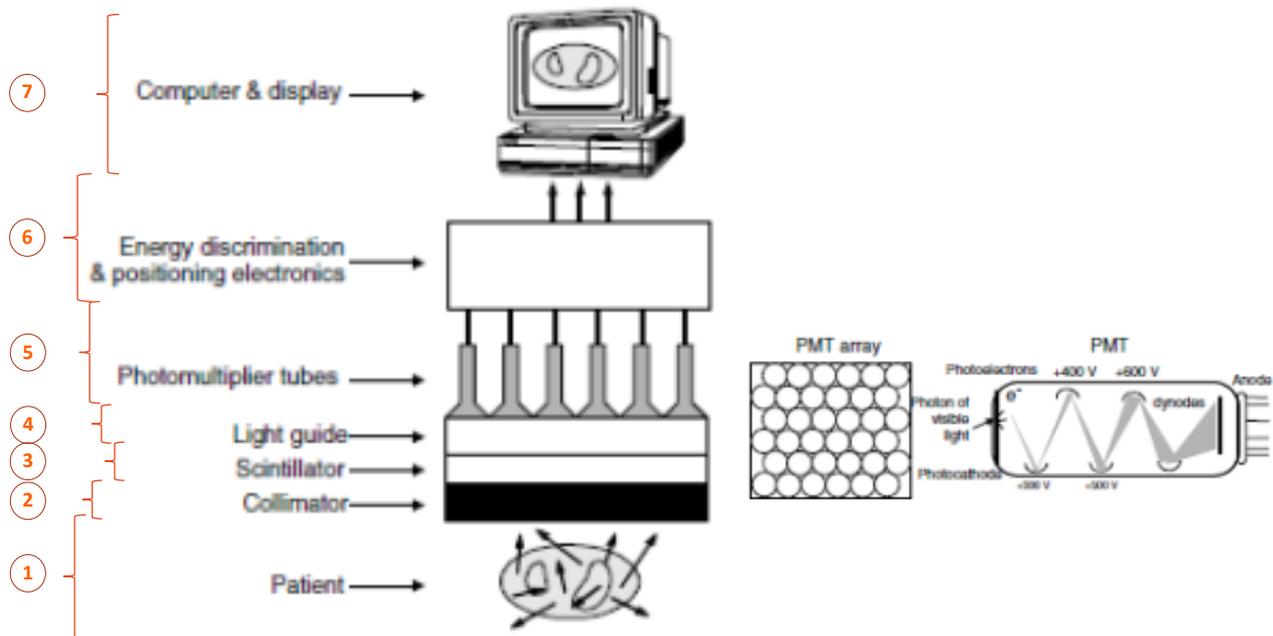
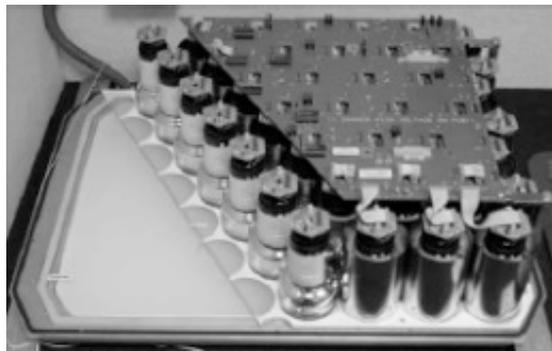
Mode tomographique
Fusion avec le CT



Technologie SPECT

Principe de fonctionnement

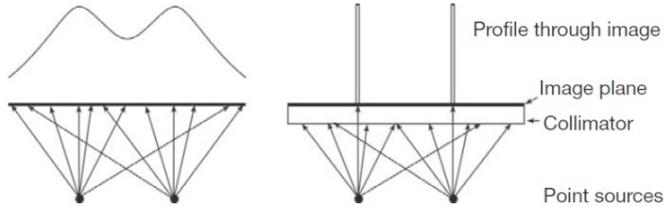
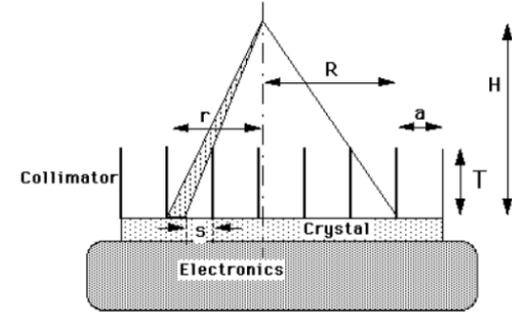
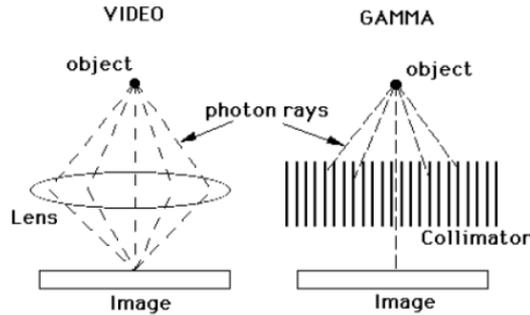
Système à étages



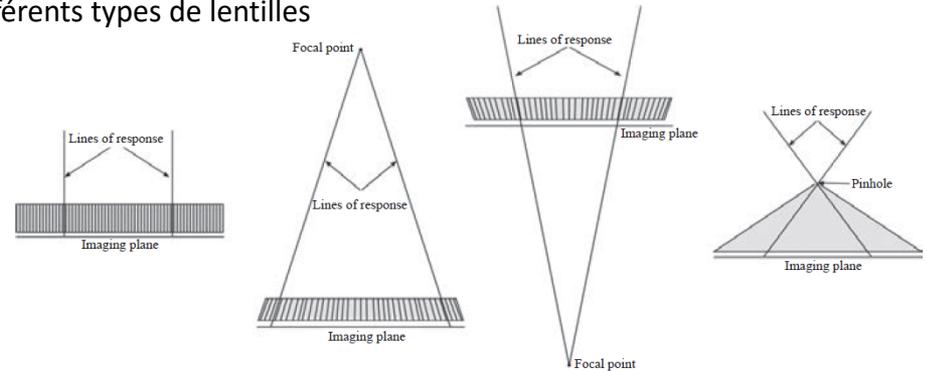
Technologie SPECT

2 Le collimateur

Similitude du rôle avec l'optique conventionnel



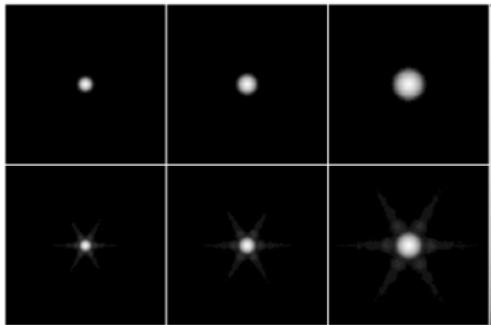
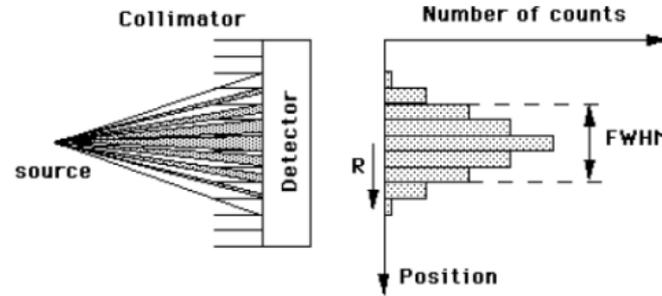
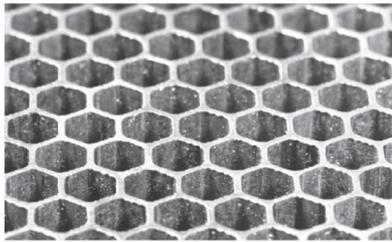
Différents types de lentilles



Technologie SPECT

2 Le collimateur

Performances liées au collimateur



5cm

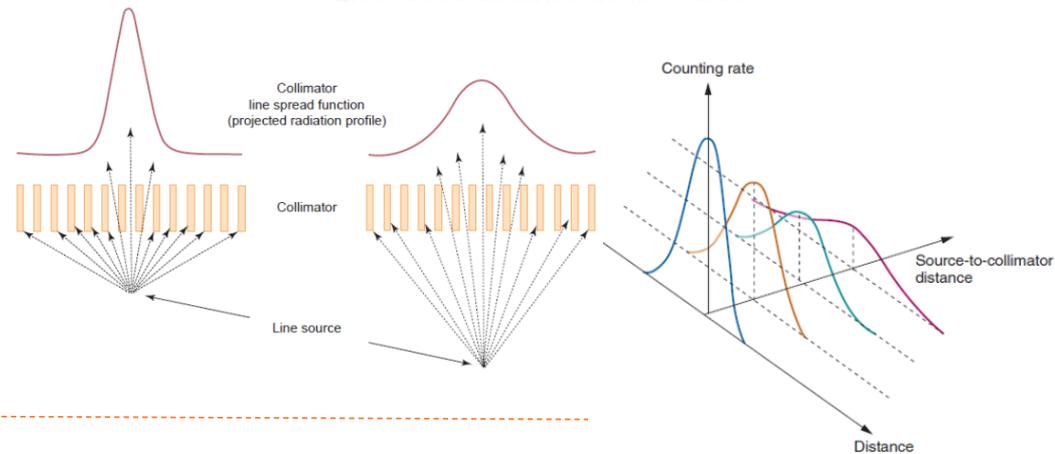
10cm

20cm

HE

MEGP

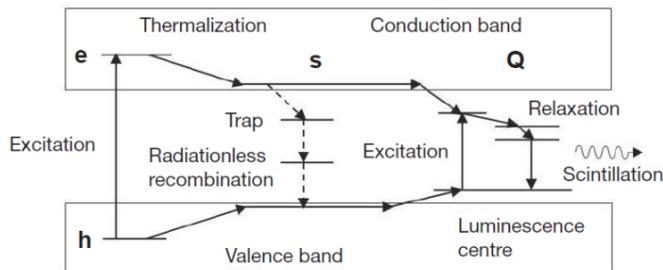
Effet de la distance de la source



Technologie SPECT

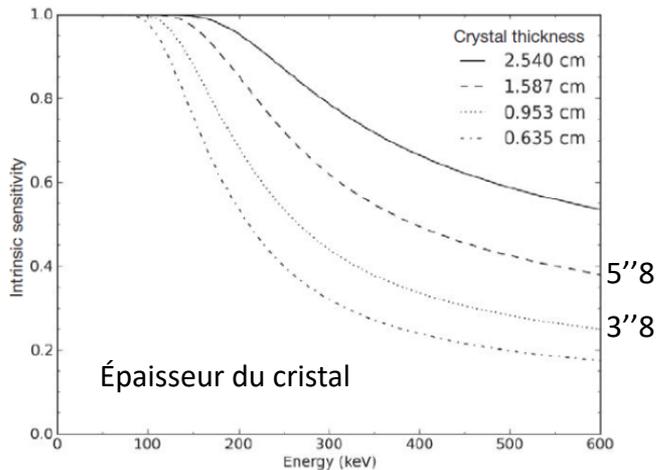
3 Le cristal scintillant

Performances liées au cristal

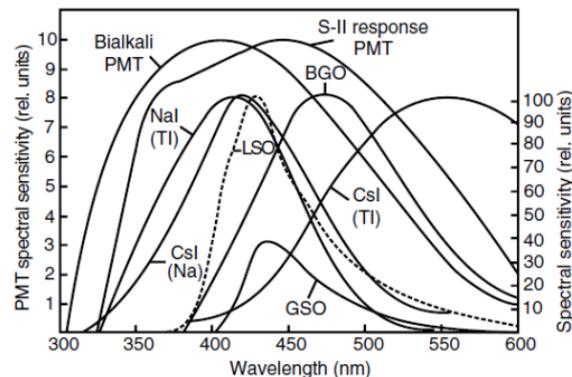


Scintillator	ρ (g/cm ³)	Z_{eff}	$1/\mu_{511}$ (mm)	Photoelectric effect (%)	λ_{max} (nm)	N_{ph} (photons/MeV)	R_{662} (%)	τ (ns)
NaI:TI ^a	3.67	51	29	17	410	41 000	6.5	230
CsI:TI	4.51	54	23	21	540	64 000	4.3	800, 10 ⁴
BaF ₂	4.88		23		220 310	1 500 10 000		0.8 600
Bi ₃ Ge ₅ O ₁₂ (BGO)	7.1	75	10.4	40	480	8 900		300
LaCl ₃ :Ce ^a	3.86	49.5	28	15	350	49 000	3.3	25
LaBr ₃ :Ce ^a	5.07	46.9	22	13	380	67 000	2.8	16
YAlO ₃ :Ce (YAP)	5.5	33.6	21	4.2	350	21 000	4.4	25
Lu _{0.8} Y _{0.2} Al:Ce (LuYAP)	8.3	65	11	30	365	11 000		18
Gd ₂ SiO ₅ :Ce (GSO)	6.7	59	14.1	25	440	12 500	9	60
Lu ₂ SiO ₅ :Ce,Ca (LSO)	7.4	66	11.4	32	420	~36 000	7	36-43
Lu _{1.8} Y _{0.2} SiO ₅ :Ce (LYSO)	7.1		12		420	30 000	7	40

^a Hygroscopic.



Épaisseur du cristal

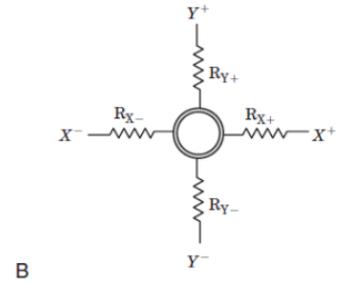
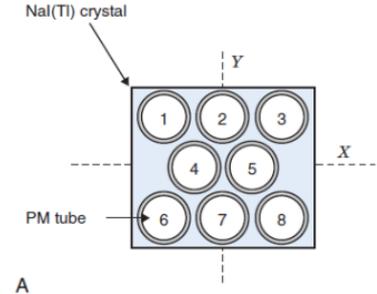
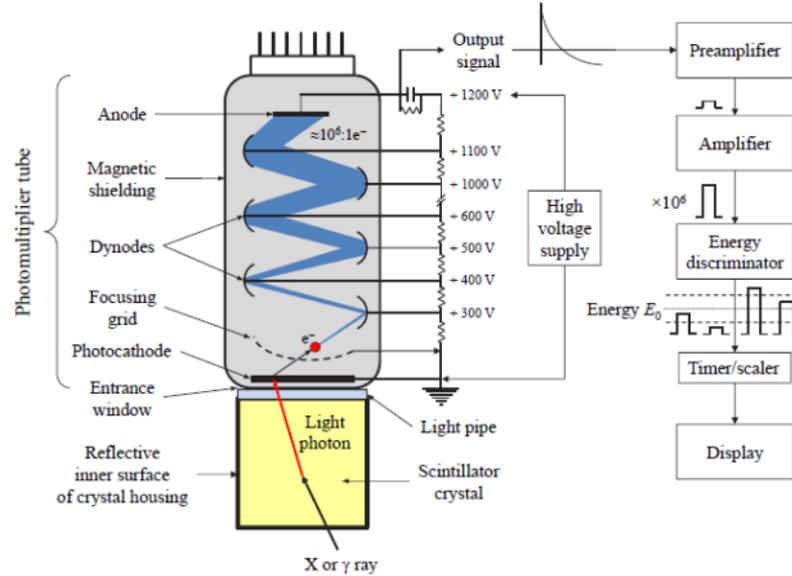
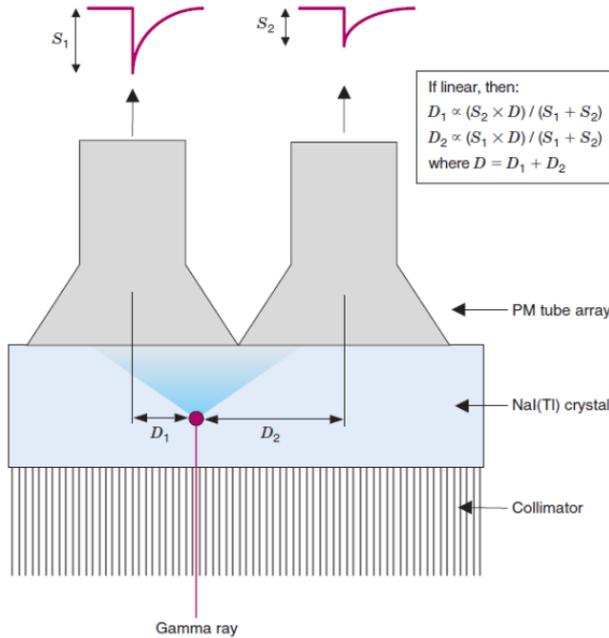


Couplage entre le cristal et les PMs

Technologie SPECT

5

Les photomultiplicateurs

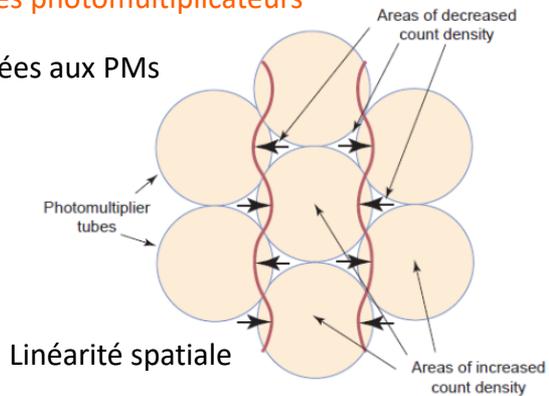


Technologie SPECT

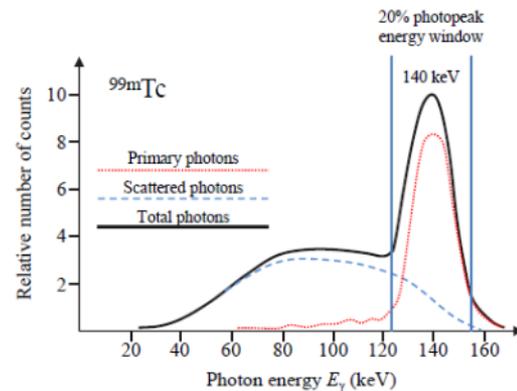
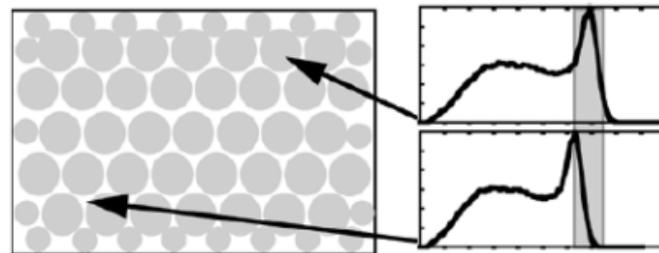
5

Les photomultiplicateurs

Performances liées aux PMs



Spectre énergétique



Technologie SPECT

Principe de fonctionnement

Linéarité spatiale

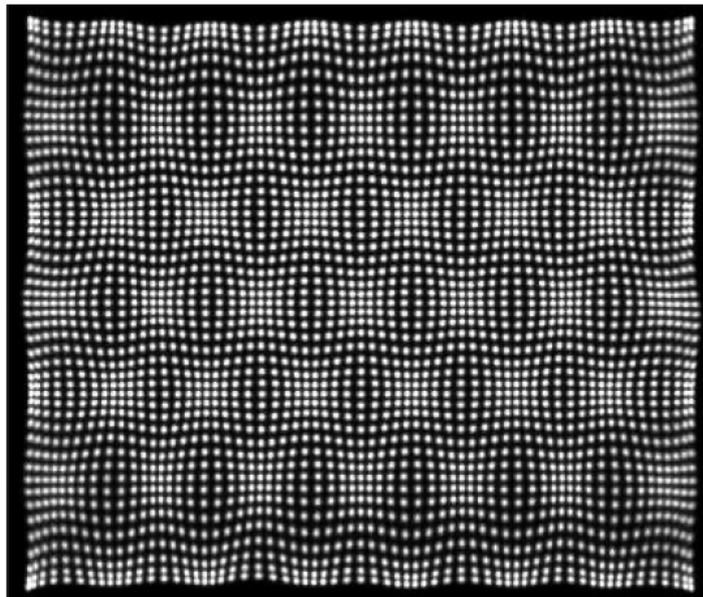


Image non corrigée

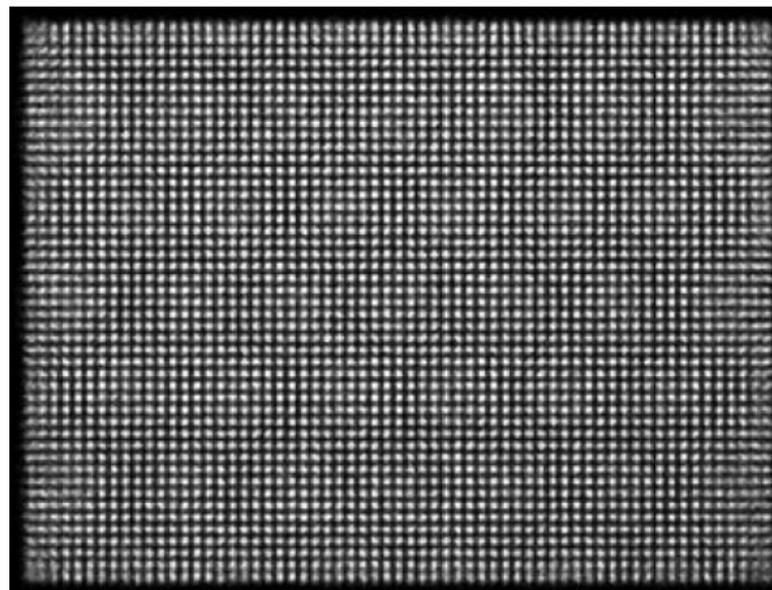


Image corrigée

Technologie SPECT

Principe de fonctionnement

Uniformité

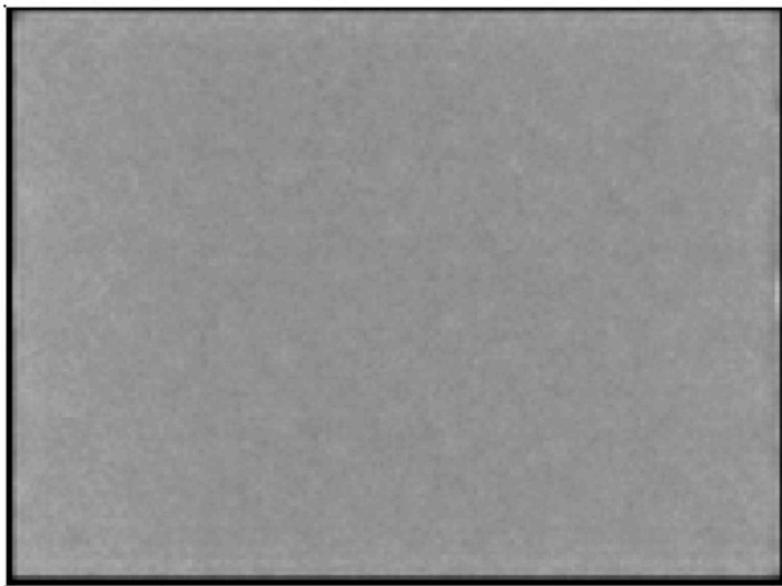


Image non corrigée

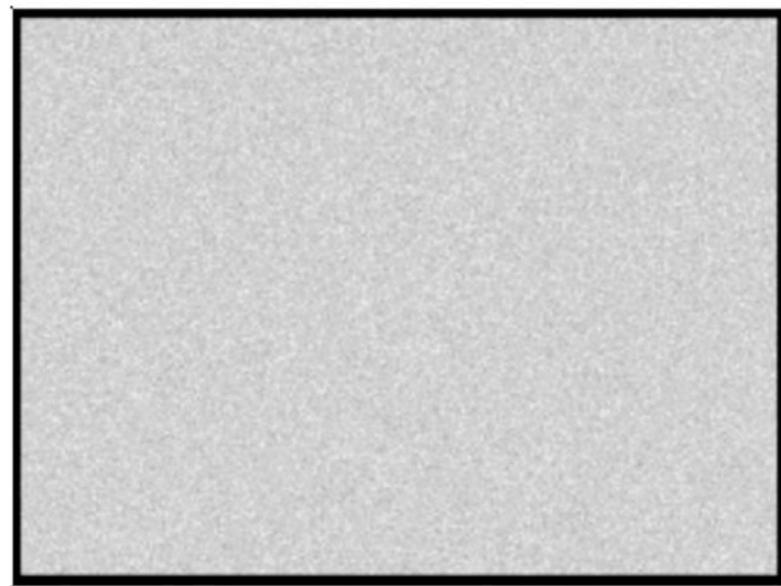
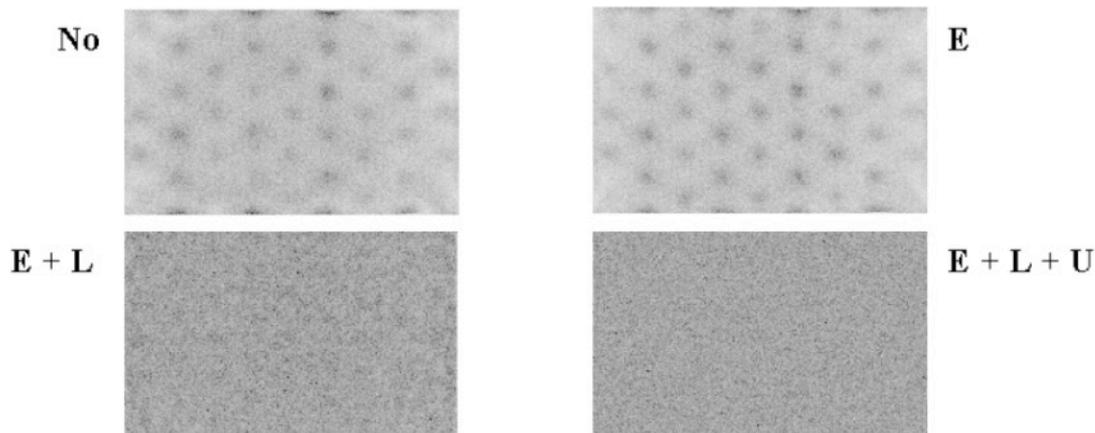


Image corrigée

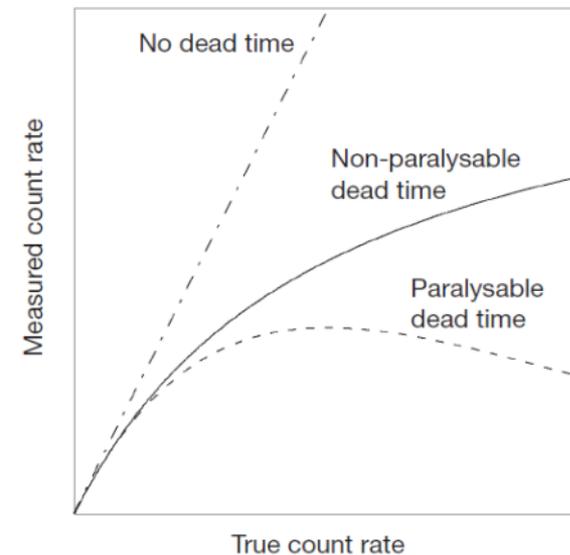
Technologie SPECT

Principe de fonctionnement

Corrections

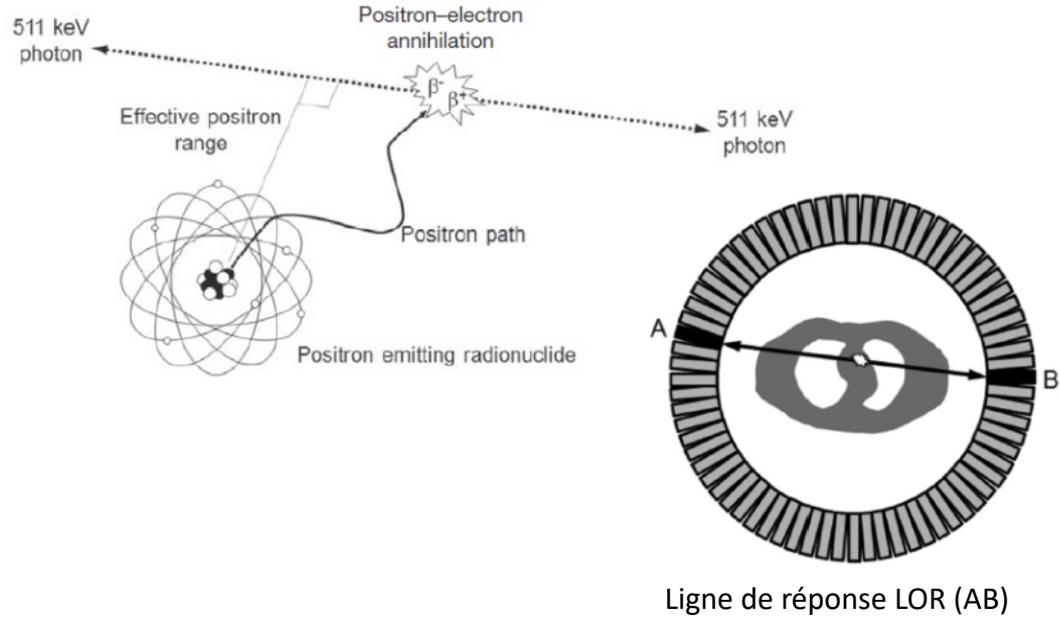


Temps mort



Technologie PET

Principe de fonctionnement

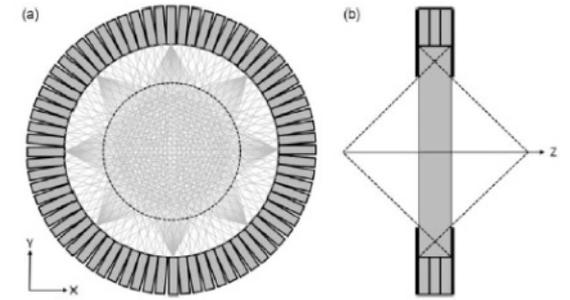
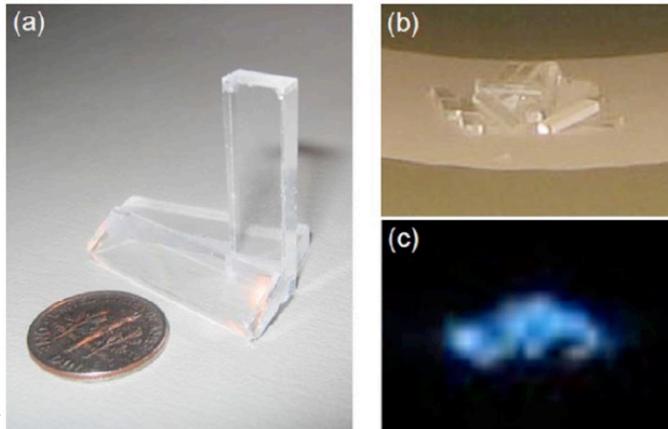
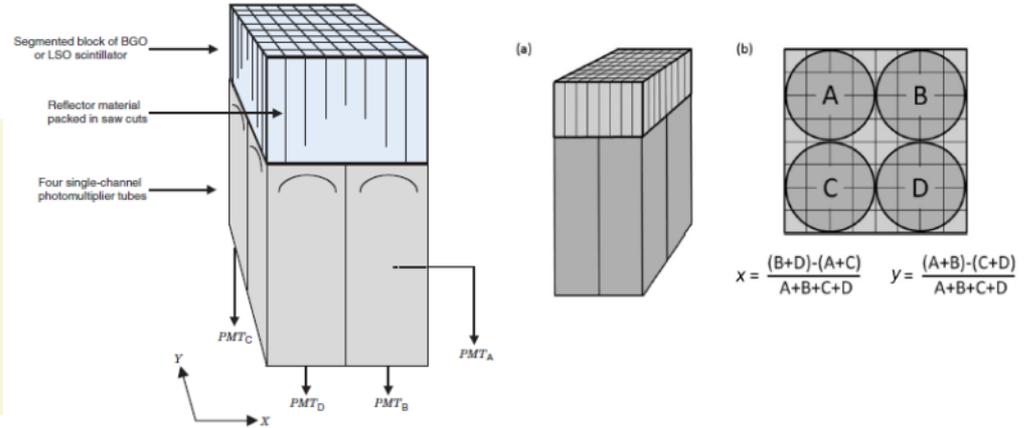


Technologie PET

Principe de fonctionnement

TABLE 19-2 PROPERTIES OF SEVERAL INORGANIC SCINTILLATORS OF INTEREST IN PET

SCINTILLATOR	DECAY CONSTANT (ns)	PEAK WAVELENGTH (nm)	ATOMIC NUMBERS	DENSITY (g/cm ³)	ATTENUATION COEFFICIENT 511 keV (cm ⁻¹)	CONVERSION
						EFFICIENCY RELATIVE TO NaI
NaI(Tl)	250	415	11,53	3.67	0.343	100%
BGO	300	460	83,32,8	7.17	0.964	12%–14%
GSO(Ce)	56	430	64,14,8	6.71	0.704	41%
LSO(Ce)	40	420	71,14,8	7.4	0.870	75%



Champ de vue utile

Technologie PET

Principe de fonctionnement

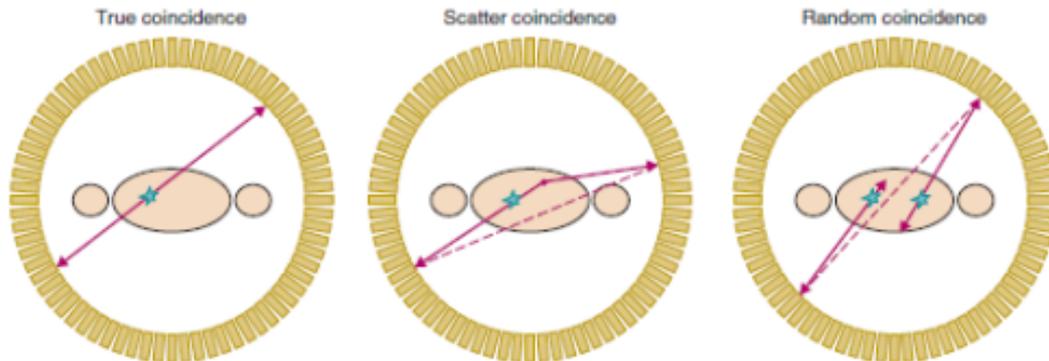


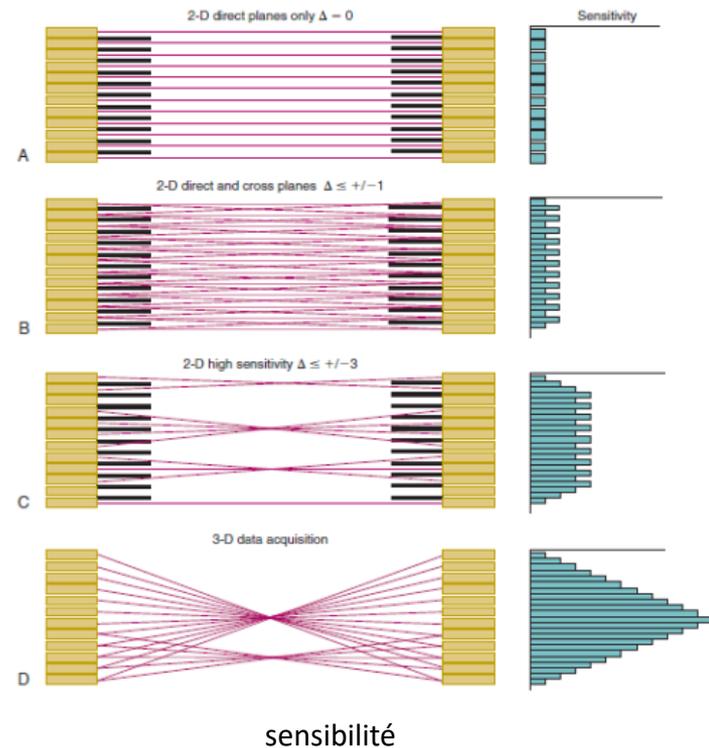
FIGURE 18-13 True coincidence event (left), scatter coincidence event (center), and random or accidental coincidence (right). Scatter and accidental coincidences yield incorrect positional information and contribute a relatively uniform background to the image that results in a loss of contrast. (Courtesy Dr. Magnus Dahlbom, University of California—Los Angeles.)

$$R_{\text{true}} = R_{\text{prompt}} - R_{\text{scatter}} - R_{\text{random}}$$

Noise equivalent counting rate

The NECR is defined as¹³

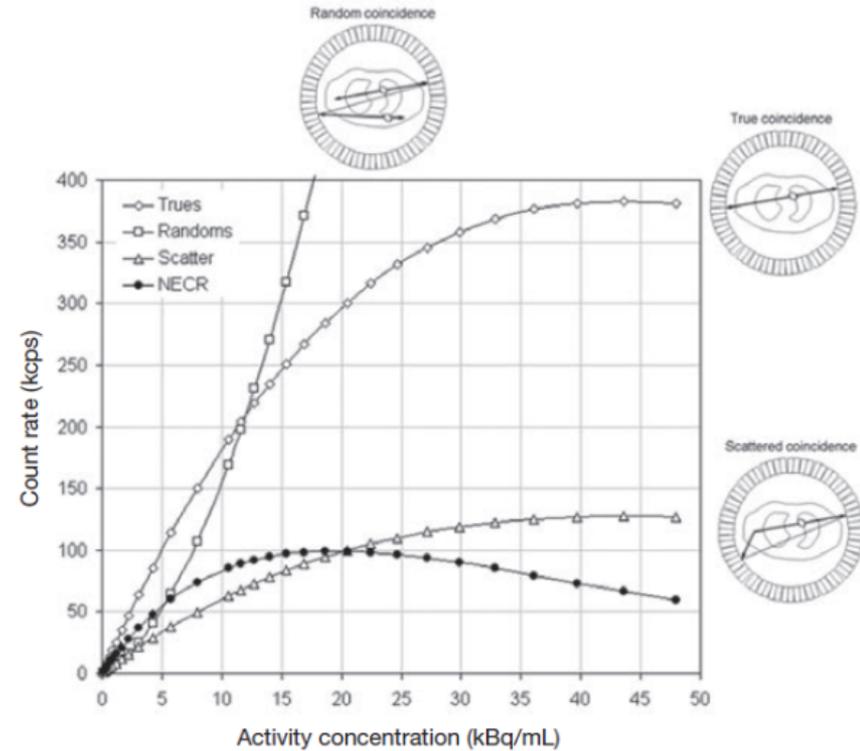
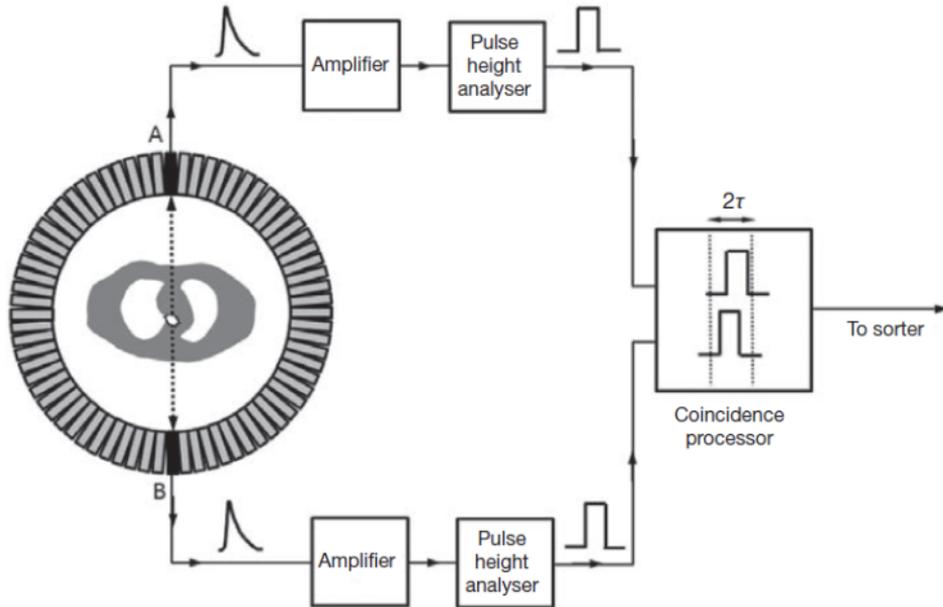
$$NECR = \frac{R_{\text{true}}^2}{R_{\text{true}} + aR_{\text{scatter}} + bR_{\text{random}}}$$



sensibilité

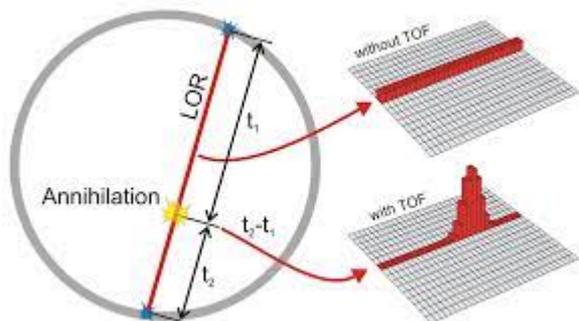
Technologie PET

Principe de fonctionnement

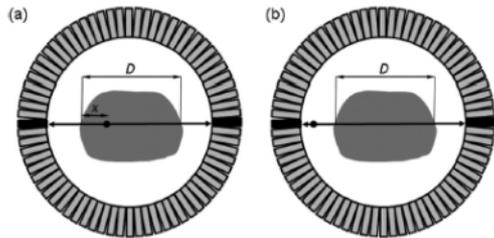


Technologie PET

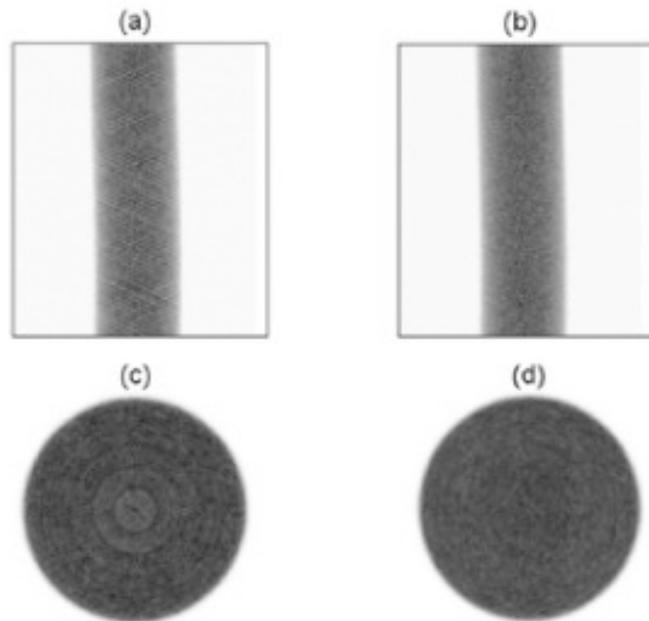
Principe de fonctionnement



Amélioration de l'information spatiale



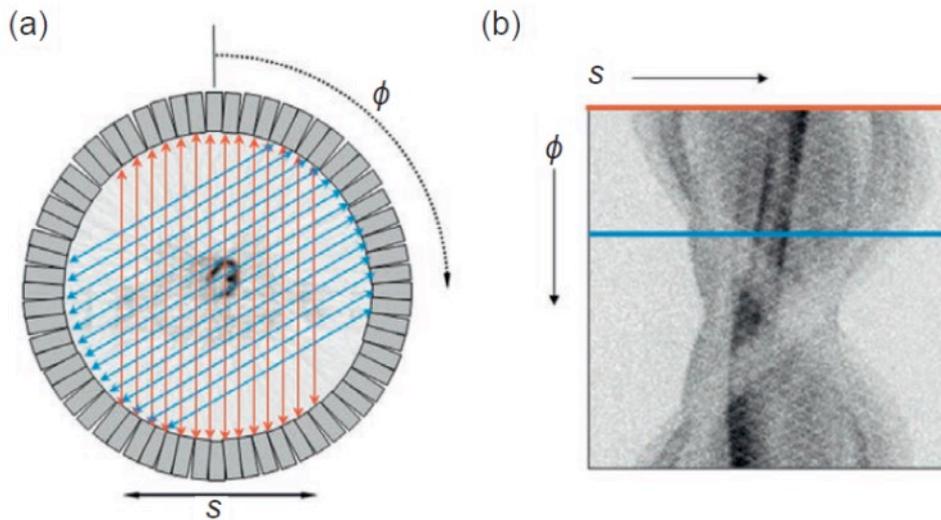
Correction de l'atténuation



Amélioration due à la normalisation

Technologie PET

Principe de fonctionnement



Formation du sinogramme à partir des LOR

Imagerie tomographique

Principe de fonctionnement: rétroprojection

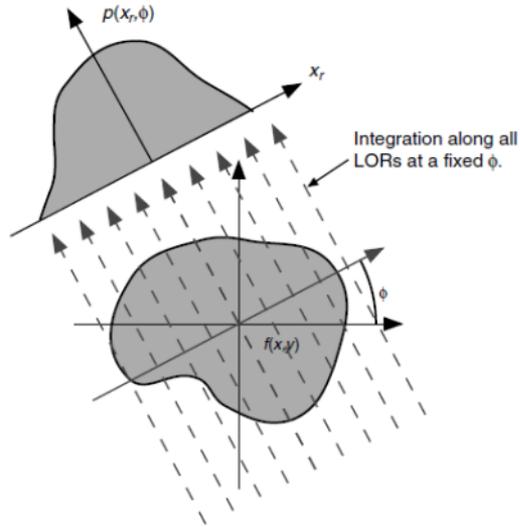


FIGURE 3 A projection formed from integration along all parallel LORs at an angle ϕ .

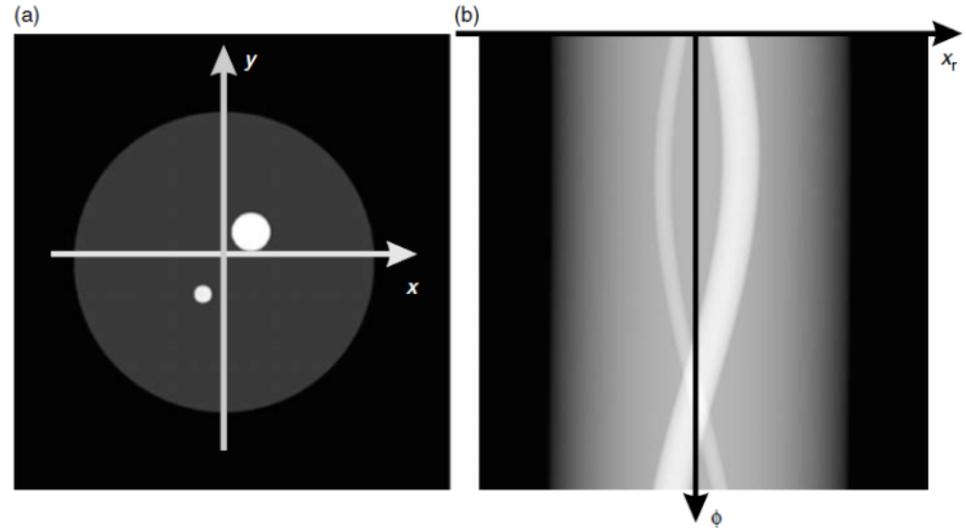


FIGURE 9 (a) Image of object slice $f(x, y)$ and (b) sinogram $p(x_r, \phi)$ of this slice.

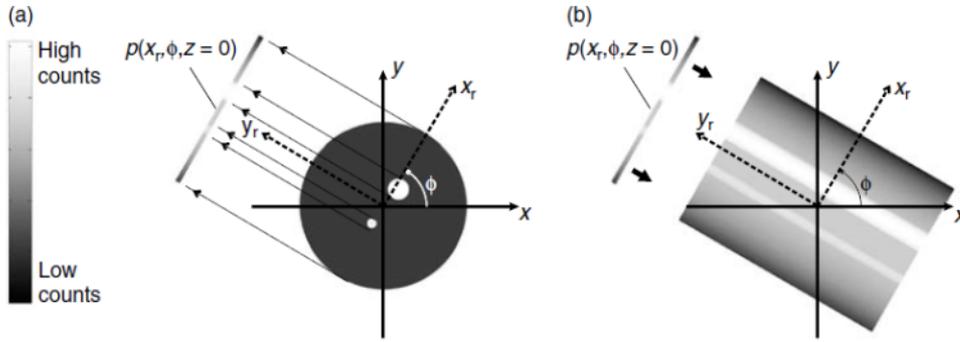
Projections



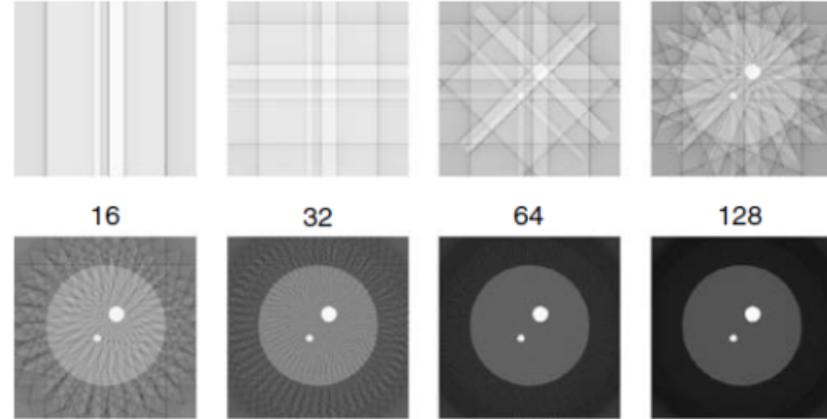
Sinogramme et reconstruction
par rétroprojection

Imagerie tomographique

Principe de fonctionnement: rétroprojection



Projections



Reconstructions

FIGURE 11 Images reconstructed by filtered backprojection from different numbers of equally spaced projections. The number of views included in each reconstruction is shown above its image. The original object is shown in Figure 9.

Imagerie tomographique

Principe de fonctionnement: méthode itérative

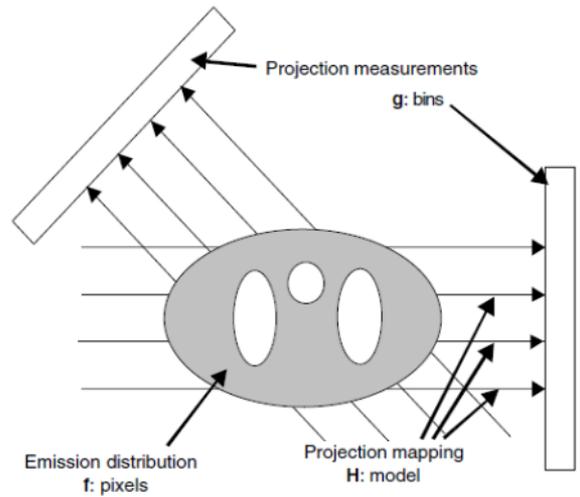


FIGURE 1 A general model of tomographic projection in which the measurements are given by weighted integrals of the emitting object distribution.

Problème inverse

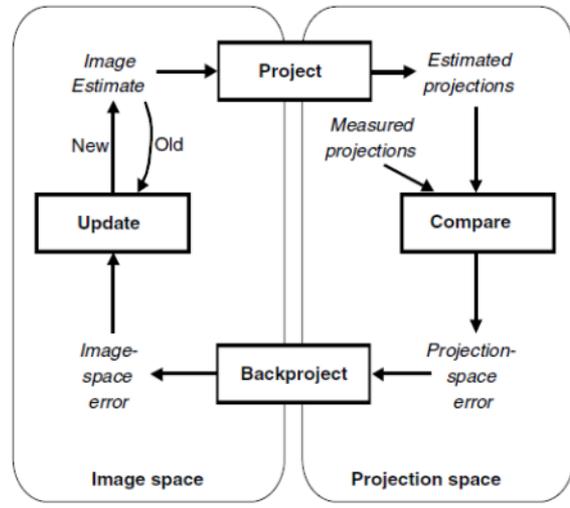


FIGURE 6 Flowchart of a generic iterative reconstruction algorithm.

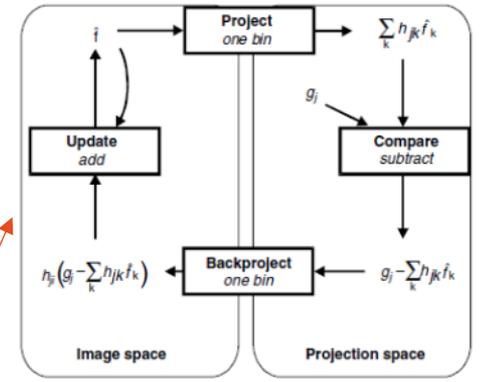


FIGURE 9 The algebraic reconstruction technique in the form of the general iterative model.

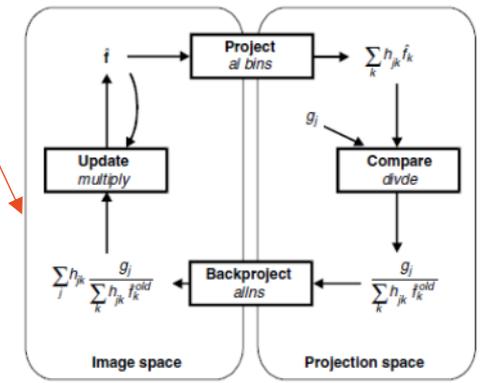
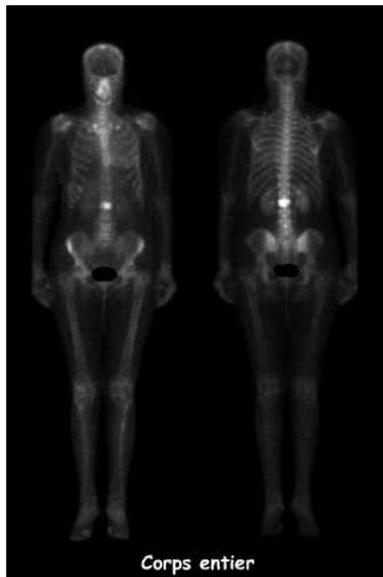


FIGURE 10 The maximum-likelihood expectation-maximization algorithm in the form of the general iterative model.

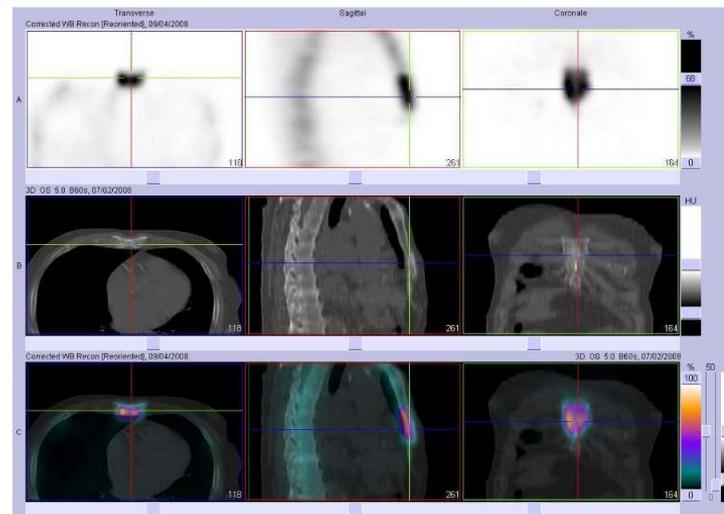
Critères de convergence et rapidité d'exécution

Médecine nucléaire

Exemples de cas cliniques

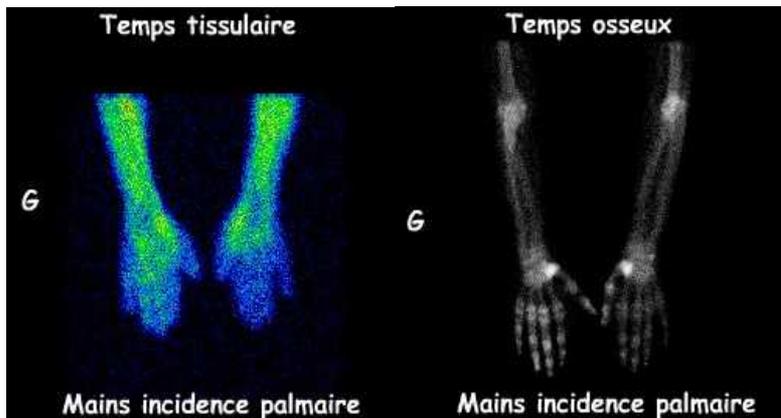


SPECT Image planaire corps entier
Métastase osseuse du corps vertébral de L2
Cancer du sein

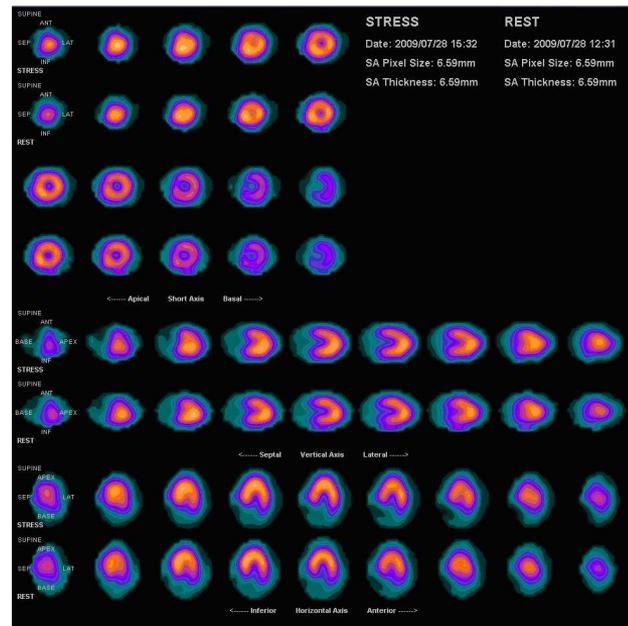


SPECT Image tomographique
Métastase osseuse au niveau du sternum
Cancer de la prostate

Exemples de cas cliniques



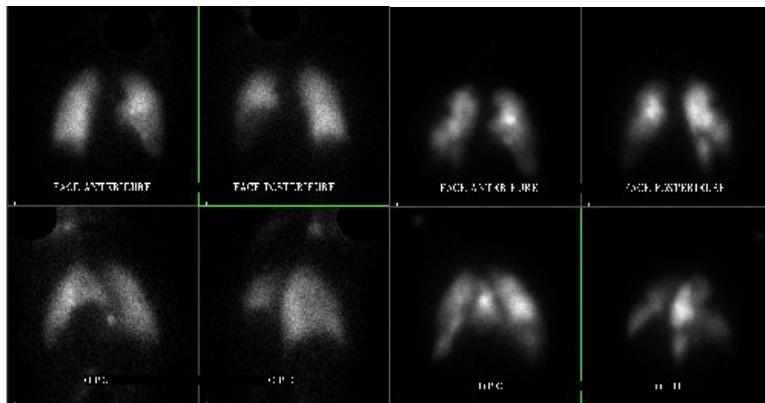
SPECT planaire deux temps
Algodystrophie



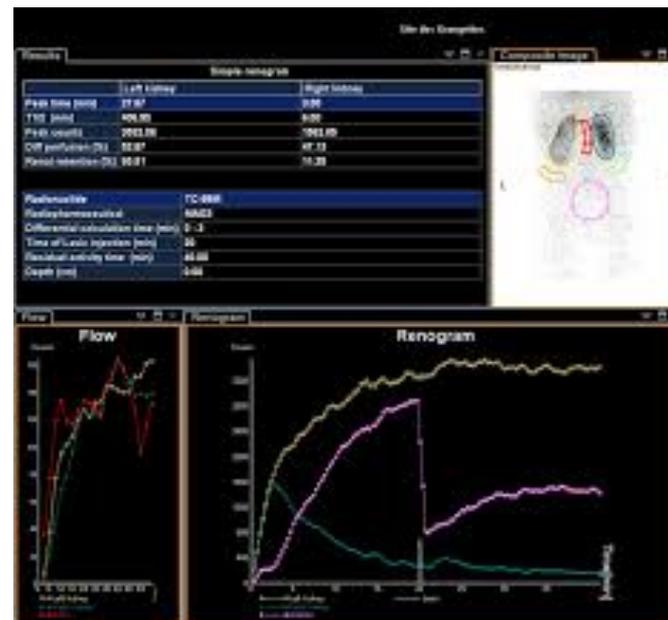
SPECT cardiaque
Perfusion myocardique

Médecine nucléaire

Exemples de cas cliniques



SPECT planaire ventilation / perfusion
Embolie pulmonaire bilatérale sévère



SPECT dynamique
Calcul de la fonction rénale

Médecine nucléaire

Exemples de cas cliniques

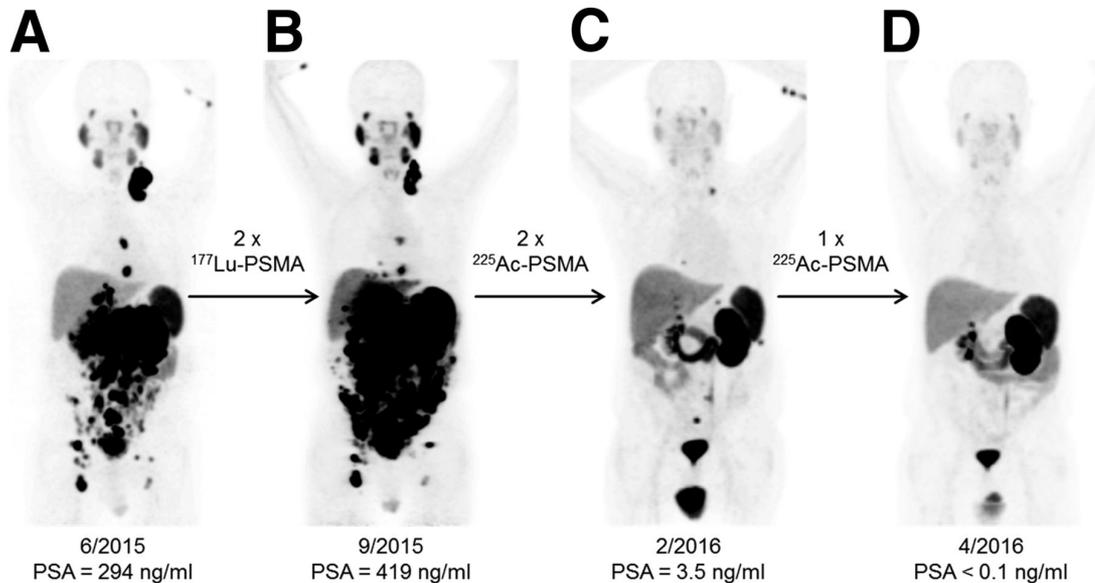


PET/CT évaluation de la maladie
Classification d'un lymphome

El-Galaly et al. 2018

Médecine nucléaire

Exemples de cas cliniques

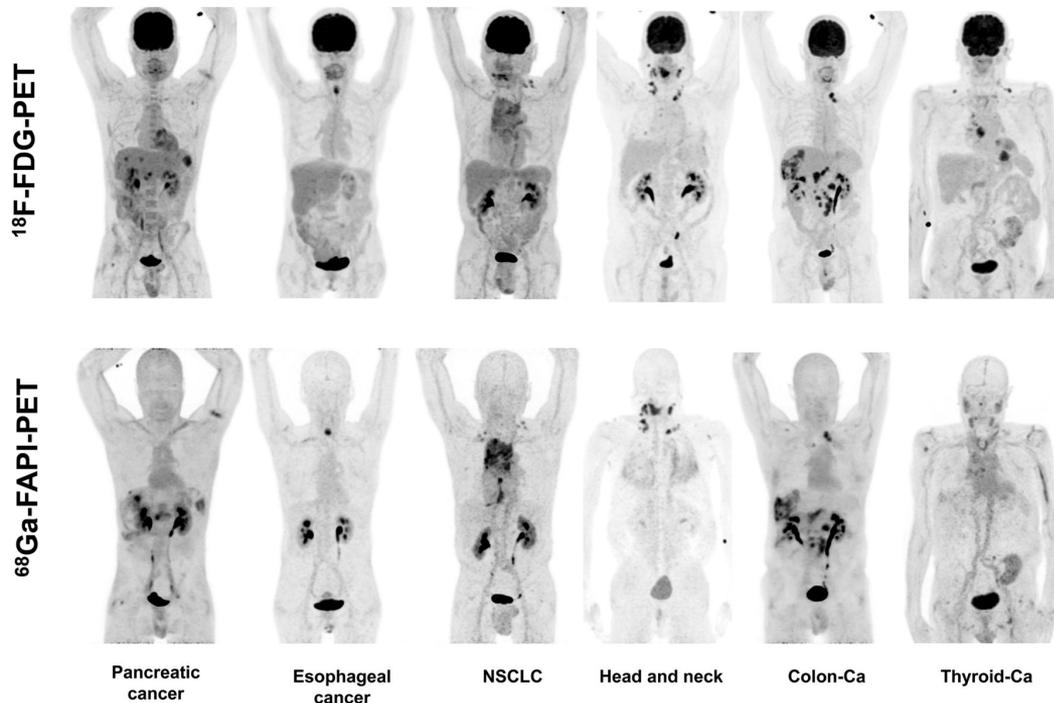


PET/CT évaluation efficacité thérapeutique
Traitement au ^{177}Lu (β^-) suivi traitement au ^{225}Ac (α)

Kratochwil et al. 2016

Médecine nucléaire

Exemples de cas cliniques

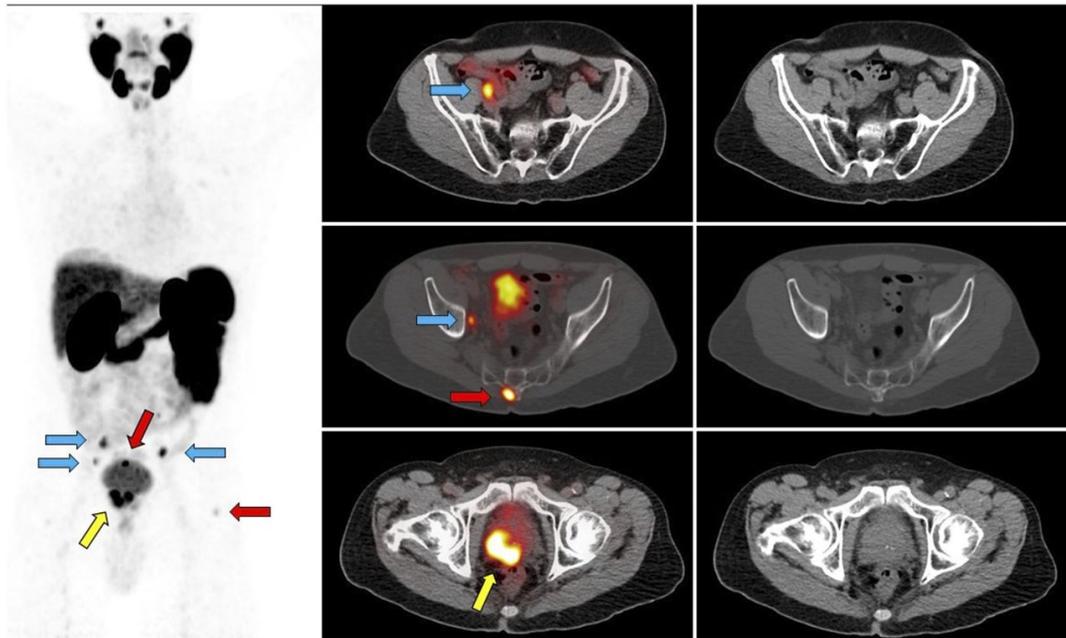


PET/CT apport de nouveaux traceurs

Giesel et al. 2018

Médecine nucléaire

Exemples de cas cliniques



PET/CT aide à la définition des volumes cibles pour la radiothérapie externe

Calais et al. 2018

Merci de votre attention