

Introduction à l'Imagerie Médicale

Cours Anatomie radiologique Bac 13

18/09/2019

Pr. Emmanuel Coche

Département d'Imagerie Médicale

Cliniques Universitaires St-Luc

E-mail: emmanuel.coche@uclouvain.be

Radiologie conventionnelle

Historique

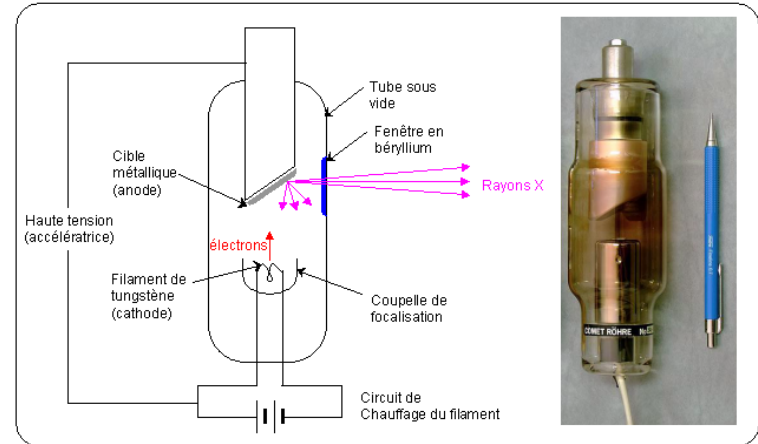
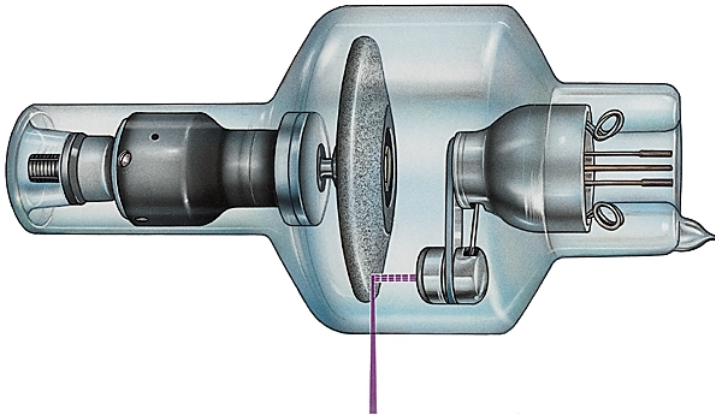


Wilhem Conrad
Roentgen , né le 27 mars
1845 à Lennep
(Allemagne), décédé le
10 février 1923 à Munich
(Allemagne)

Découverte des rayons X
par Willhem Roentgen
en 1895

Prix Nobel de Physique
en 1901

Principes



Rx: rayonnement électromagnétique situé entre les UV et les rayons gamma

Production:

dans un tube sous vide

Bombardement d'une anode par un flux d'électrons émis par une cathode

Quantité du rayonnement : mA

Dureté du rayonnement: Kv

30-80 kV: basse tension, rayons peu pénétrants

100-150 kV: haute tension, rayons plus pénétrants

Formation de l'image

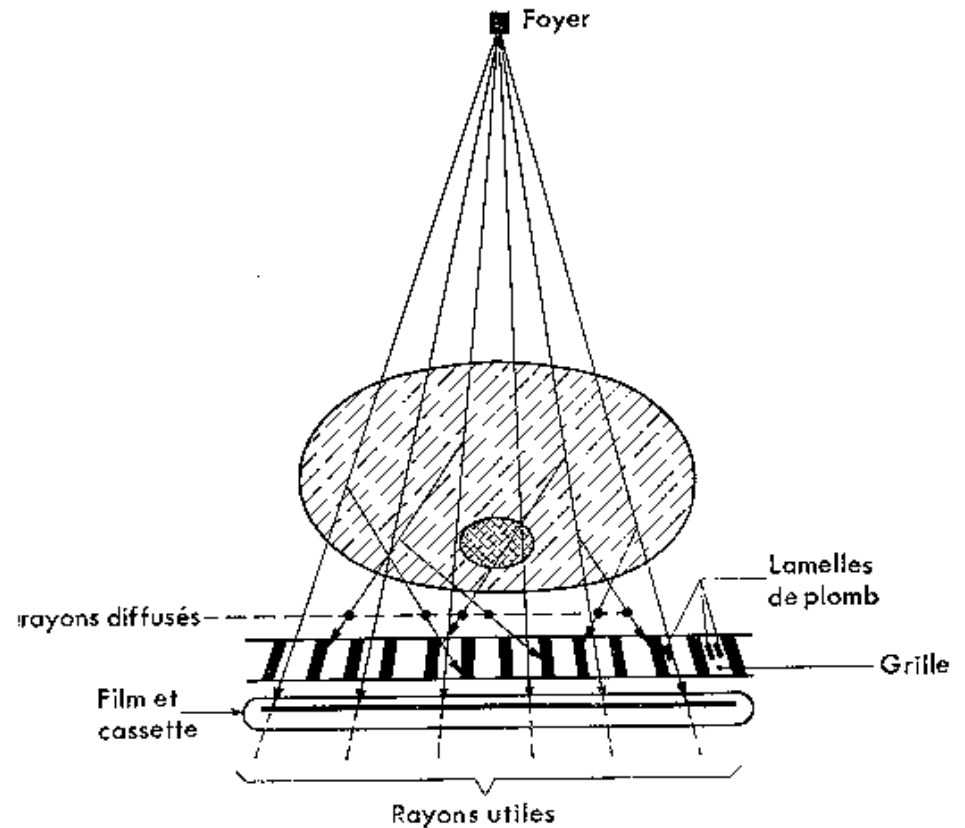
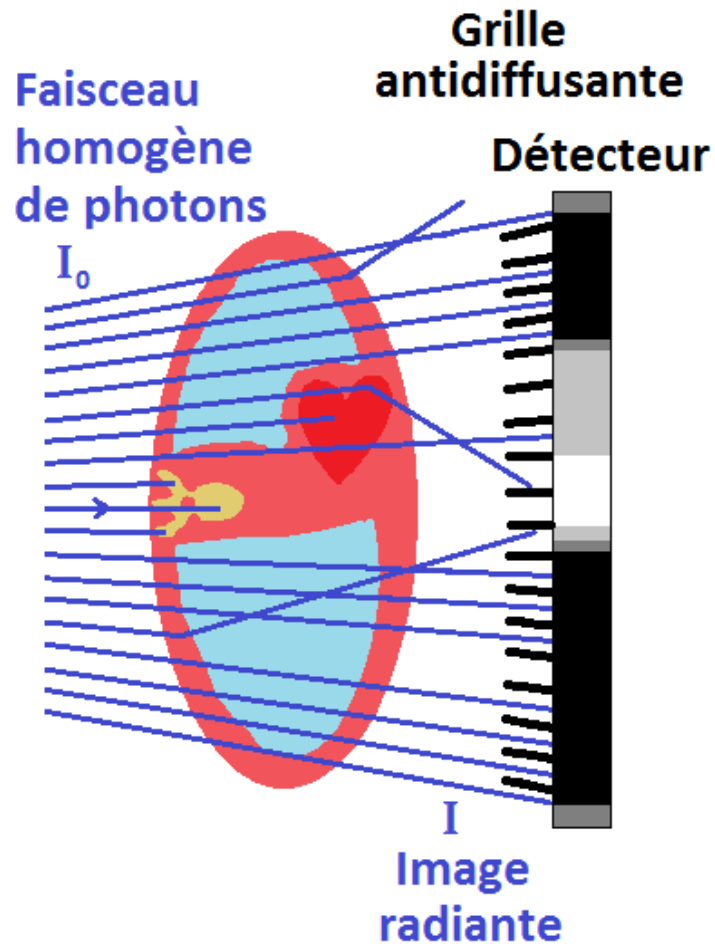


FIG. 193. — Principe de la grille anti-diffusante.

Formation de l'image radiologique

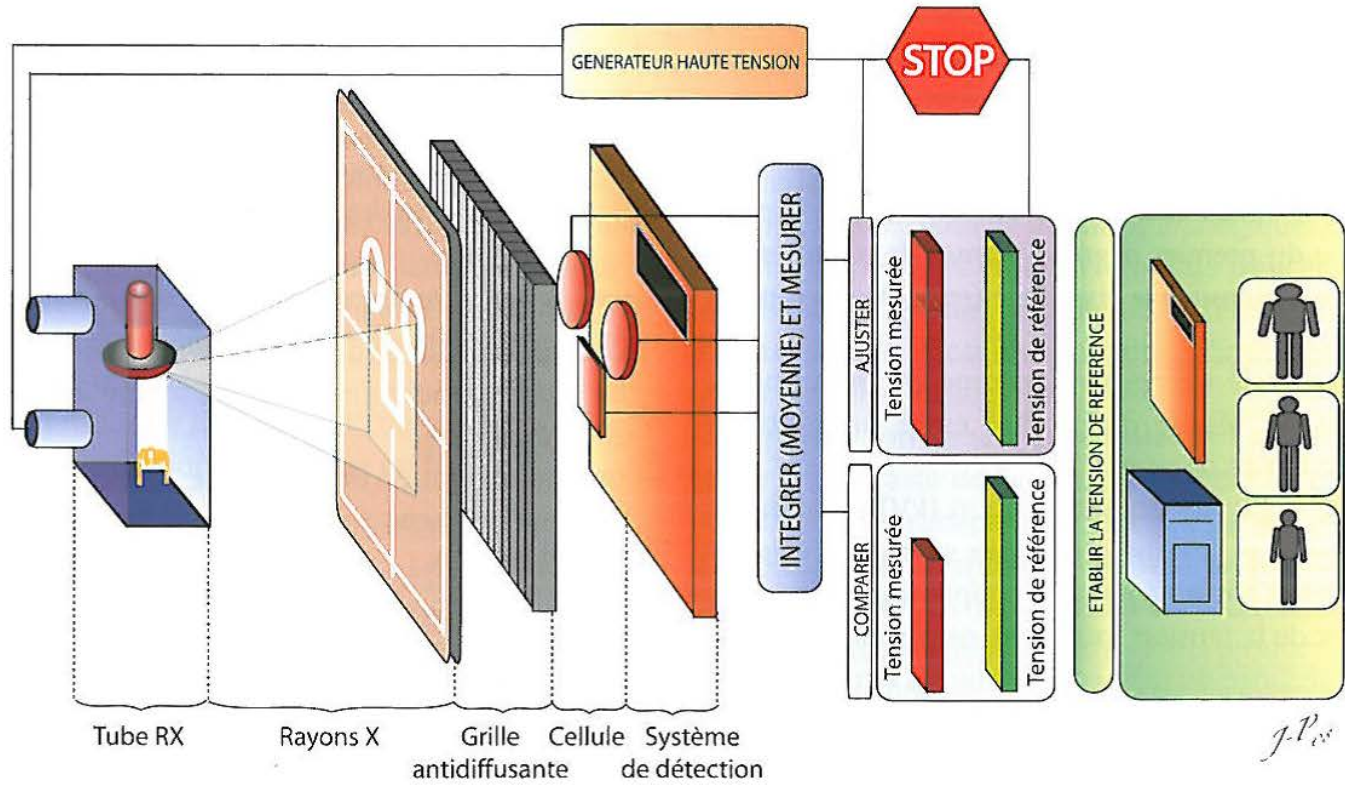


Table de radiologie conventionnelle





Assis



Couché

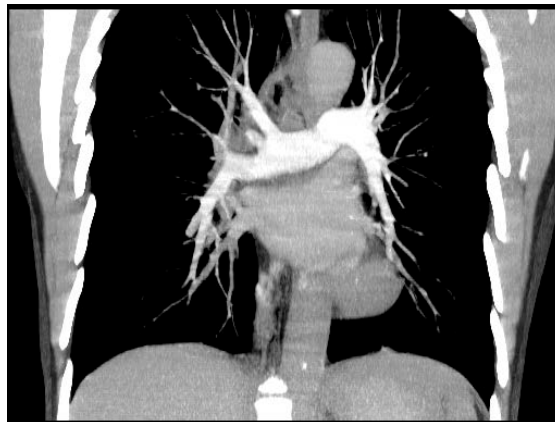
Formation de l'image

- Absorption des Rx
 - Épaisseur de l'objet
 - Nombre atomique de ses composants
 - Densité physique du corps

Formation de l'image



Gd



Gd



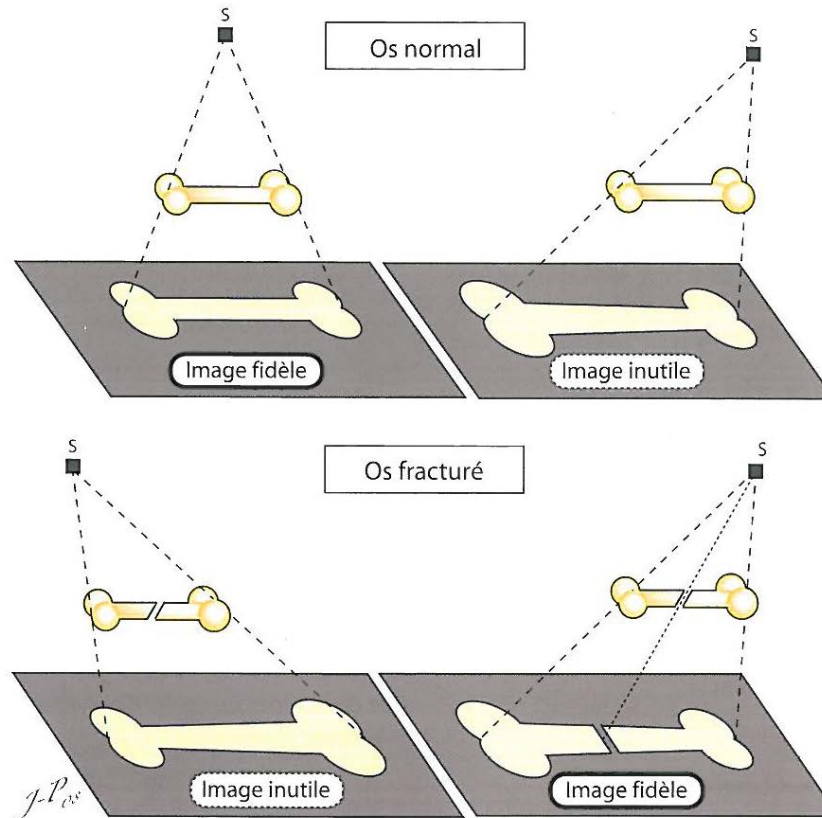
Iode

- Gadolinium -DTPA: $Z= 64$
- Iode: $Z= 53$
- Gd-DTPA est moins concentré que l'iode



Densité air < densité graisse < densité eau < densité os

Lois des tangences





Occlusion intestinale

Hydro-pneumothorax



Signe de la silhouette

- Définition
- Deux opacités de densité hydrique situées dans le même plan frontal, sans interposition d'air pulmonaire *se confondent*
- Deux opacités de tonalité hydrique situées dans des plans différents, avec interposition d'air pulmonaire *se superposent*

Signe de la silhouette

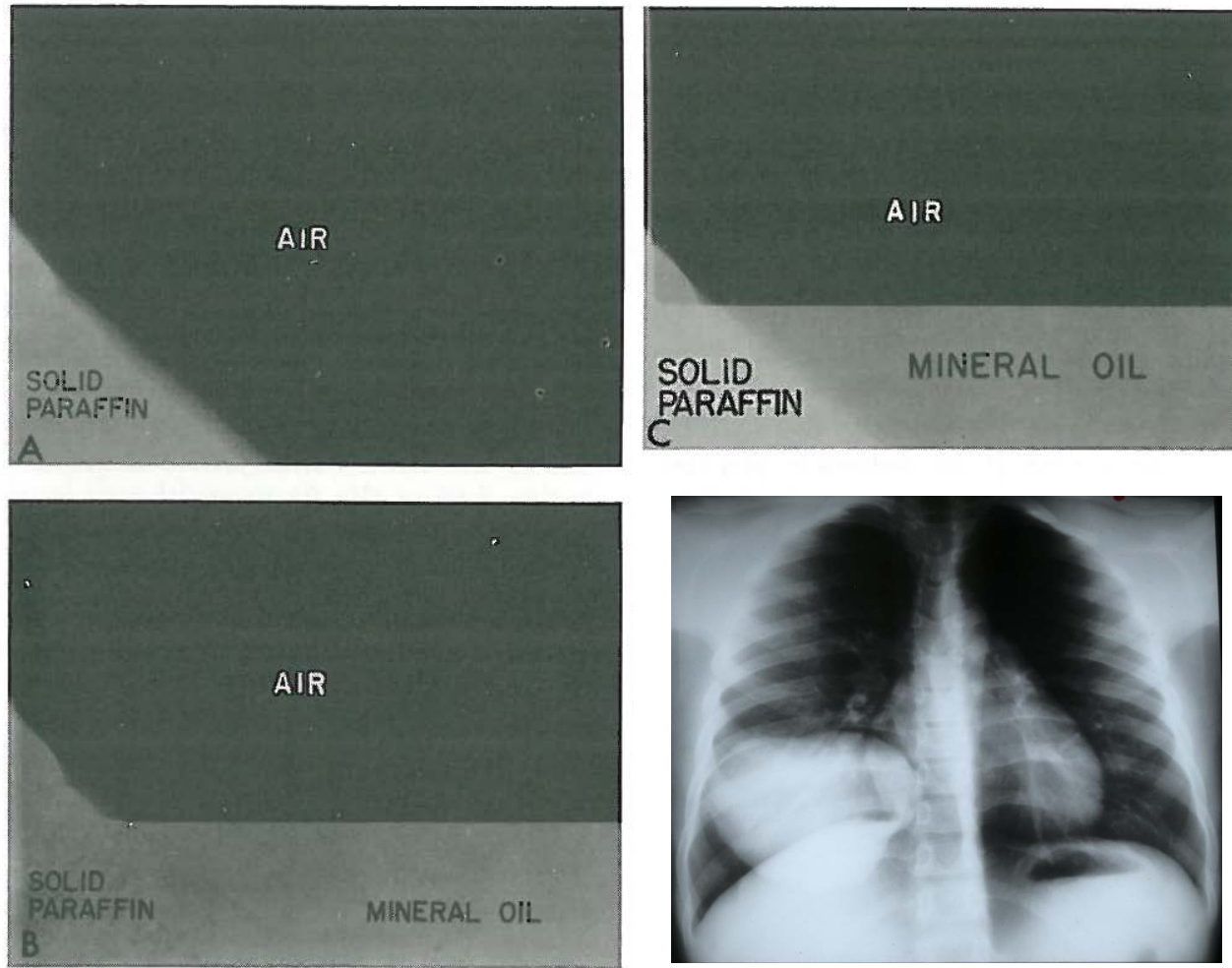
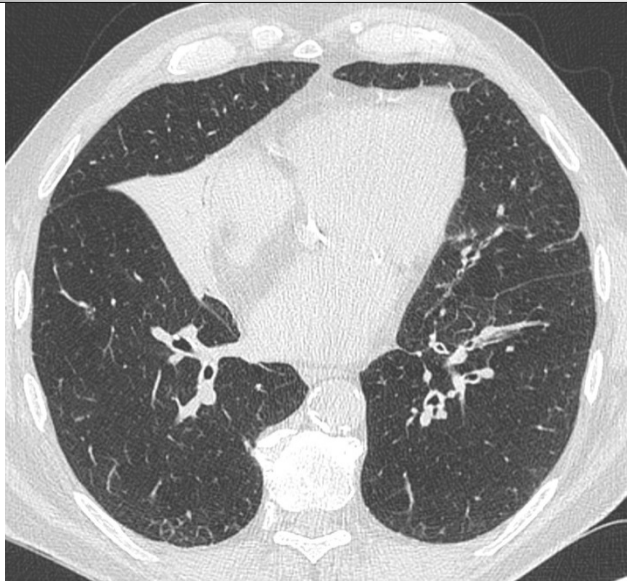
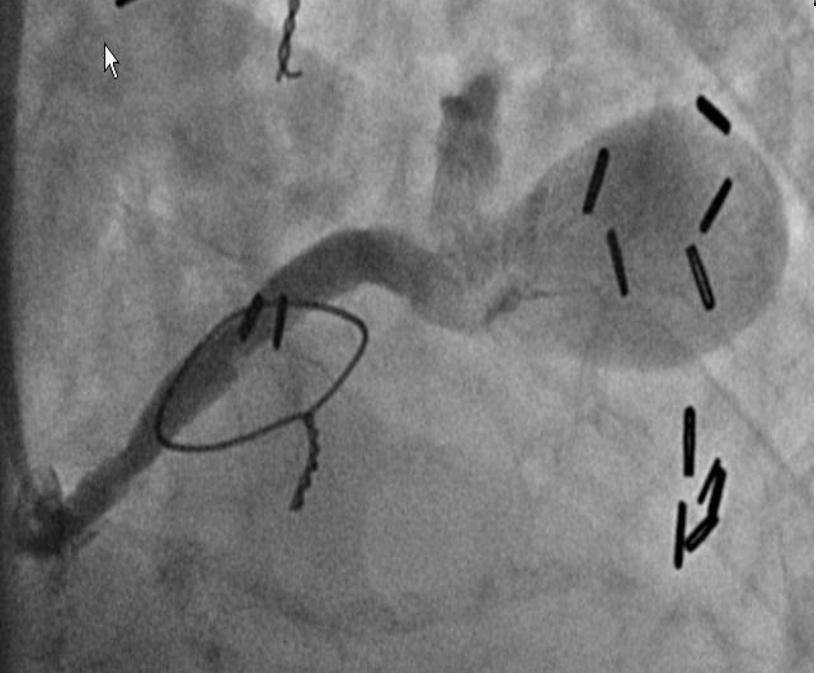
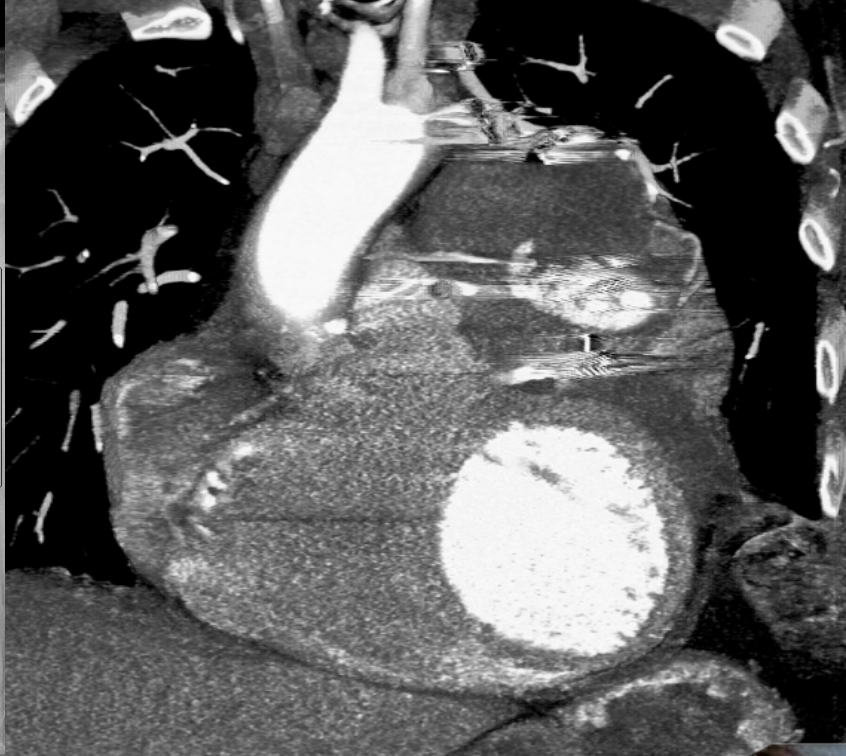
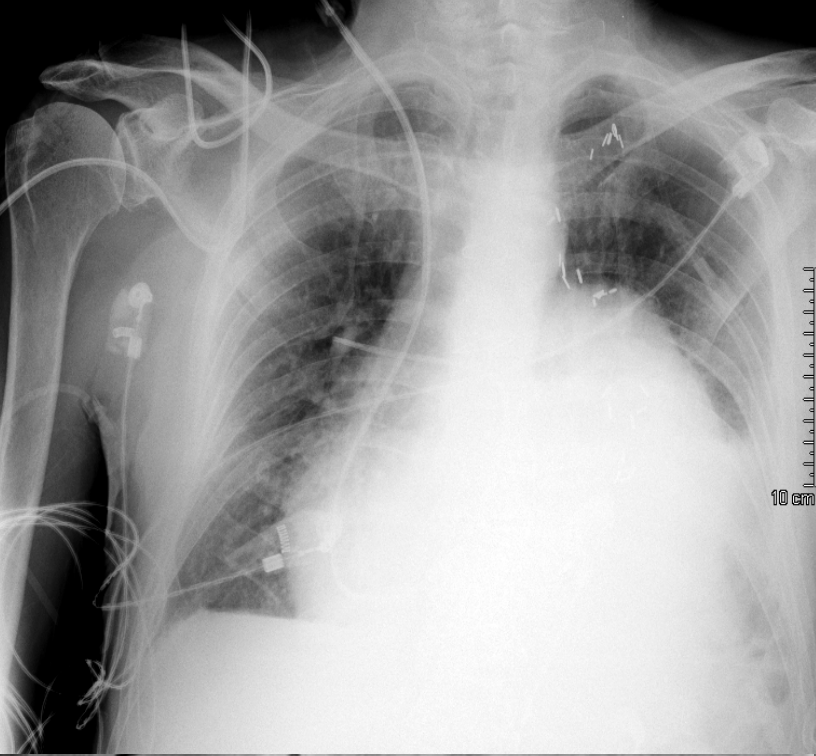


Figure 2-4. EXPERIMENT ILLUSTRATING THE PRINCIPLE OF THE SILHOUETTE SIGN
(From Felson, B., and Felson, H.³⁴³; reproduced with permission of Radiology.)



Atélectasie lobaire moyenne



Homme de 79 ans
Décompensation cardiaque
Douleurs rétrosternales

Les produits de contraste



Opacification du Tube digestif





TOMODENSITOMETRIE

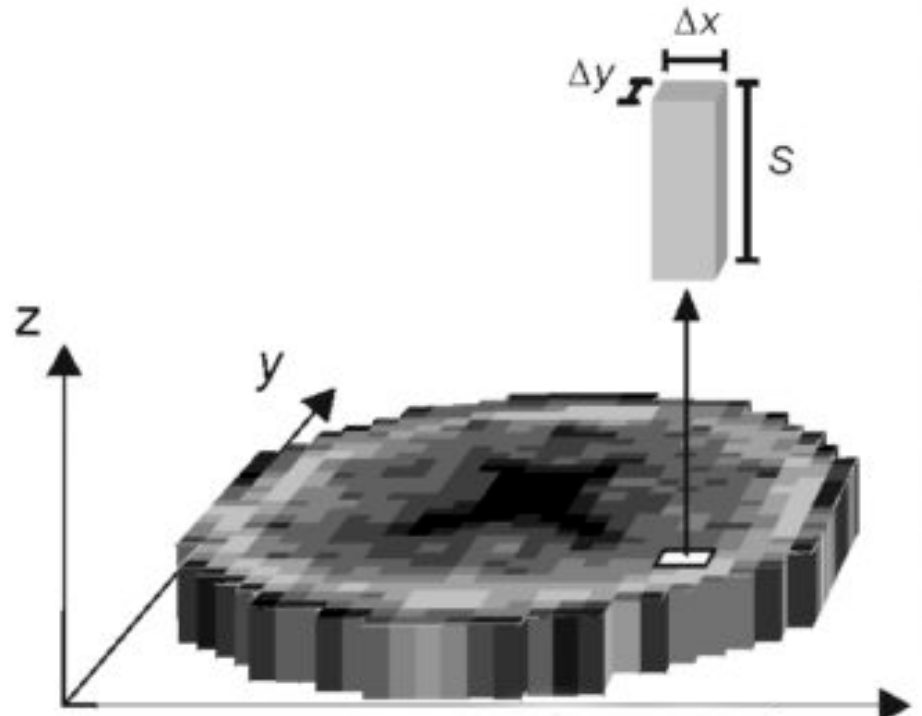
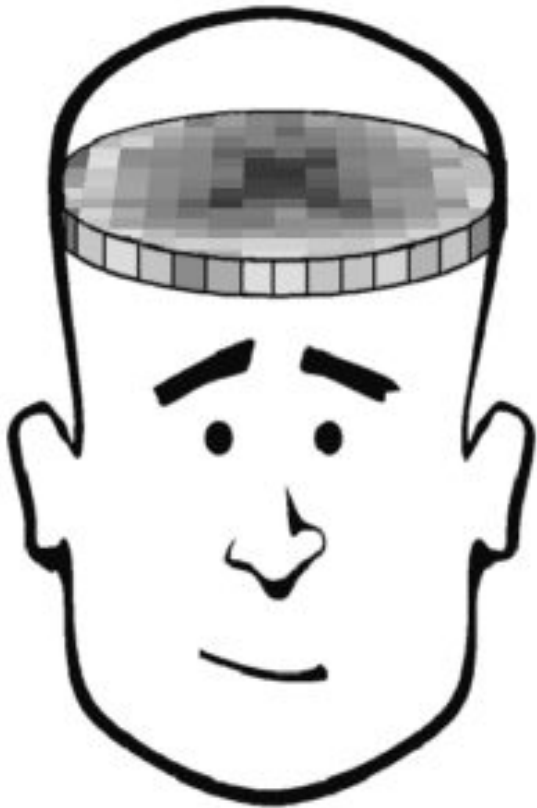
Historique du CT scanner



Godfrey Hounsfield

- 1895: Roëntgen, RX
- 1973: GN Hounsfield premiers essais CT
- 1989: Kalender, Vock CT scanner spiralé
- 1992: CT Twin
- 1998: CT multi-coupes
- 2000: 30 000 CT units

Principes de la tomodensitométrie

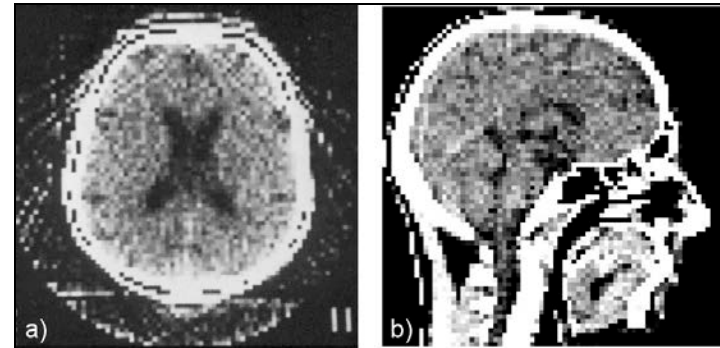


KA 2000

Principes de la tomodensitométrie

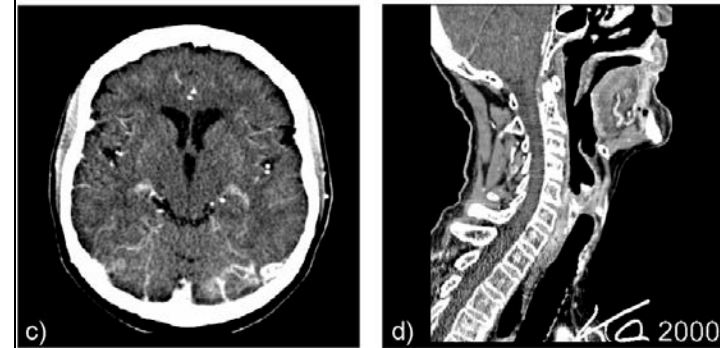
- A-B (1974): matrice:

80 x 80



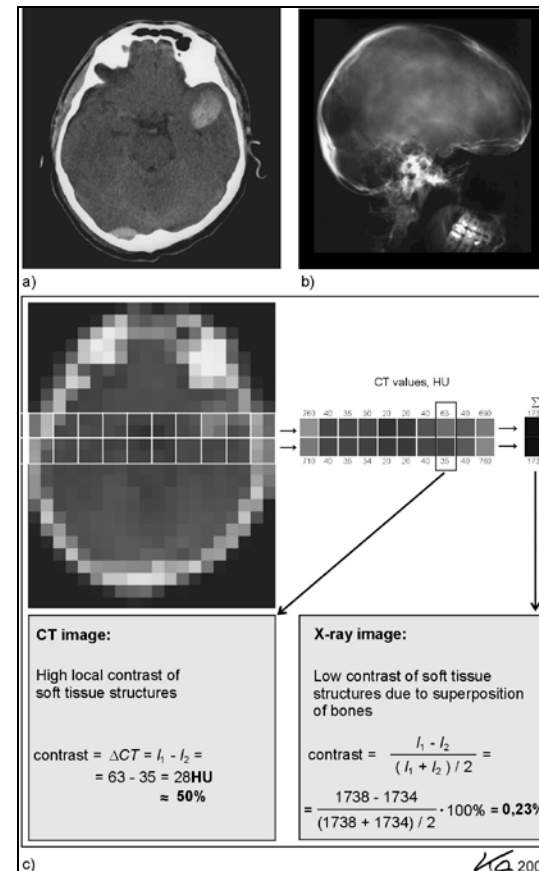
- C-D: (2000): matrice:

1024x1024



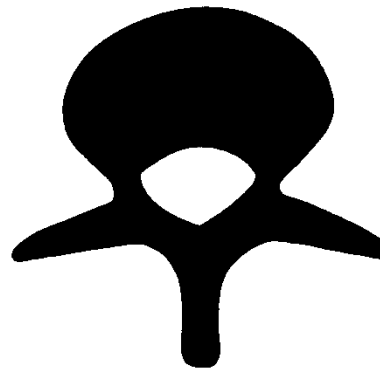
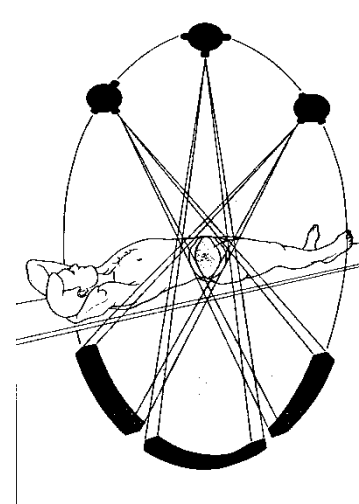
Principes de la tomodensitométrie

- A/ Lésion cérébrale spontanément dense
- B/Rx crâne: lésion non visible
- C/Contraste CT/Rx



Principes de la tomodensitométrie

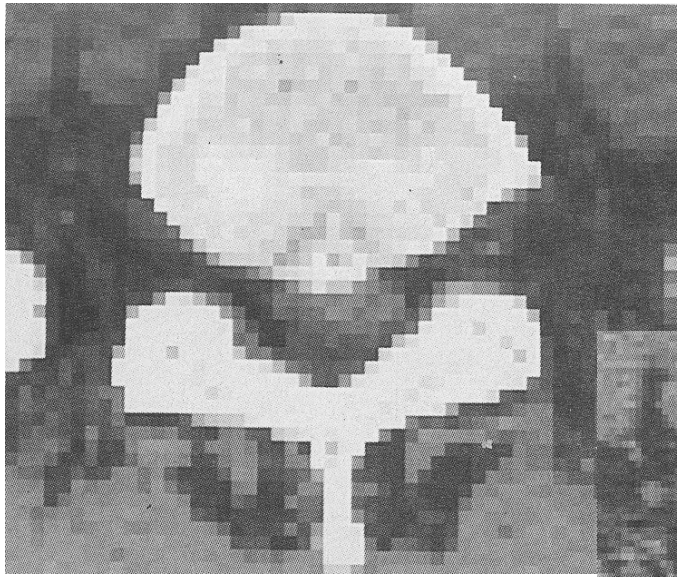
- Image matricielle d'une tranche du corps exprimant la densité radiologique des unités de volume (voxels) dans cette tranche
- Image tomodensitométrique est reconstruite par ordinateur à partir d'une série de mesures successives
- Elle diffère de l'image radiographique conventionnelle
 - Support d'enregistrement : détecteurs versus film
 - Série de mesures versus une projection
 - Reconstruction d'une image matricielle



0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0
0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0
0	0	0	0	0	1	1	1	0	0	0	1	1	1	1	0	0	0	0	0
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0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
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0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0

Actuellement matrice 768 x 768

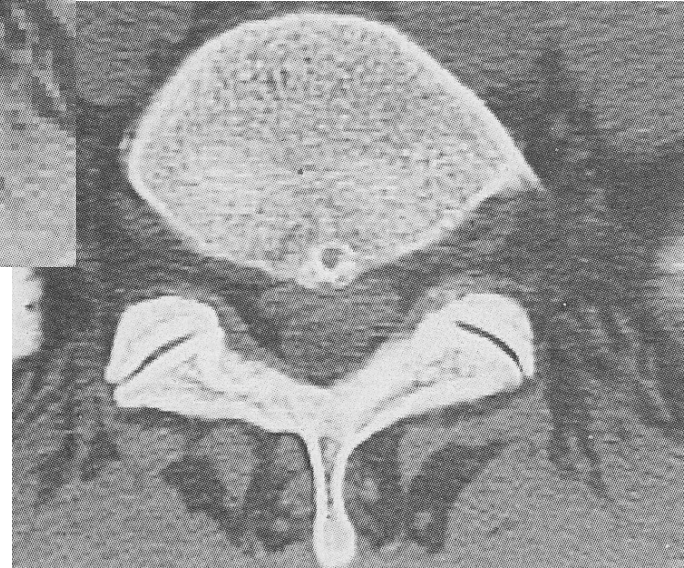
Illustration



Matrice 64 x 64



Matrice 128 x 128



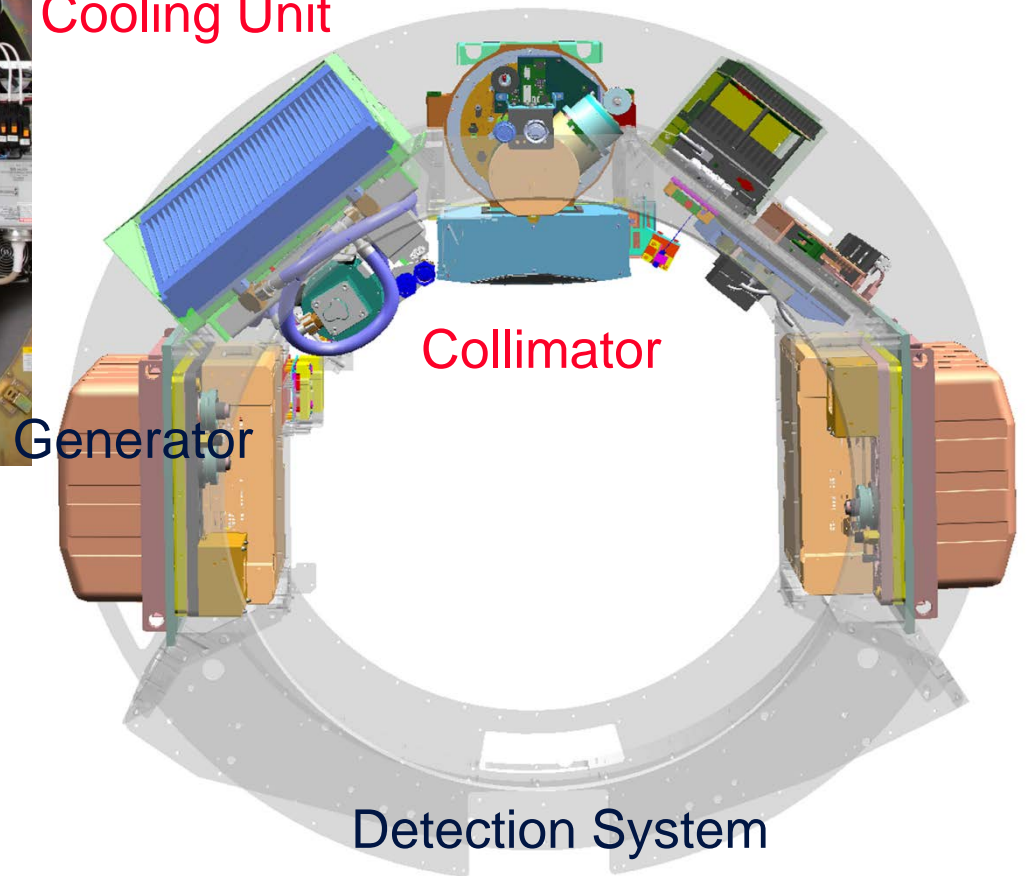
Matrice 256 x 256



Controller Unit

- Focal Spot Unit
- Anode Drive
- kV Controller

Cooling Unit



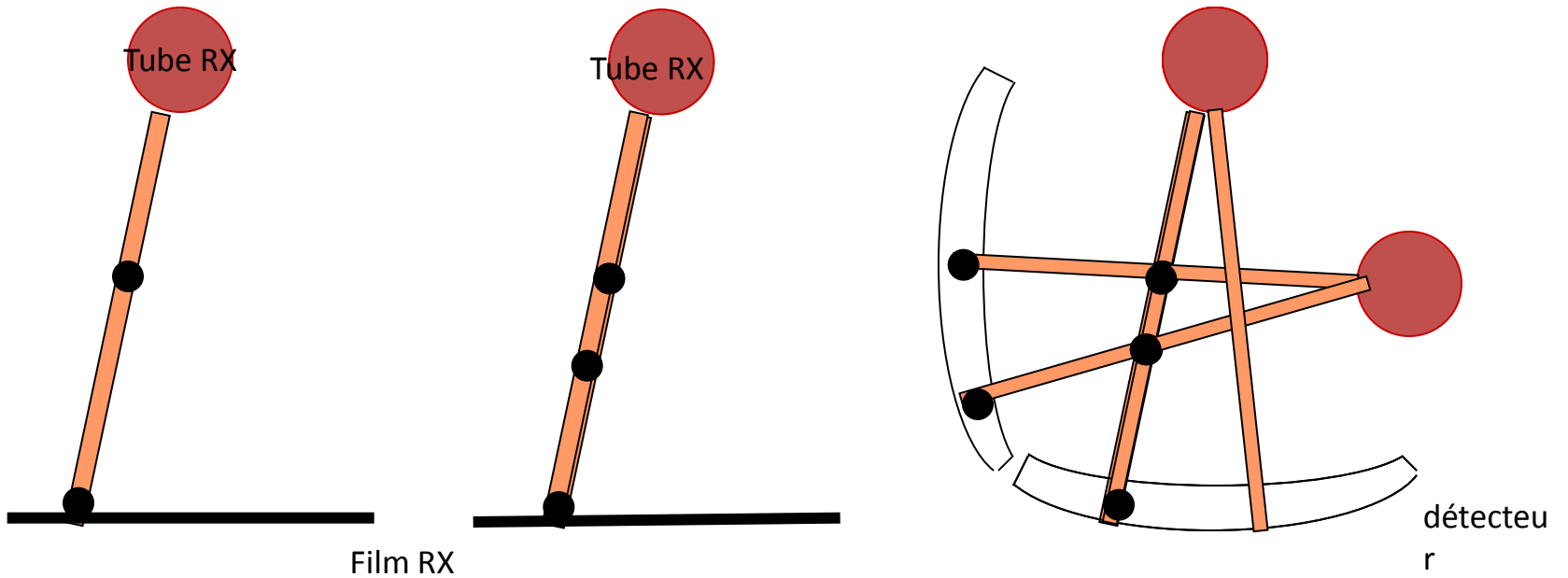
Collimator

Generator

Detection System

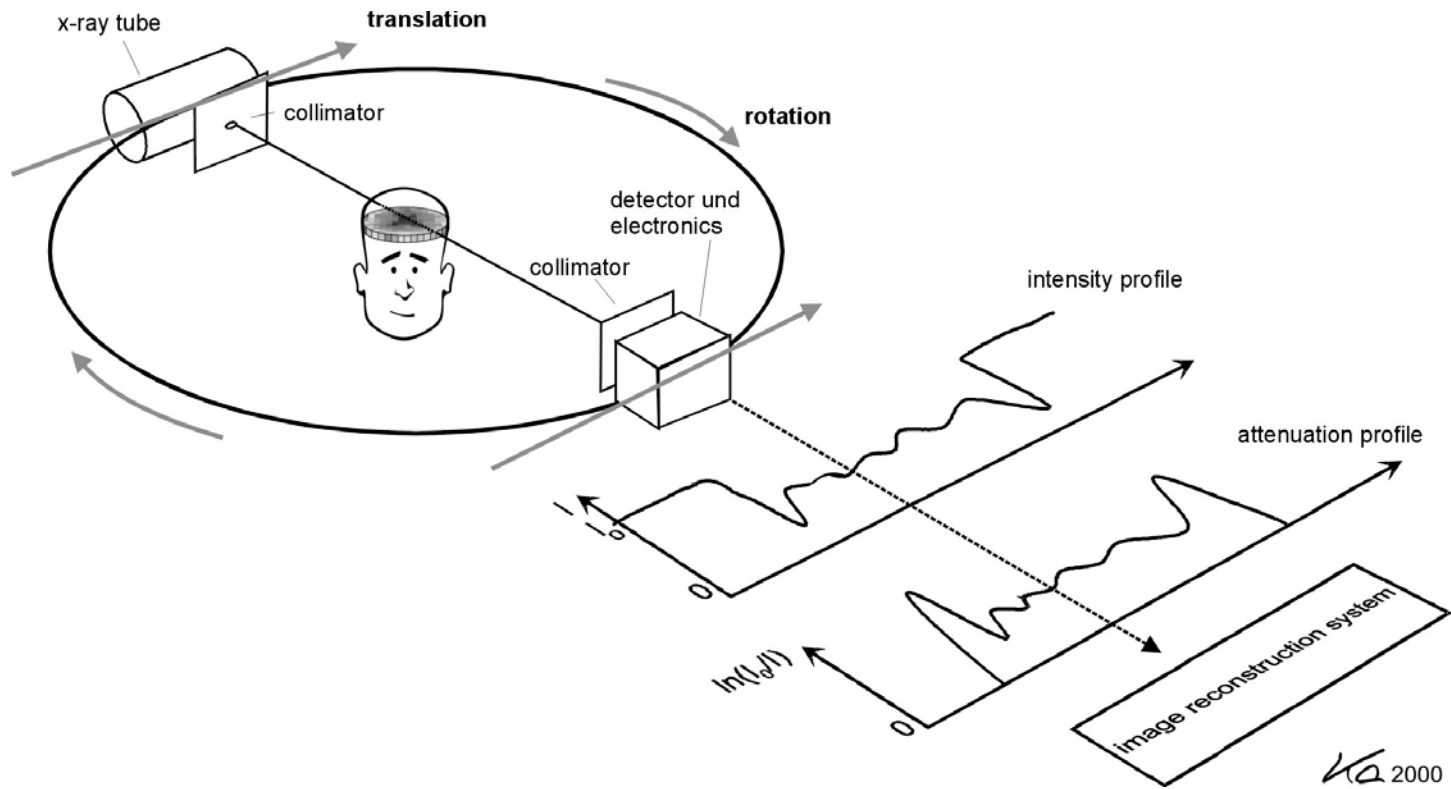
Avantage du scanner par rapport à la radiologie conventionnelle

1 ou 2 nodules?

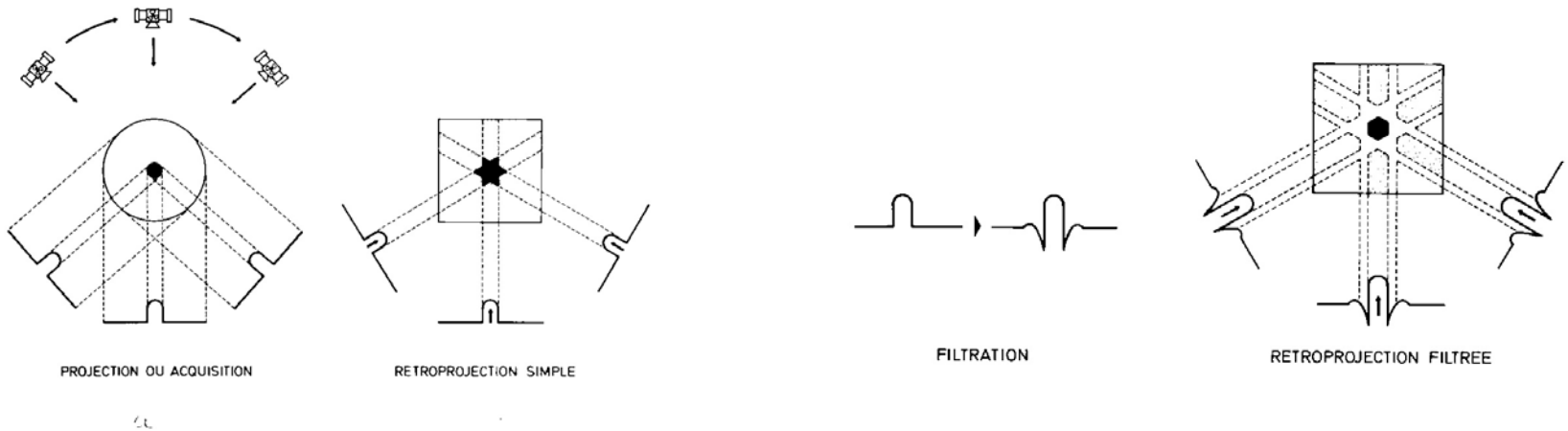


On sait qu'il s'agit d'un objet unique

Principes de la tomodensitométrie



Principe de rétroprojection filtrée



Rétroprojection simple

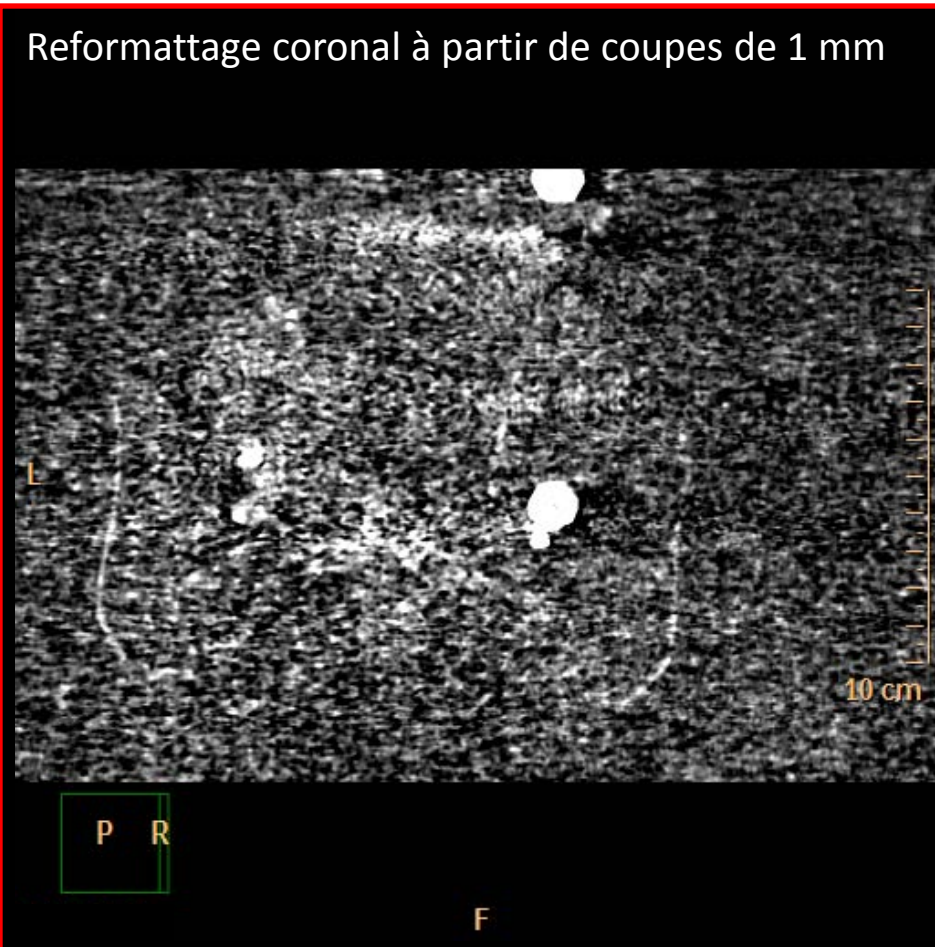
Rétroprojection avec un filtre de convolution
fournit image plus conforme à l'original

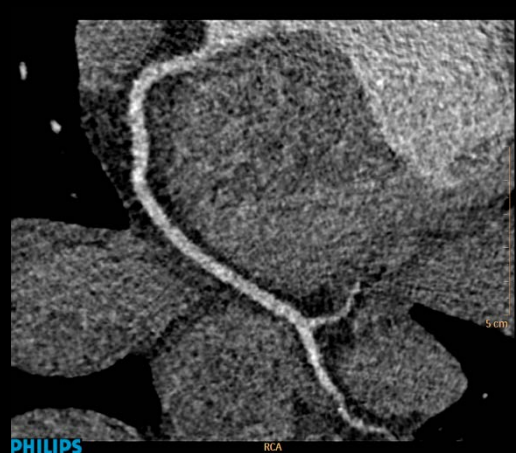
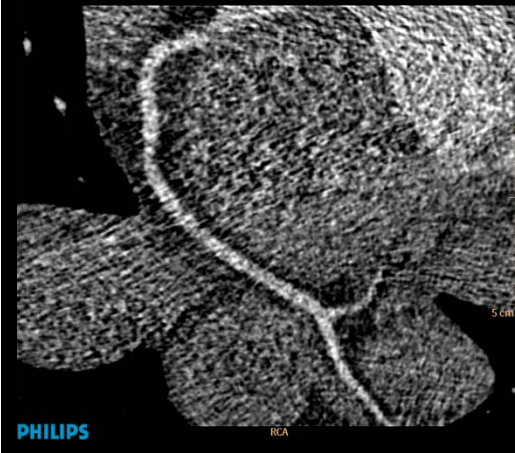
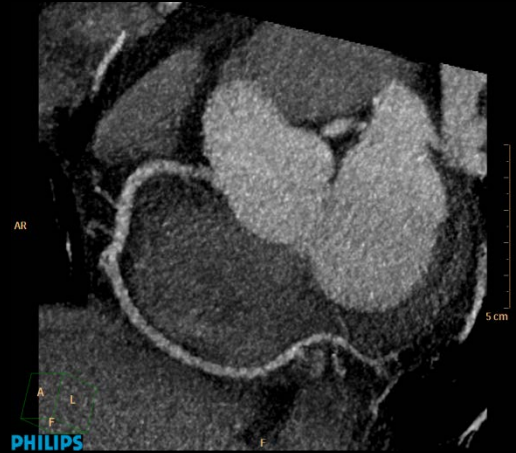
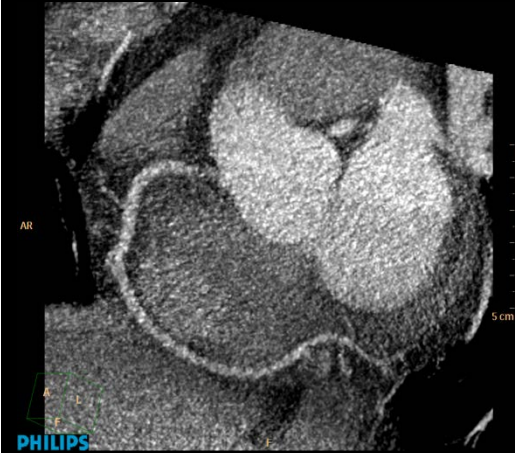
Reconstructions itératives

STD

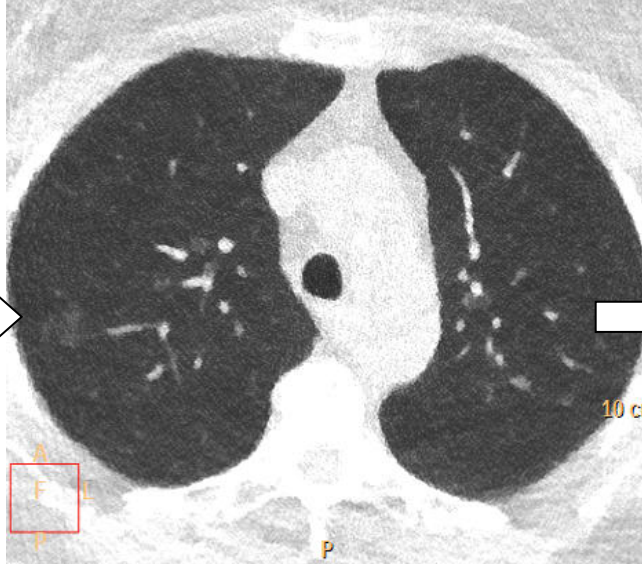
iDose⁴

Reformattage coronal à partir de coupes de 1 mm





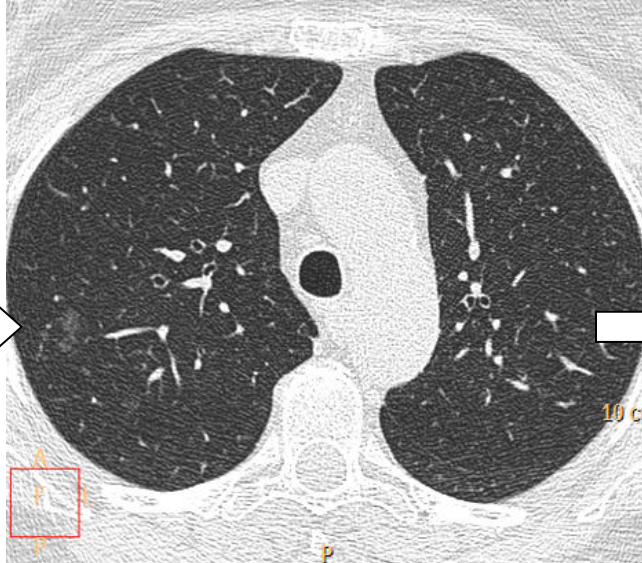
IMR, 0.11 mSv



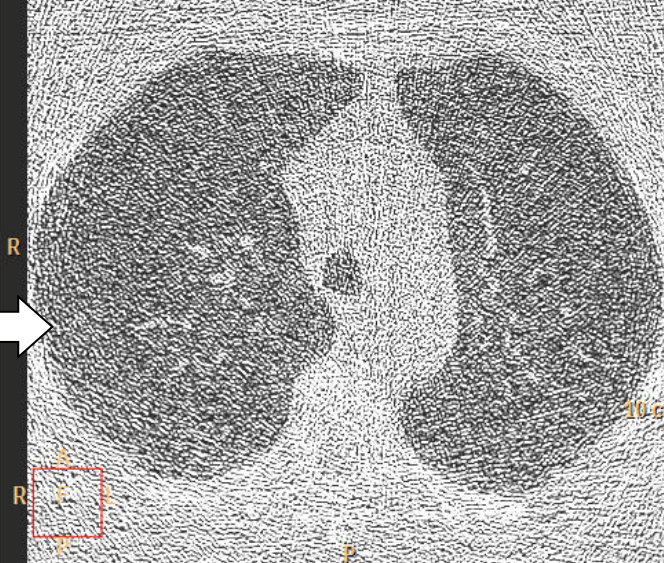
iDose, +7, 0.11 mSv



FBP, 5.2 mSv



FBP, 0.11 mSv



Echelle des Unités Hounsfieid (U.H.)

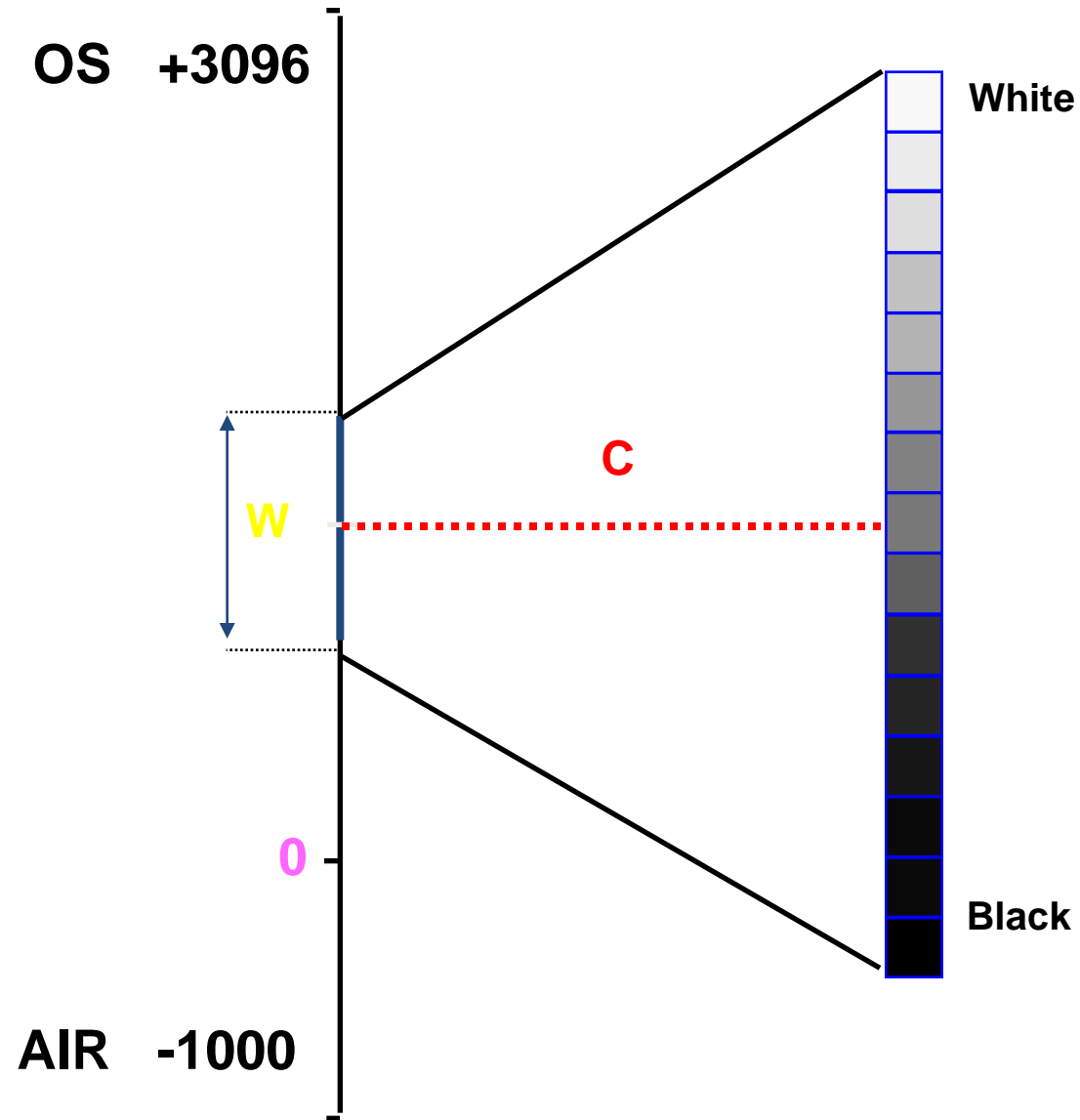
- La **dose résiduelle** reçue par les détecteurs doit être convertie en niveau de gris
- Hounsfieid a établi une échelle de ces **densités résiduelles**
Elle s'étend de -1000 à $+3096$ U.H. (*total 4096 niveaux*)
- La valeur de l'eau est fixée à '0'
Les extrêmes sont : le vide et l'air (-1000) et l'os ($+3096$)

Il y a un Hic....

- Tous les tissus mous (de 0 à + 100 UH) ont des valeurs de **densité** très proches les unes des autres par comparaison avec l'étendue de l'échelle Hounsfield (-1000 à +3000 UH)
Même la graisse est très proche (-250 à -50 UH)
- Si on déploie les **15 teintes de gris** identifiables à l'œil, (*de - 1000 à + 3096 UH, soit 4096 niveaux de gris*), tous les tissus mous se trouvent représentés dans la même teinte de gris puisque chaque niveau de teinte reprend 273 UH ($4096 : 15$), et ne peuvent donc pas être distingués visuellement les uns des autres.

Paramètres de fenêtrage

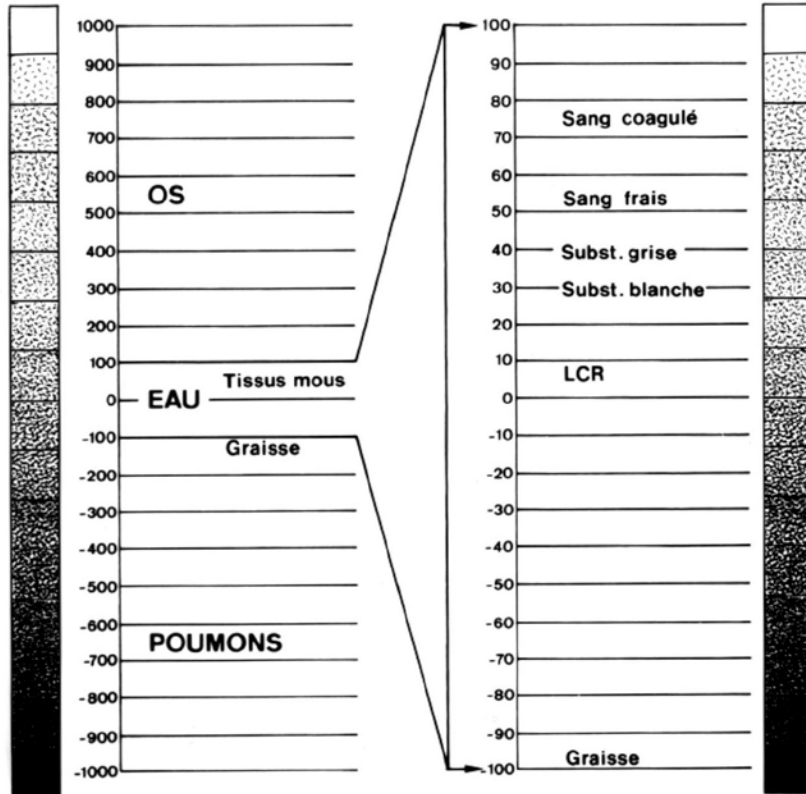
- Le **centre**
(**C** = "center")
- La largeur (**fenêtre**)
(**W** = "width")



Centre / Fenêtre

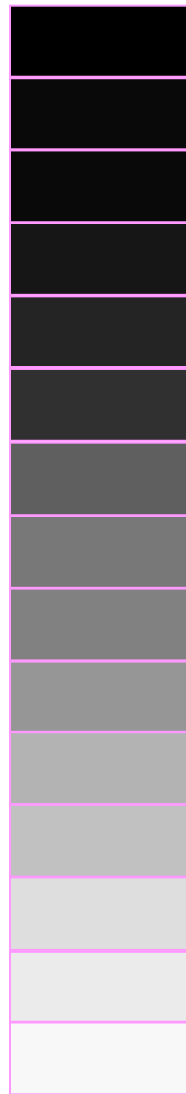
- Par une manipulation informatique, on va fixer la valeur du **CENTRE** dans la zone d'intérêt
(le milieu des densités désirées)
- Ensuite on va choisir la plus petite valeur de **FENÊTRE** qui va couvrir l'ensemble des densités d'intérêt
(largeur des 15 niveaux de gris)

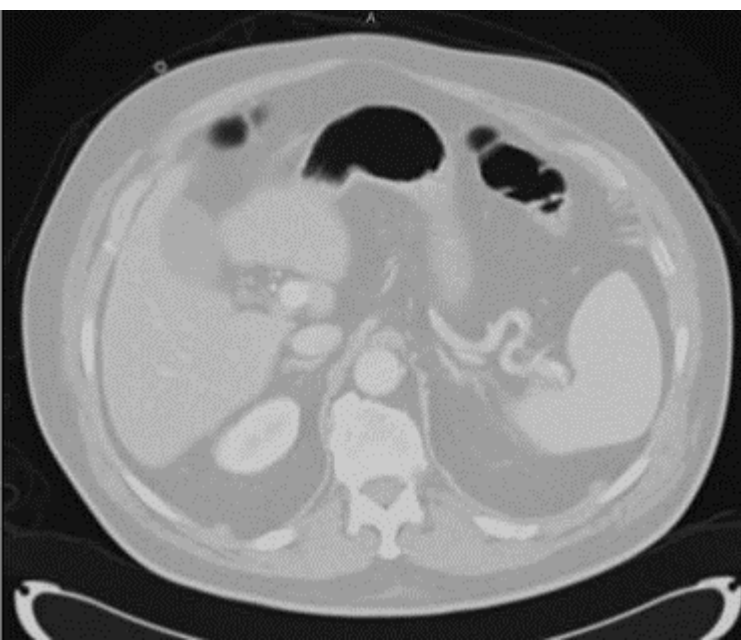
Notion de fenêtre d'image scanner



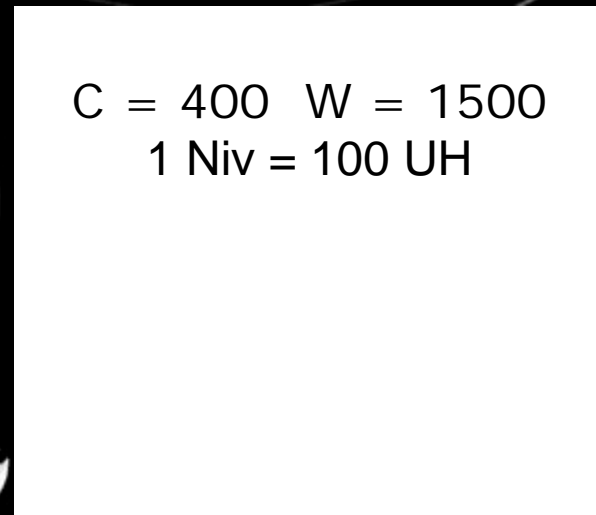
Chaque élément de l'image a une densité entre -1000 et +1000 UH, mais que 14 variations sur l'échelle de gris

- 1000 UH	AIR , vide
- 950 / - 400	poumon
- 250 / - 30	graisse
0 UH	EAU
0 / + 30	liquides plus ou moins purs
+ 30 / + 70	tous les tissus mous
+ 60 / + 80	hématomes, caillots
+ 150 / + 1000	calcifications
+ 400 / + 3096 UH	OS





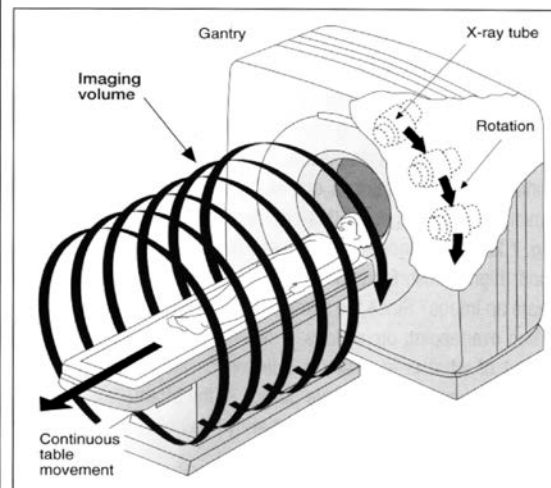
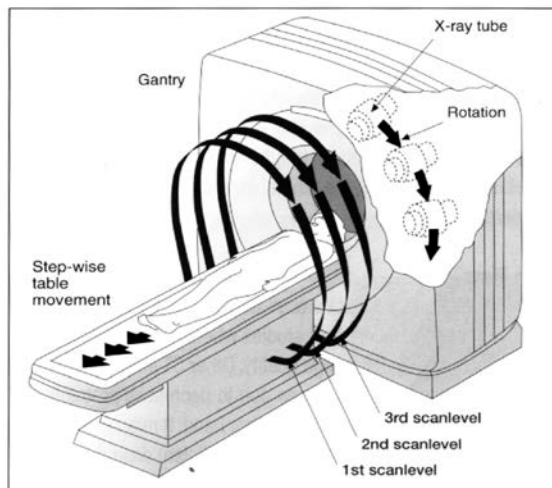
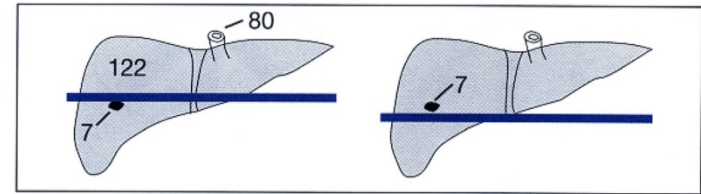
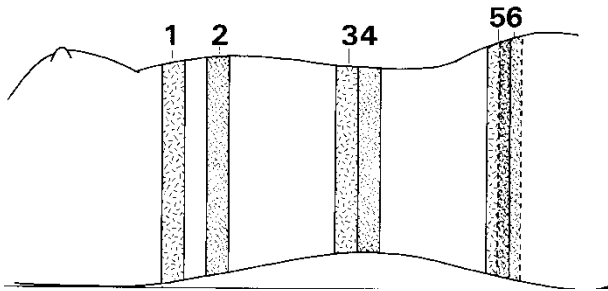
C = 550 W = 1500
1 Niv = 100 UH



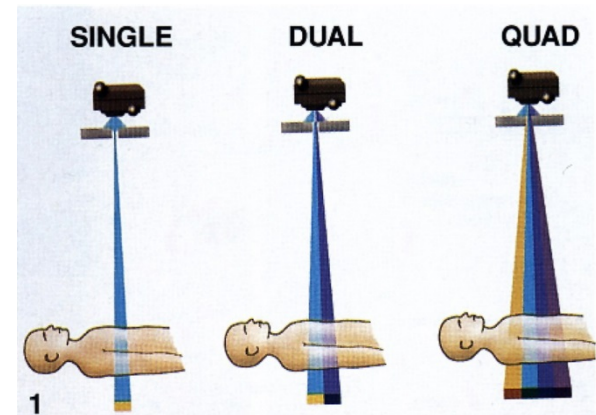
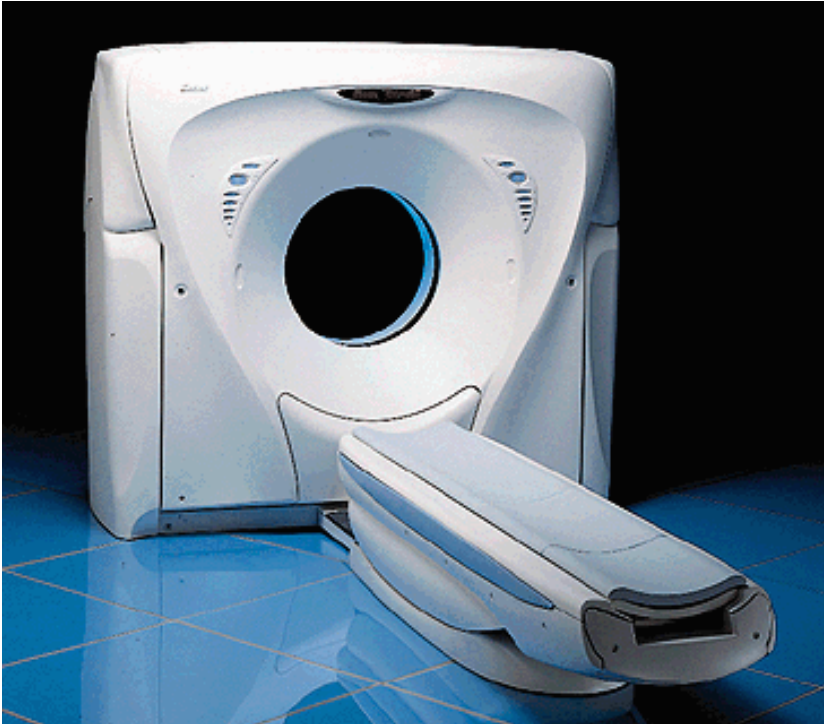
C = 400 W = 1500
1 Niv = 100 UH

C = 20 W = 240
1 Niv = 16 UH

Scanner séquentiel versus scanner spiralé



Scanner multicoupes ou multibarrettes

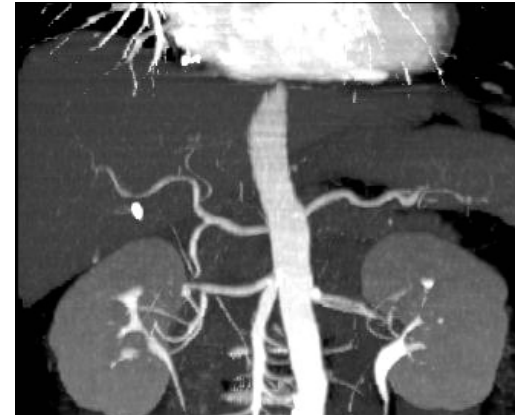
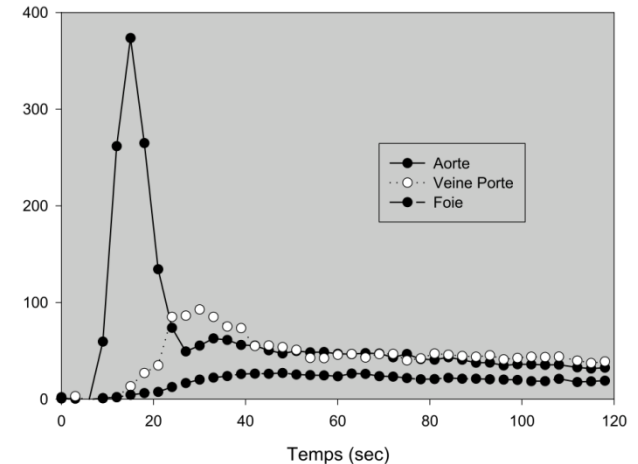


Plusieurs rangées de détecteurs

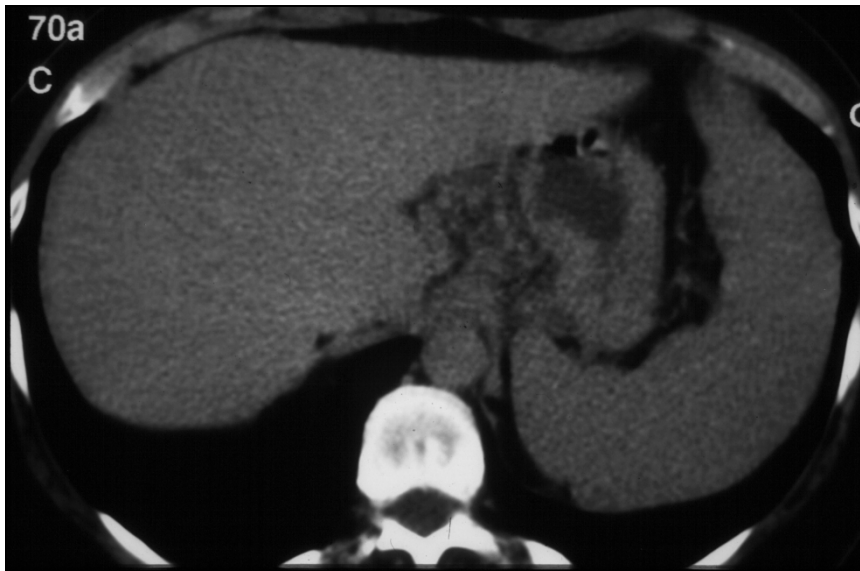
Permet de faire plusieurs coupes à chaque rotation

Avantages du scanner spiralé multicoupes

- Plus rapide
 - Soit analyse d'un volume anatomique plus étendu en une apnée
 - Soit, pour un même volume, apnée plus courte ou coupes plus fines
 - Suppression de zones aveugles entre les coupes acquises de manière discontinue
 - Reconstruction multiplanaires de bonne qualité
 - Coupes plus fines
 - Coupes chevauchées
 - Absence de discontinuités
 - Imagerie au moment optimal pour opacification vasculaire



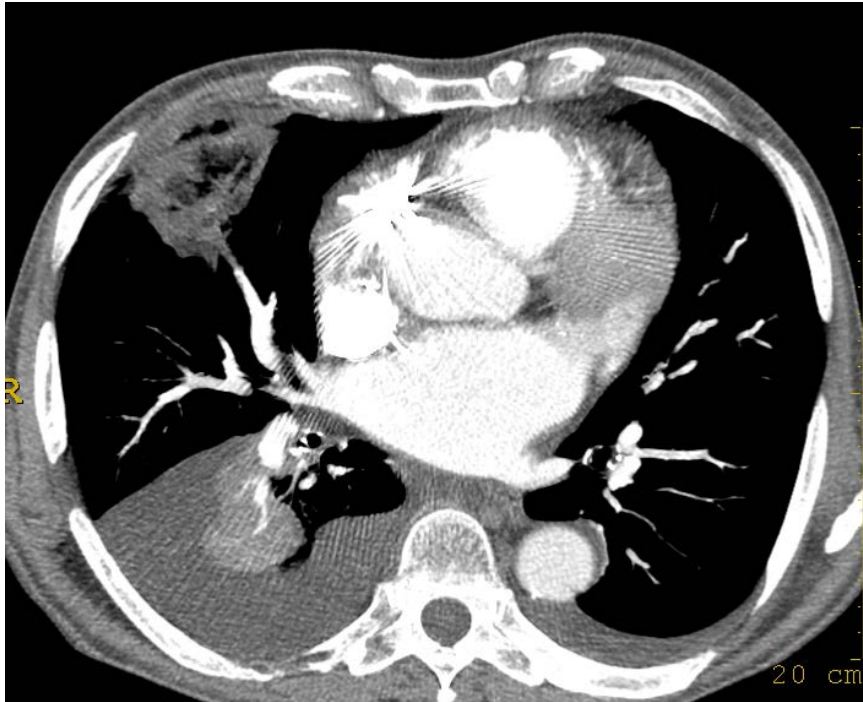
Tomodensitométrie de l'abdomen



Injection intraveineuse en bolus d'un produit de contraste iodé

Opacification du tube digestif

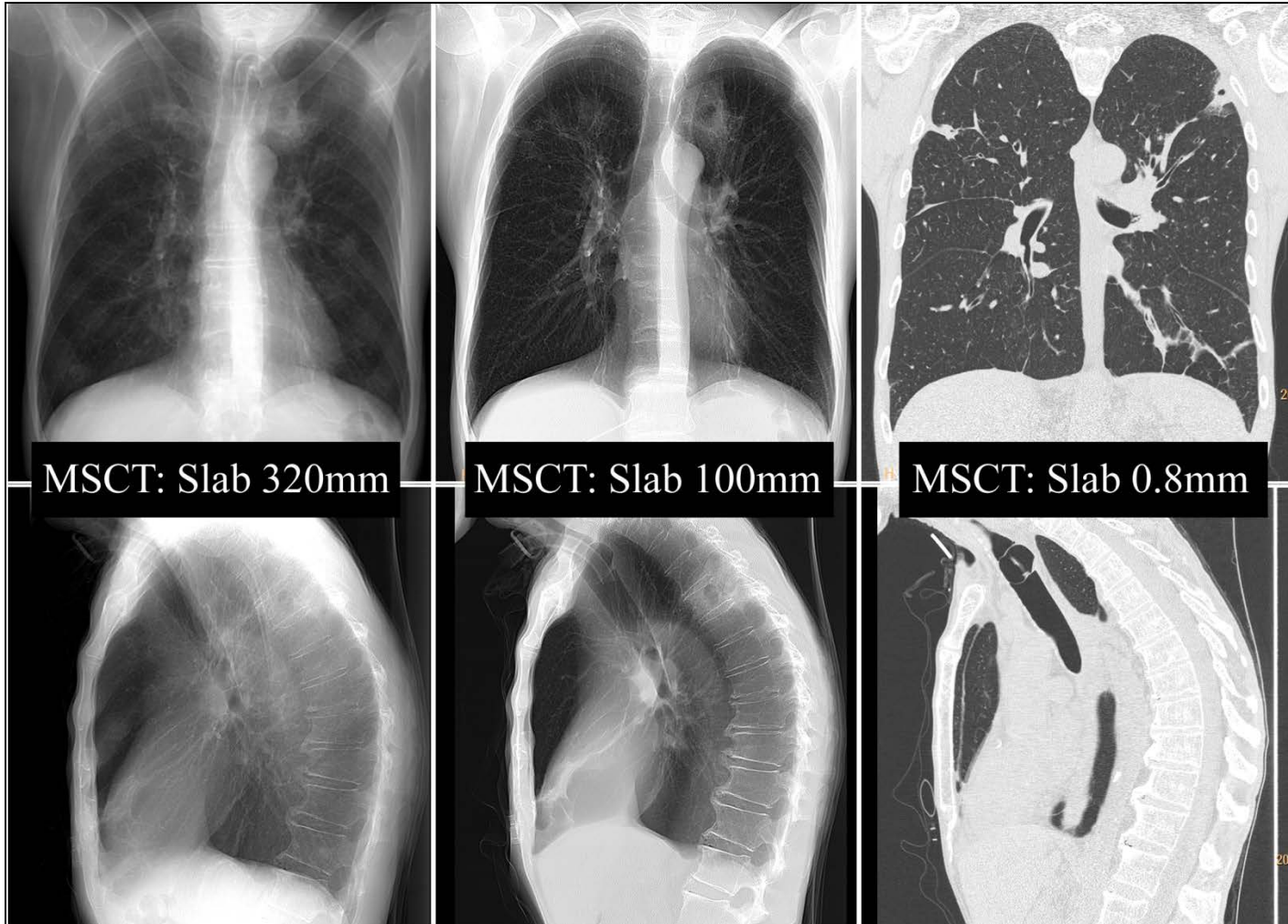
Tomodensitométrie thoracique



Injection intraveineuse en bolus d'un produit de contraste iodé

En contraste spontané si étude du parenchyme pulmonaire uniquement

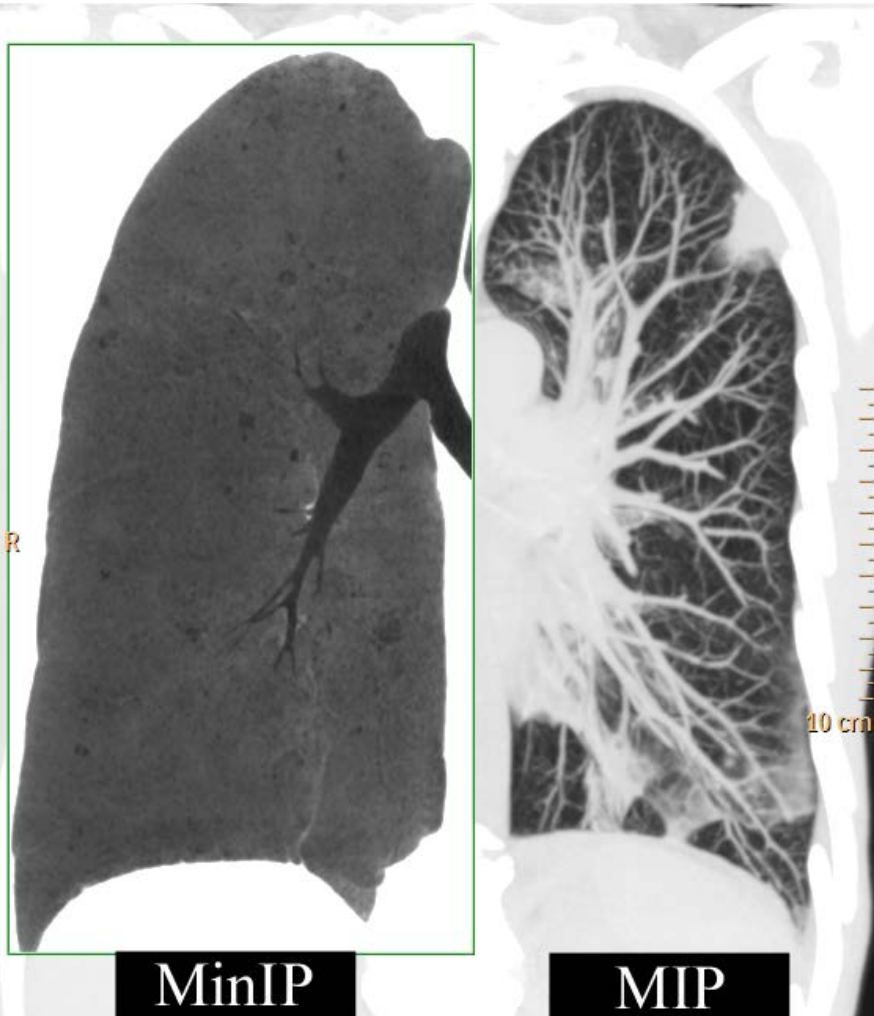
Post-processing: MPR



Post-processing: MPR



Post-processing: MiP/MinIP



MIP: Intensité maximale de projection

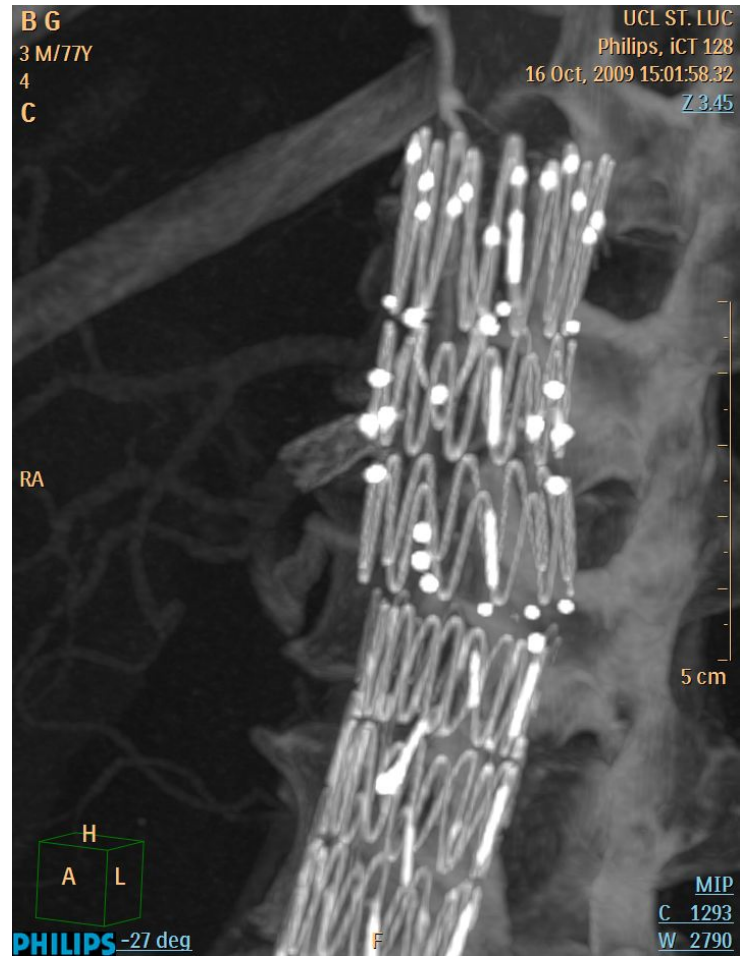
Intérêts: Vsx, nodules

MinIP: Intensité minimale de projection

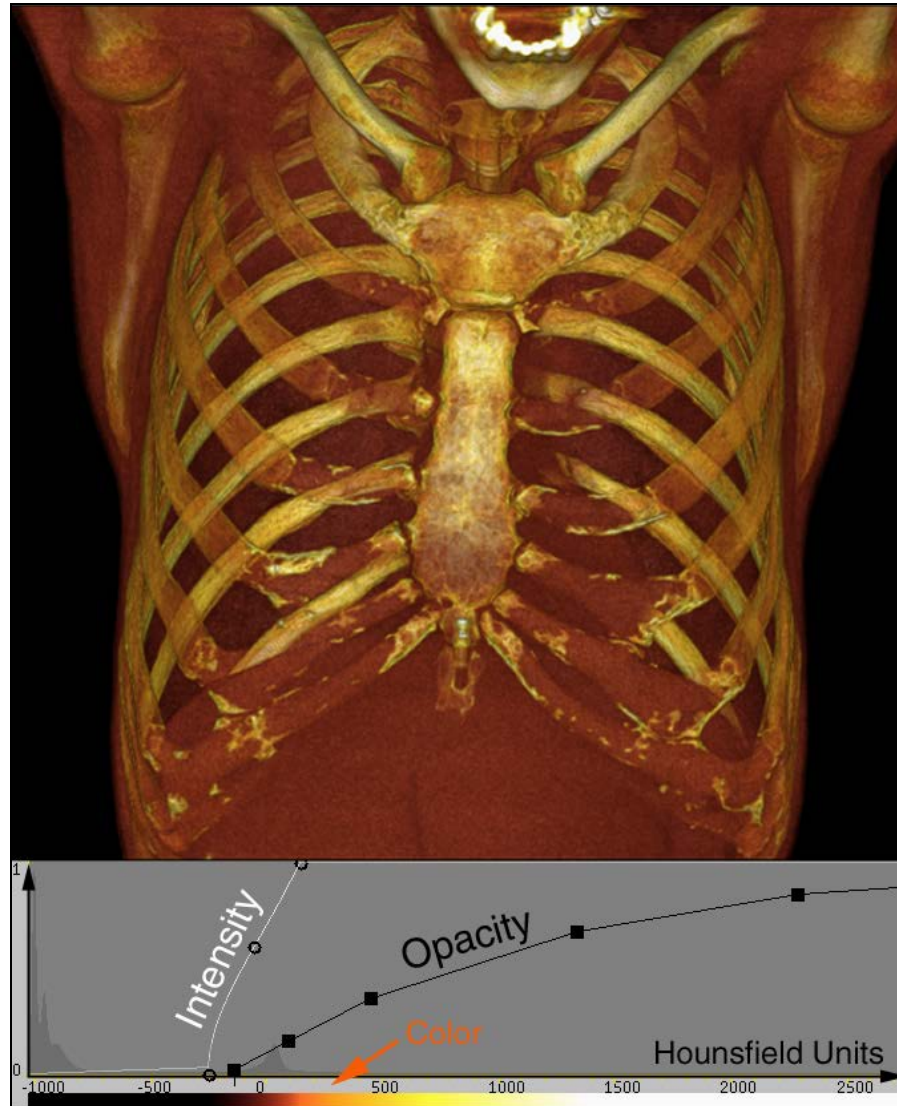
Intérêts:

Emphysème, VA

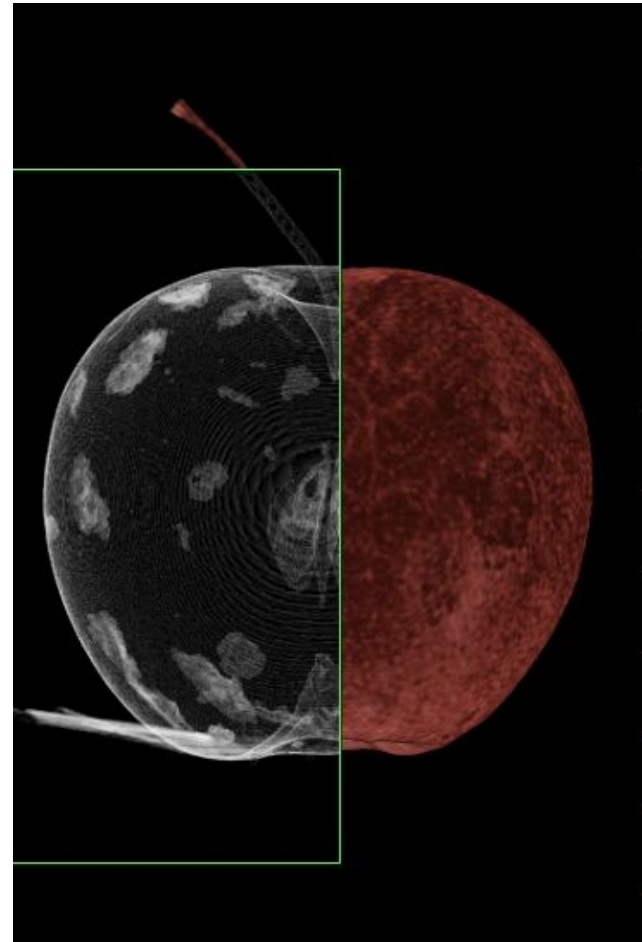
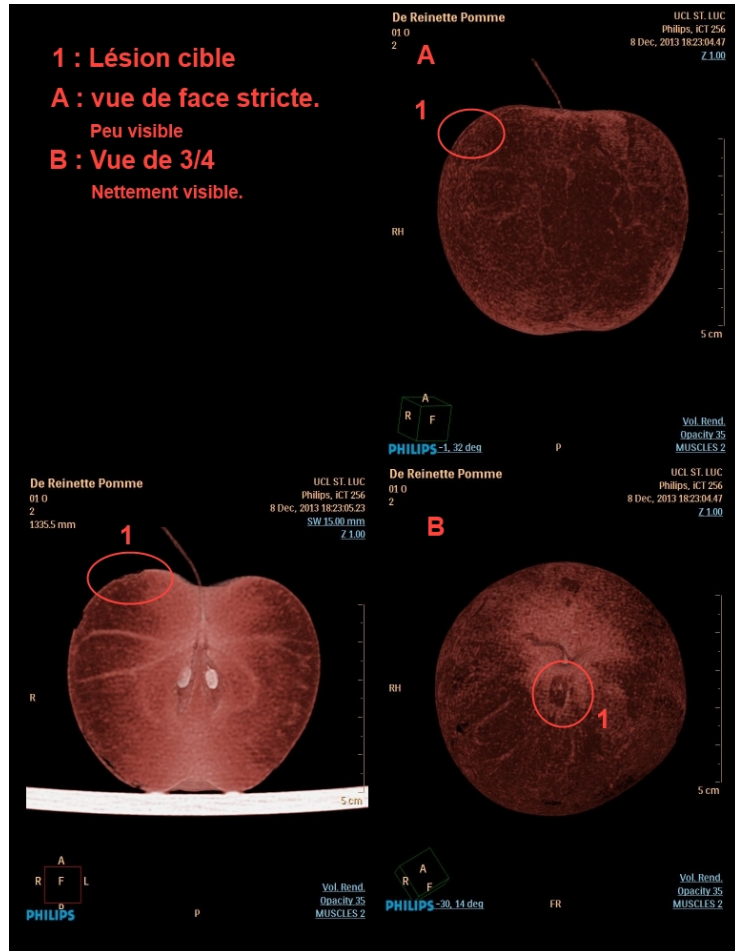
MIP



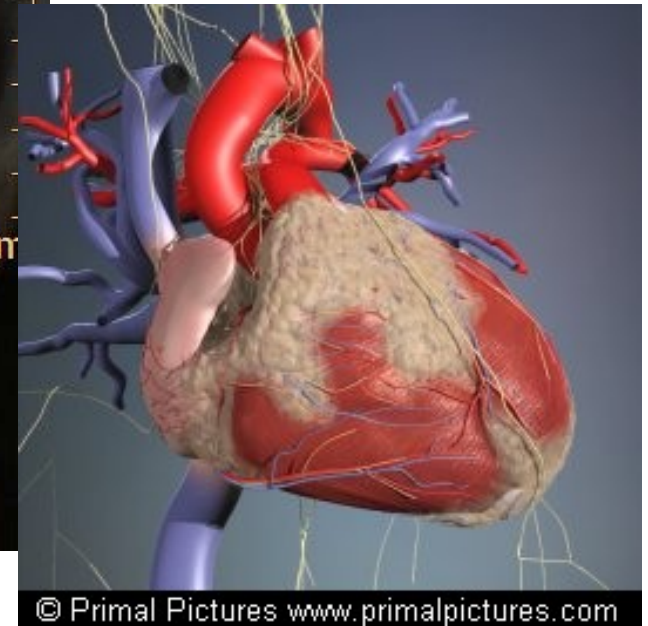
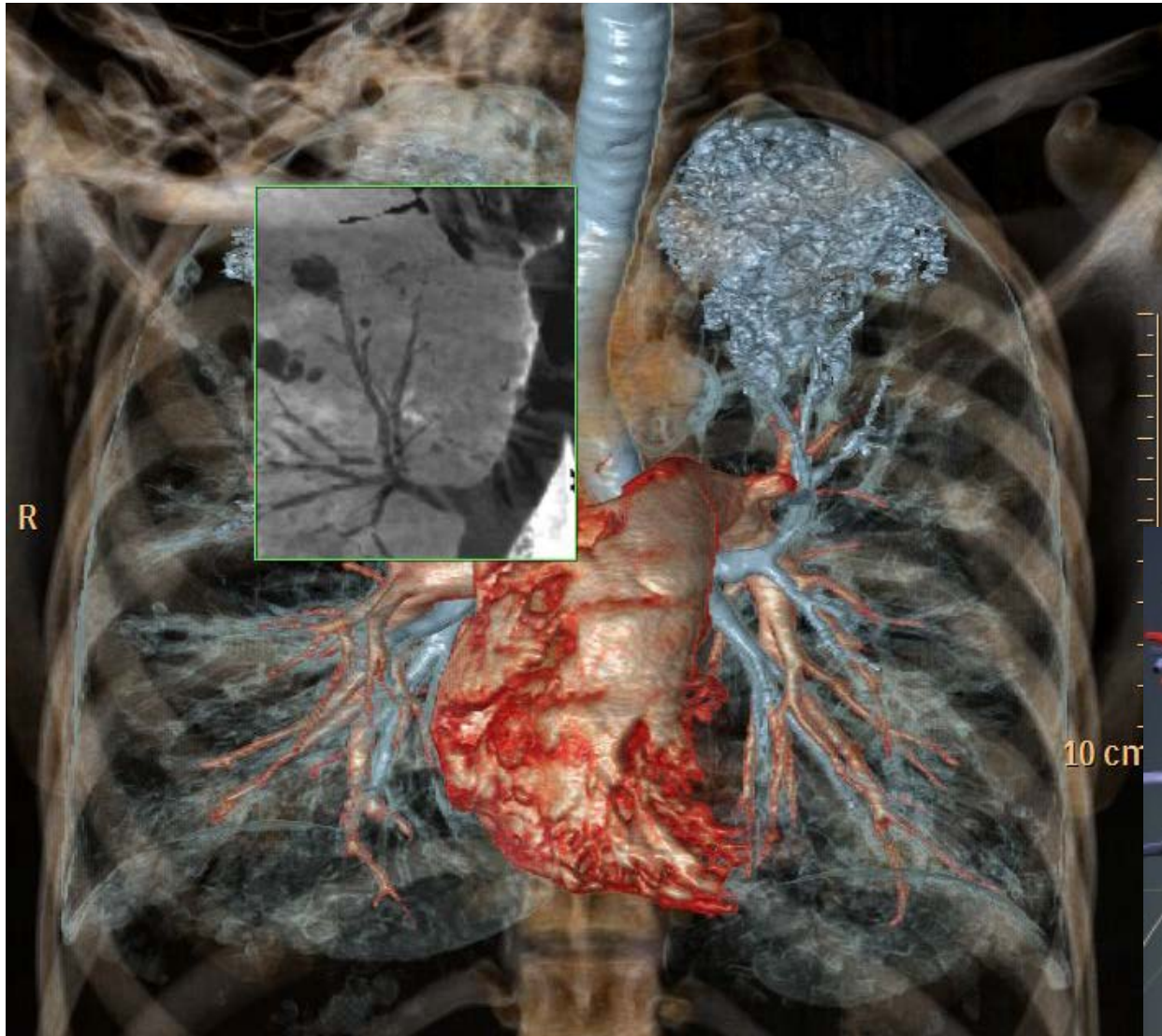
Post-processing: Rendu Volumique



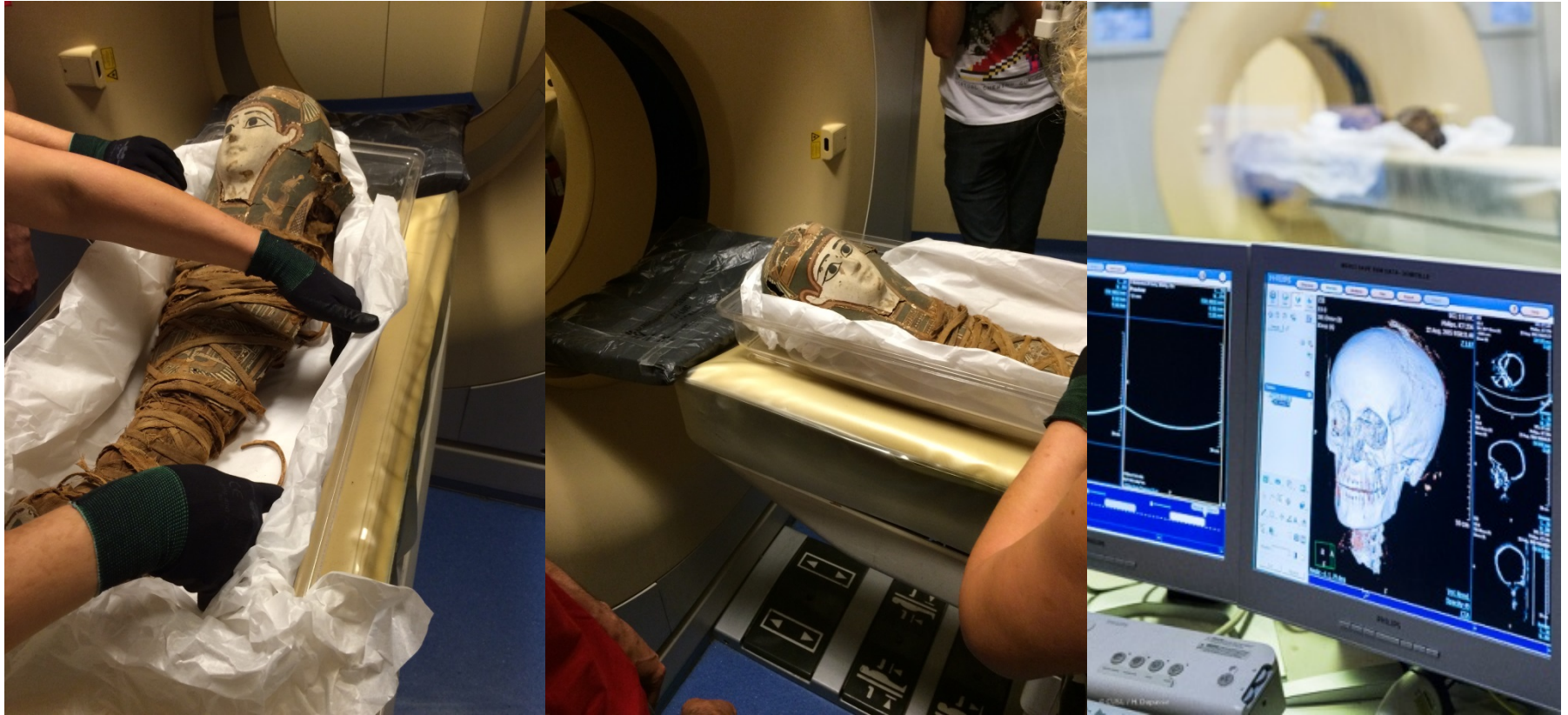
Rendu de Volume



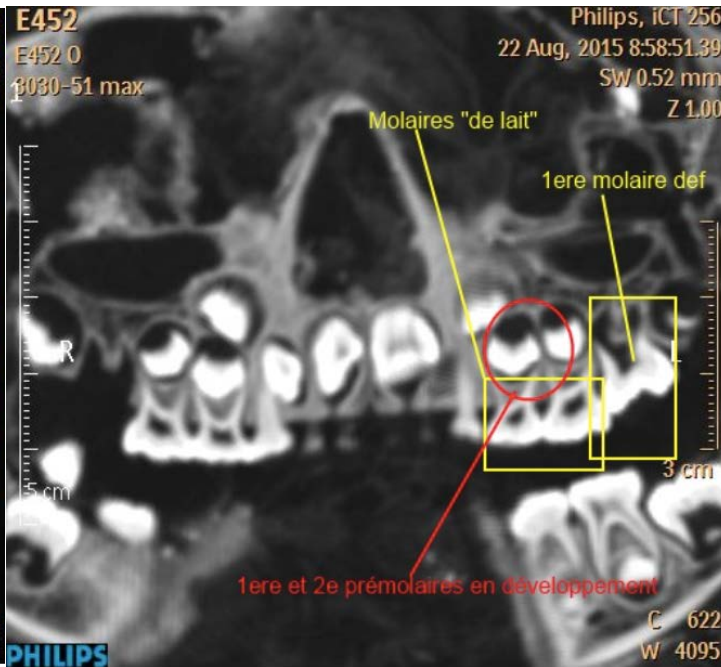
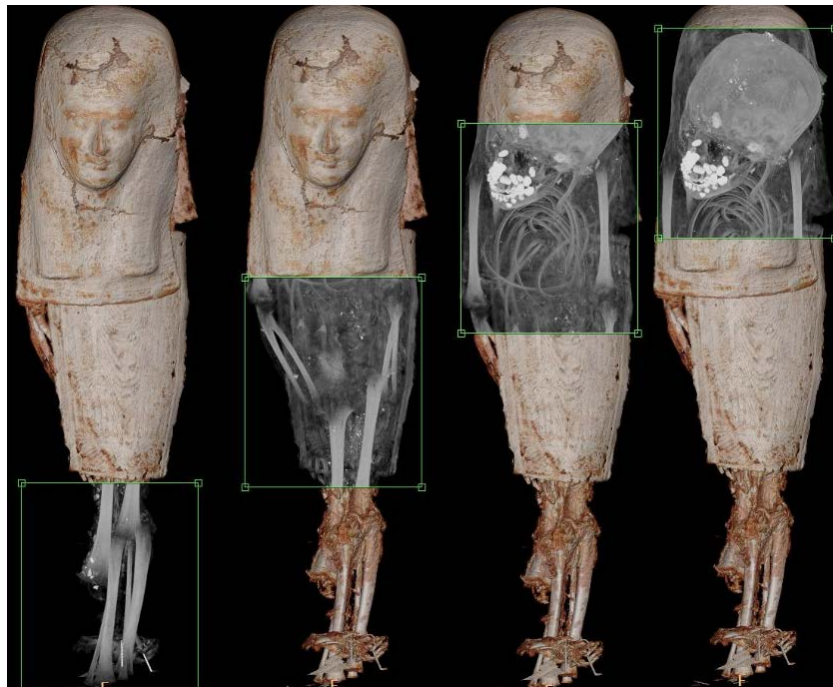
Derniers développements



Autopsie virtuelle



CT scanner des momies du musée du cinquanteaire
Participants: E.Danse, J-P Hastir, A. Vlassenbroek, E.Coche

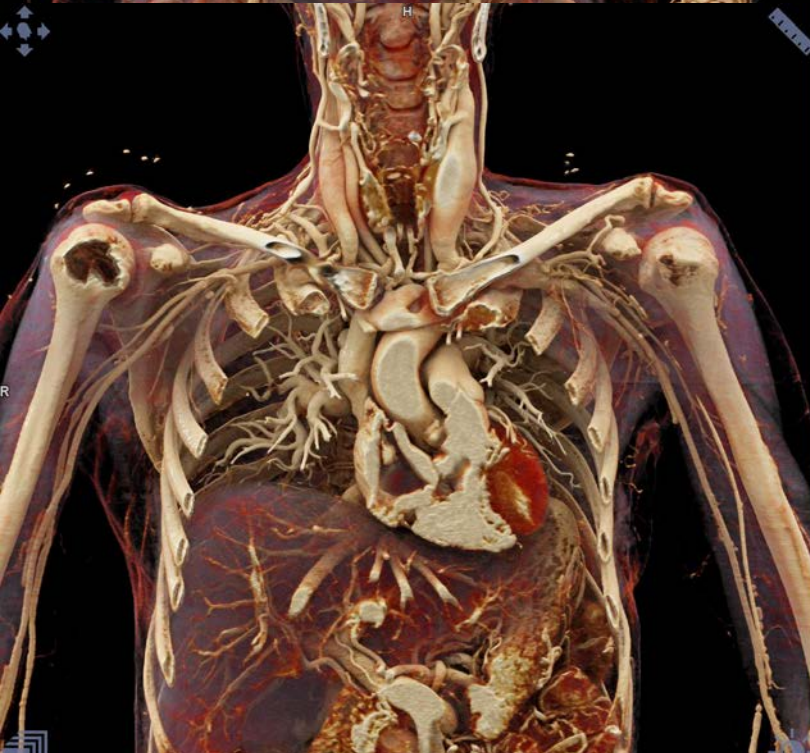


Juillet 2017

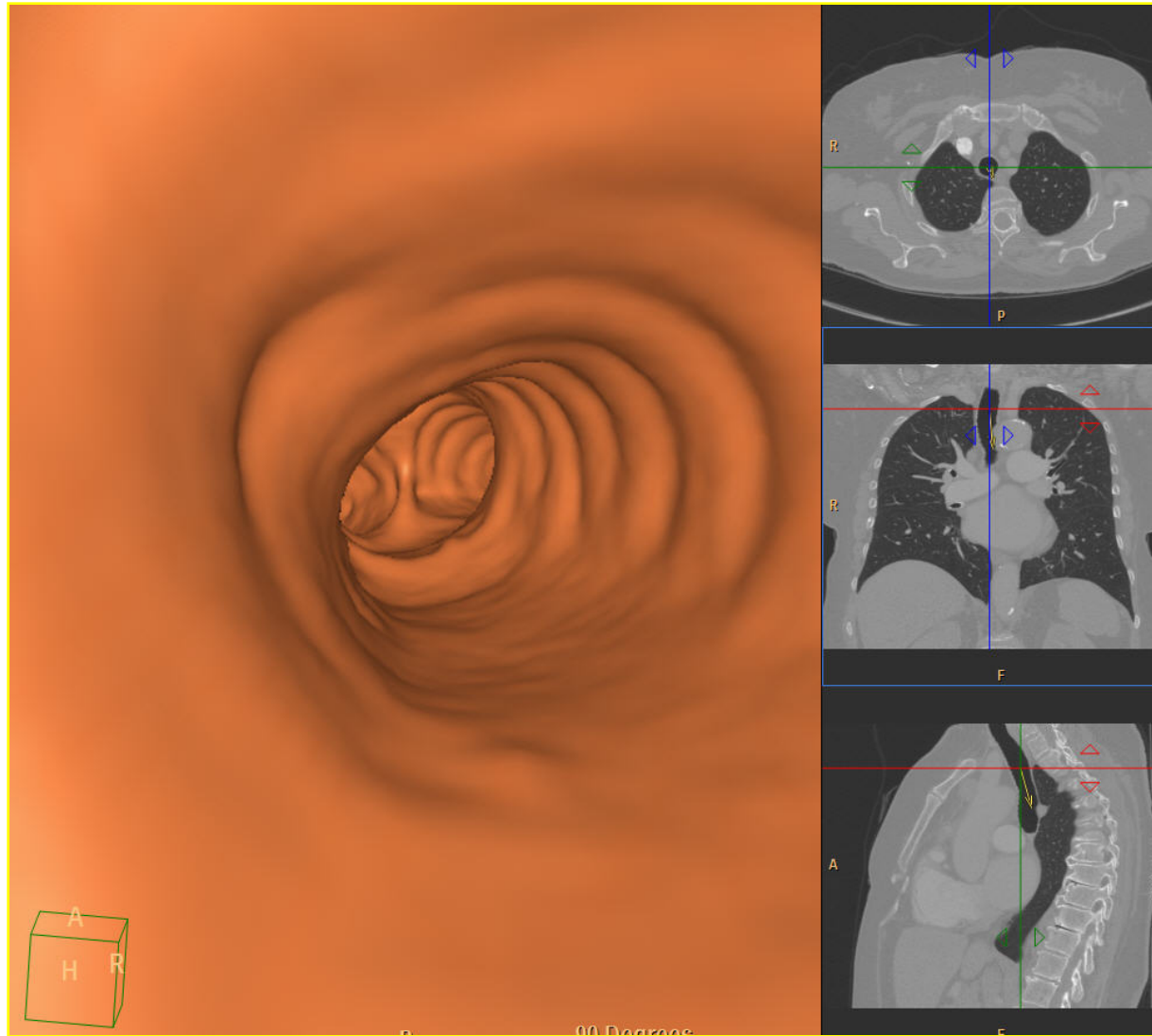
Courtoisie
X. de Spiegeleer



Rendu 3D

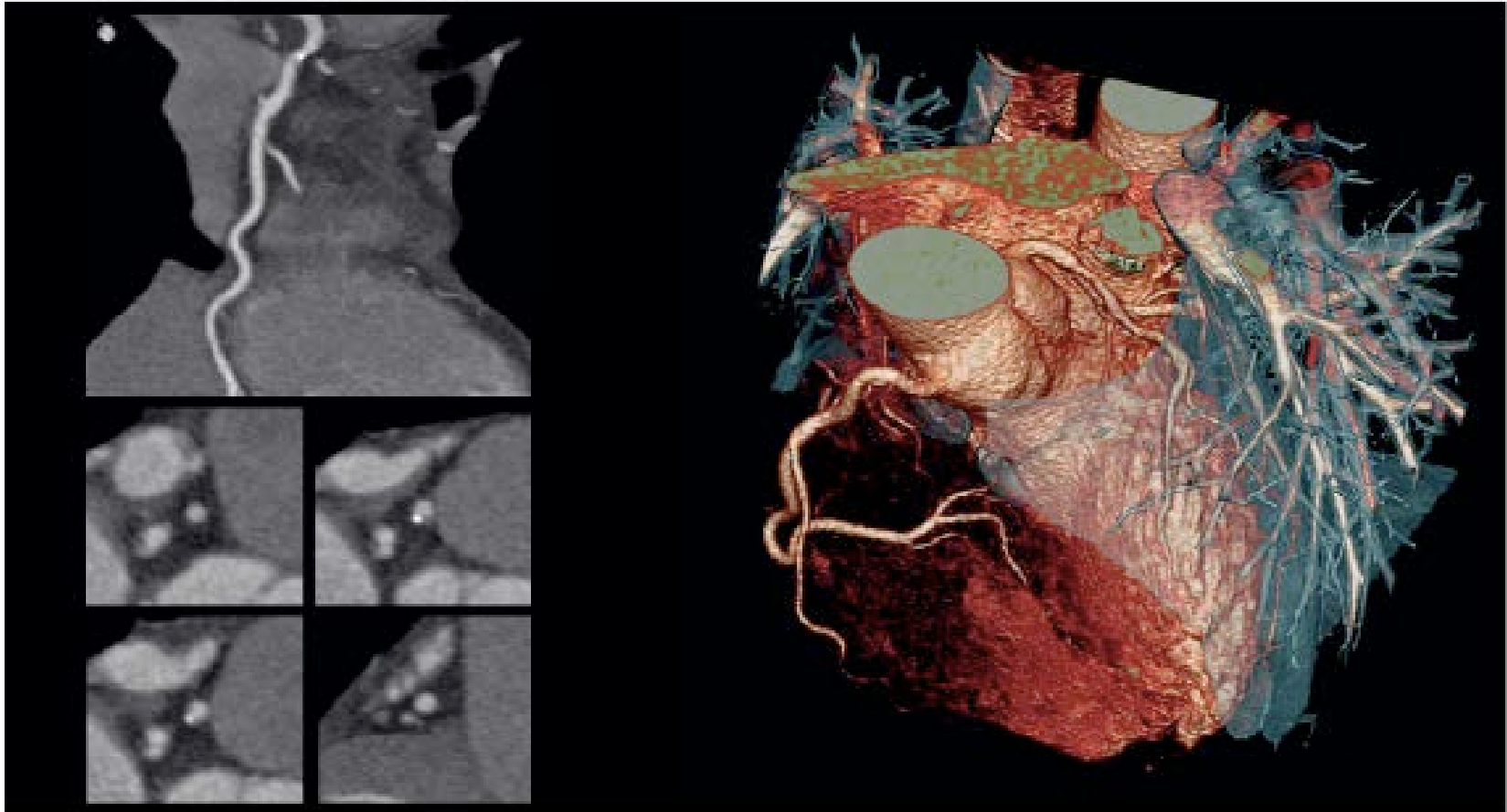


Post-processing: Navigation virtuelle



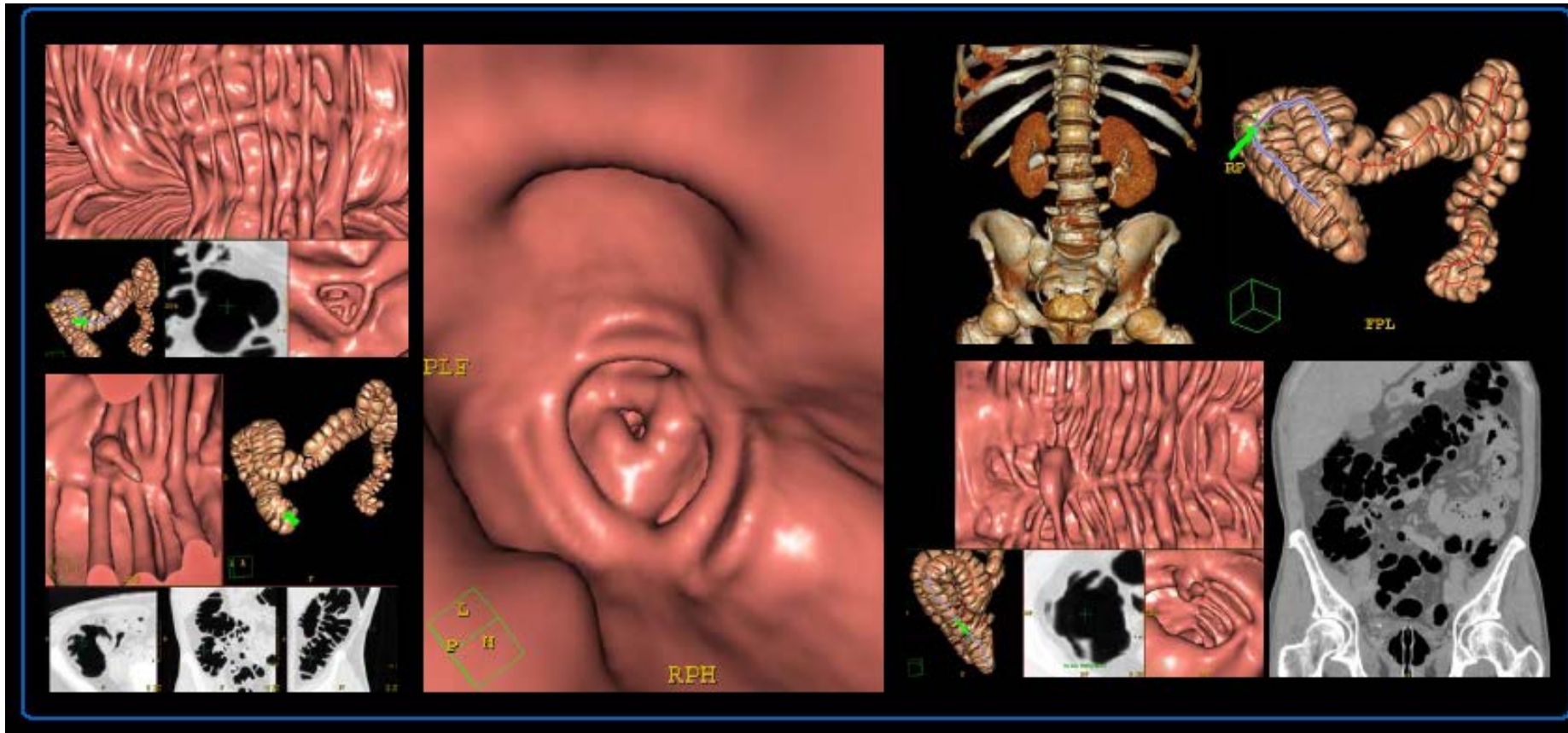


Applications spéciales: CT coeur



Rule-out coronary artery disease for early detection and prevention – Flash Spiral CTA with 0.9 mSv

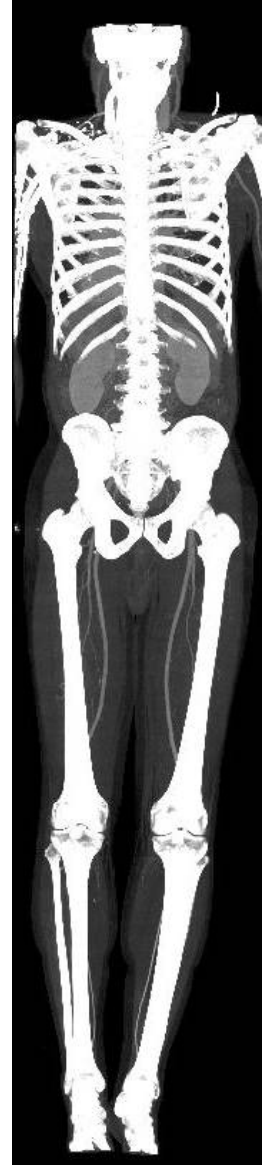
Colono-CT

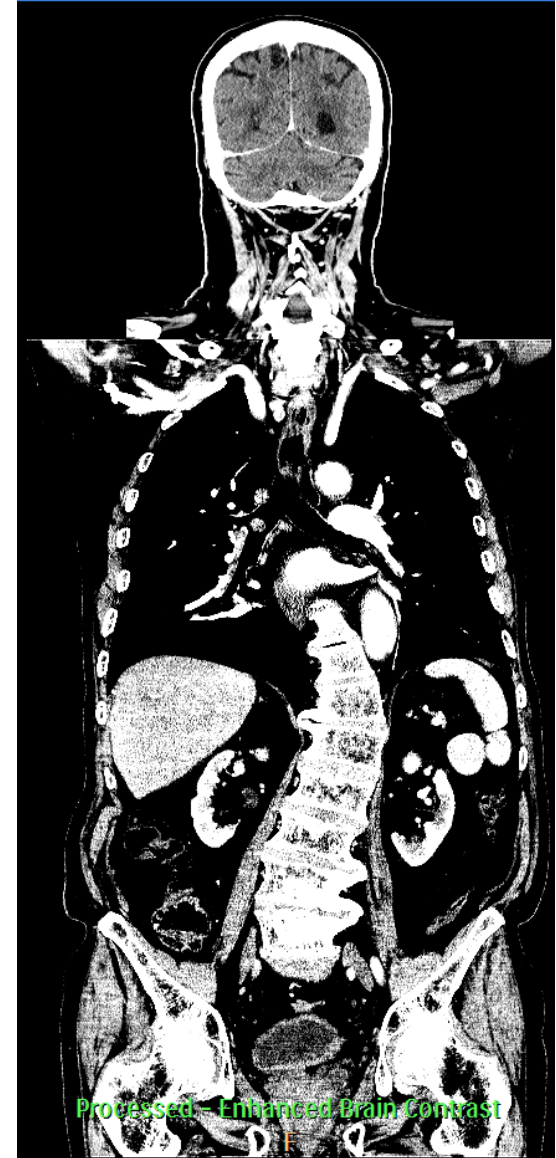


CT angio périphérique

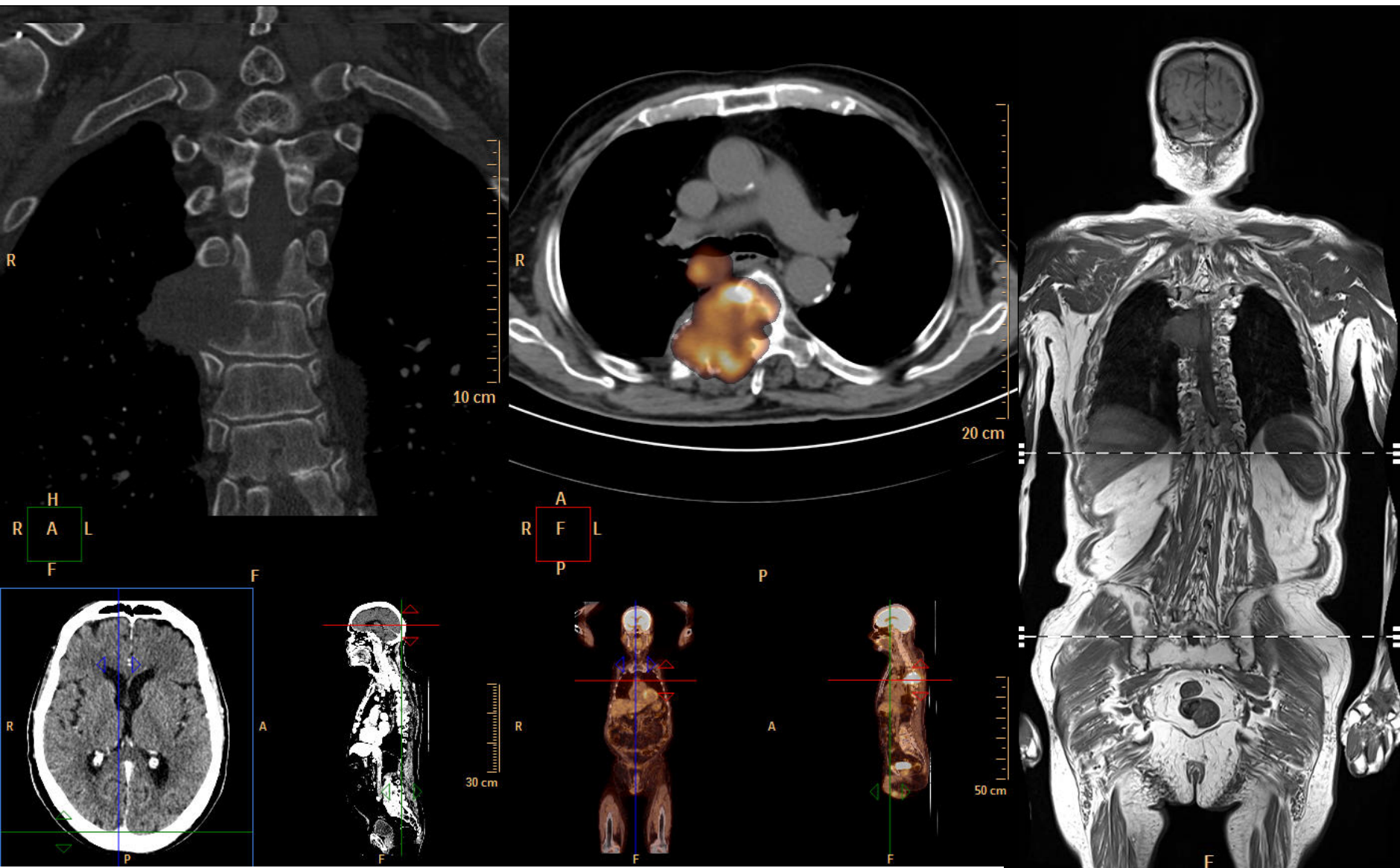


CT scanner corps entier



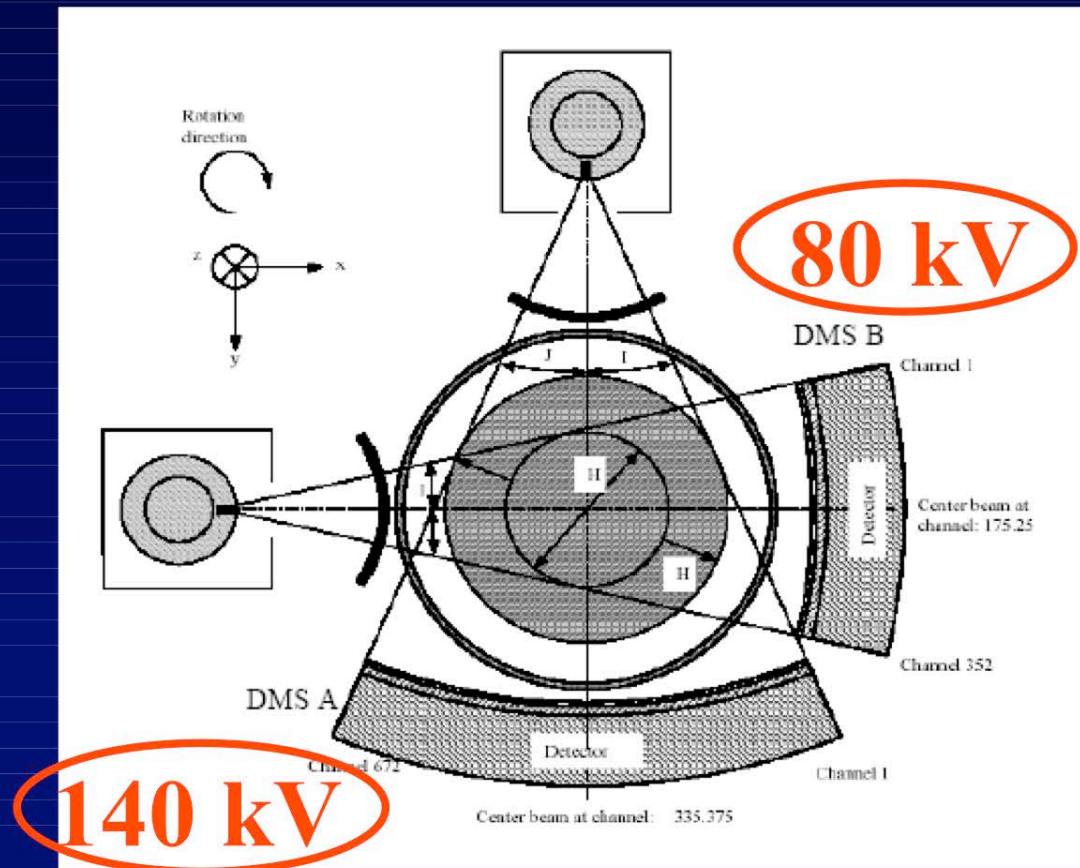


CT «corps entier»

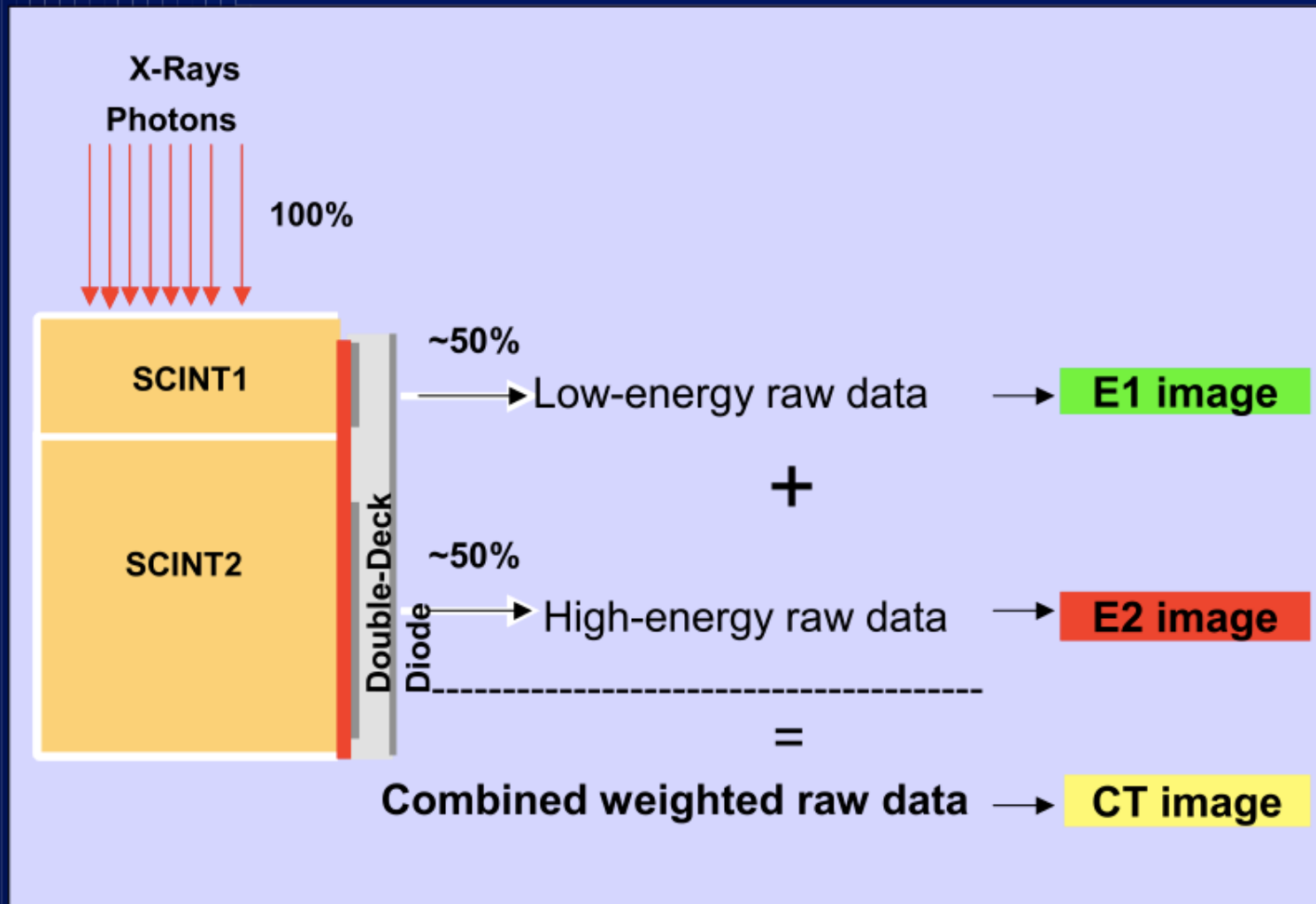


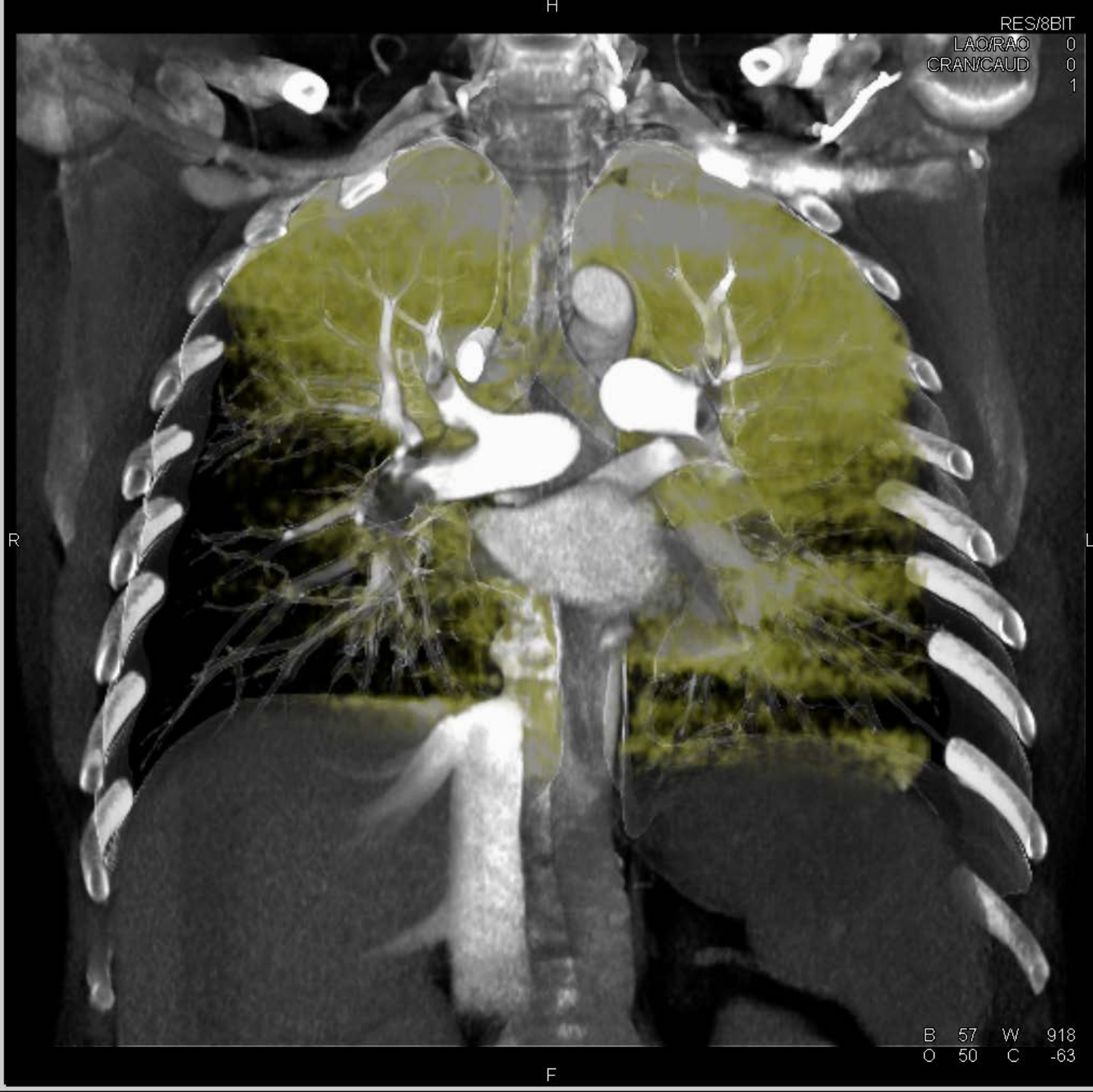
Données morphologiques et fonctionnelles (PET)
Corrélation à l'IRM

Dual energy CT (DECT)



Single Source Dual Energy MDCT: 2 Detection Systems Situated 1-on-1





RES:8BIT

LAO/RAO 0

CRAN/CAUD 0

1

R

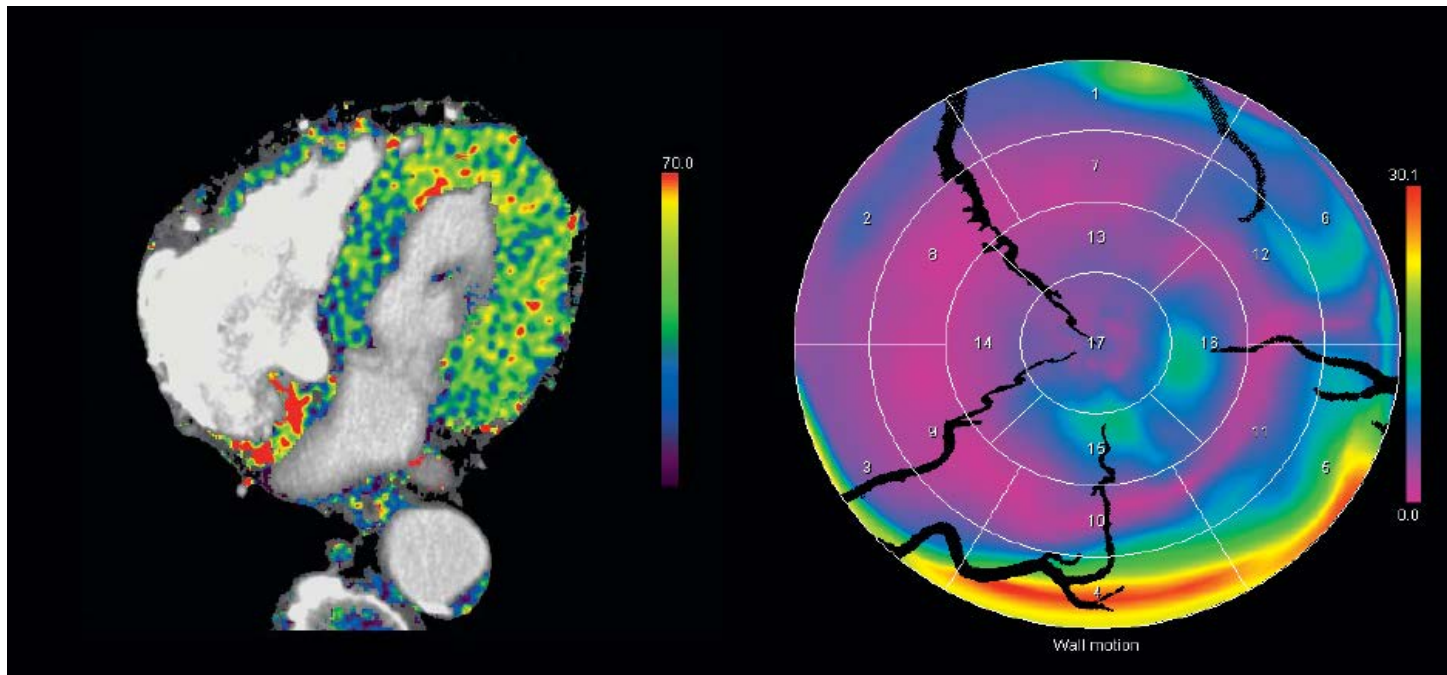
L

B 57 W 918

O 50 C -63

F

CT quantitatif



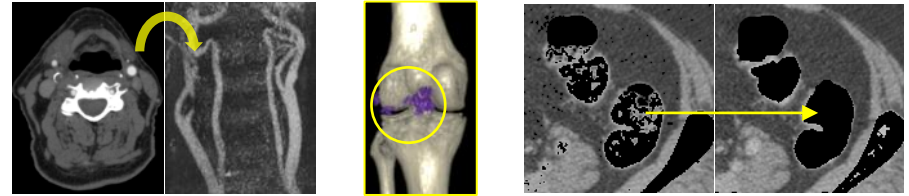
Systolic image of a triggered heart perfusion scan to check for hemodynamic abnormalities in the myocardium

Low dose functional imaging with Flash Cardio Sequence

Clinical Applications of Dual Energy Spectral CT

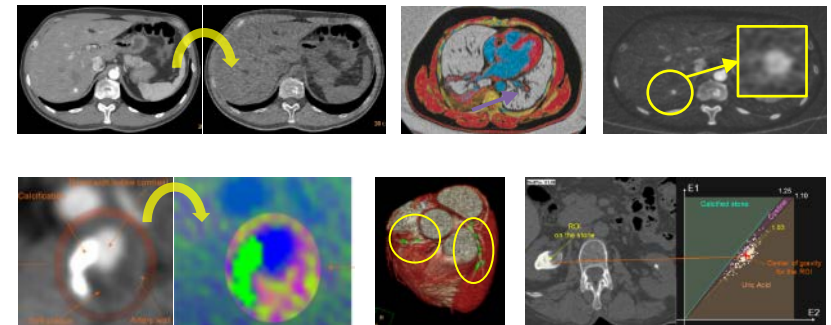
Material Separation

- Direct CTA
- Gout Diagnosis
- Prep-Less CT Colonography



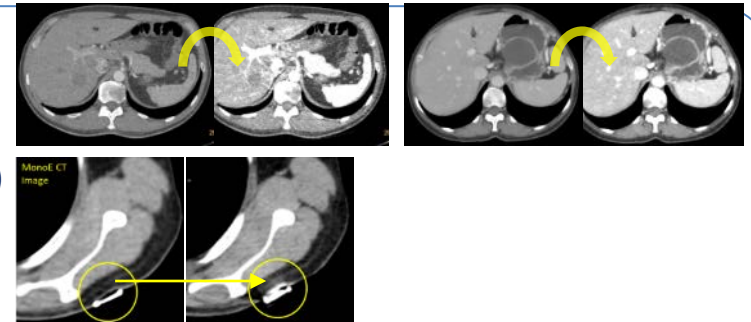
Material Decomposition

- Virtual Non-Contrast
- Blood Flow Iodine Perfusion (PE)
- Lesion Uptake & Volume Assessment
- Plaque Characterization
- Cardiac CT
- Urinary Stone Characterization



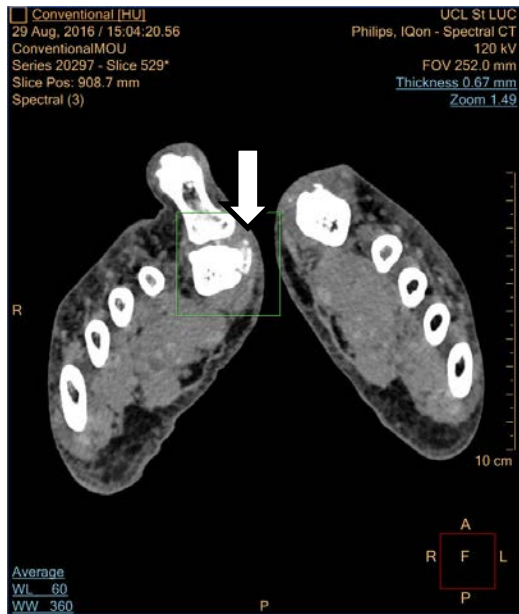
Monochromatic Imaging

- Salvaging Sub-Optimal CTAs
- Optimum CNR Imaging (\uparrow Lesion visualization)
- Metal & Beam Hardening Reduction

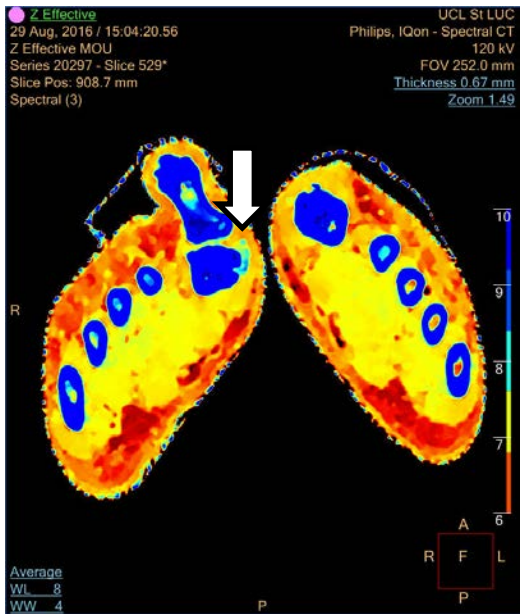


Gout

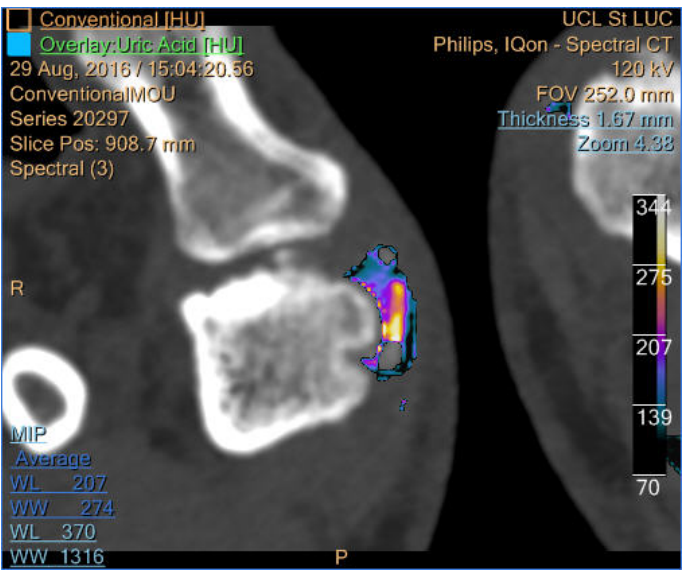
Conventional



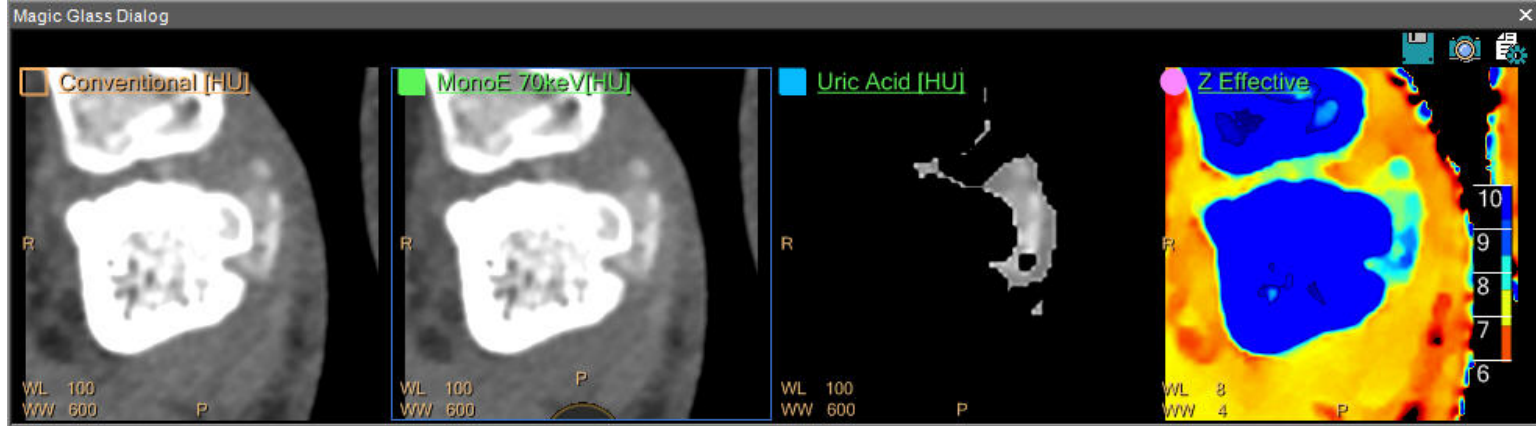
Z_{eff}



Uric Acid Colored Overlay



Magic Glass



Limites du CT scanner

Irradiation

CT: 15% des examens-75% irradiation délivrée

Besoin de réduire les doses au CT

Indications

Procédés physiques

Produit de contraste

Réactions mineures

Chocs anaphylactiques (1/300 000)

Volume d'informations

Doses d'irradiation des examens en imagerie médicale

Examen	Dose effective	Equivalent Rx thorax	Equivalent Irradiation naturelle
Thorax (PA)	0.02 mSev	1	3 jours
CT thorax	8 mSev	400	3.6 années
CT abdomen ou pelvis	10 mSev	500	4.5 années

Referral guidelines for imaging. European comission. Directorate-General for the environment 2000

Aide au diagnostic: CAD

Segmentation

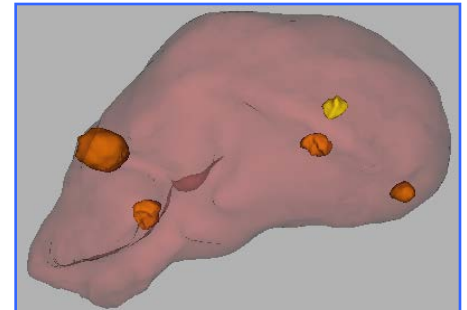
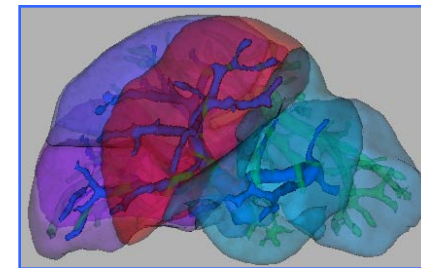
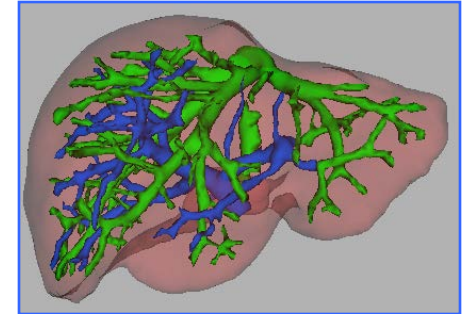
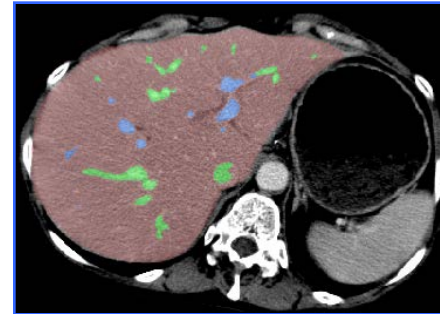
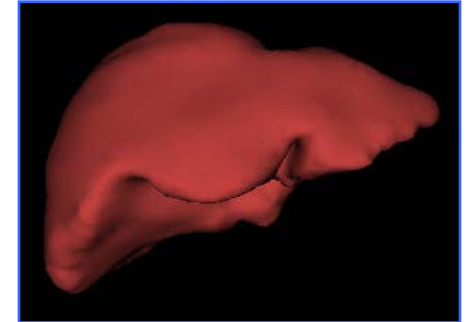
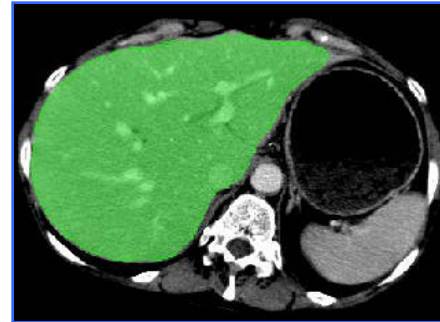
Hépatique

Artères pulmonaires

Détection

Nodules pulmonaires

Lésions hépatiques



Intelligence artificielle

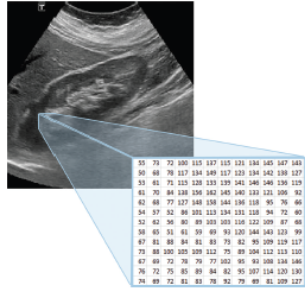


Figure 3. Human versus computer vision. A human expert easily classifies this image as an image of the right kidney. Why is this task difficult for a computer? Instead of shades of gray, a computer "sees" a matrix of numbers representing pixel brightness. Computer vision typically involves computing the presence of numerical patterns (features) in this matrix, then applying machine learning algorithms to distinguish images on the basis of these features.

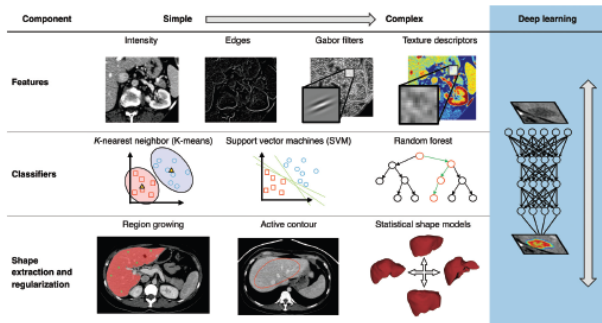


Figure 4. Computer vision tasks such as detection, segmentation, and classification are typically carried out with algorithms based on features, classifiers, and shape extraction methods. Recent approaches based on deep learning represent an important paradigm shift where features are not handcrafted, but learned in an end-to-end fashion. Features describe the appearance of organs and points of interest in medical images. Classifiers integrate features to output a decision. Shape extraction and regularization recover a consistent shape despite classification noise. Deep learning proposes an end-to-end approach where features are learned to maximize the classifier's performance. Shape regularization becomes implicit and often requires only mild postprocessing to recover the target shape.

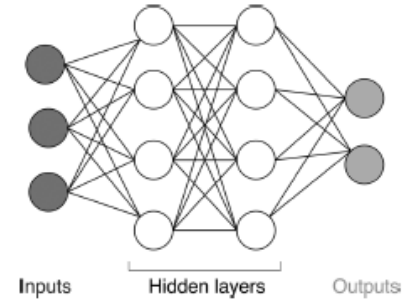


Figure 6. The basis for most deep learning research is the artificial neural network, a computational framework of interconnected nodes inspired by biologic neural networks. The "deep" aspect of deep learning refers to the multilayer architecture of these networks, which contain multiple hidden layers of nodes between the input and output nodes. This example has three input nodes, two hidden layers (each with four nodes), and two output nodes.

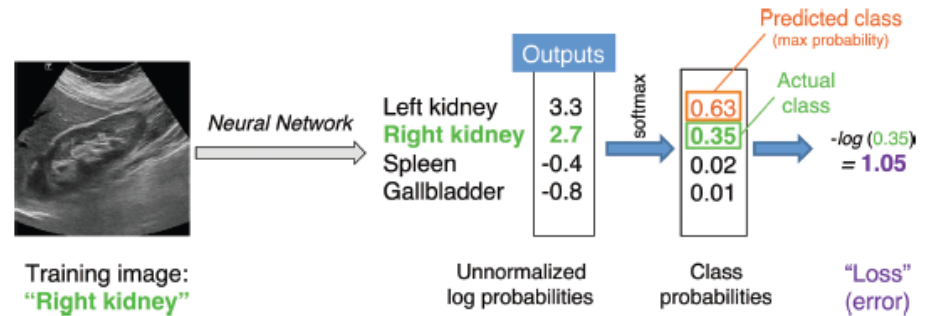
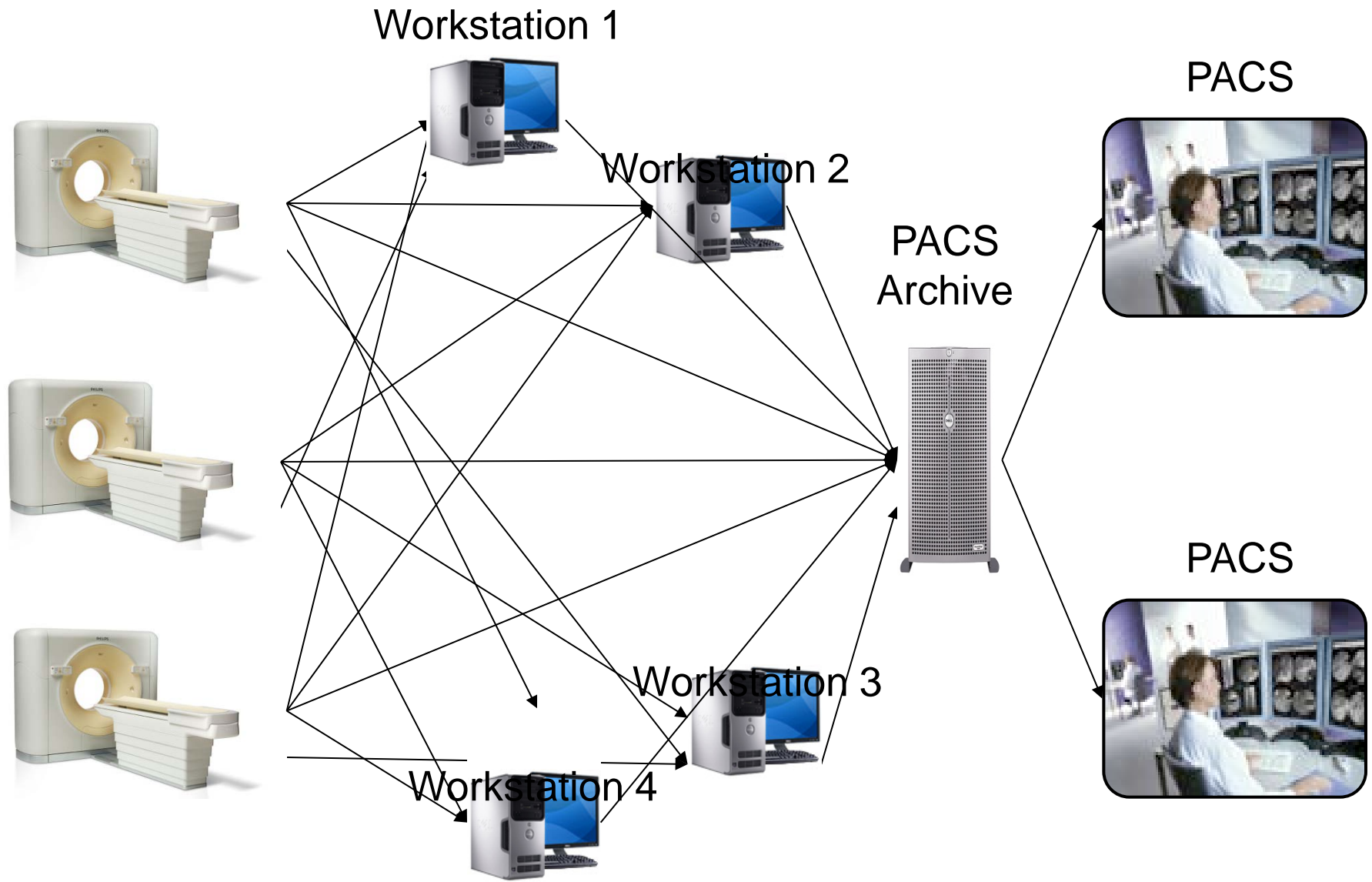


Figure 7. Softmax classifier. For classification, the output nodes of a neural network can be regarded as unnormalized log probabilities for each class. The softmax function converts these into class probabilities: During training, a "loss" value is computed to represent the error between the network's output-predicted class and the actual class of the input. This error is back-propagated from the final layer to adjust the weights throughout the network in a manner that minimizes the loss.

IA: Intelligence artificielle/Intelligence augmentée

Nombreux domaines: priorisation, aide au diagnostic, workflow, qualité.....

Connectivité et transmission des informations

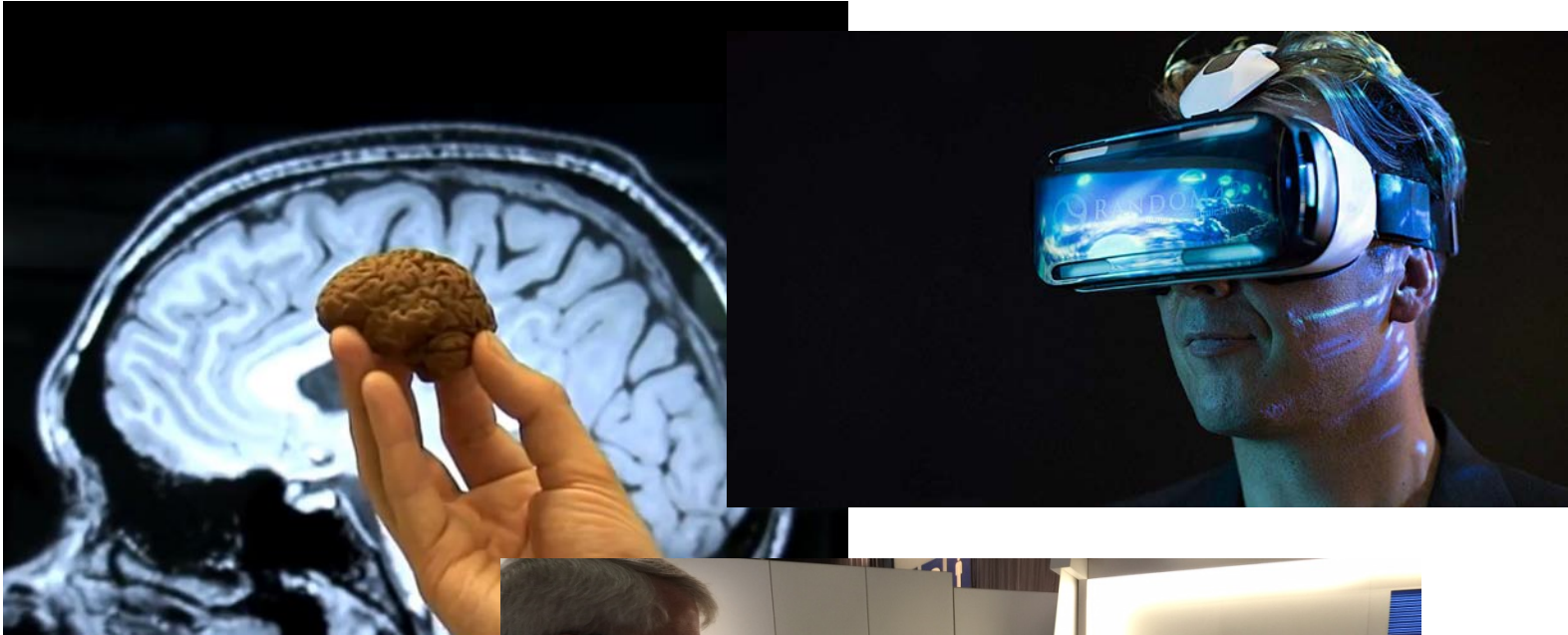


La visibilité du radiologue



Glazer GM, Ruiz-Wibbelsmann. The invisible radiologist. *Radiology* (2011);258:18-22

Perspectives



Illustrations et livre de référence

Computed Tomography

Willi A.Kalender

Publicis MD Verlag

Germany, 2000