Scanner cardiaque de demain : haute résolution, comptage photonique, intelligence artificielle

JFR 2021

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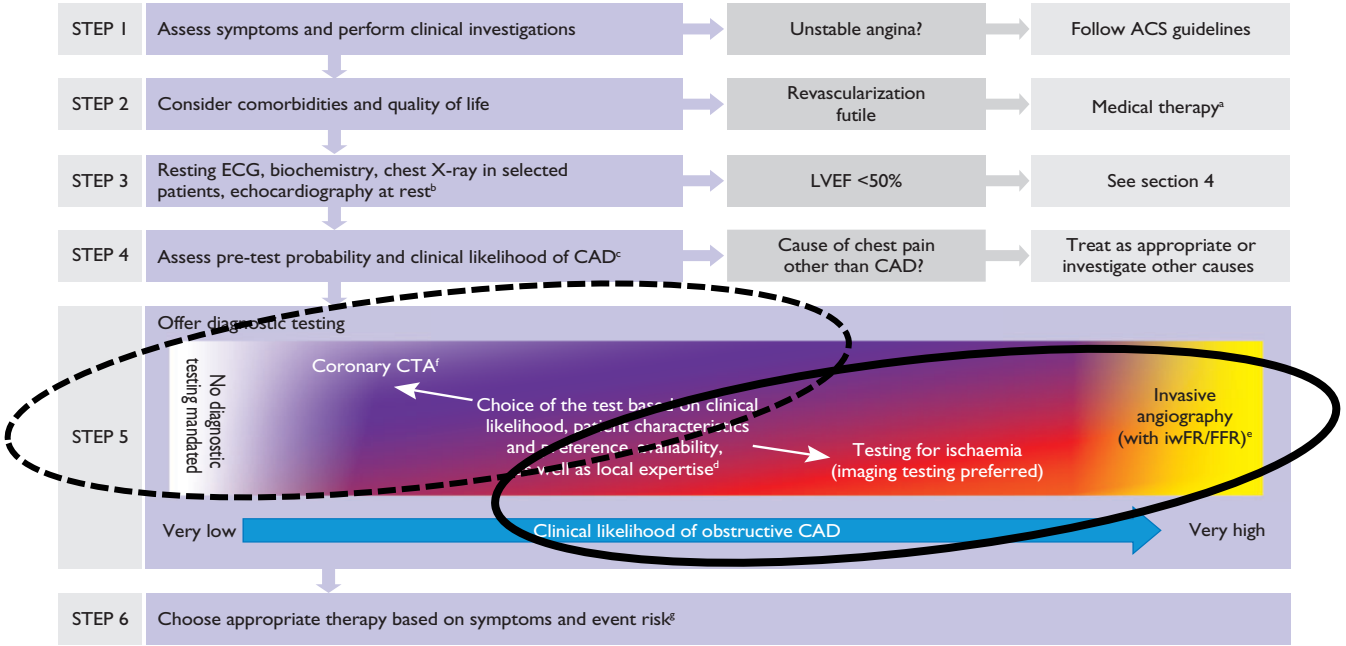
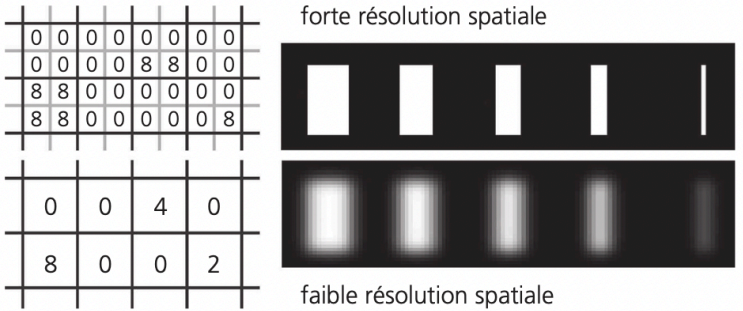


ESC Guidelines for the diagnosis and management of chronic coronary syndromes. ***2019***

Limitations importantes en scanner conventionnel

- Résolution spatiale
- Résolution en contraste
- Pas de quantification absolue
- Pas d'imagerie spécifique d'agents de contraste



Durand et Blondieaux. Imagerie Médicale. Elsevier Masson. 2017

Limitations importantes en scanner conventionnel

- Résolution spatiale
- Résolution en contraste
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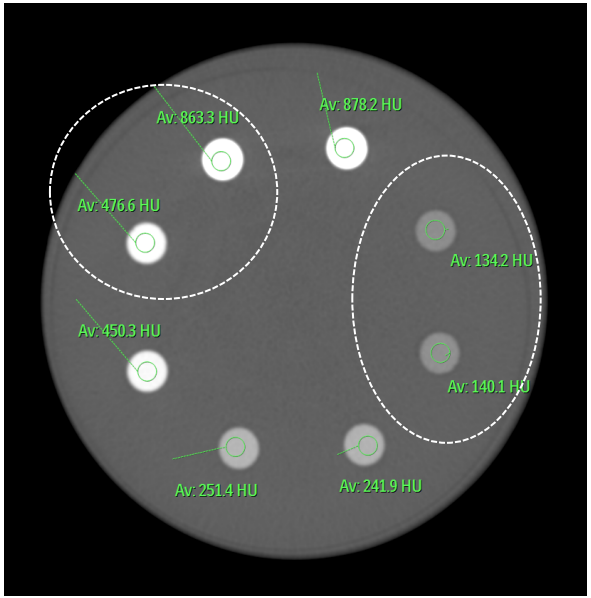
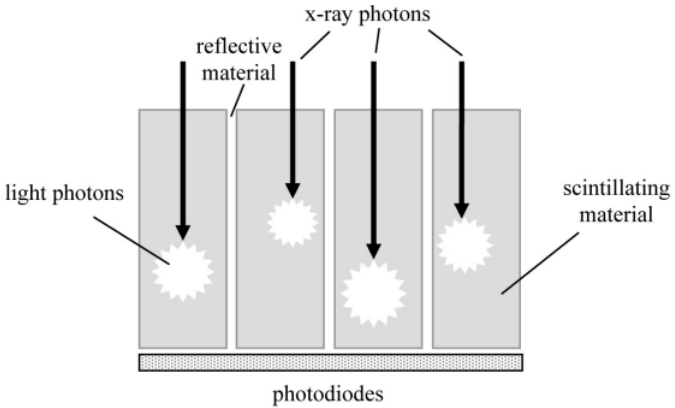
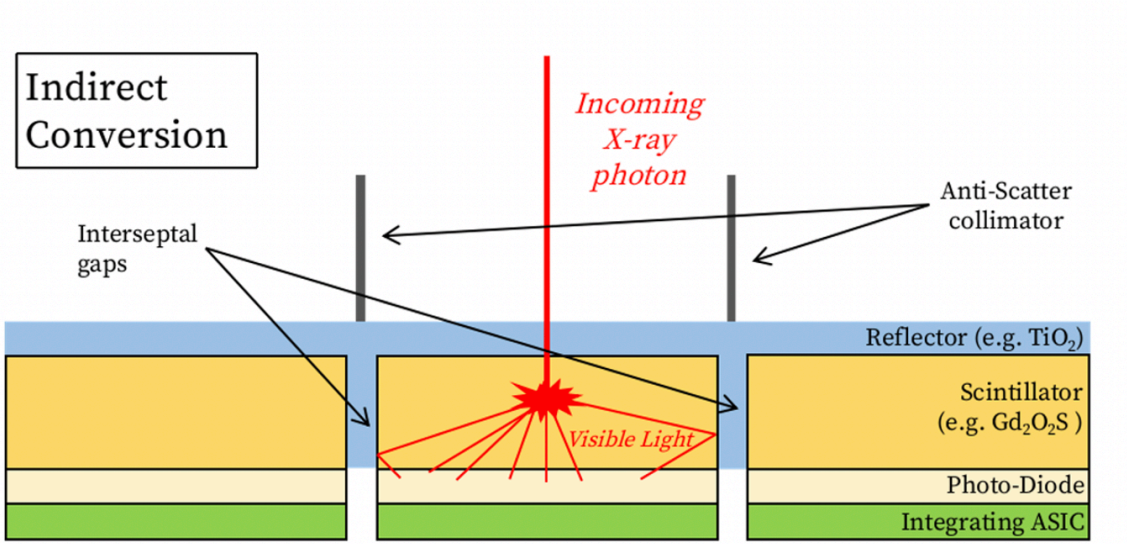
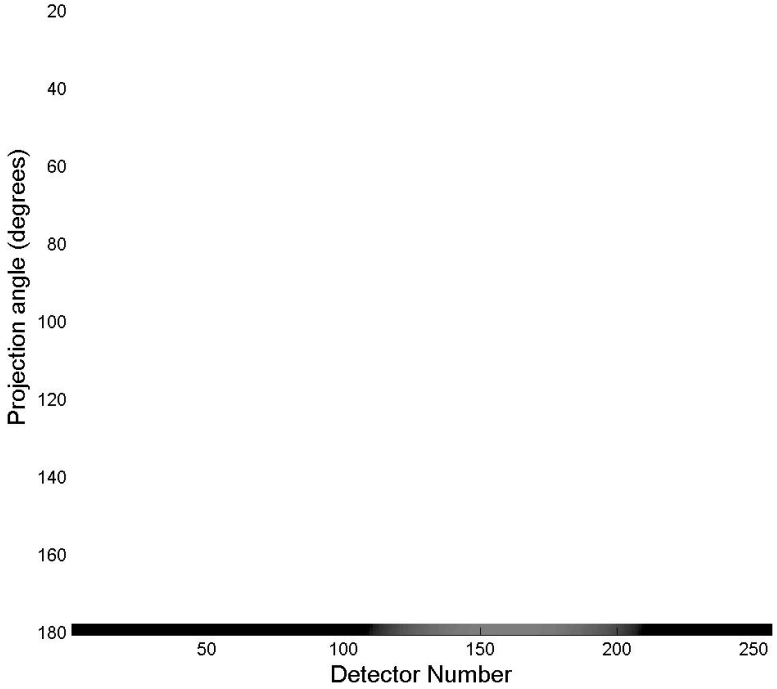


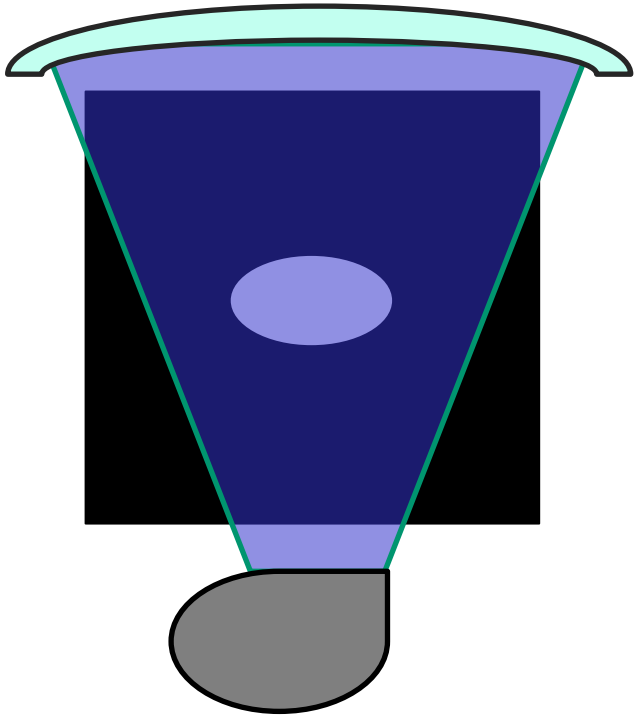


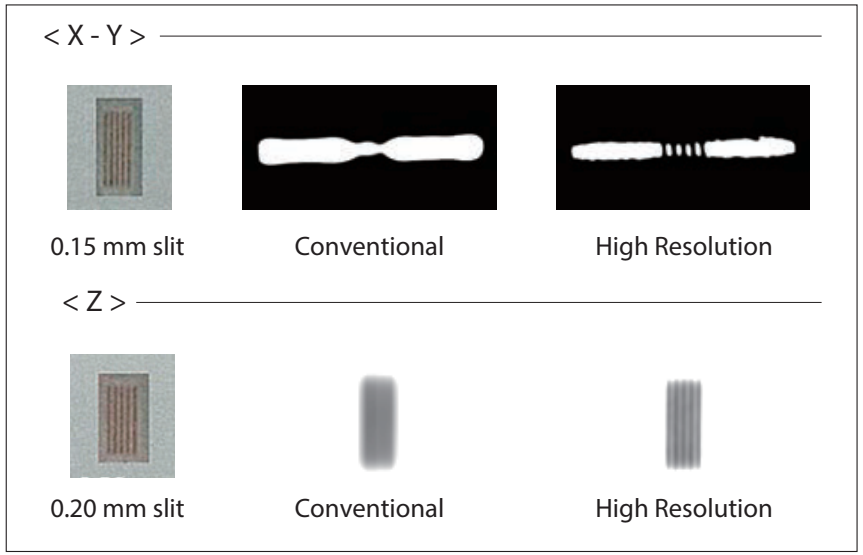
Détecteurs à intégration

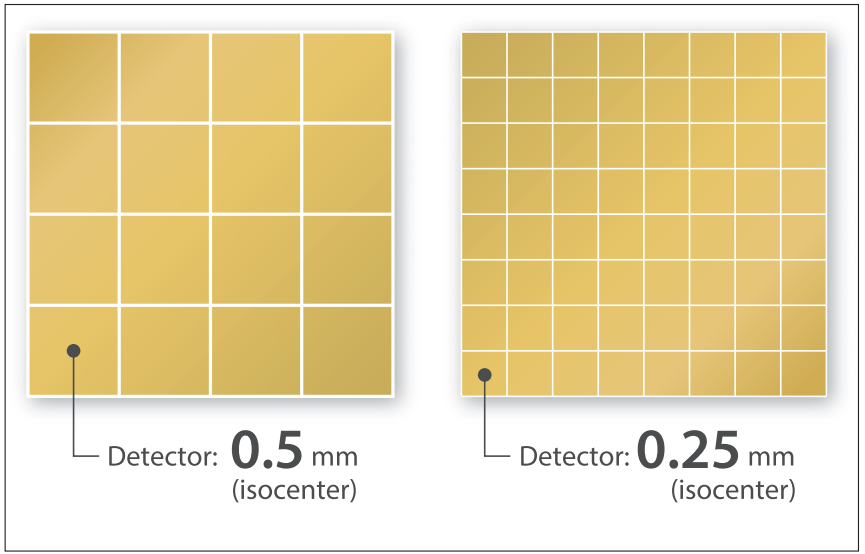


Si-Mohamed et al. Review: Spectral Photon-Counting CT technology in Chest Imaging. In revision. JCM ***2021***

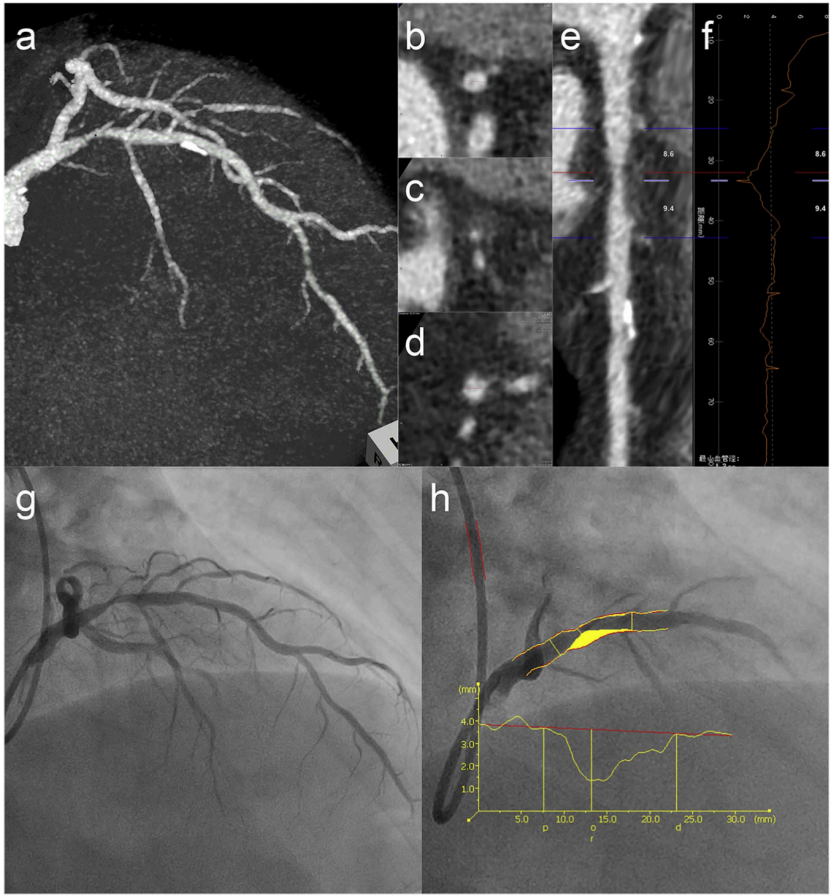

Projection angle (degrees)
20
40
60
80
100
120
140
160
180
50
100
150
200
250
Detector Number







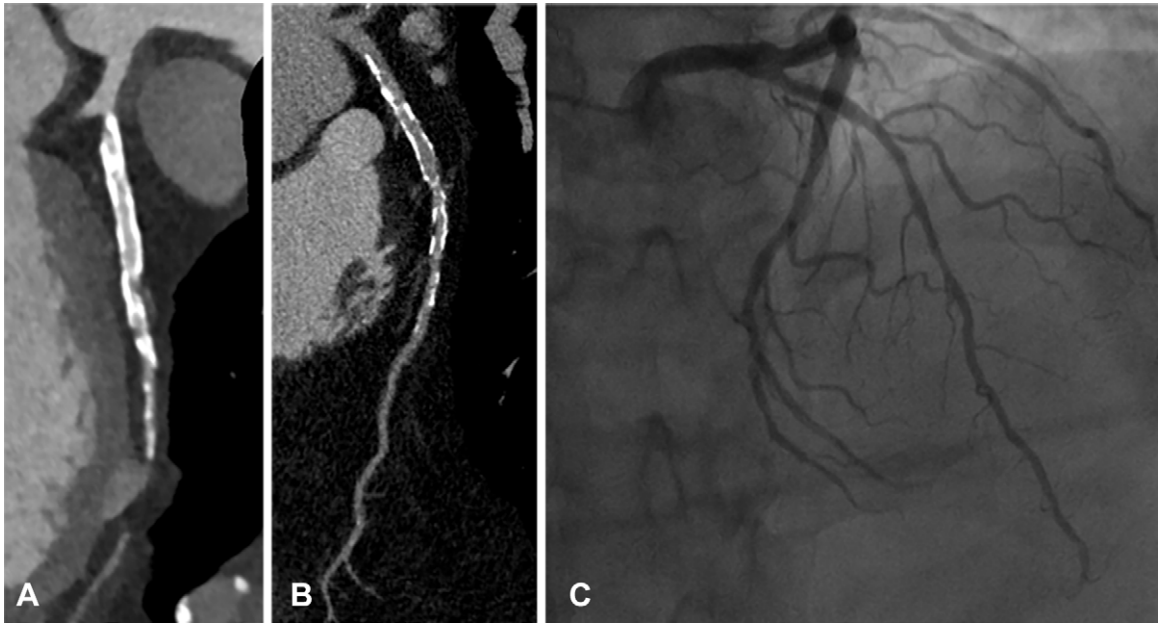
Kirsten Boedeker. Brochure du constructeur CANON du système Aquilion Precision UHR CT



Takagi et al. Eur J Radiol. 2018

Measurement of accuracy	Per-patient level (n = 38)	Per-vessel level (n = 113)	Per-segment level (n = 540)
True positive	32 (84)	49 (43)	62 (11)
True negative	4 (11)	50 (44)	458 (85)
False positive	2 (5)	12 (11)	17 (3)
False negative	0 (0)	2 (2)	3 (1)
% Sensitivity	100 (95–100)	96 (89–99)	95 (89–98)
% Specificity	67 (38–67)	81 (75–83)	96 (96–97)
% NPV	100 (57–100)	96 (89–99)	99 (98–100)
% PPV	94 (89–94)	80 (74–83)	79 (73–81)
% Accuracy	95 (86–95)	88 (81–90)	96 (95–97)
AUC	0.83 (0.53–0.96)	0.88 (0.81–0.93)	0.96 (0.92–0.98)

Takagi et al. Eur J Radiol. 2018



Latina et al. Radiology. 2021

Table 3: Comparison of Stenosis Assessment by UHR-CT and Invasive Coronary Angiography on Vessel-level Analysis

UHR-CT Stenosis Assessment	Invasive Angiography Stenosis Assessment				
	<30%	30%–49%	50%–69%	≥70%	Total
<30%	18*	5	0	0	23
30%–49%	17	4*	3	1	25
50%–69%	1	2	6*	2	11
≥70%	0	4	4	19*	27
Total	36	15	13	22	86

Note.—Tabulated are the maximum coronary arterial lumen stenoses for the left main coronary artery, left anterior descending artery, left circumflex coronary artery, and right coronary artery for each patient using visual assessment with CT and with invasive angiography (n = 36).
*Agreement between the two modalities.

Se: 86% (95% CI: 65%, 97%)
Sp: 88% (95% CI: 77%, 95%) vs 56% dans CORE-64

Latina et al. Radiology. 2021, Arbab-Zadeh A et al.J Am Coll Cardiol 2012

Table 5
Radiation exposure for coronary computed tomography angiography (CCTA).

	Overall	Prospective ECG gating		Retrospective ECG gating (n = 1)
		35–80% RR interval (n = 6)	65–80% RR interval (n = 31)	
$CTDI_{vol}$, mGy	27 (14–78)	64 ± 12	27 ± 7	55
DLP, mGy cm	388 (208–1286)	925 ± 223	389 ± 93	802
Effective radiation dose, mSv	5.4 (2.9–18.0)	12.9 ± 3.1	5.4 ± 1.3	11.2

Collimation de 128 X 0.25

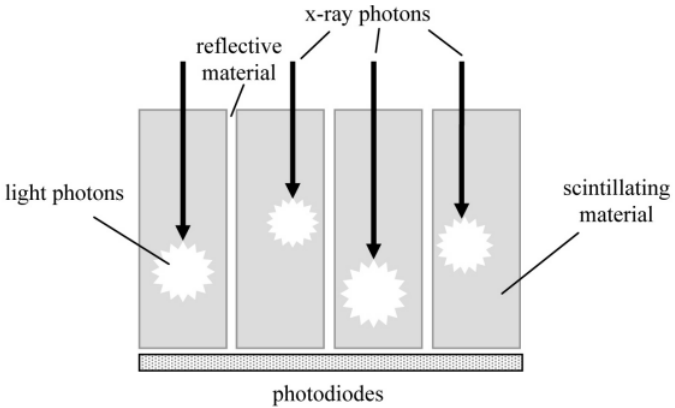
Takagi et al. Eur J Radiol. 2018

Mode prospectif 70-99%

Total CTDI (mGy)	146.4 (7.7)
Total DLP (mGy · cm)	678.5 (100.5)
Total effective radiation dose (mSv)‡	11.4 (2.5)

Collimation de 160 X 0.25

Latina et al. Radiology. 2021



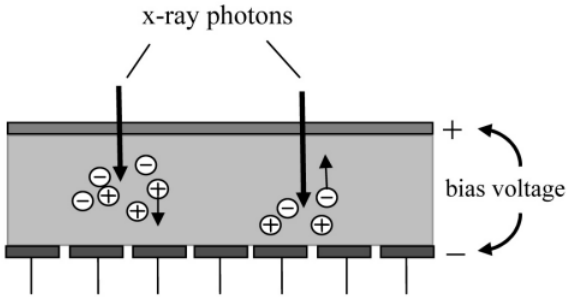


Figure 6.14 Schematic diagram of a semiconductor direct-conversion detector.

Détecteurs à intégration

Détecteurs à comptage photonique

Détecteurs à intégration

Détecteurs à comptage photonique

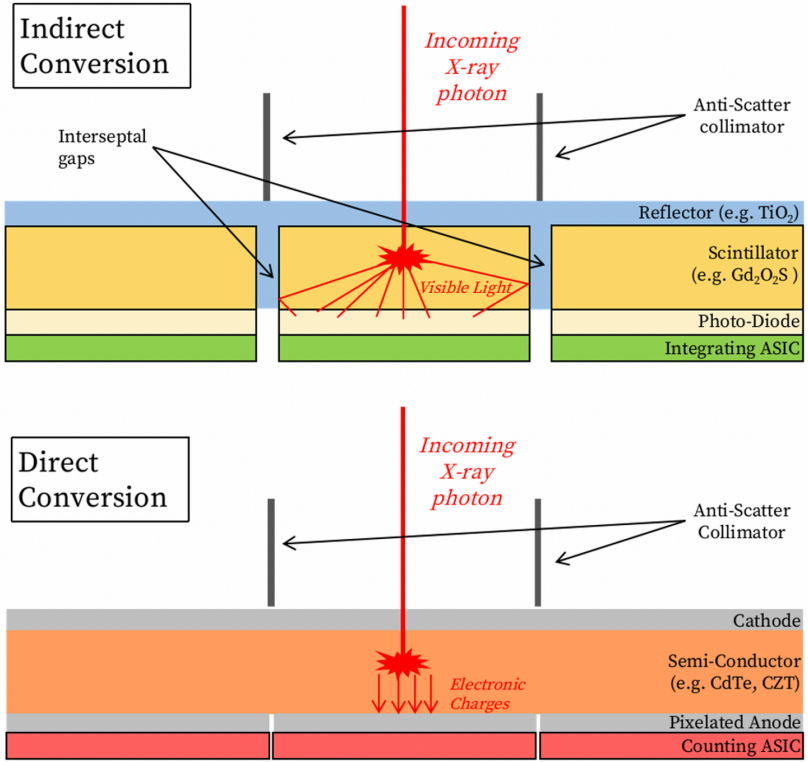
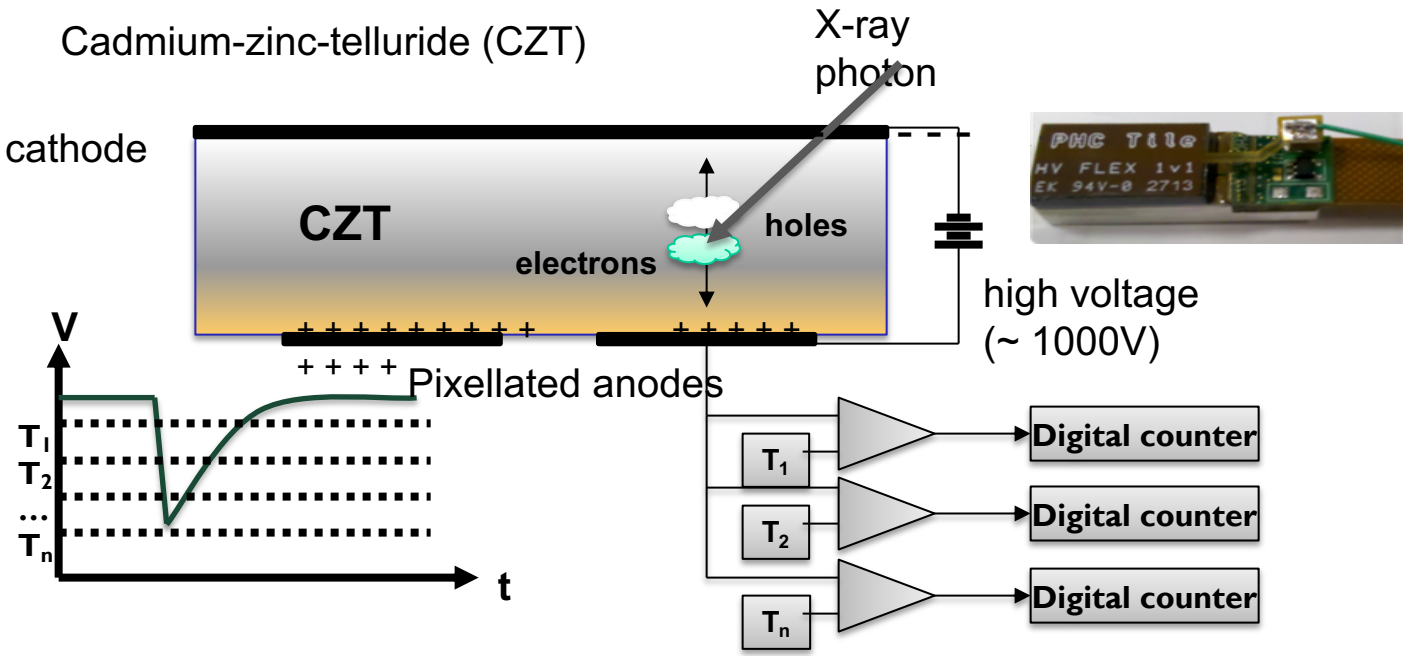
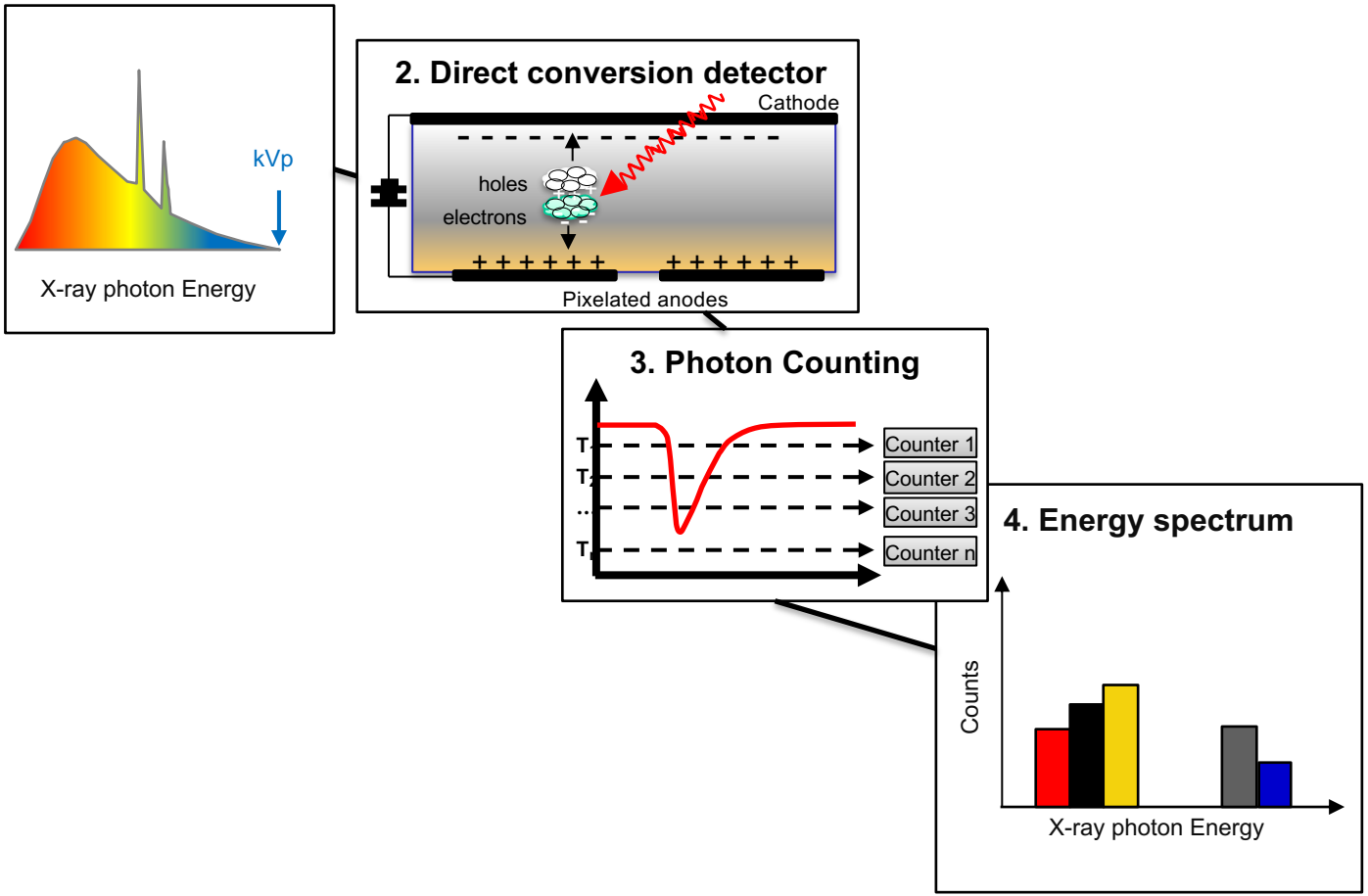


Figure 1: Schemes of each photon detection technologies: Photon-Counting (top) and Energy-Integrating (bottom).

S-Mohamed et al. Review: Spectral Photon-Counting CT technology in Chest Imaging. In revision. JCM ***2021***


Cadmium-zinc-telluride (CZT)
X-ray
photon
cathode
CZT
holes
electrons
high voltage
(~ 1000V)
Pixellated anodes
V
T_1
T_2
...
T_n
t
T_1
T_2
T_n
Digital counter
Digital counter
Digital counter



*S Si-Mohamed et al. DII. **2021***

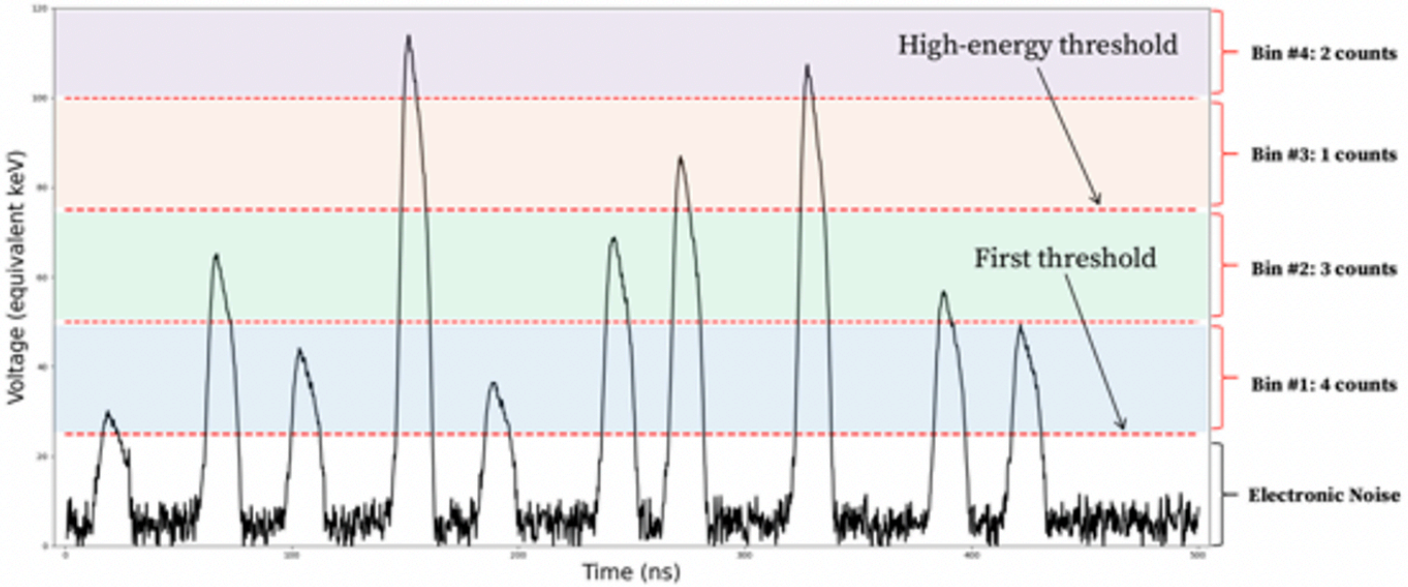
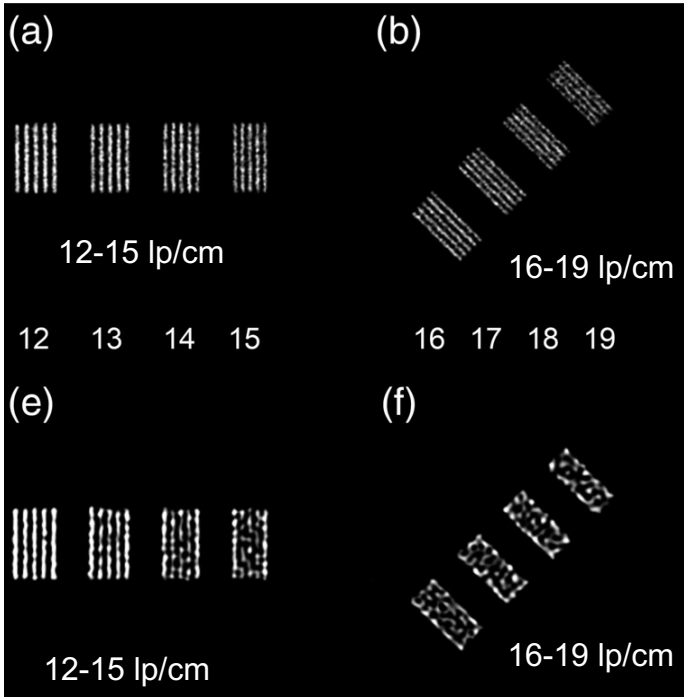


Figure 2. Example of a 500ns signal output of a PCD pixel.

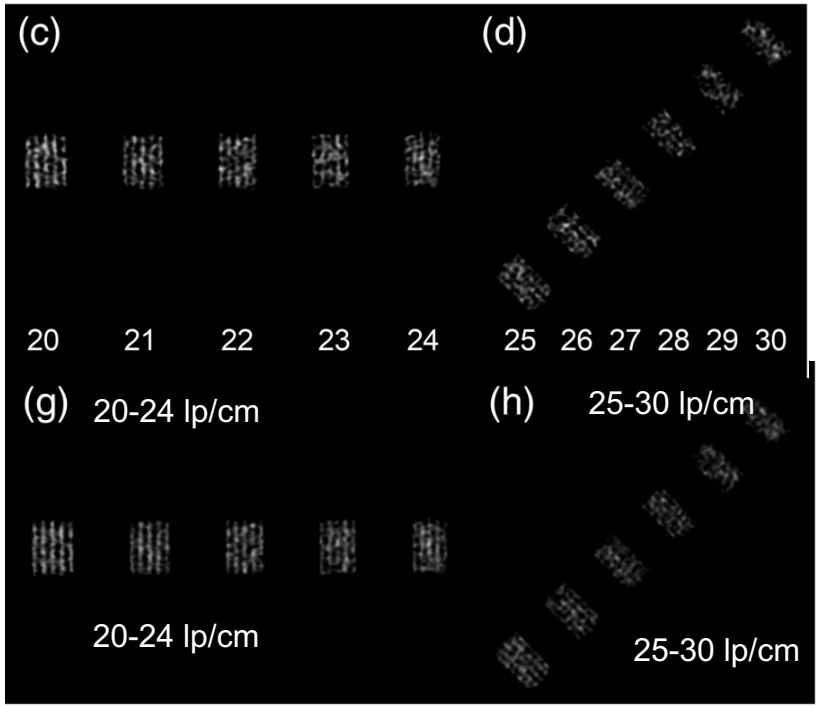
PCCT

EID-CT

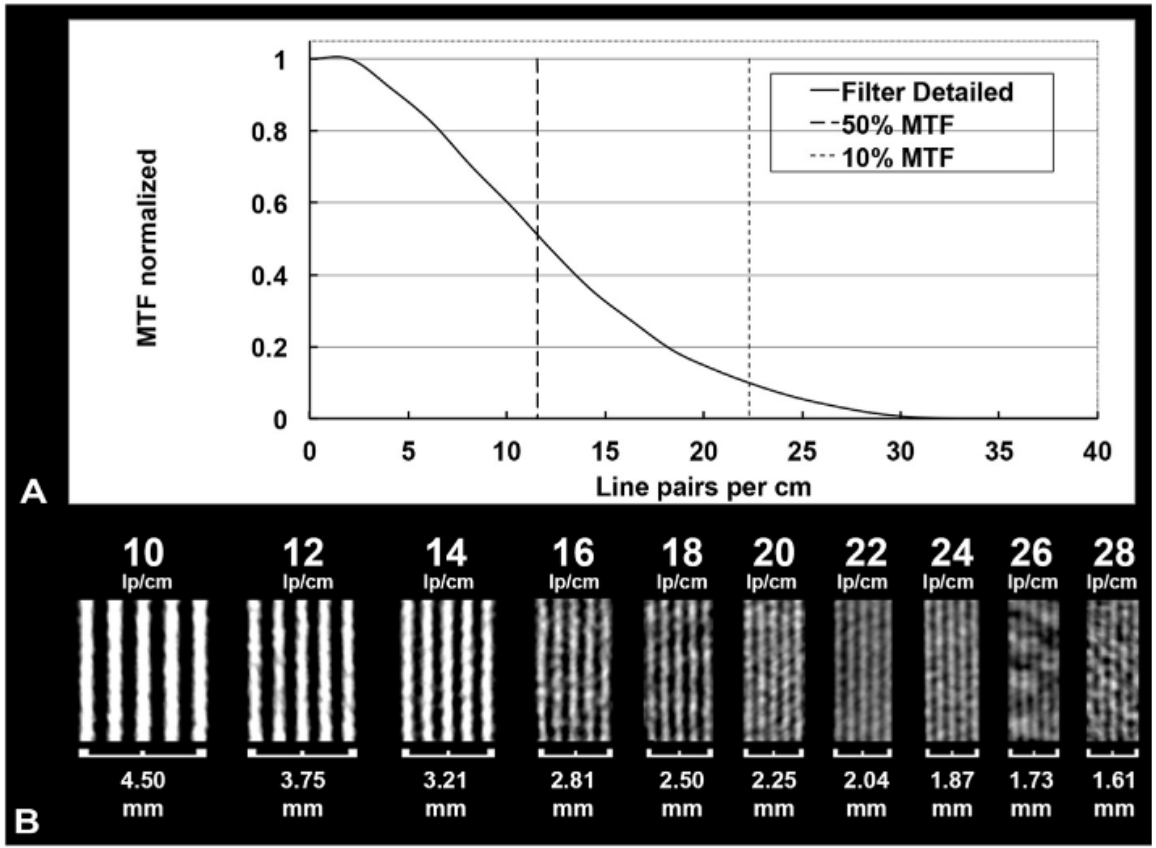


PCCT

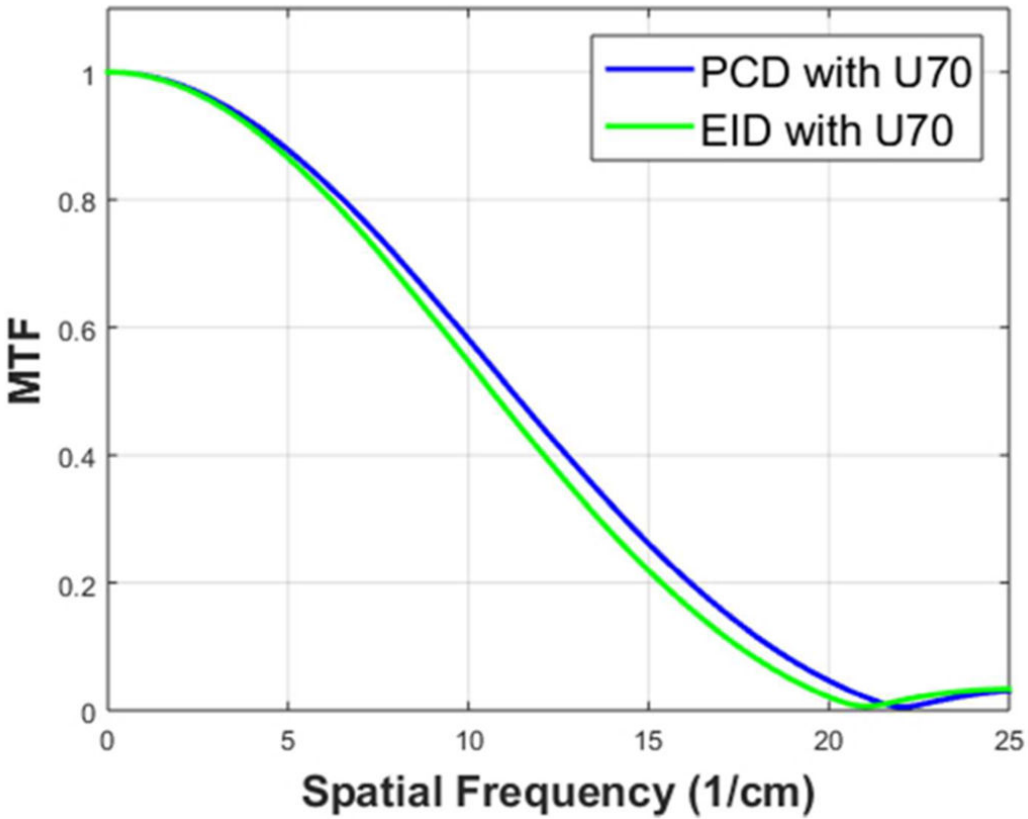
PCCT
Half-dose



Da Silva et al. Journal of Medical Imaging. 2019

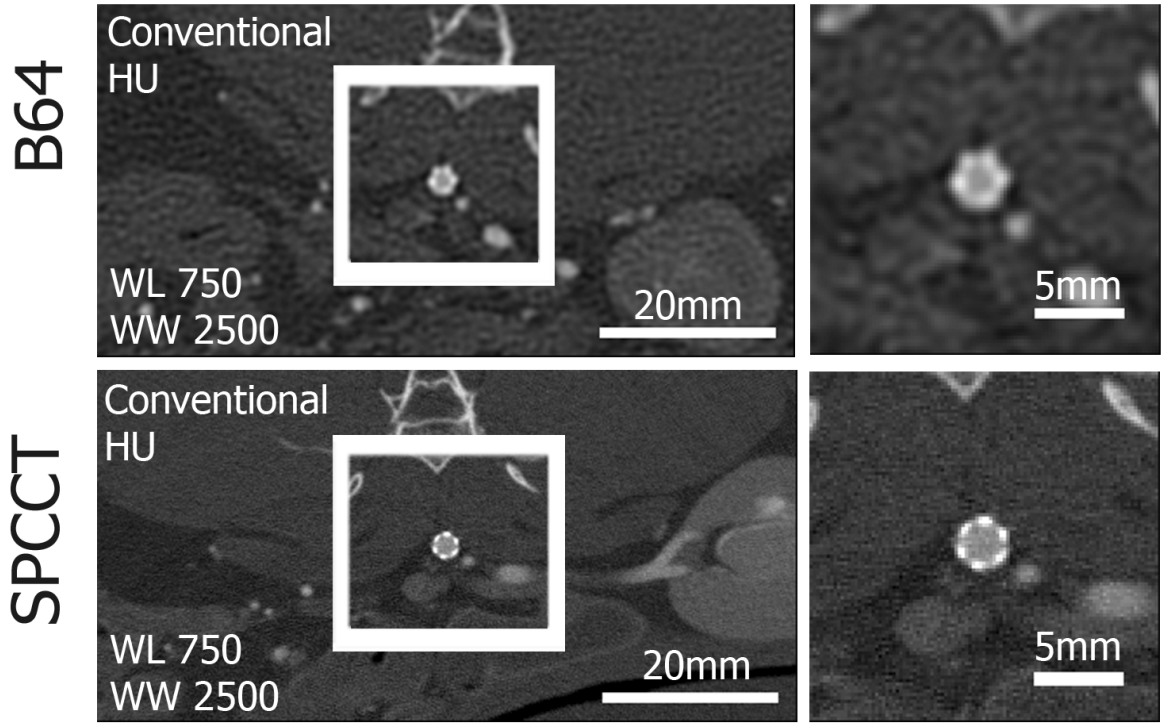


Si-Mohamed et al. DIII. 2021



Zhou et al. AJNR. 2019

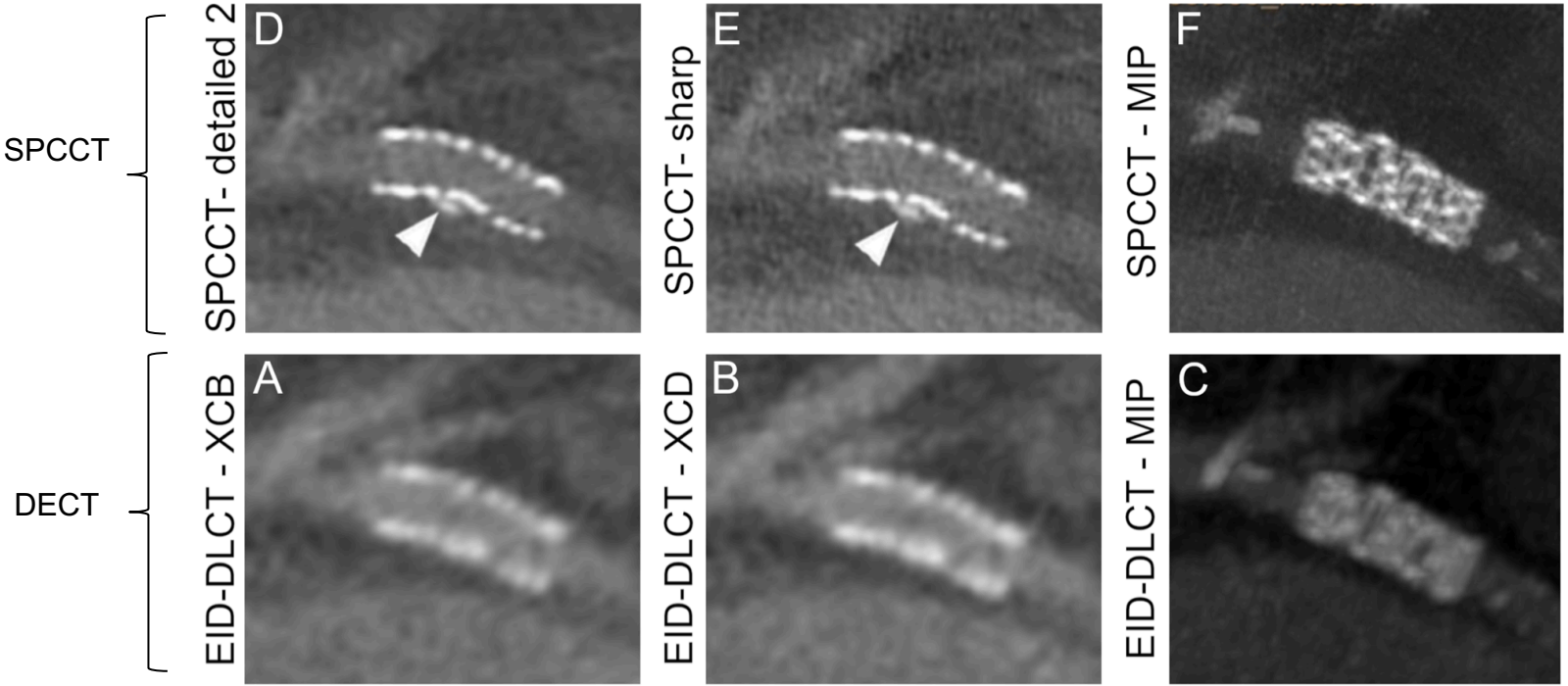
Imagerie du stent coronarien



Sigovan and Si-Mohamed et al. Sci Rep. 2019

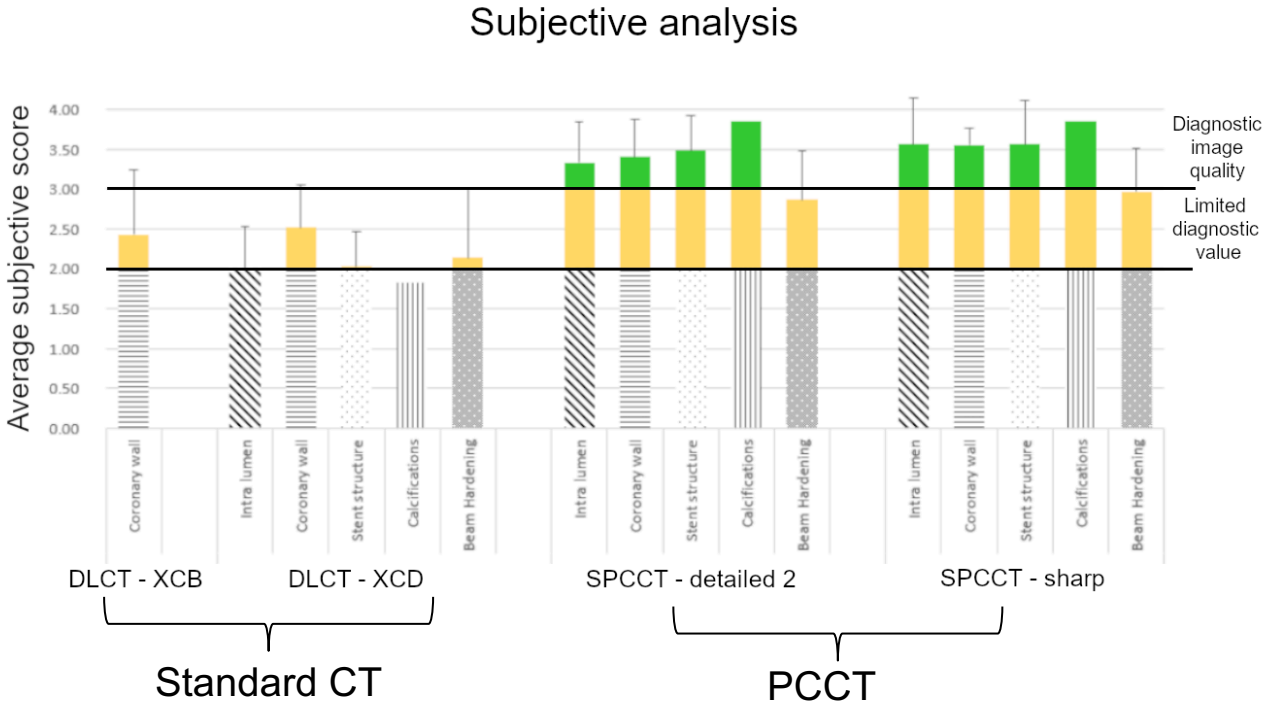
Imagerie du stent coronarien

H 71 ans, contrôle de stent (*synergy 3.5x 12 mm)*



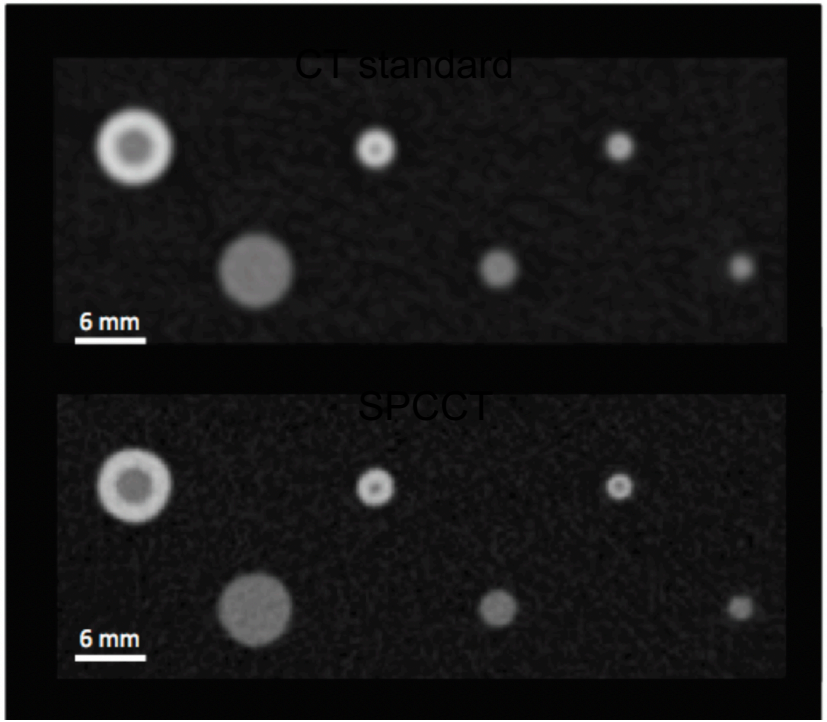
Boccalini S and Si-Mohamed S et al. Accepted in Investigative Radiology ***2021***

Imagerie du stent coronarien



Boccalini S and Si-Mohamed S et al. Accepted in Investigative Radiology ***2021***

Imagerie des sténoses coronariennes

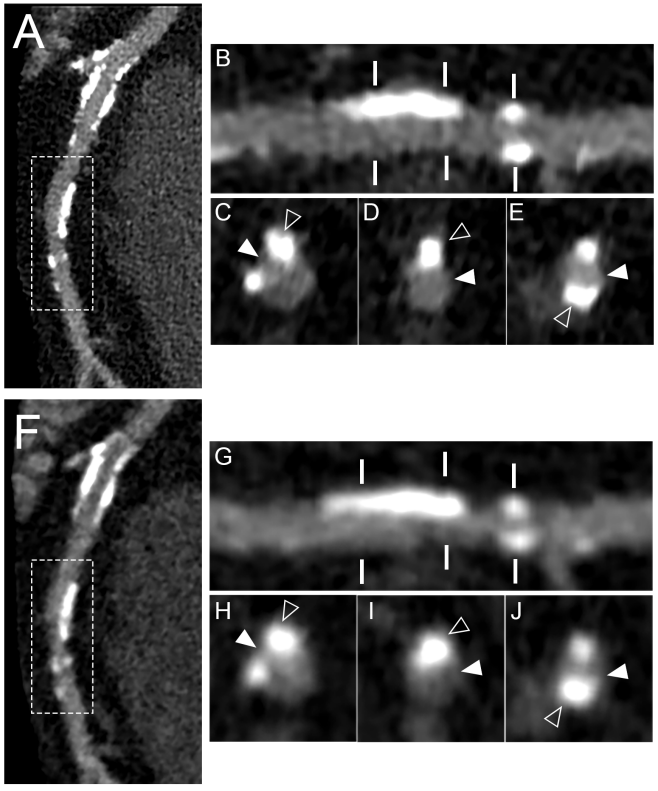


Si-Mohamed, S, L. Boussel, et P. Douek. « Clinical applications of spectral photon-counting CT ». In *Spectral, Photon Counting Computed Tomography: Technology and Applications*, CRC Press., **2020.**

Imagerie des sténoses coronariennes

SPCCT

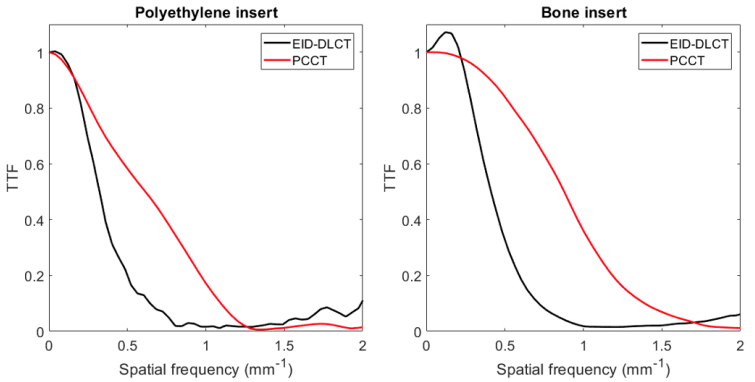
DECT



		PCCT	EID-DLCT	p
Diameter (mm)				
External	Reader 1	4.1 (1.9)	4.5 (2.0)	<.001
	Reader 2	4.1 (1.9)	4.5 (2.1)	<.001
Internal (lumen)	Reader 1	2.5 (1.5)	2.1 (1.6)	<.001
	Reader 2	2.3 (1.4)	2.1 (1.6)	<.01
Blooming (%)	Reader 1	36.4 (22.5)	48.4 (28.7)	<.001
	Reader 2	39.3 (22.3)	47.1 (28.5)	<.001

Si-Mohamed and Boccalini et al. Radiology. En révision. ***2021***

Imagerie de la plaque coronarienne



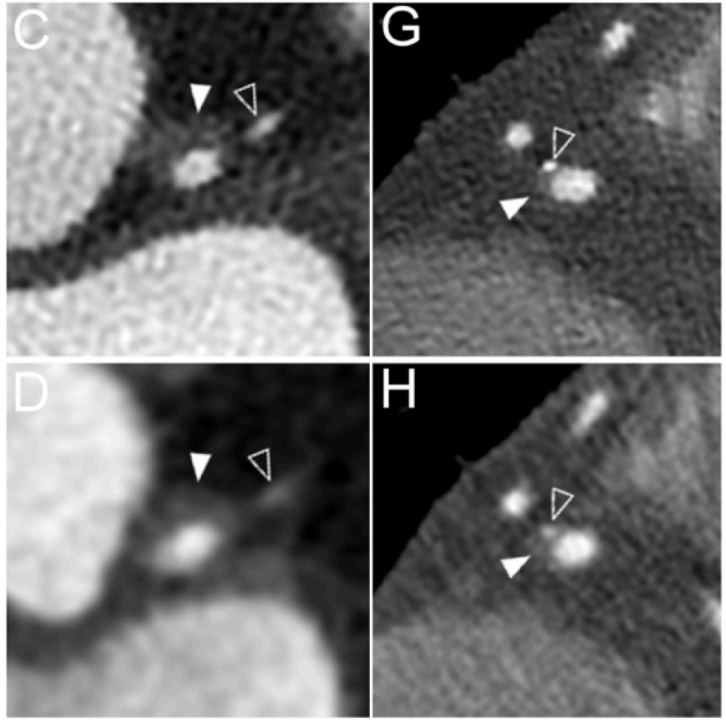
		PCCT	EID-DLCT
Detectability Index (d')	d' 350 HU - 4 mm	41.78 ± 1.44	18.38 ± 0.36
	d' 40 HU - 2 mm	2.64 ± 0.06	0.92 ± 0.02

F, 40 ans, MINOCA

H 69 ans, syndrome coronarien stable

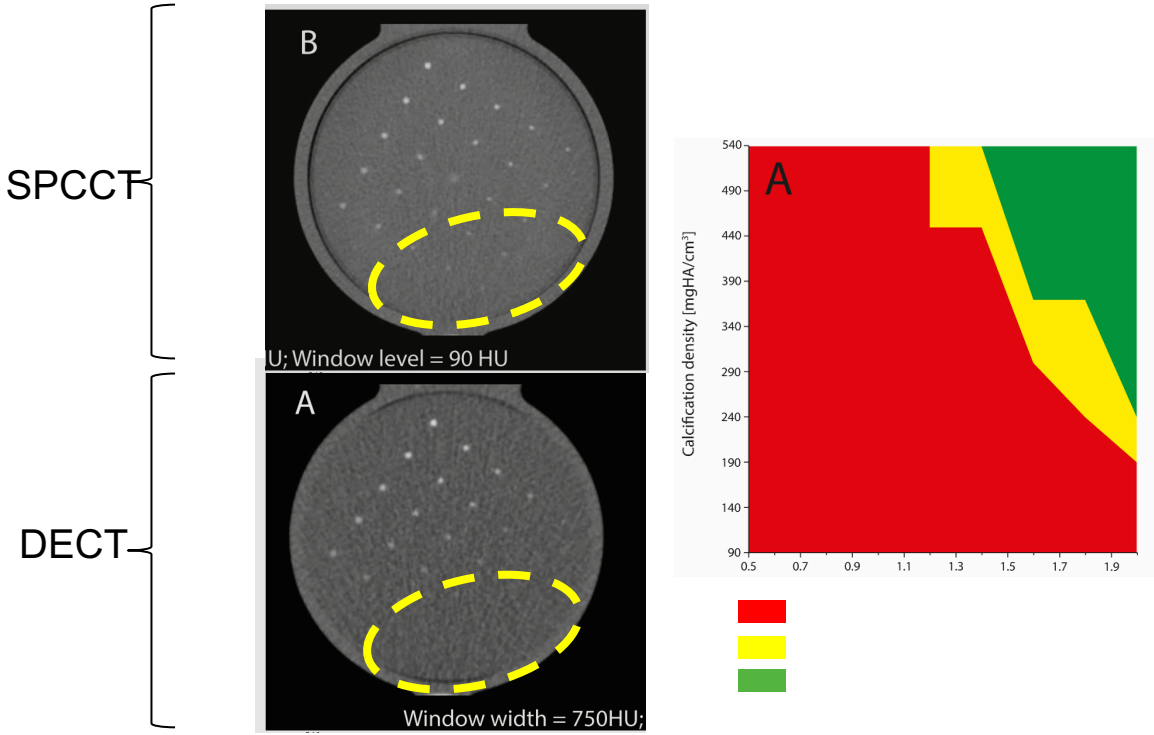
SPCCT

DECT



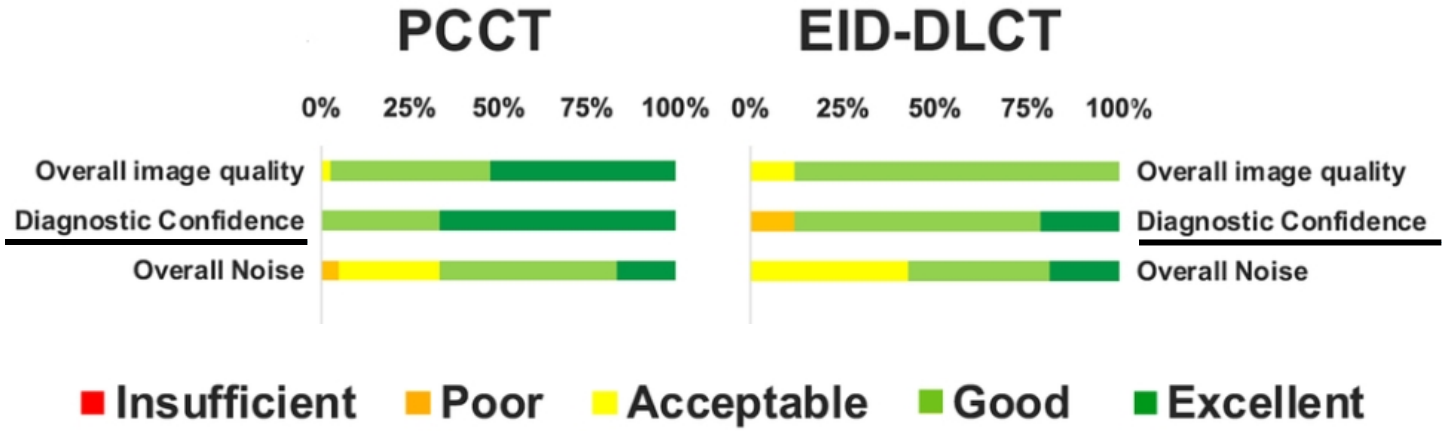
Si-Mohamed and Boccalini et al. Radiology. En révision. ***2021***

Imagerie des calcifications coronariennes

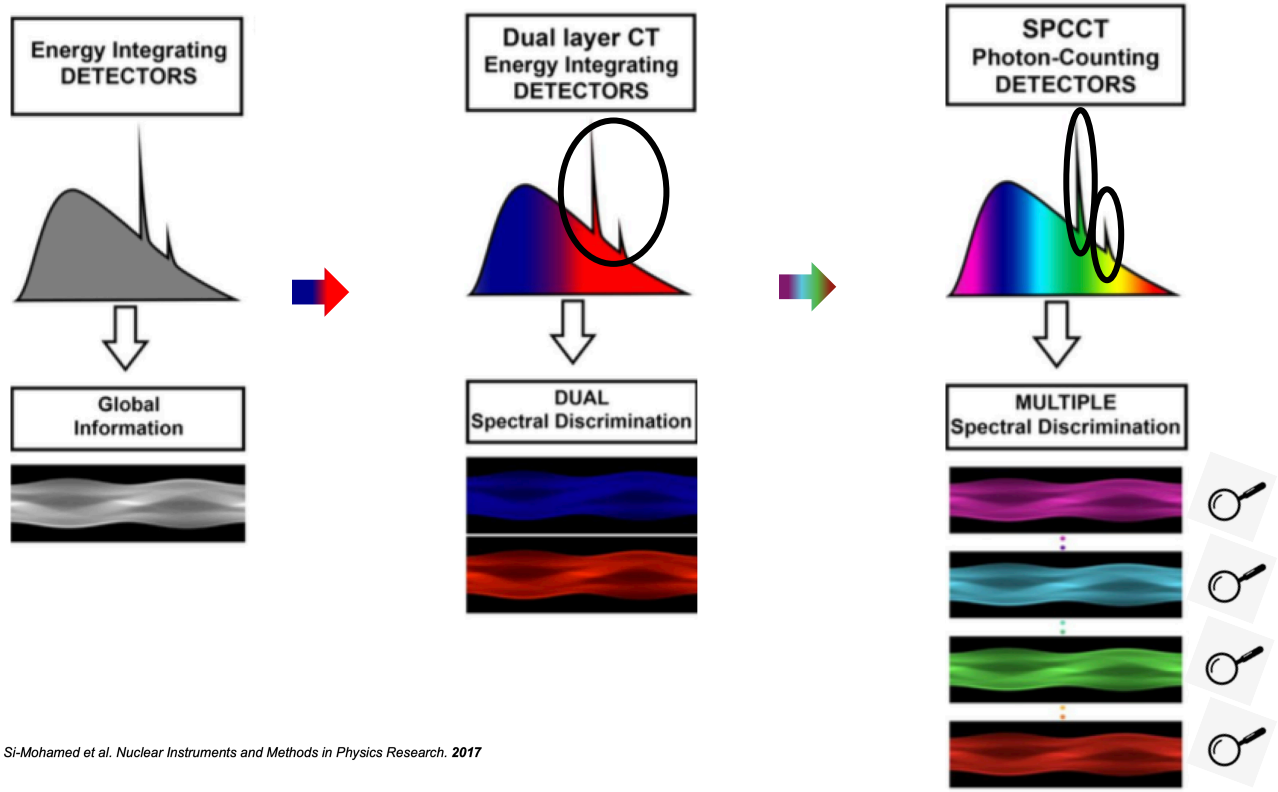


van der Werf and Si-Mohamed et al. Eur Radiol. ***2021***

Imagerie cardiaque

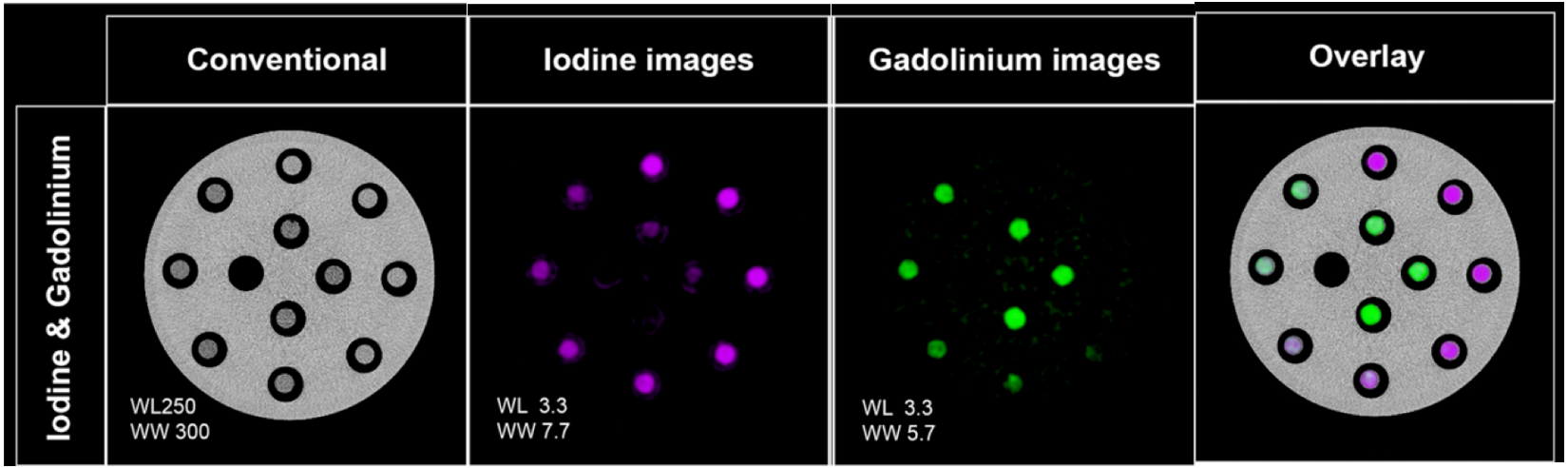


Si-Mohamed and Boccalini et al. Radiology. En révision. ***2021***



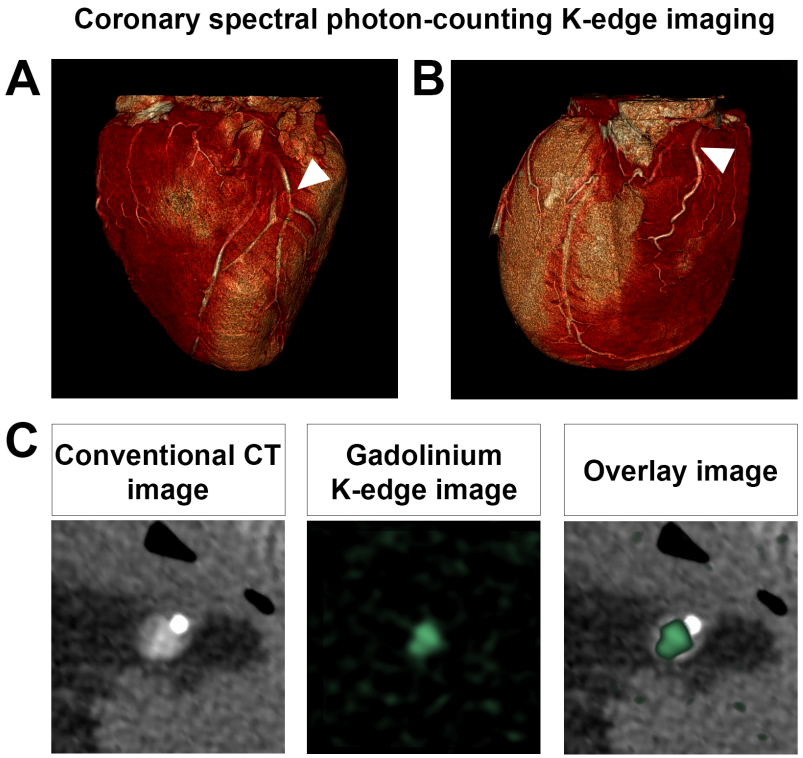
S Si-Mohamed et al. Nuclear Instruments and Methods in Physics Research. ***2017***

Imagerie multicouleur



Si-Mohamed et al. Eur Rad Exp. ***2018***

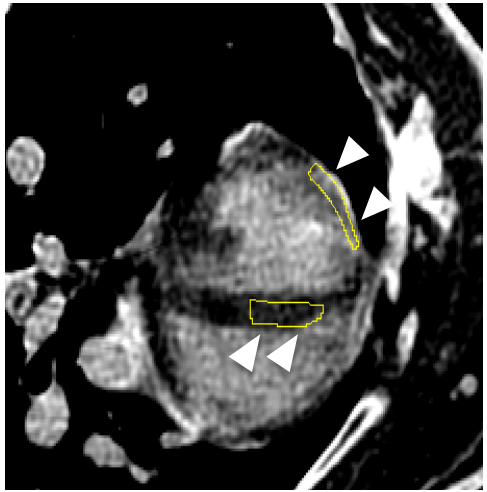
Imagerie coronarienne K-edge



Si-Mohamed et al. RSNA. Poster. ***2017***

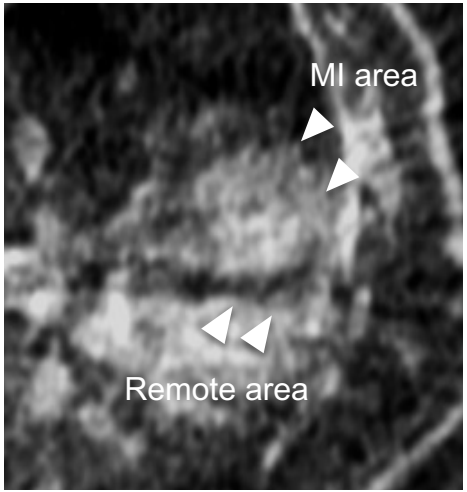
Imagerie monocouleur du volume extracellulaire spécifique et quantitative

HU images



Infarcted zone: 384.1±53 HU
Non infarcted zone: 233.6±36.5 mg/ml

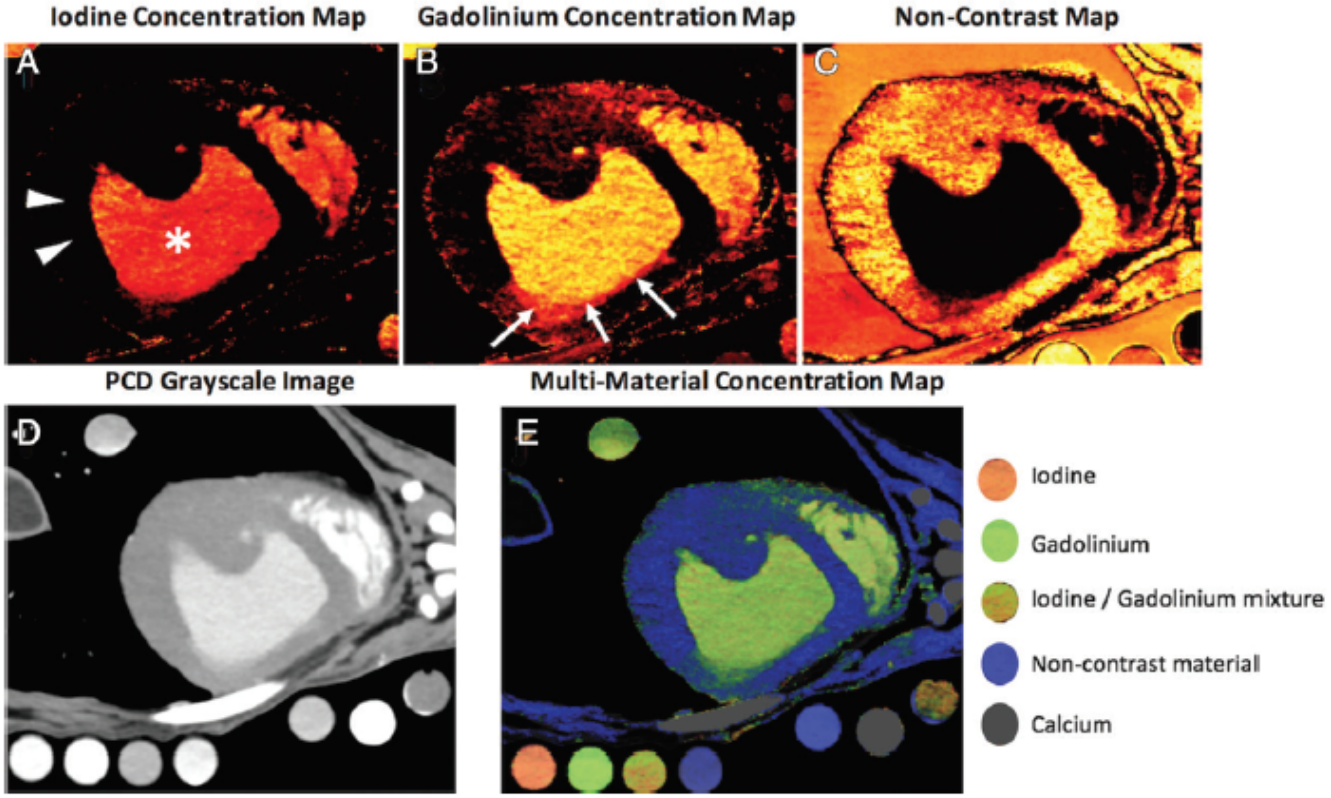
Gd K-edge images



Infarcted zone: 8.53±1.66 mg/ml
Non infarcted zone: 4.9±1.56 mg/ml

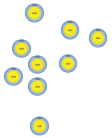
Si-Mohamed, S, L. Boussel, et P. Douek. « Clinical applications of spectral photon-counting CT ». In *Spectral, Photon Counting Computed Tomography: Technology and Applications*, CRC Press., 97-116. Devices, circuits, and systems, **2020.**

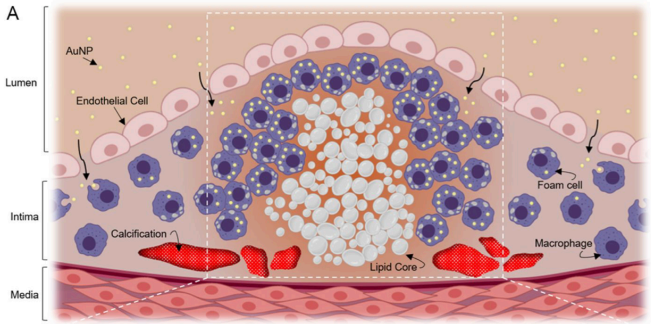
Imagerie multicouleur du volume extracellulaire spécifique et quantitative

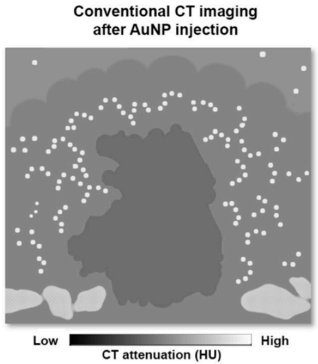


Symons R, et al. Int J Cardiovasc Imaging 2017

Imagerie moléculaire de la plaque d'athérosclérose coronarienne

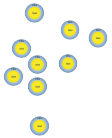


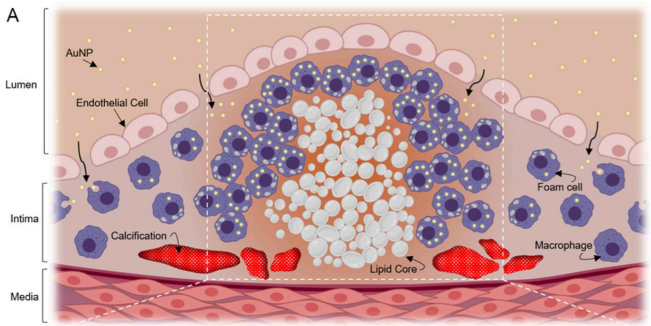


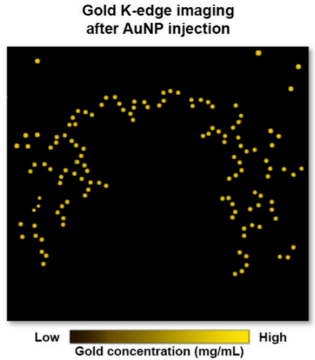


Si-Mohamed et al. Radiology. ***2021***

Imagerie moléculaire de la plaque d'athérosclérose coronarienne







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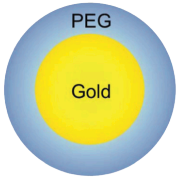
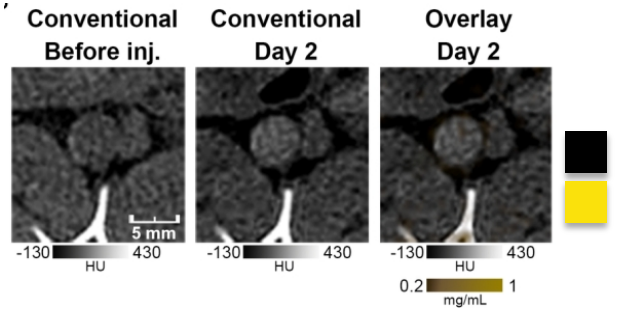
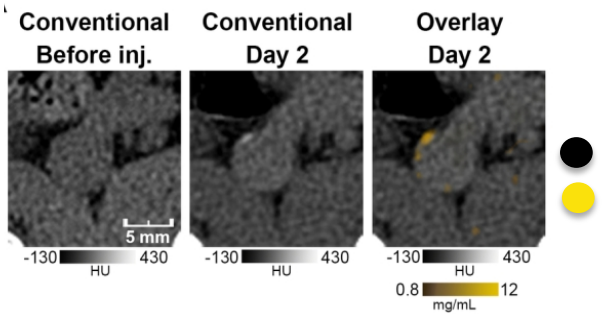
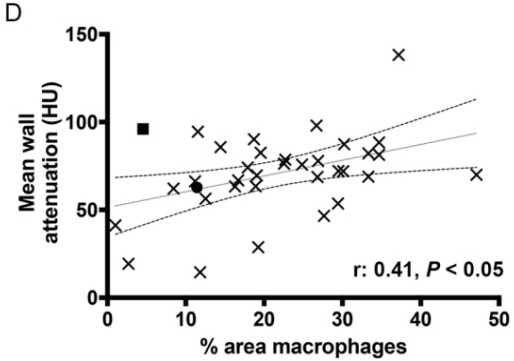
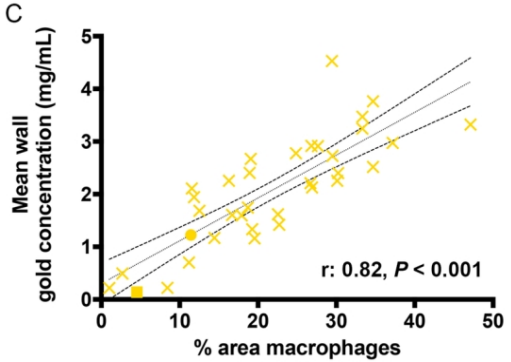
Imagerie moléculaire de la plaque d'athérosclérose coronarienne





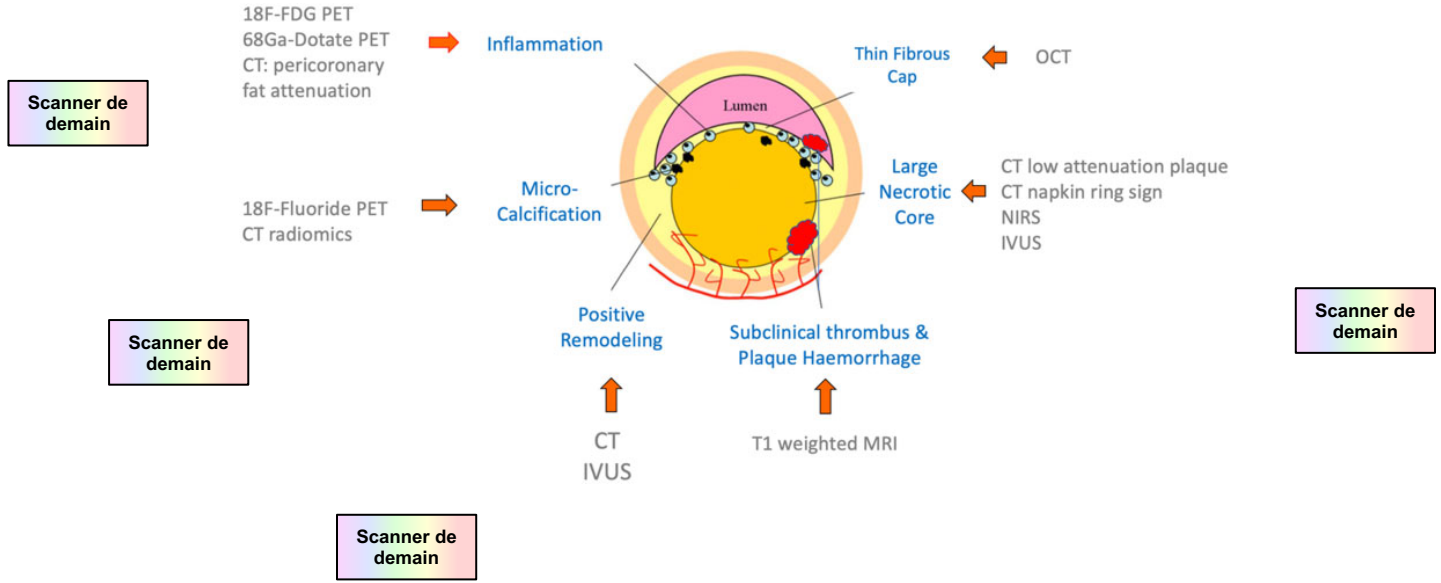






Si-Mohamed et al. Radiology. ***2021***

HR et Comptage photonique : SCANNER CARDIAQUE DE DEMAIN ?



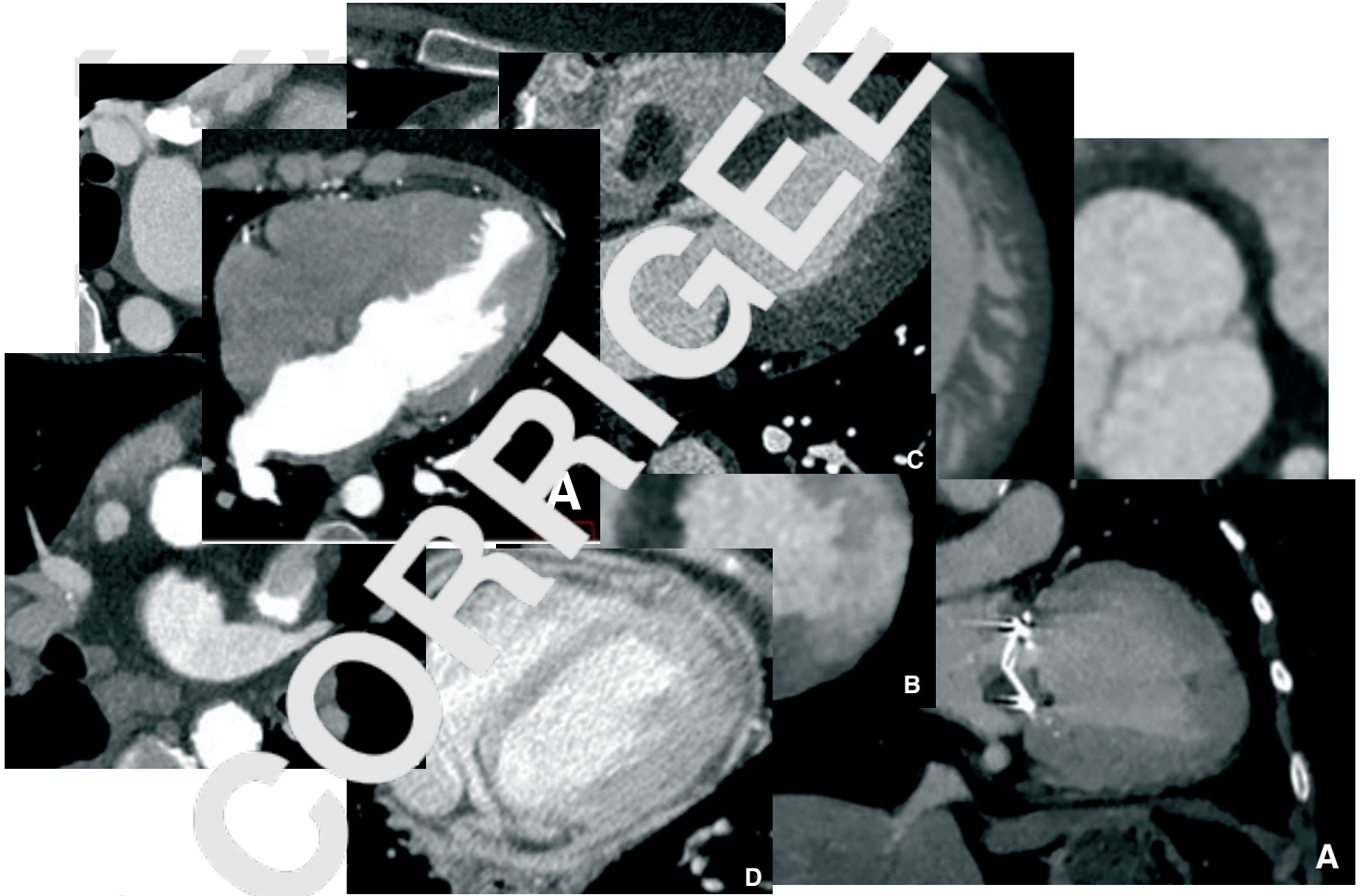
Evaluation morphologique

- Lumière
- Plaque

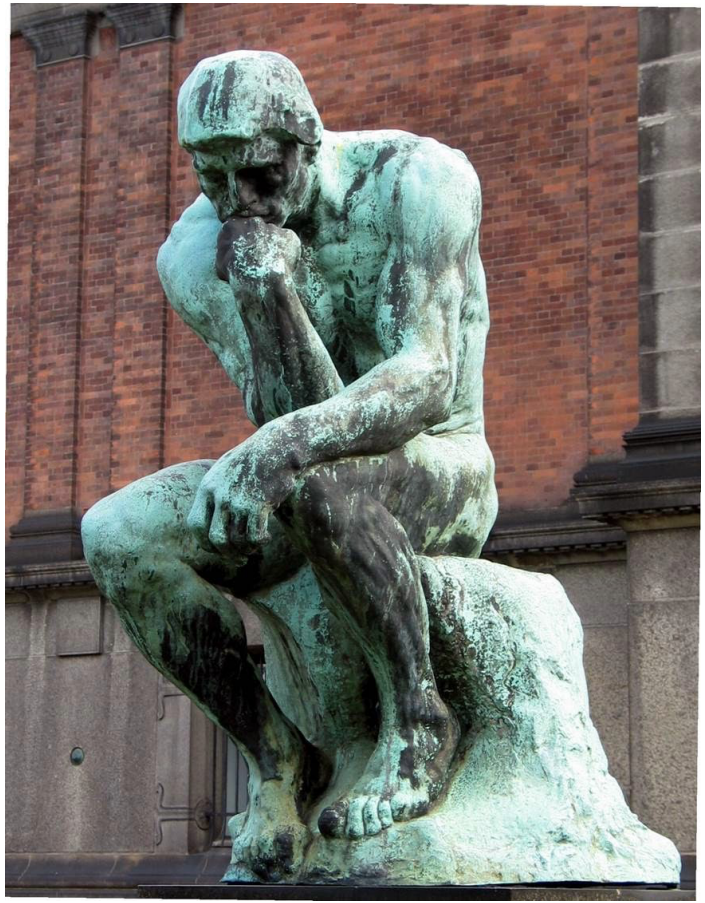
Evaluation fonctionnelle

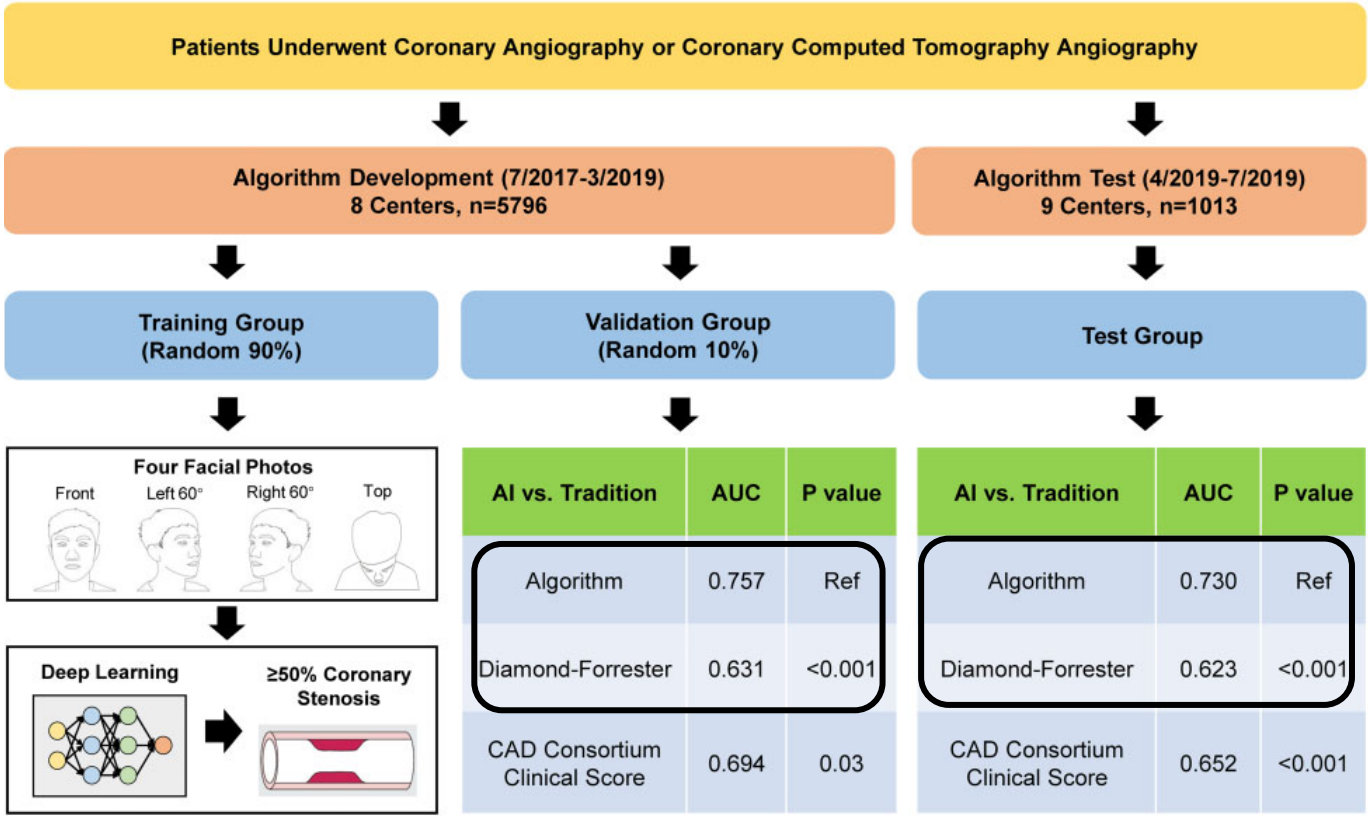
- Imagerie de l'inflammation spécifique et quantitative

Dweck et al. Eur Heart J. ***2020***



Si-Mohamed et al. Tomodensitométrie du cœur. EMC cardiologie. 2021

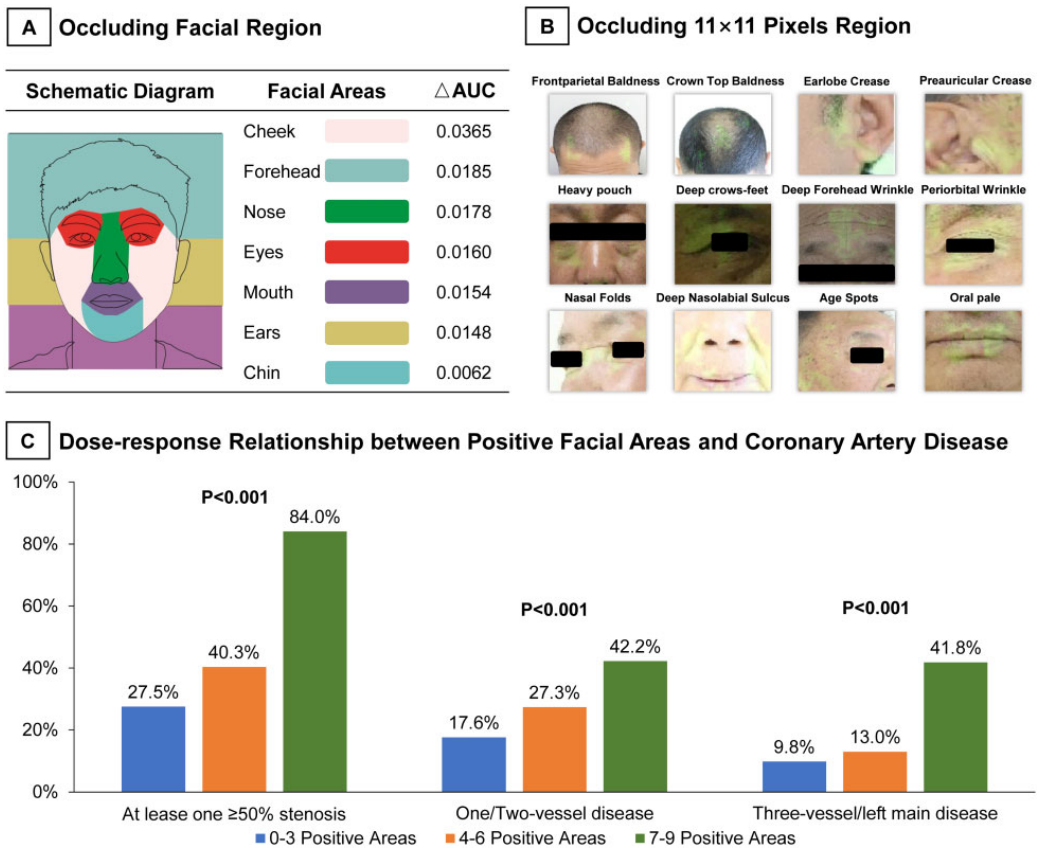




AI vs. Tradition	AUC	P value
Algorithm	0.757	Ref
Diamond-Forrester	0.631	<0.001
CAD Consortium Clinical Score	0.694	0.03

AI vs. Tradition	AUC	P value
Algorithm	0.730	Ref
Diamond-Forrester	0.623	<0.001
CAD Consortium Clinical Score	0.652	<0.001

Lin et al. European Heart Journal. 2020



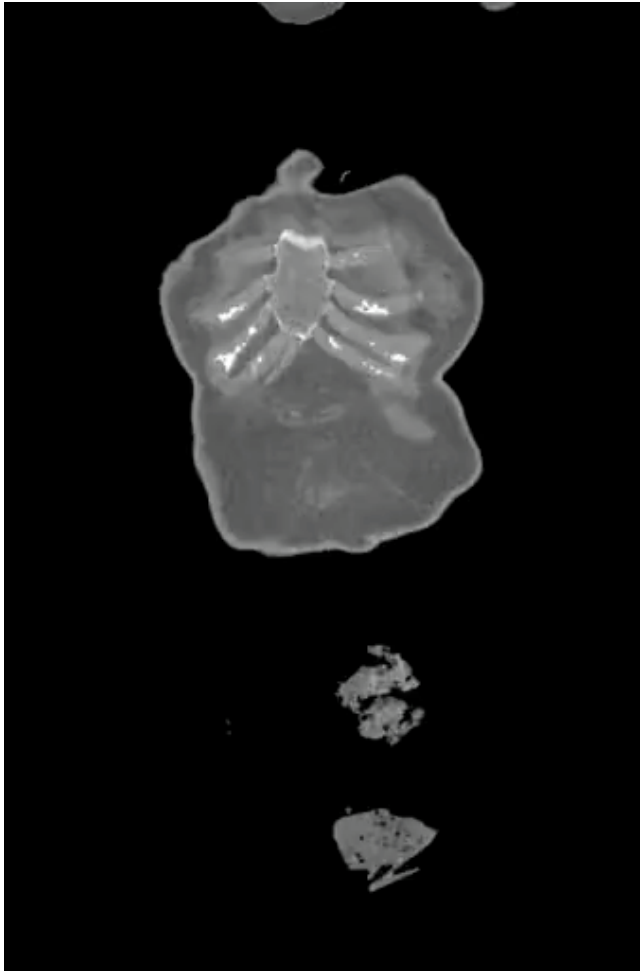
Lin et al. European Heart Journal. 2020

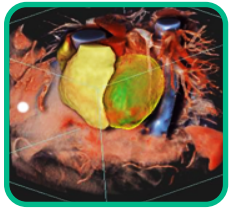
Quizz

His score is 133, and anything over 100 indicates plaque is present and that the patient has heart disease. According to Trump's official medical records, in 2009 his coronary calcium score was 34. In 2013, it was 98.

Most people might have not heard of this test, also

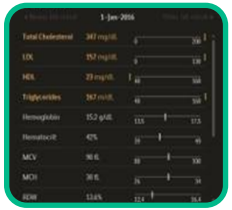
Sténose coronarienne ?





Automatic segmentation

- Main organs and vessels
- Robust to protocol (contrast, FOV, kernel…)
- Spectral dedicated tools



Biomarkers extraction

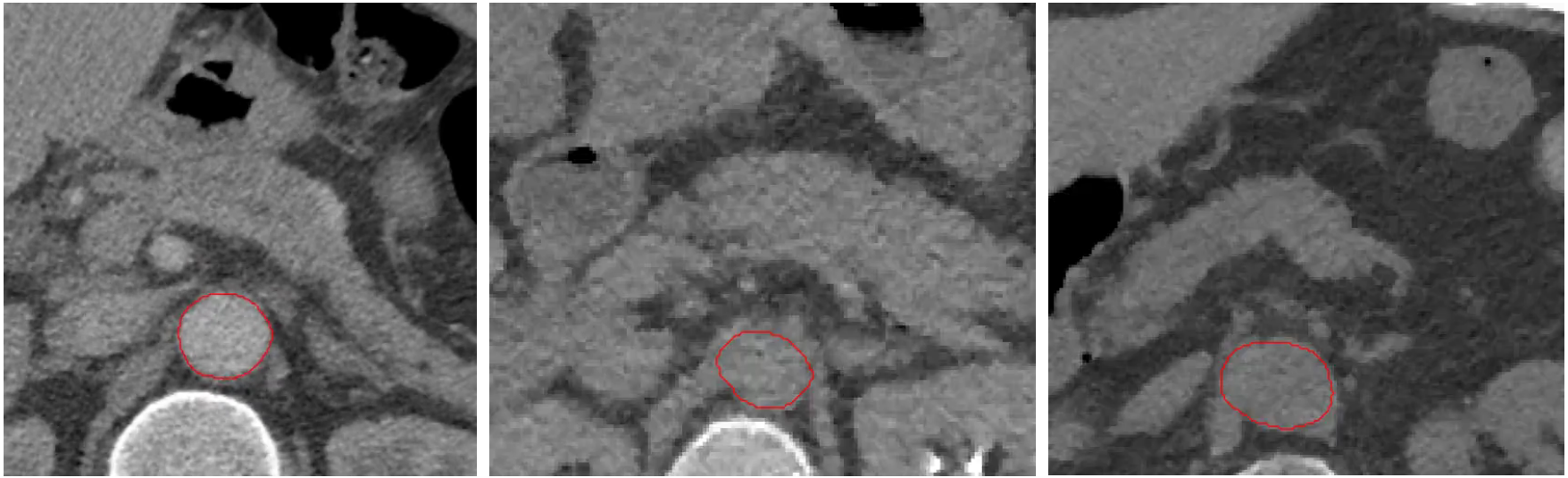
- Volumes: cardiac chambers, lungs, liver…
- Vessels diameters
- Lungs kurtosis, skewness…

…

Patient characterization

- Identify abnormal measurements : SPECTRAL ALERTS
- Predict risk
- Augment patient record

Hospices Civils de Lyon, Philips Research



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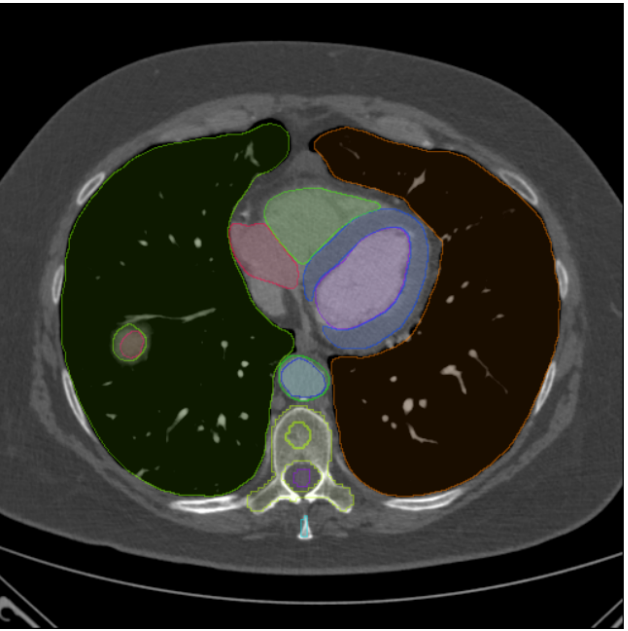
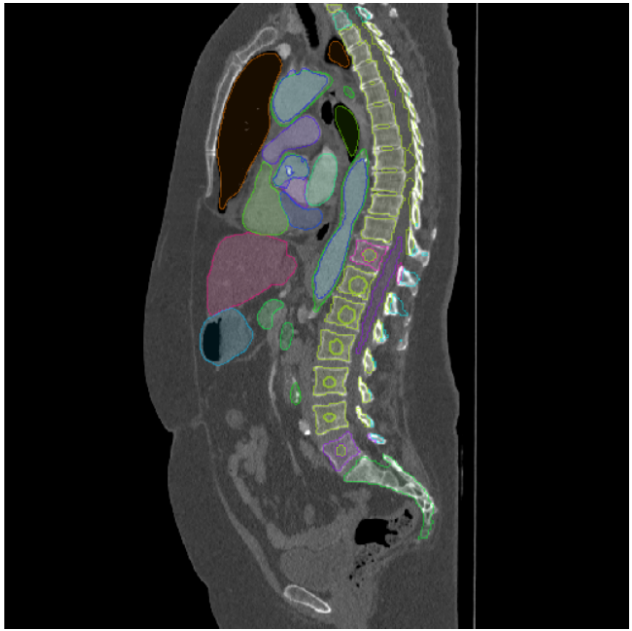
Segmentation multi-organes





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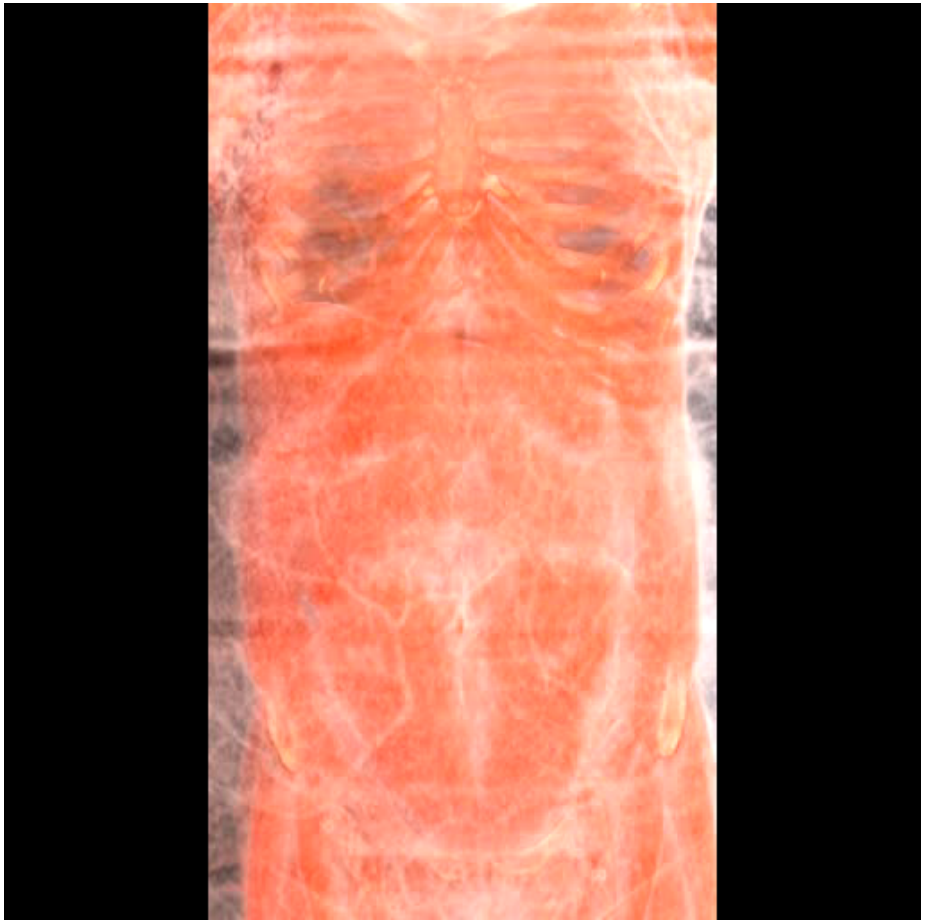
Report with Chest CT Biomarkers				
Cardiac	Left Ventricle	Volume	**67mL**	
	Left Atrium	Volume	**45mL**	
	Right Ventricle	Volume	**84mL**	
	Right Atrium	Volume	**39mL**	
Vascular	Aorta	Diameter max	**44 mm**	
		Diameter min	**15mm**	
	Pulm. Arteries	Diameter max	**27mm**	
Pulmonary	Lungs	Volume	**6.4L**	
		Emphysema	**24%**	(*)
	Left Lung	Volume	**3.1L**	
		Emphysema	**16%**	(*)
	Right Lung	Volume	**3.3L**	
		Emphysema	**32%**	
Bone Density	L1	HU	**128HU**	
		VNC	**59HU**	(*)
	Spine	HU	**130HU**	
		VNC	**62HU**	(*)
Metabolic	Liver	Density HU	**42 HU**	
		Density VNC	**37 HU**	(*)
	Spleen	Density HU	**103 HU**	
		Density VNC	**55 HU**	
	Abdominal Muscle	L3 area	**124 cm^3**	
Conclusion: Emphysema 24 % – Important Steatosis - Osteoporosis				



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PATIENT INFORMATION

Name	ChestAI_Nbg108
ID	CAINbg108
DateOfBirth	1941-01-01
Sex	M
SeriesDescription	IMPACT Thorax Insp. 1.0 I26f 3
AccessionNumber	
AcquisitionDateTime	2017-09-28 , 12:23

LESIONS	Lobe	Volume [mm³]	max. Diam. 2D [mm]	max. Diam. 3D [mm]
L1	LeftUpperLobe	320.8	11.2	13.0
L2	RightLowerLobe	159.5	9.6	9.6
L3	RightLowerLobe	120.7	8.2	8.4
L4	RightLowerLobe	67.5	8.2	8.7
L5	RightUpperLobe	99.8	7.5	9.2
Tumor Burden			52.0	

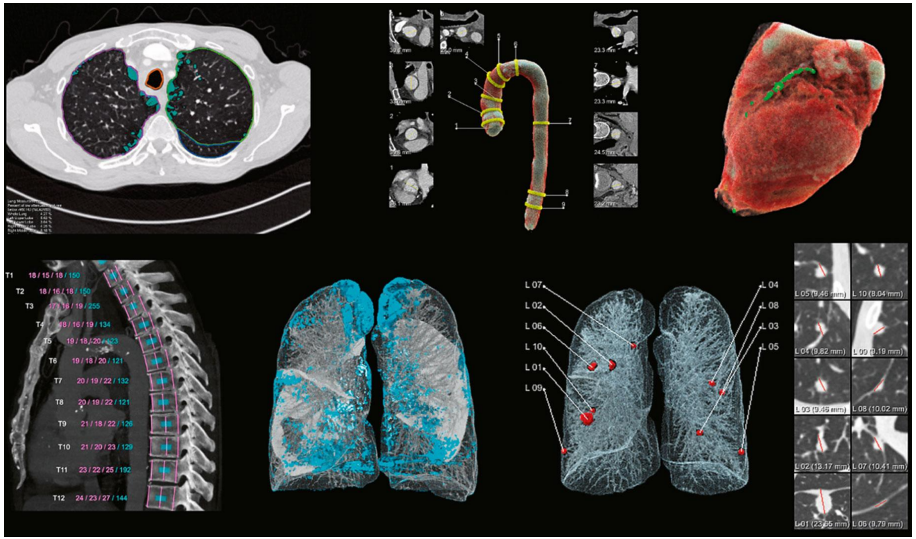
Additional lesions were detected but are not listed here.

LUNG	LAV950 [%]		LAV950 [%]
LeftUpperLobe	30.4	RightMiddleLobe	25.8
LeftLowerLobe	25.6	RightLowerLobe	27.0
RightUpperLobe	33.6	BothLungs	28.4
Lung Category		III	

HEART	
Heart volume	691.5 ml
Total Coronary Calcium Volume	257.6 mm³
Calcium Category	III

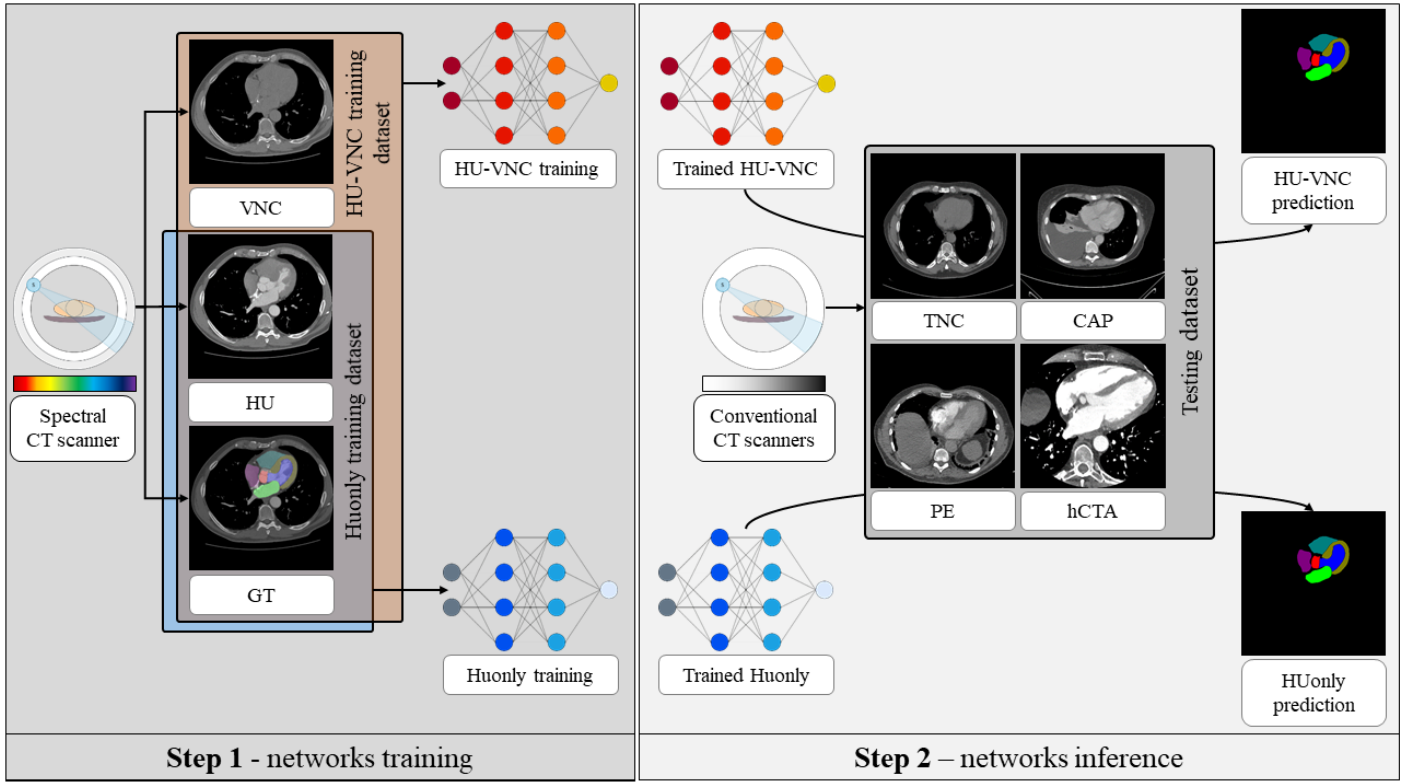
SPINE	Heights [mm] ant.	mid.	post.	Average HU		Heights [mm] ant.	mid.	post.	Average HU
T1	16	15	18	108	T7	17	18	23	109
T2	18	16	18	131	T8	19	16	22	110
T3	18	17	18	134	T9	19	18	21	85
T4	20	17	19	121	T10	20	19	23	278
T5	21	18	19	134	T11	22	21	24	94
T6	20	18	22	71	T12	22	25	26	77
Spine Category				I					

AORTA	max. Diam. [mm]		max. Diam. [mm]
1 Sin. of Vals	38	6 Prox. Desc.	33
2 Sinot. Jnct.	39	7 Mid Desc.	31
3 Mid Asc.	41	8 At Diaphr.	31
4 Prox. Arch	38	9 Abd. Aorta	29
5 Mid Arch	36		
Aorta Category	II		



AI-Rad Companion Chest CT (Siemens)

IA et données spectrales



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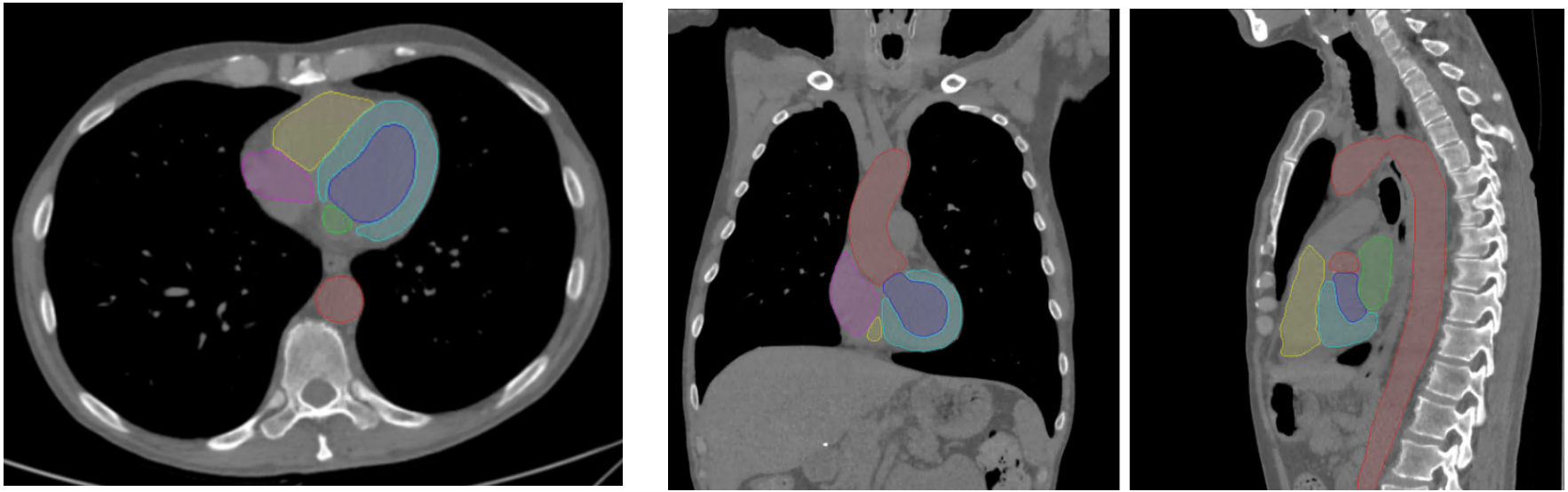
Segmentation des cavités cardiaques



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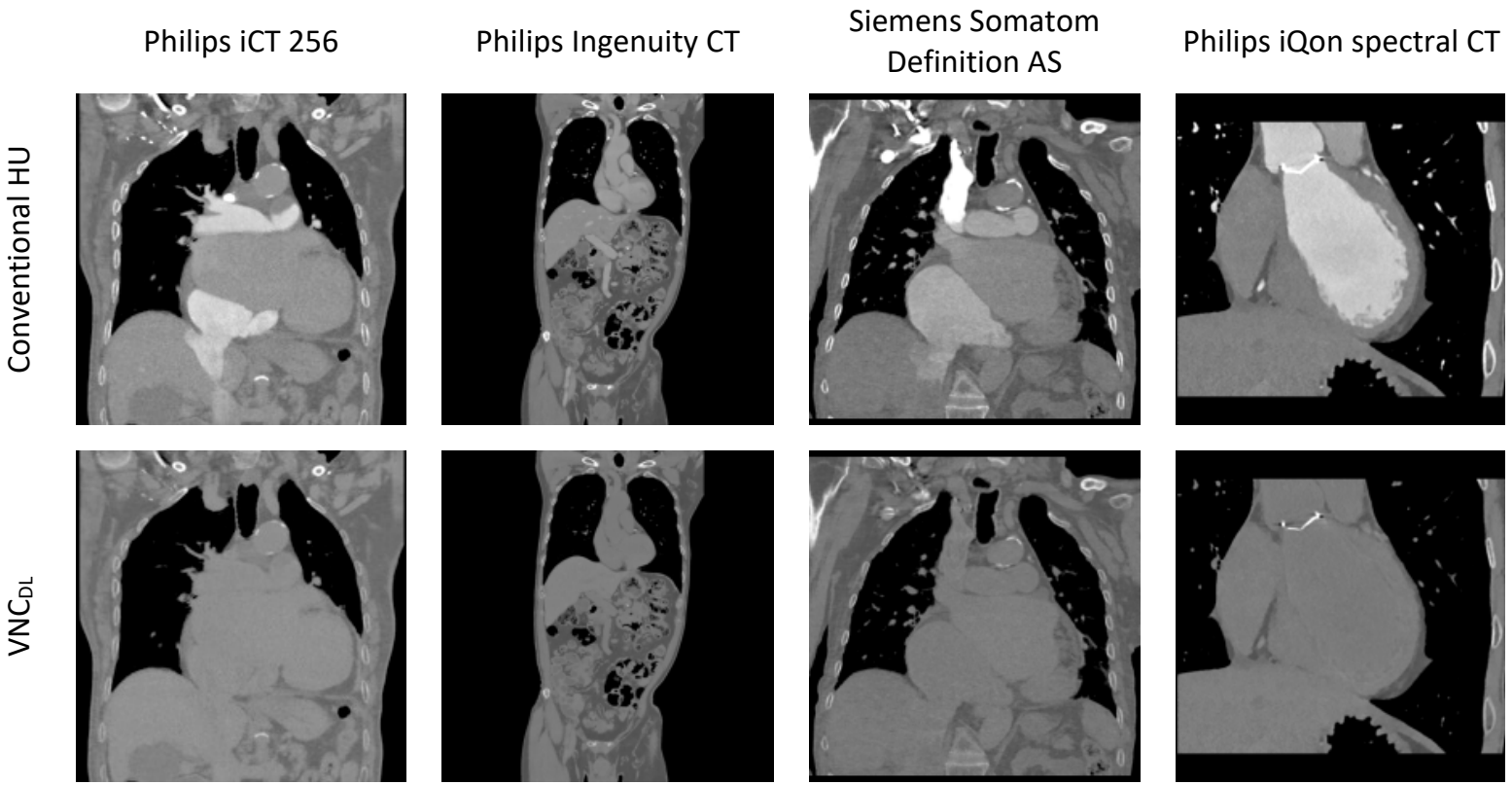
Exploitation des données spectrales - CASPER



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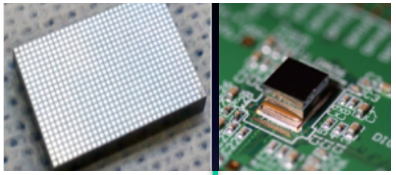
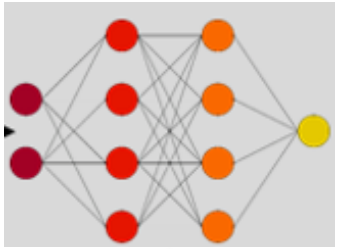
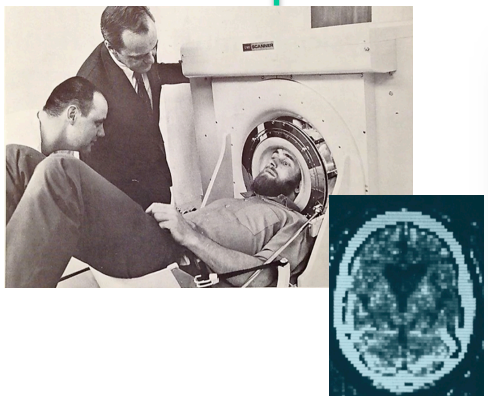
Conclusion

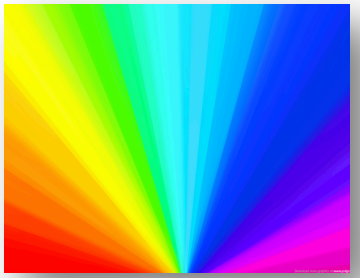
https://museum.aapm.org/exhibit/07-ct/





1971 *1976* *1990* ***Demain***





MERCI POUR VOTRE ATTENTION

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Laboratoire CREATIS, Equipe cardiovasculaire
CNRS – INSERM – Université Lyon 1

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