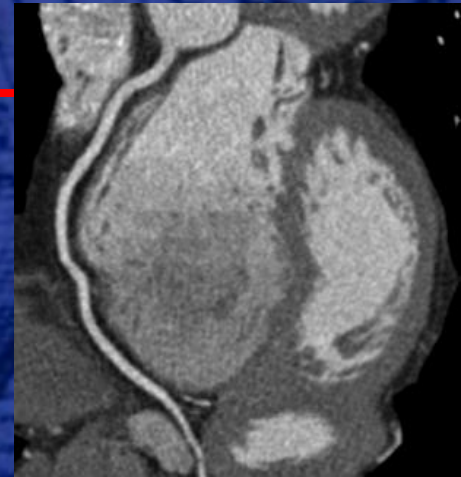
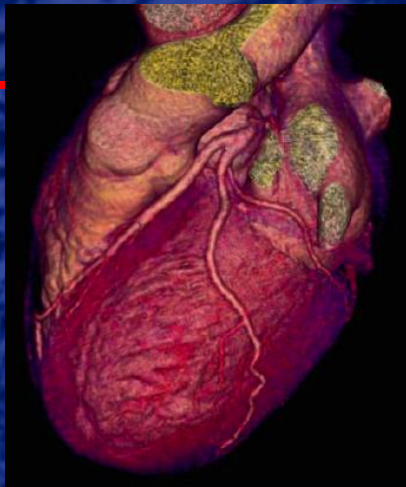


# Visualisation des artères coronaires et des pontages en TDM



Jacques Boschat et Martine Gilard  
Brest France





# TDM cardiaque à BREST

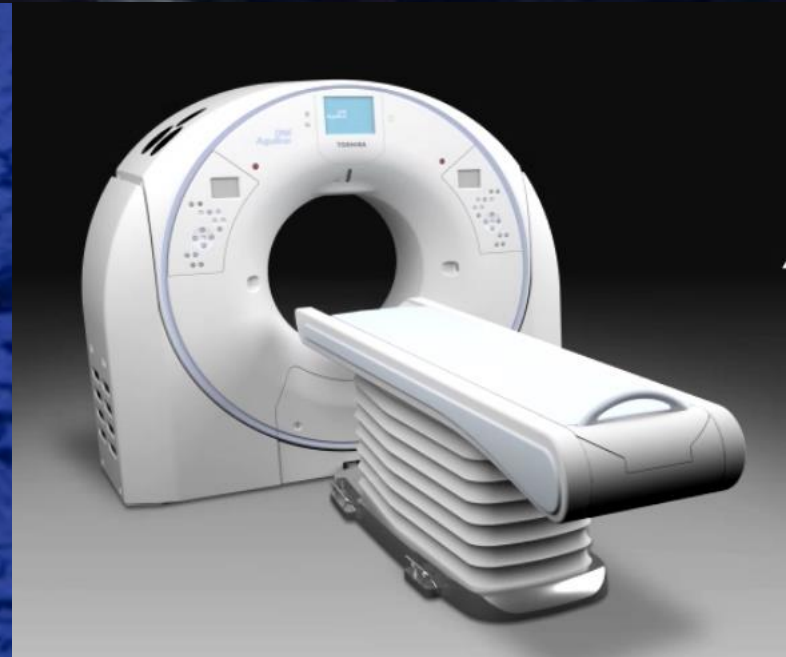


**Depuis 2003...**

Philips Mx8000 IDT 16

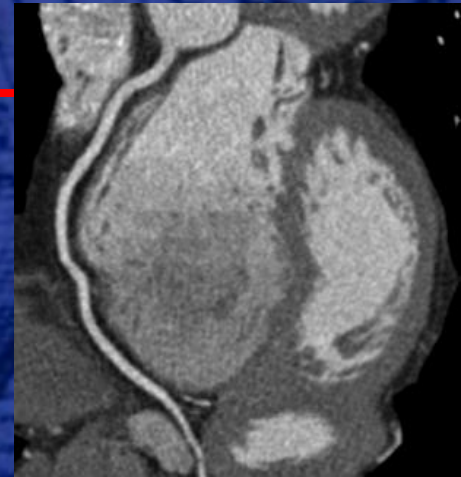
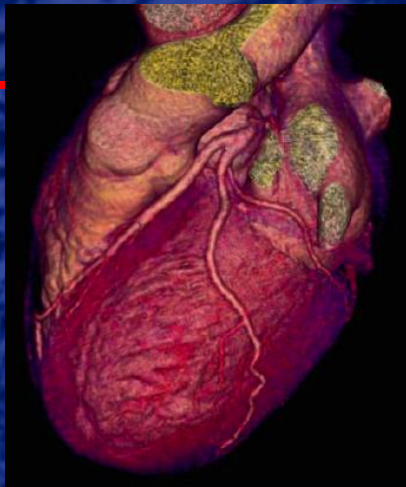
Siemens Somatom Definition AS (128)

Toshiba Aquilon One Genesis ( 320: 16cm))





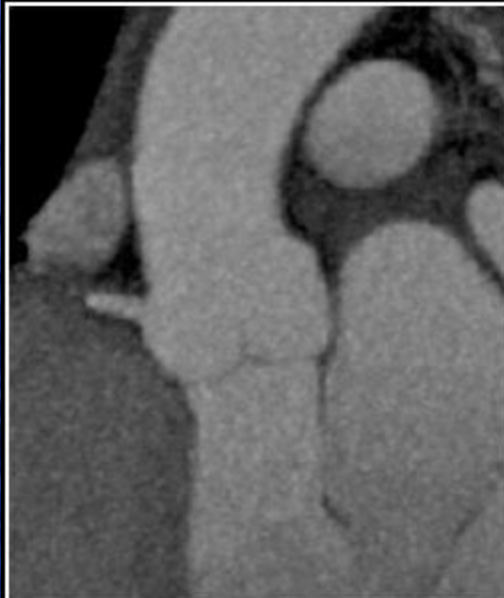
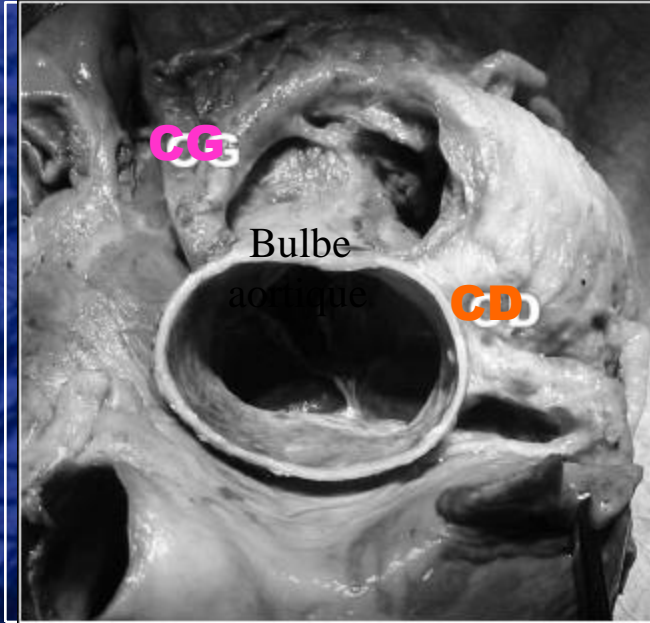
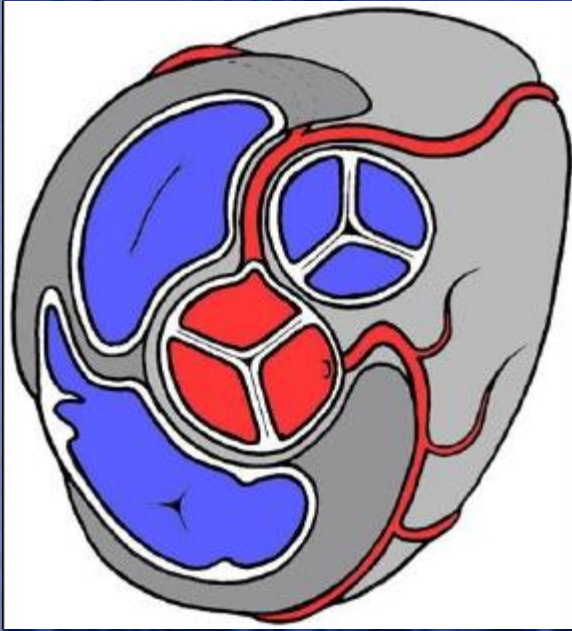
# Visualisation des artères coronaires et des pontages en TDM



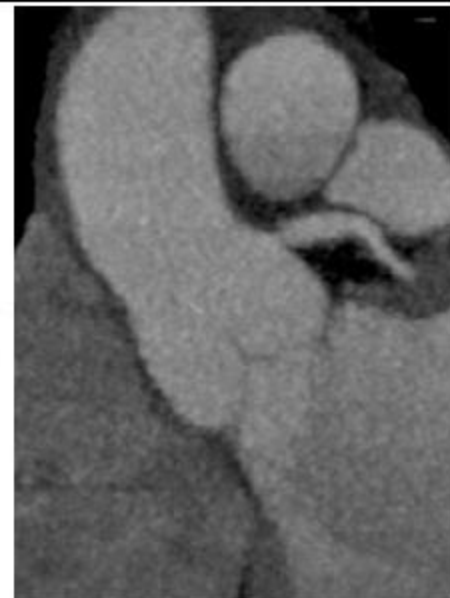
Généralités





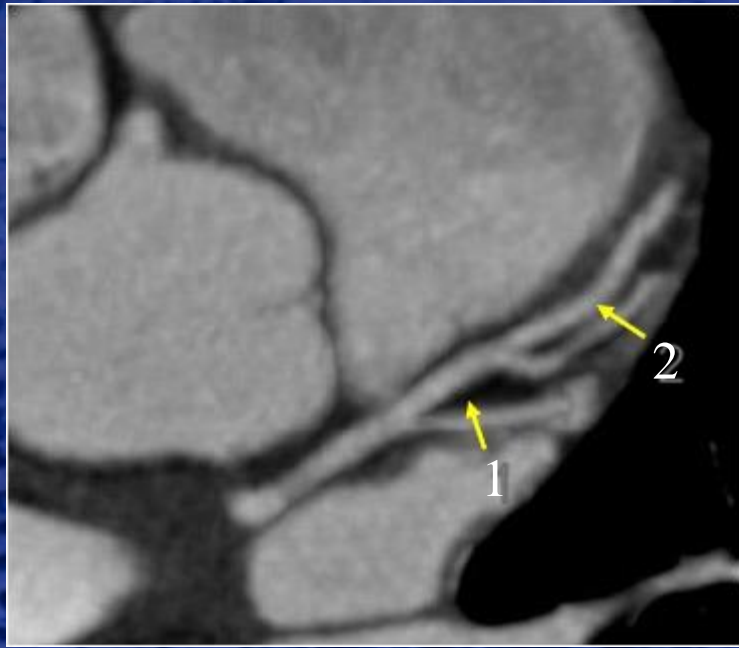


coronaire droite



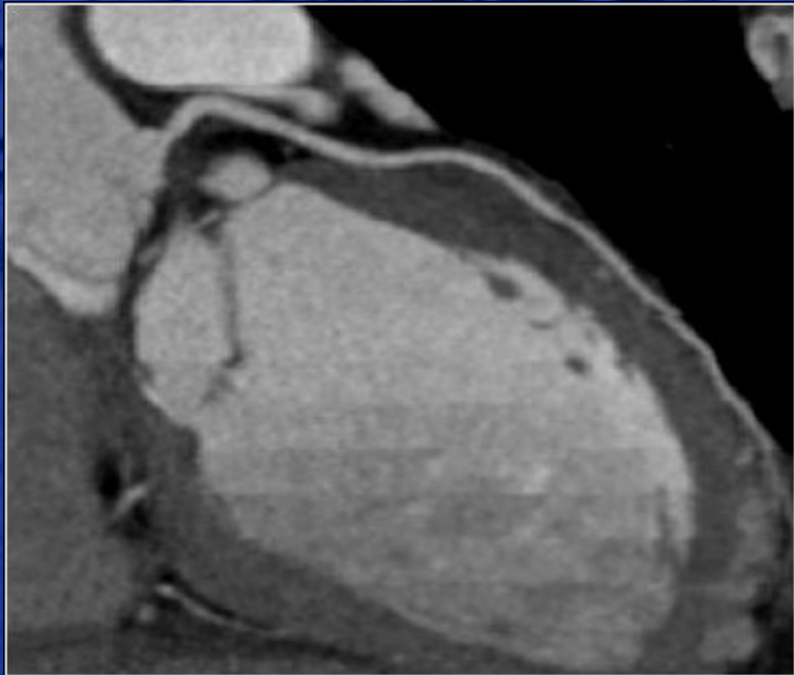
coronaire gauche

# Anatomie : Branches de l'I.V.A



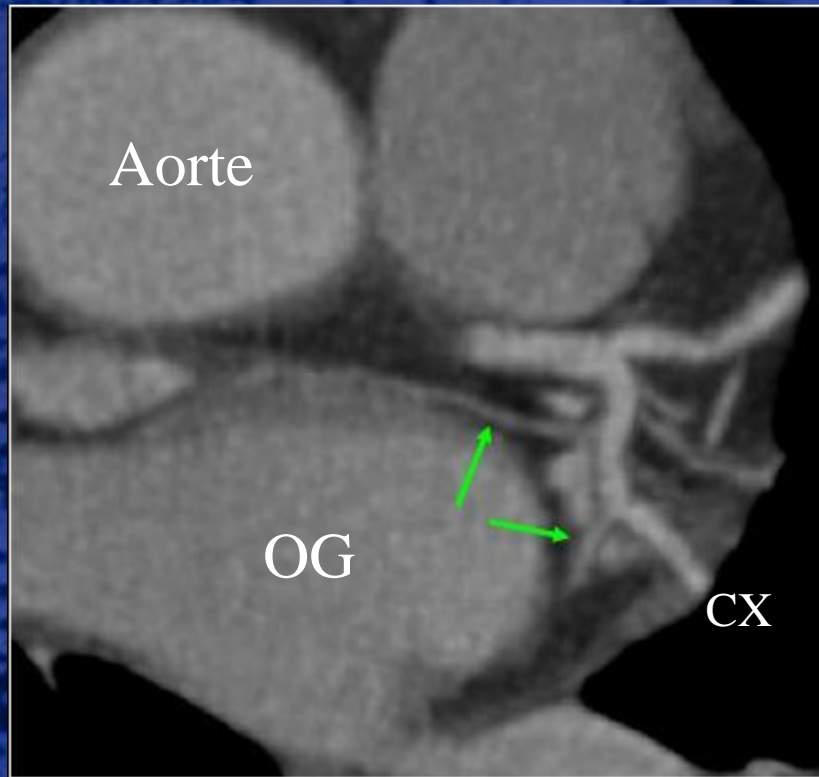
1. **Diagonales** : au nombre de 2 à 4

2. **Septales** : 10 à 15

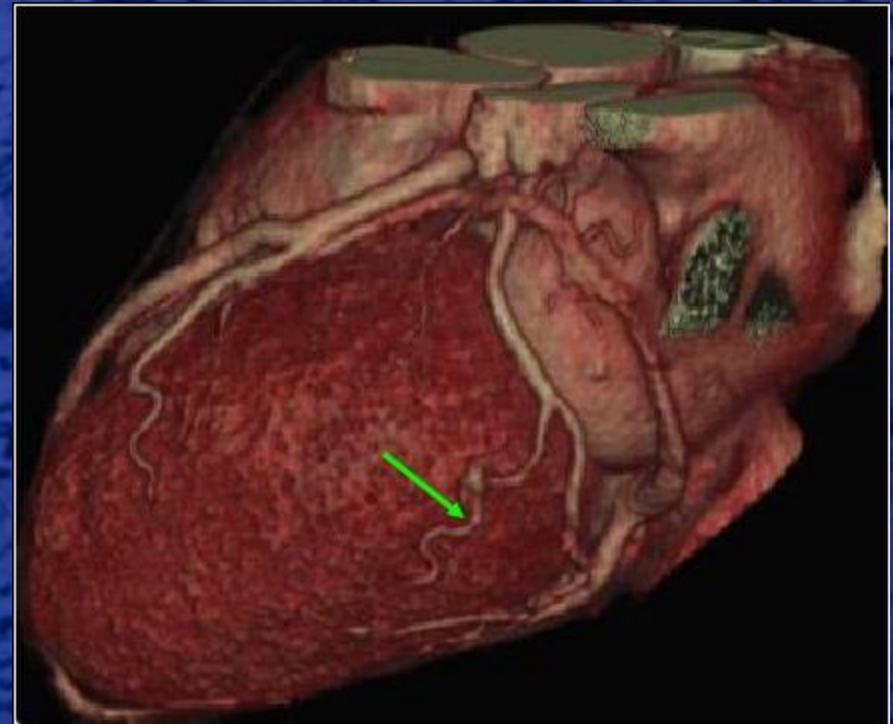




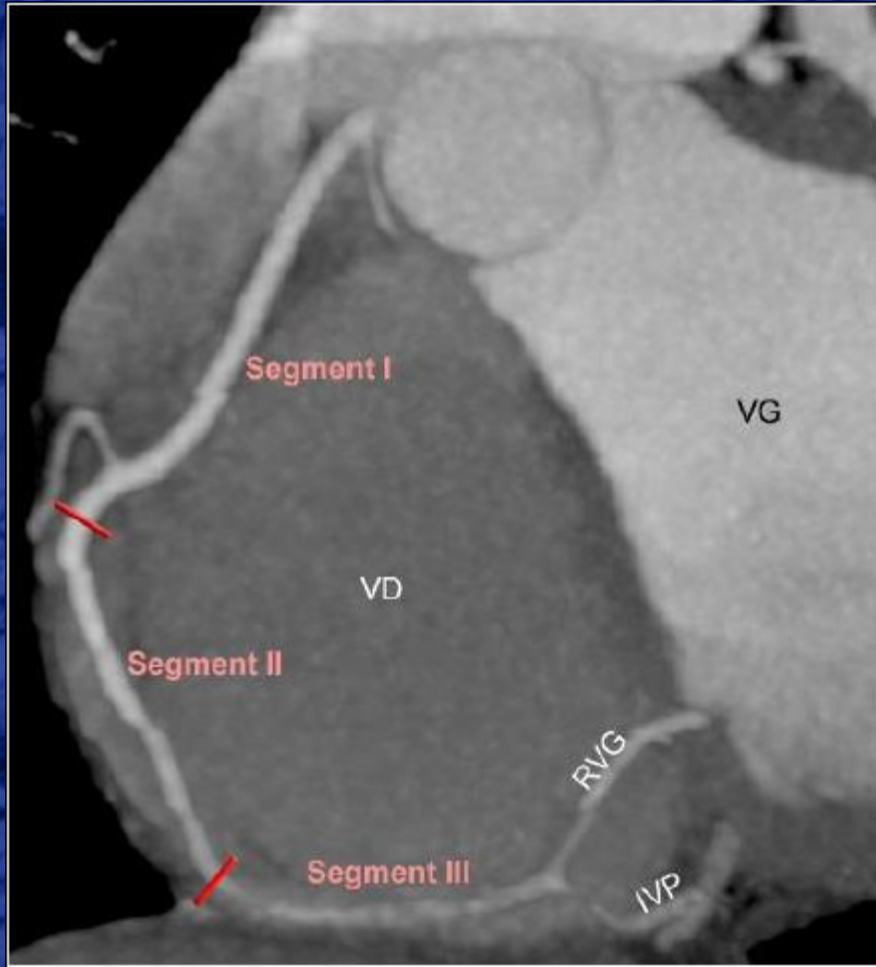
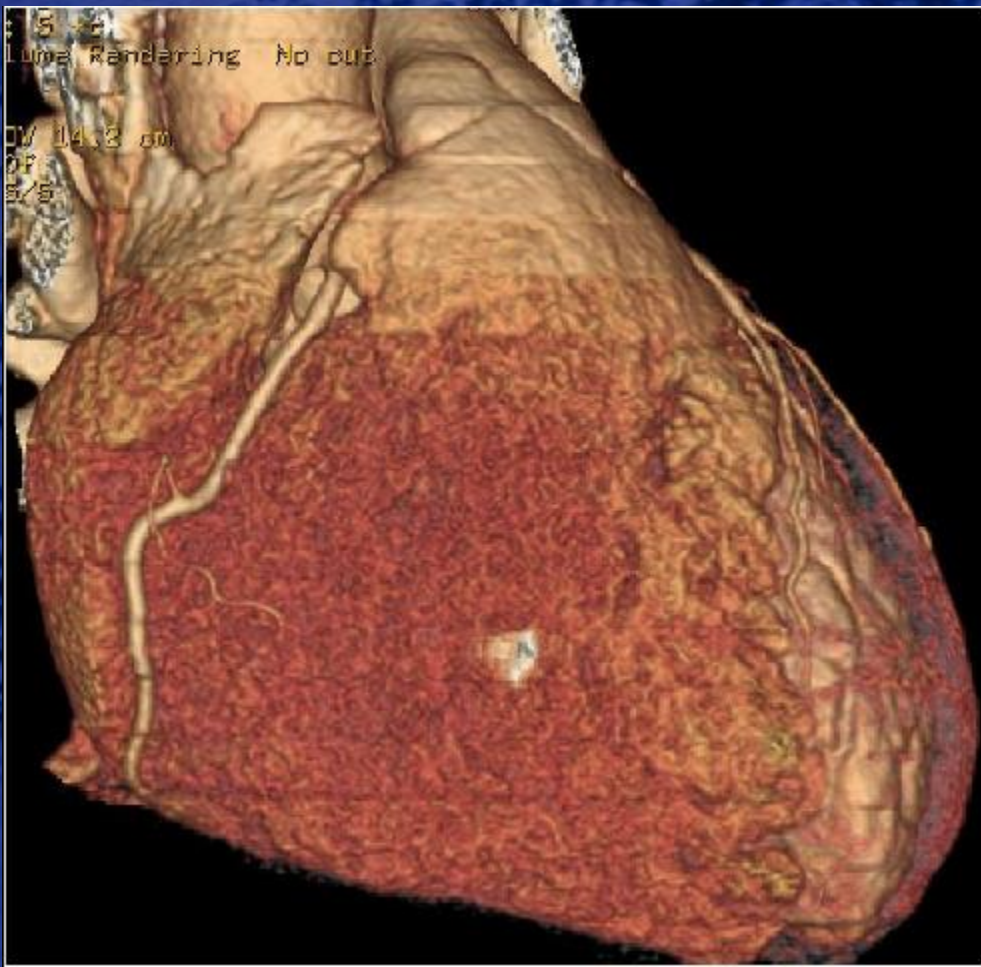
# Anatomie : Branches de la CX



**3. Artères marginales : 1 à 3**  
vascularisant la paroi latérale du VG



# Anatomie : Coronaire droite





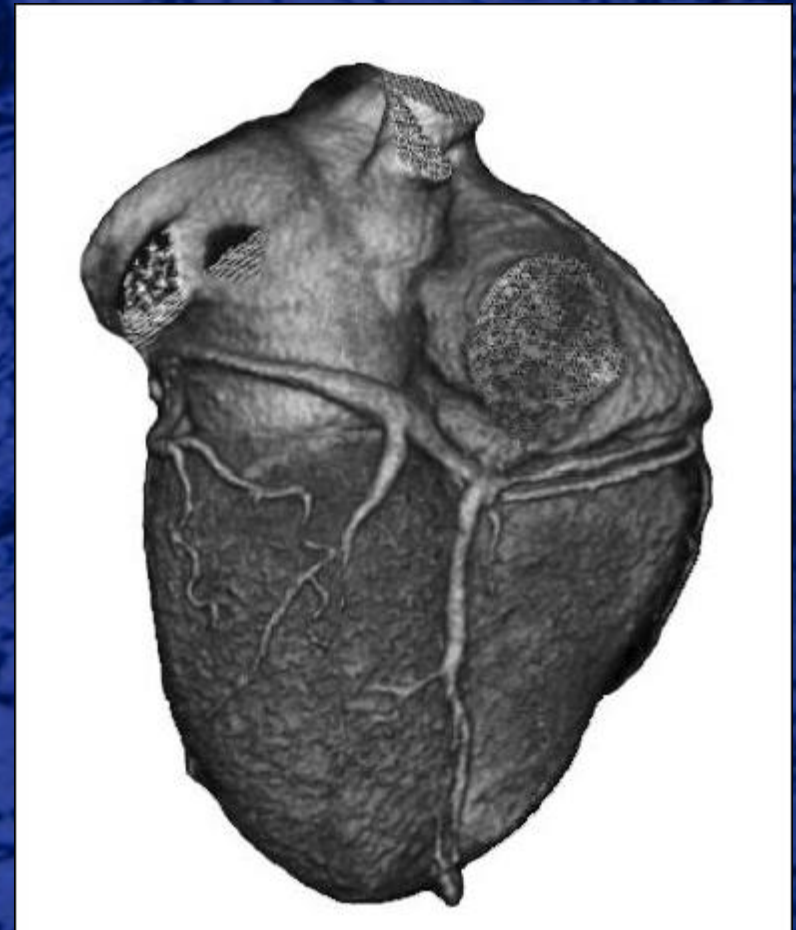
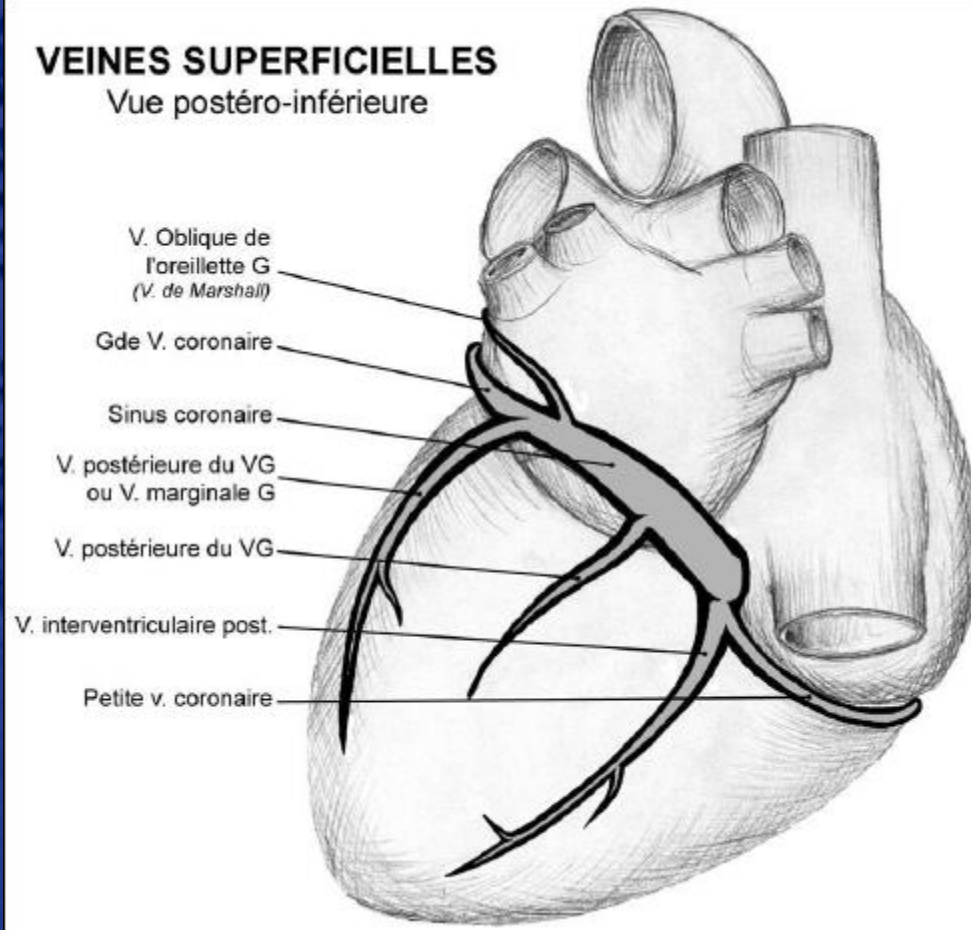
# Anatomie : Veines coronaires

Draine 70% du sang veineux myocardique.

- **Des veines superficielles**, tributaires du sinus coronaire, principal système collecteur
- **Des veines cardiaques antérieures** (Petites veines cardiaques), plus fines, se drainant directement dans l'oreillette D

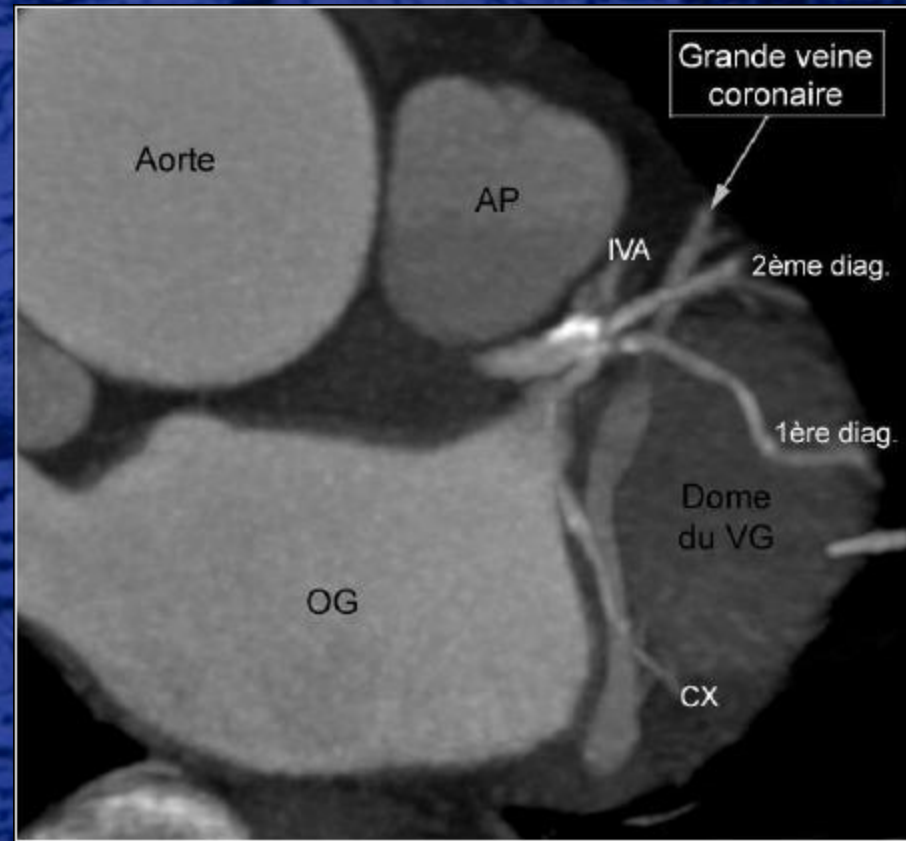
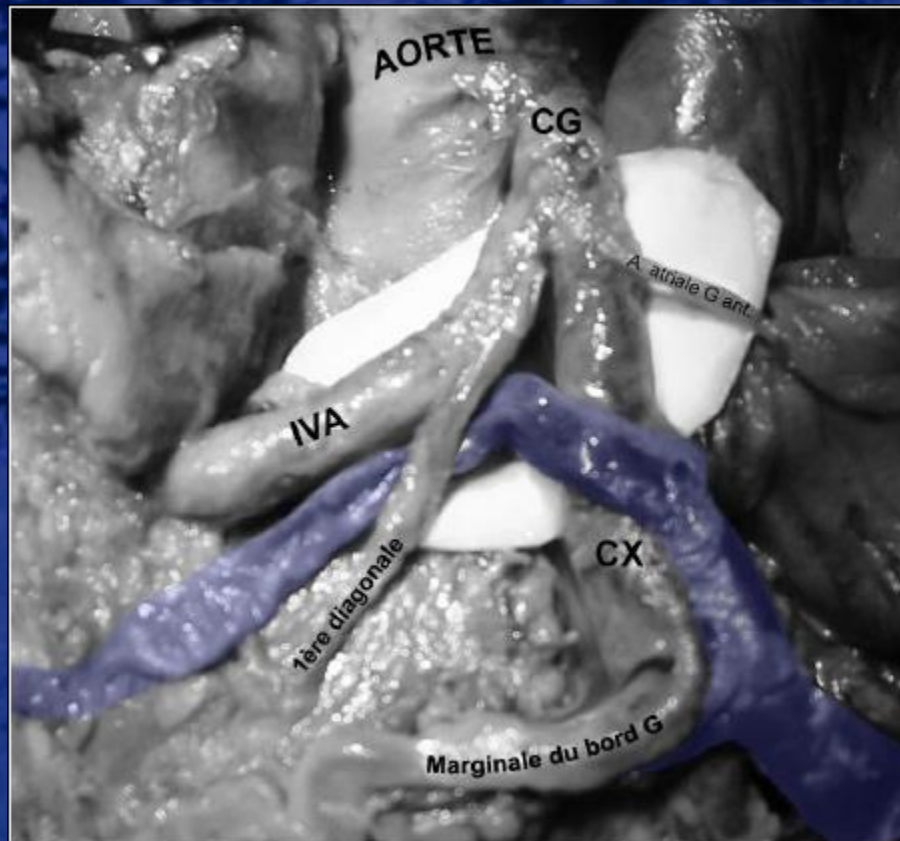
## VEINES SUPERFICIELLES

Vue postéro-inférieure





# Veines superficielles



# Imagerie coronaire : Contraintes

Petits vaisseaux (1 à 5 mm)

Structures adjacentes (graisse épicardique, veines coronaires, myocarde, ...)

Anatomie complexe et variable (tortuosités, boucles, bifurcations, calcifications, dominance, diamètre, naissance anormale, segmentation, ...)

Pont intramyocardique

Collatéralité, flux

Vasomotricité

Mouvements cardiaques

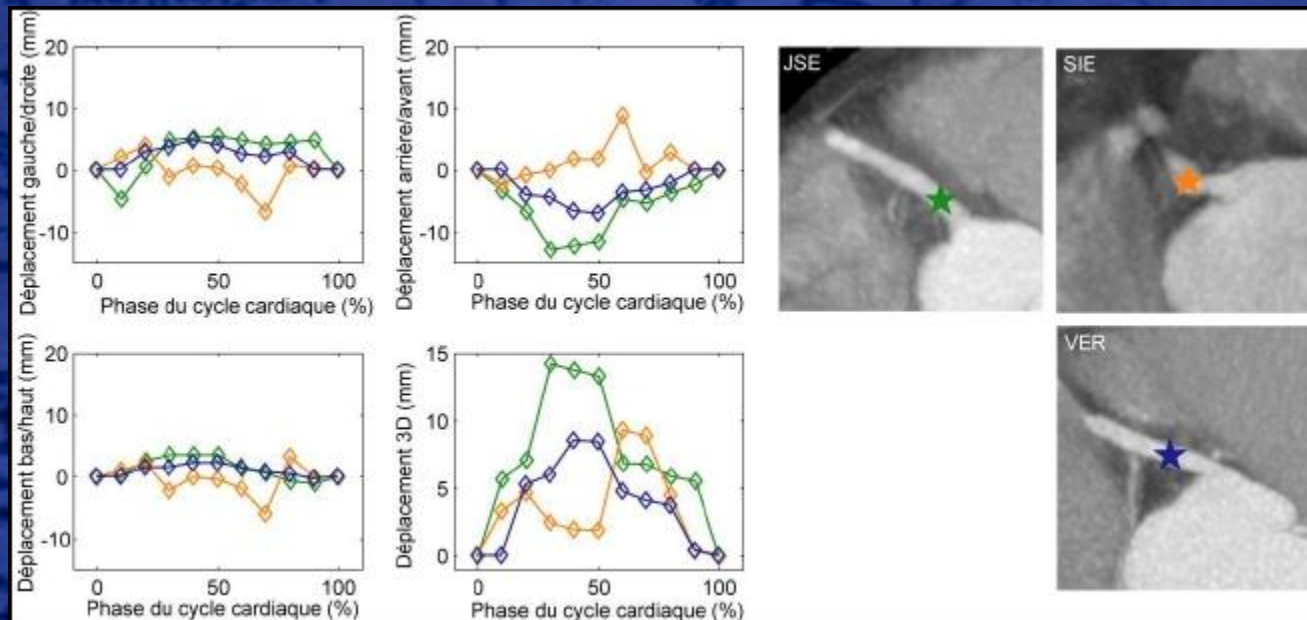
Mouvements respiratoires



IVA 22 mm/s Cx 48 mm/s CD 69 mm/s  
*Achenbach Radiology. 2000 ;216(2):457-63*

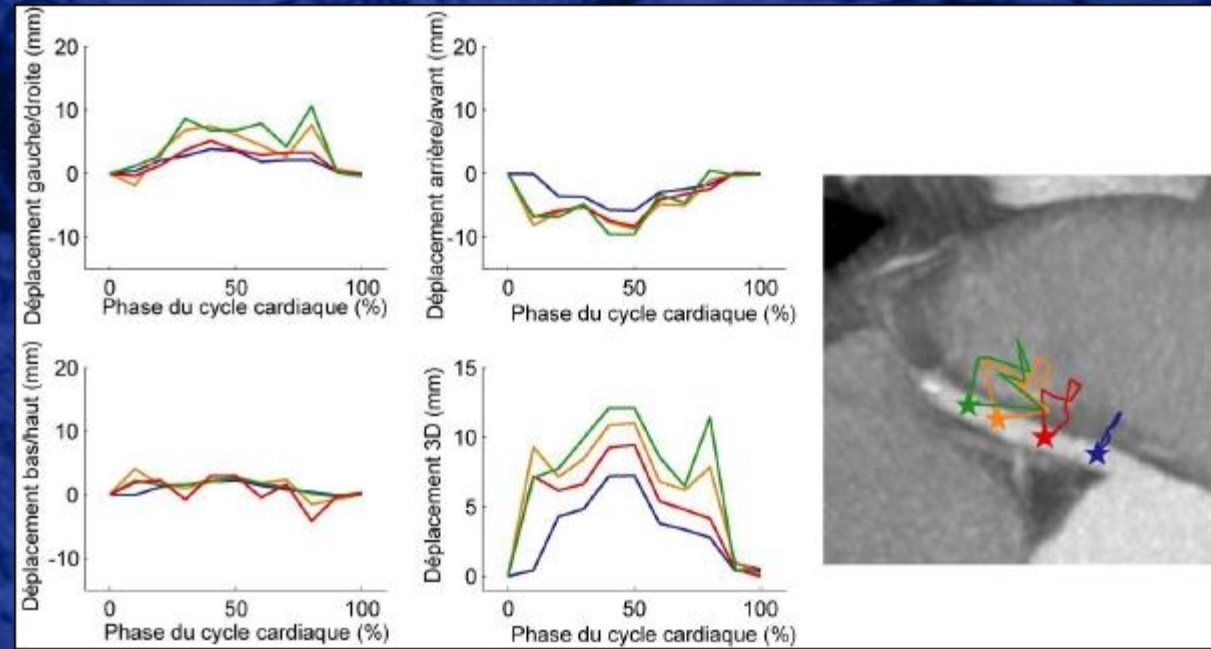


# Imagerie coronaire : Contraintes



Amplitude de déplacements de la CD1 chez 3 patients différents

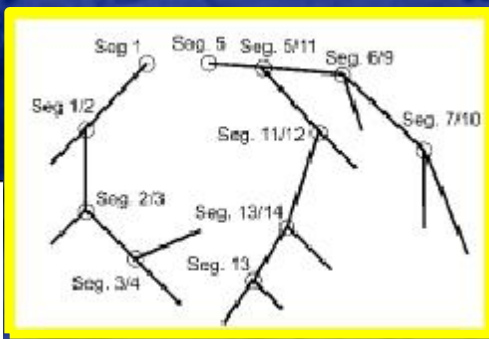
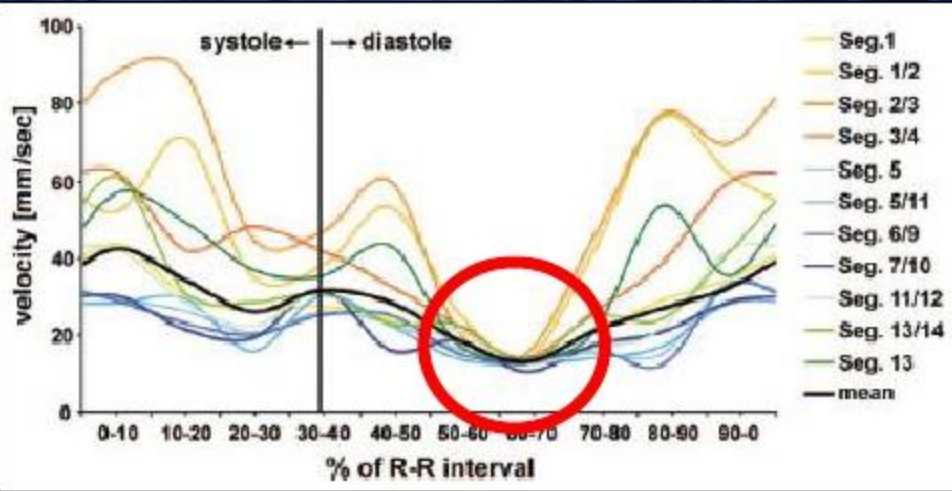
Amplitude de déplacements de 4 sites différents au niveau de la CD1 chez un même patient



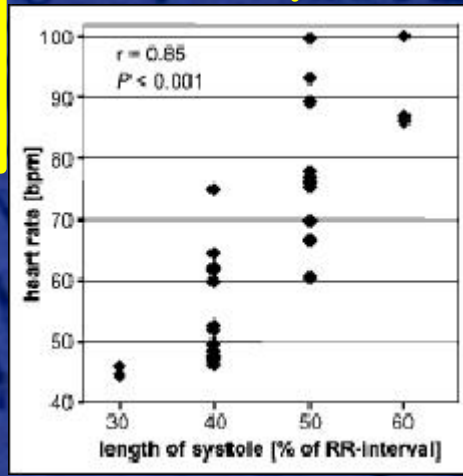
Courtoisie S Laguitton – LTSI  
Université Rennes I (Inserm 642)

# Imagerie coronaire : Contraintes

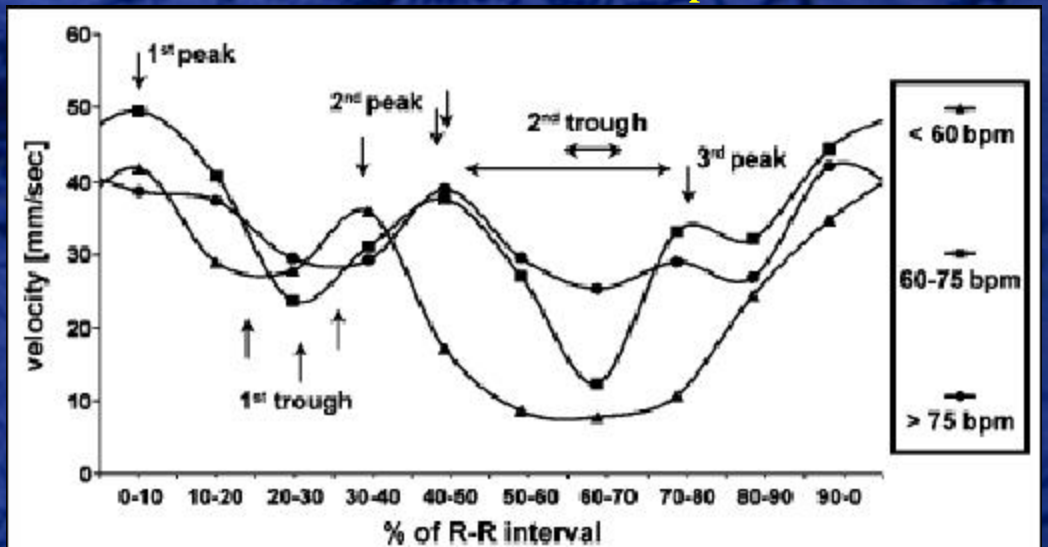
Vitesse de déplacements des différents segments coronaires chez un même patient



Influence du RR sur le moment de la systole



Influence du RR sur la vitesse de déplacement

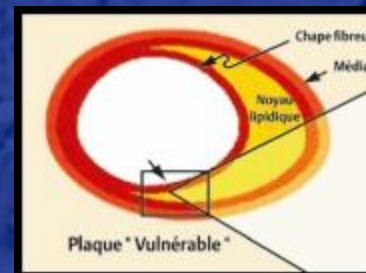
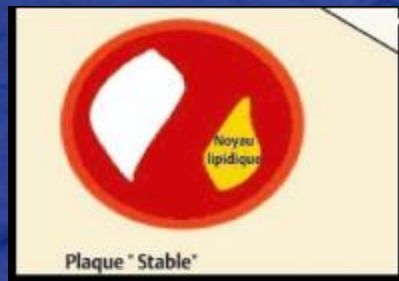


**Coronary Artery Motion and Cardiac Phases:** Dependency on Heart Rate—Implications for CT Image Reconstruction<sup>1</sup>

Husman et al. Radiology 2007; 245 (2): 567-75



# la plaque vulnérable

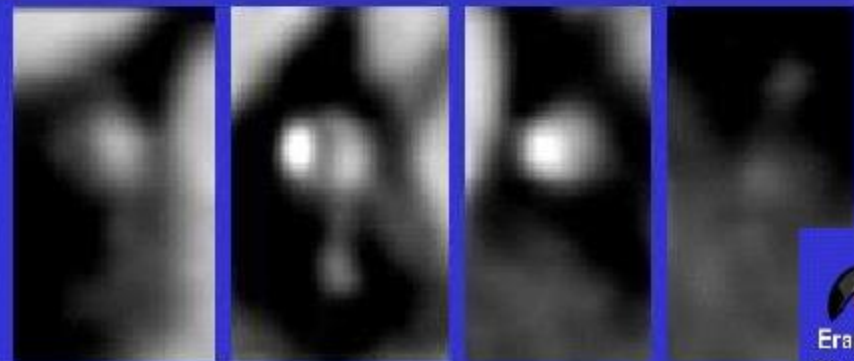
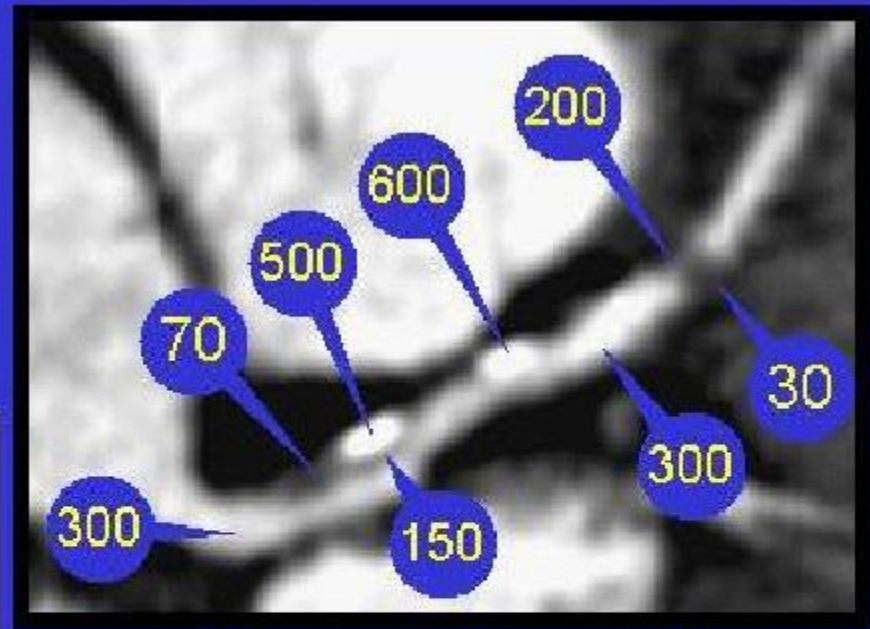
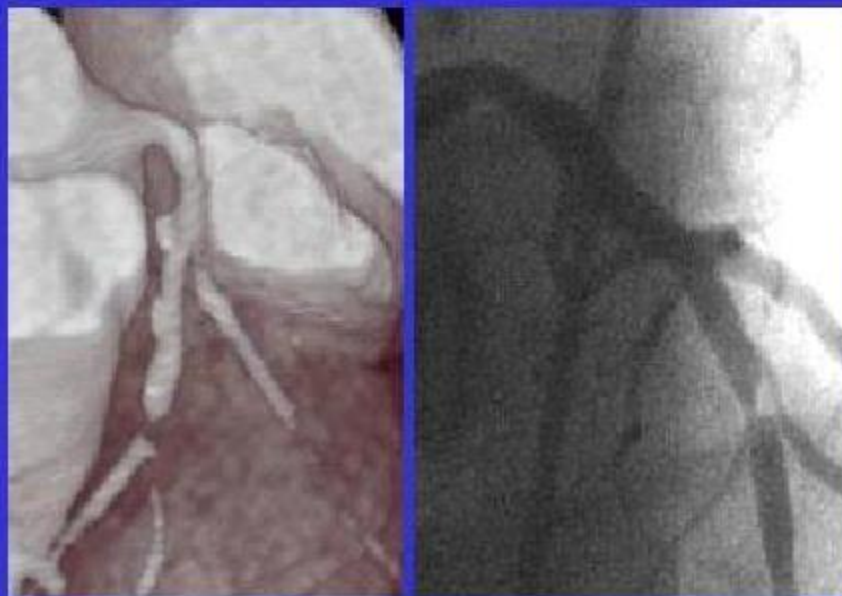


TDM :

« Plaque hypodense d'allure fibro lipidique »

N	ICUS	Multislice CT
12	<b>Soft</b>	14 ±26 HU
5	<b>Intermediate</b>	91 ±21 HU
17	<b>Calcified</b>	419 ±194 HU

By Schroeder, et al, JACC April 2001





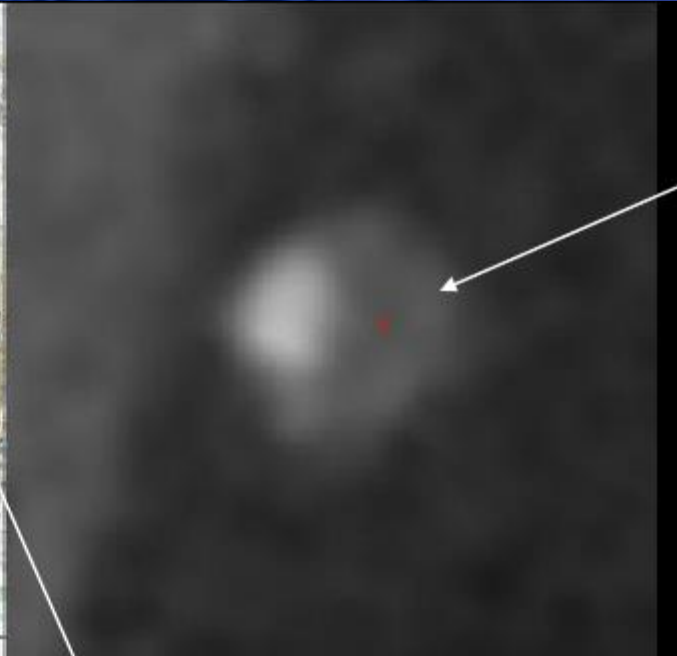
# le signe du rond de serviette



Chape fibreuse

Cœur lipidique nécrotique

Néovascularisation

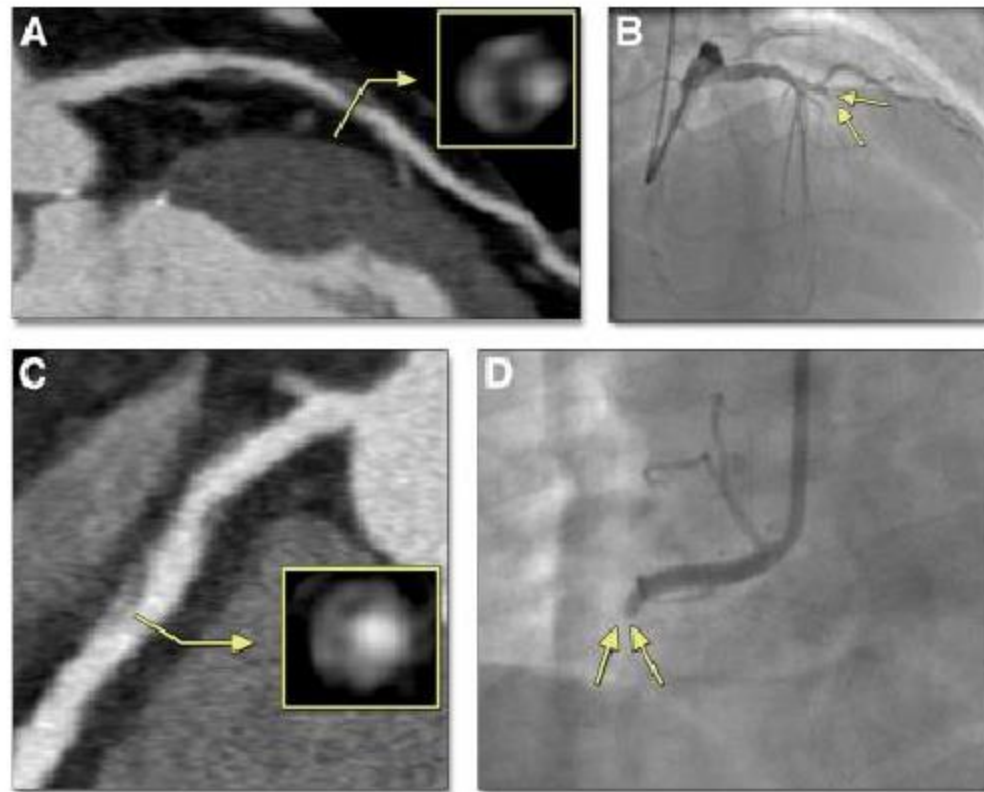


Anneau **hyperdense**  
autour de la plaque

Densité supérieure aux  
plaques adjacentes  
mais  $< 130$  UH



# le signe du rond de serviette



**Figure 1.** Representative Coronary CTA Images With Napkin-Ring Signs and Invasive Angiographic Images

(A) An atherosclerotic plaque with PR, LAP, and a napkin-ring sign in the proximal left anterior descending artery on coronary CTA. (B) Total occlusion of the proximal left anterior descending artery, causing acute myocardial infarction, by invasive coronary angiography 10 months after coronary CTA (arrows). (C and D) coronary CTA images show an atherosclerotic plaque with PR, LAP, and a napkin-ring sign in the proximal right coronary artery, which was completely occluded 1 year later (arrows). The boxed area in A and C indicates cross-sectional images of atherosclerotic plaque showing a napkin-ring sign. CTA – computed tomography angiography; LAP – low-attenuation plaque; PR – positive remodeling.

895 patients, suivi > 1 an

Le signe du rond de serviette est significativement associé à un **futur SCA** (AI – IDM – mort subite), indépendamment des autres aspects scanographiques à risque (remodelage + et plaque hypodense  
→ Aide à la détection des patients à haut risque de SCA ?

## la sténose

- Pourcentage de réduction correspondant au calibre circulant résiduel

$$\% \text{ de sténose} = \frac{\text{diamètre de référence} - \text{diamètre de la sténose}}{\text{diamètre de référence}}$$

Attention aux logiciels de quantification automatique de sténose !!

- **Standardiser** les termes employés

Degré de sténose	Interprétation
< 50%	Non significative
« Autour de 50% »	Sténose intermédiaire
> 50%	Sténose significative
> 70%	Sténose serrée



# la sténose

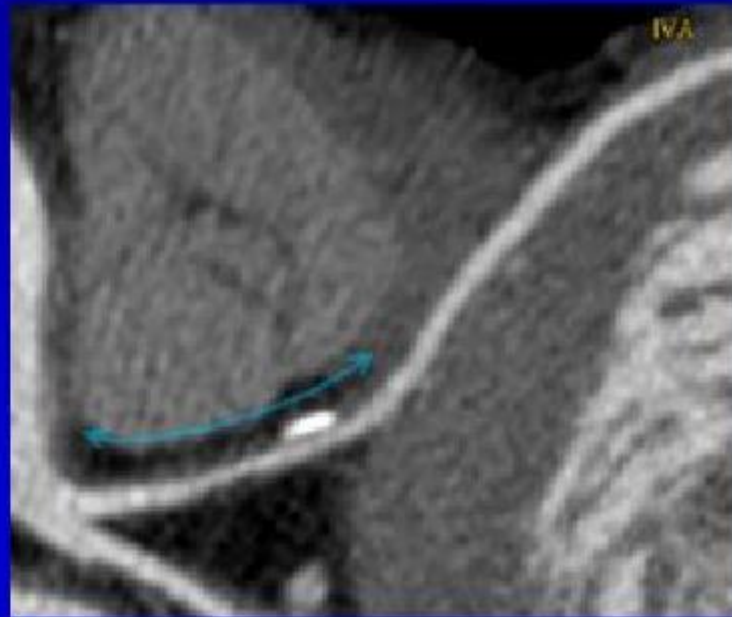
## Détermination du diamètre de référence

Si possible en AMONT

(sinon en Aval)

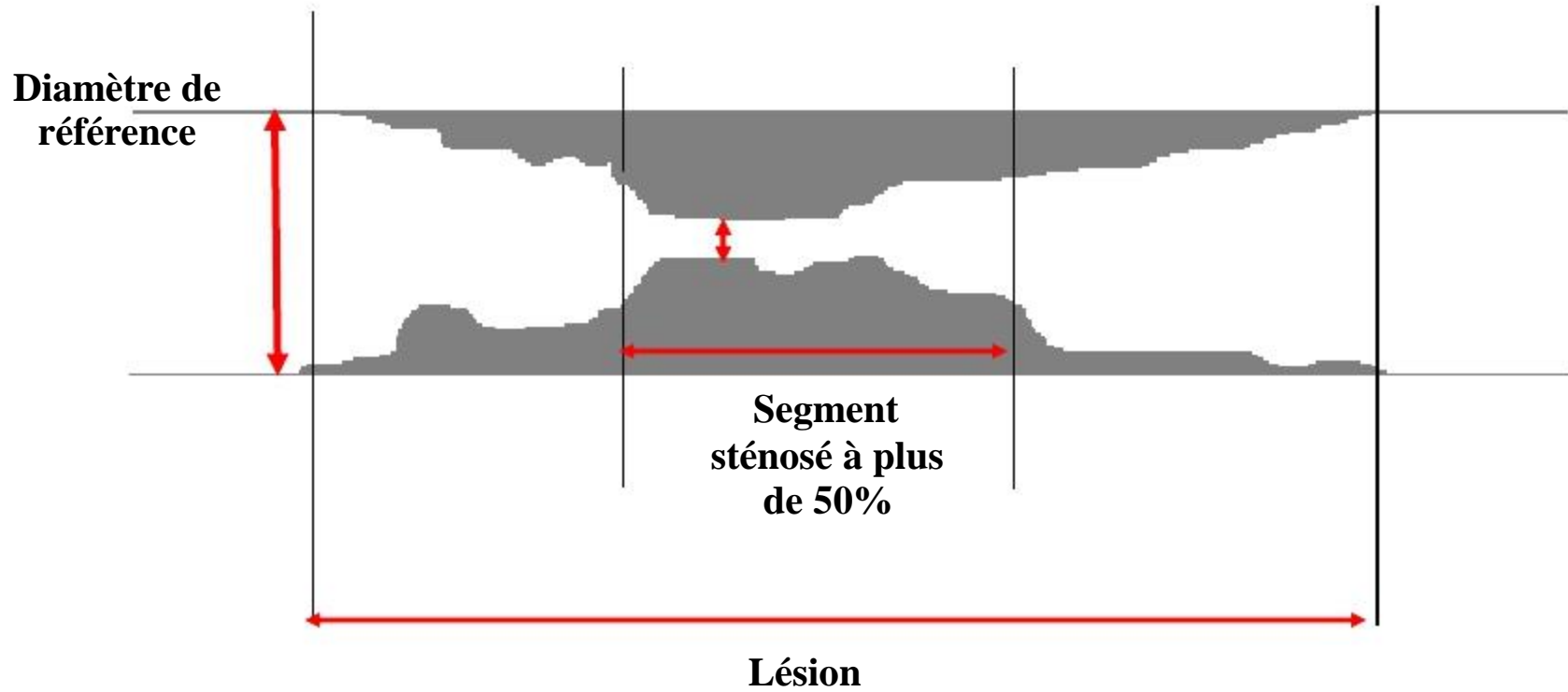
A moins de 10 mm

A distance d'une collatérale majeure



# QCA

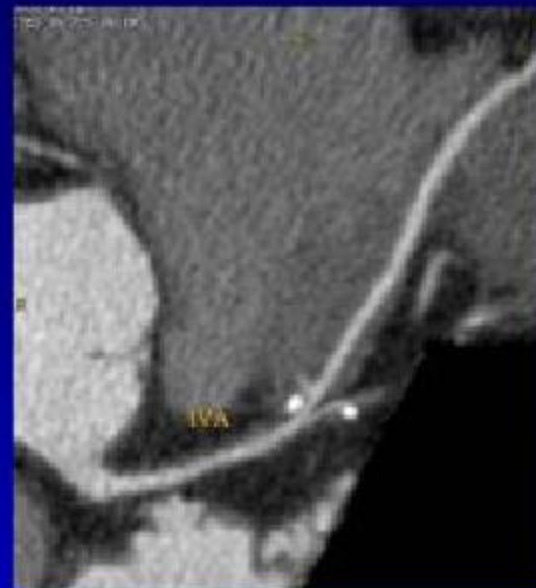
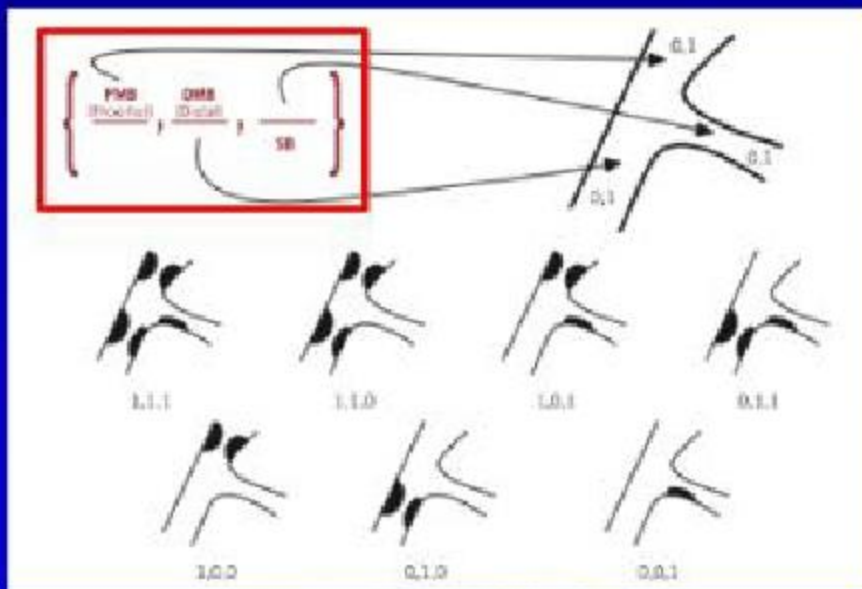
MLD



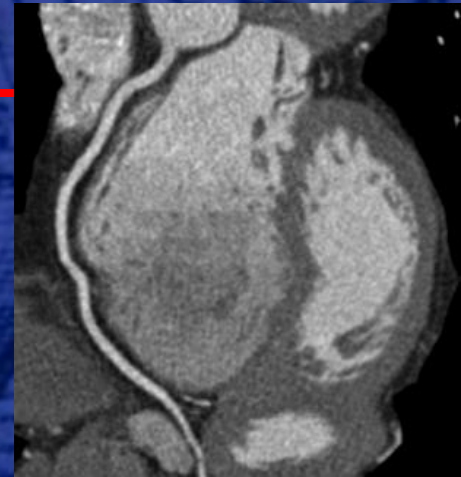


## Analyse des bifurcations

- Classification de Medina :  
Vsx proximal = 1 ou 0  
Vsx distal = 1 ou 0  
Branche latérale = 1 ou 0



# Visualisation des artères coronaires et des pontages en TDM



Techniques

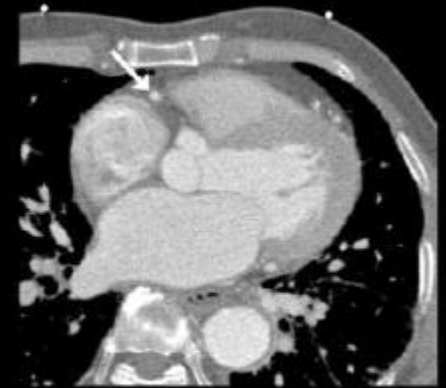




# Technique : Résolution Spatiale & Résolution Temporelle



Scanner 256 barrettes ...



Reconstructions  
multiphasiques

## Résolution Spatiale



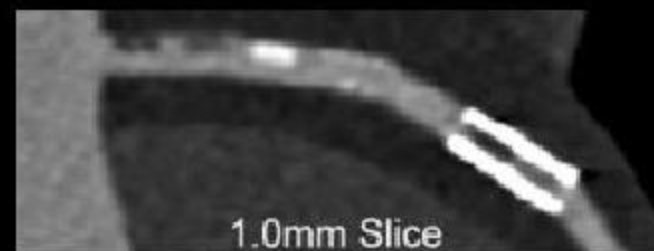
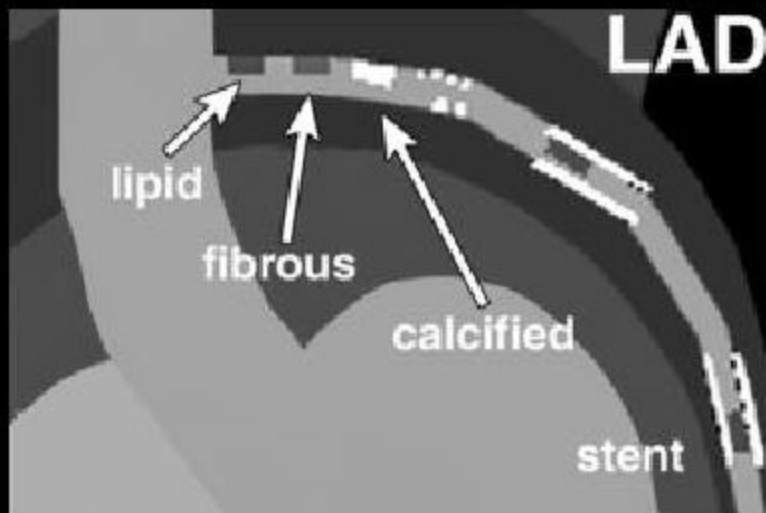
Courtesy E. Nagel, Berlin



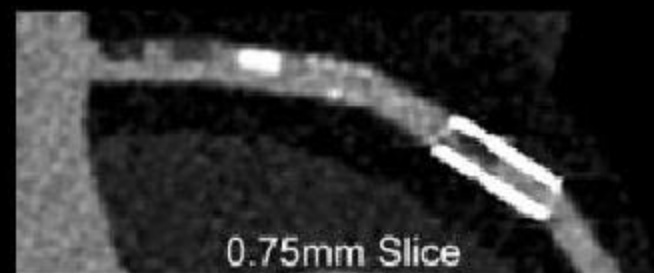
# Technique : Résolution Spatiale



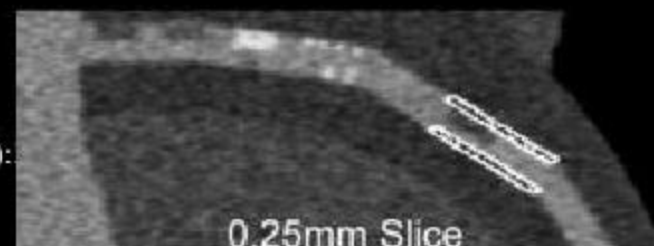
Coupes fines, MIP fin



1.0mm Slice



0.75mm Slice



0.25mm Slice

\* CT of coronary artery disease. Schoepf UJ et al Radiology. 2004 Jul;232(1):



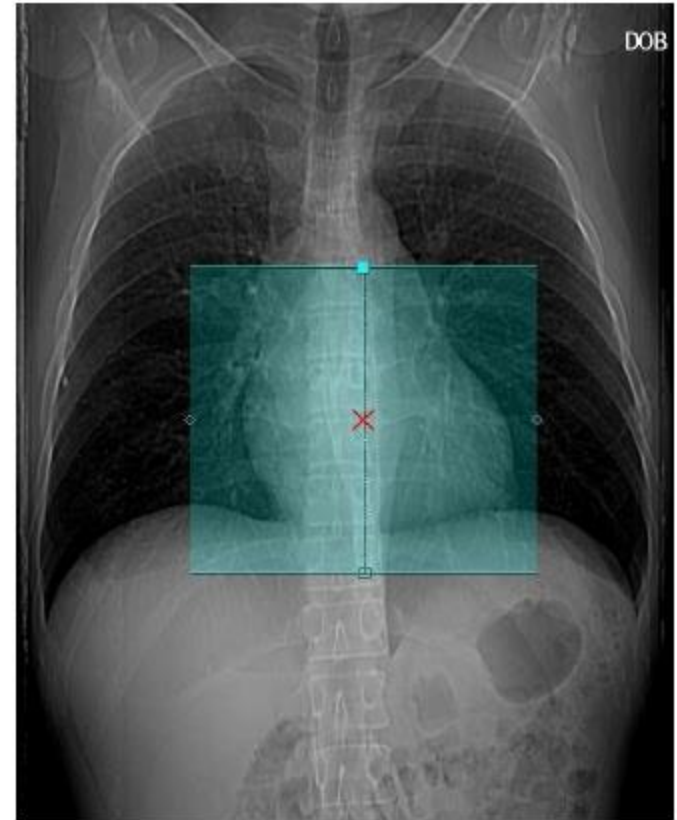
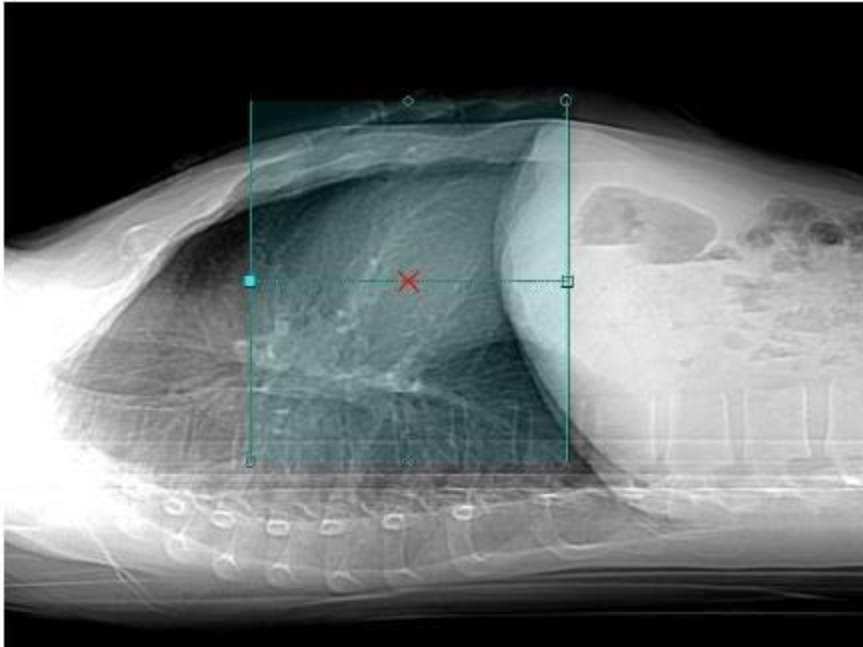
## Scanner Coronaire Les contraintes techniques

	Coronarographie	Scanner 64	Scanner 128	Scanner 320
Résolution Spatiale	200 $\mu$	350 $\mu$	350 $\mu$	290 $\mu$
Résolution temporelle	100ms	175ms		27ms?

# Technique : Résolution Spatiale

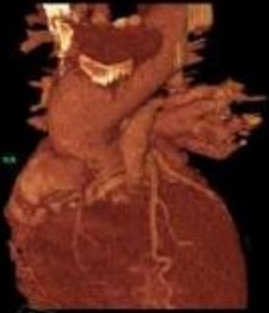
Importance du champ de vue (FOV)

- Scouts

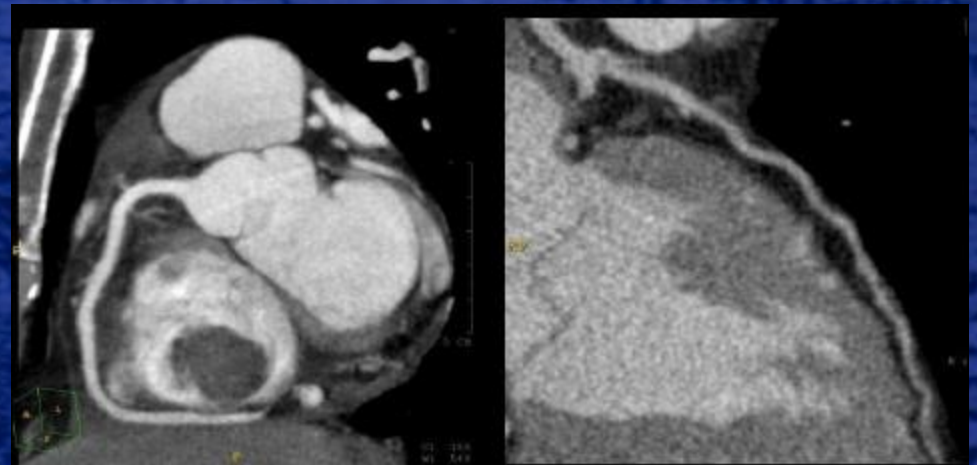




# Technique : Post Traitement

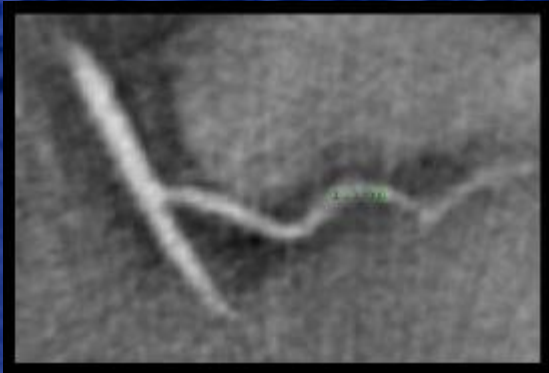


VR 3D

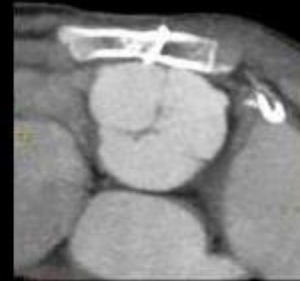


MPVR manuel

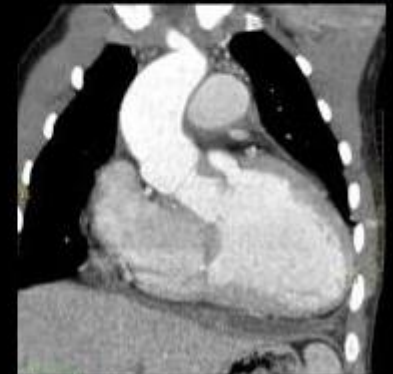
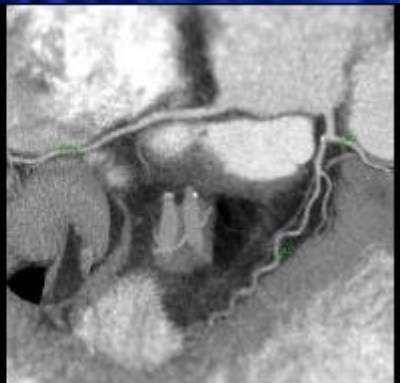
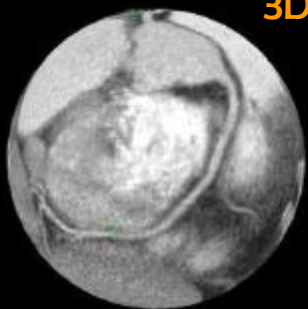
MPR



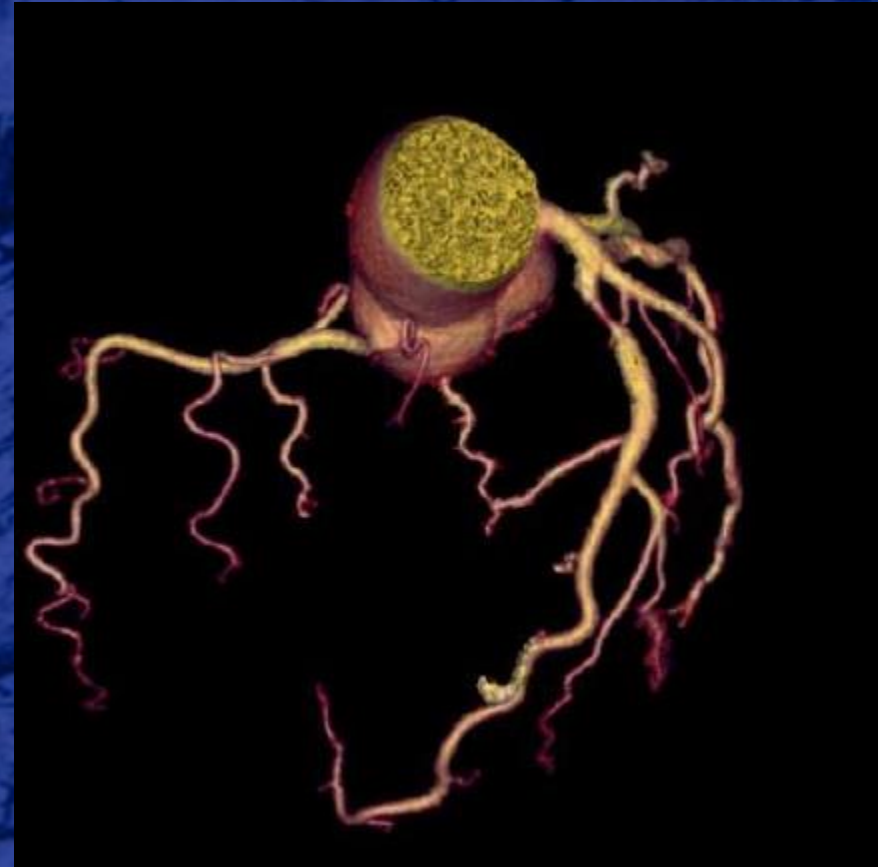
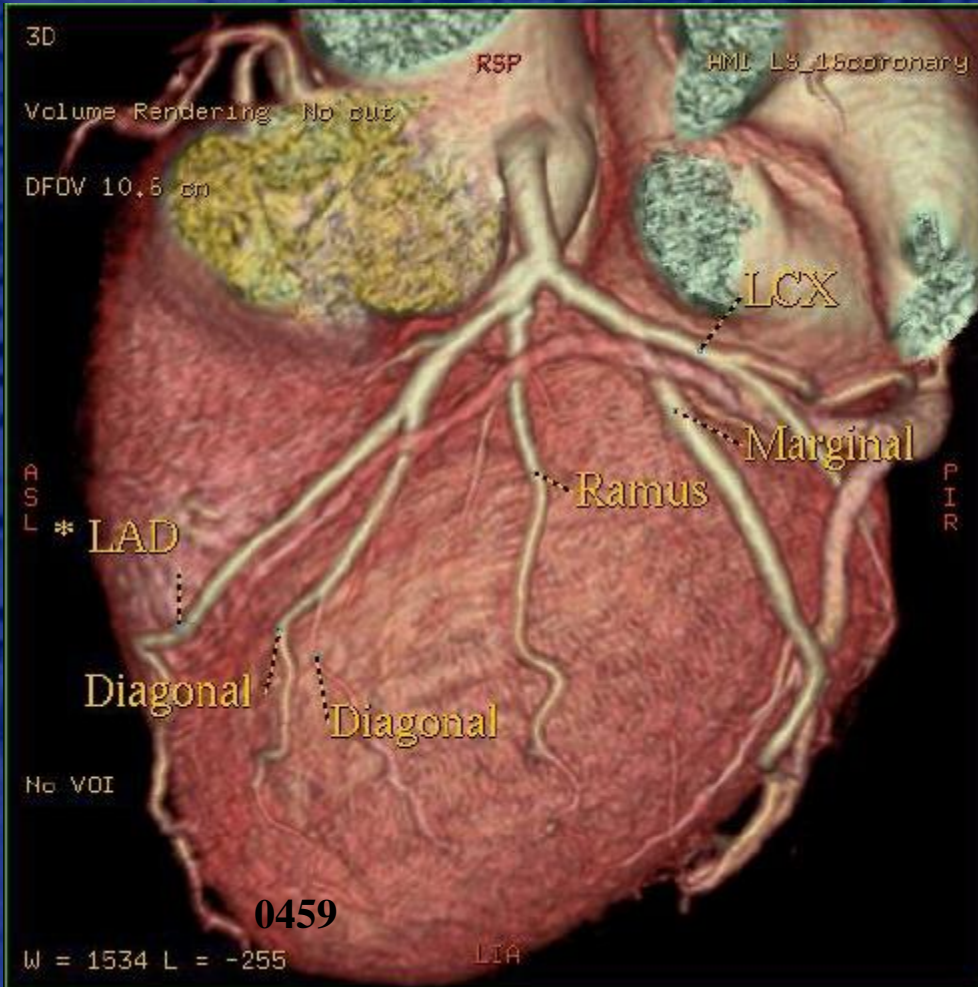
MPR MIP



3D MIP

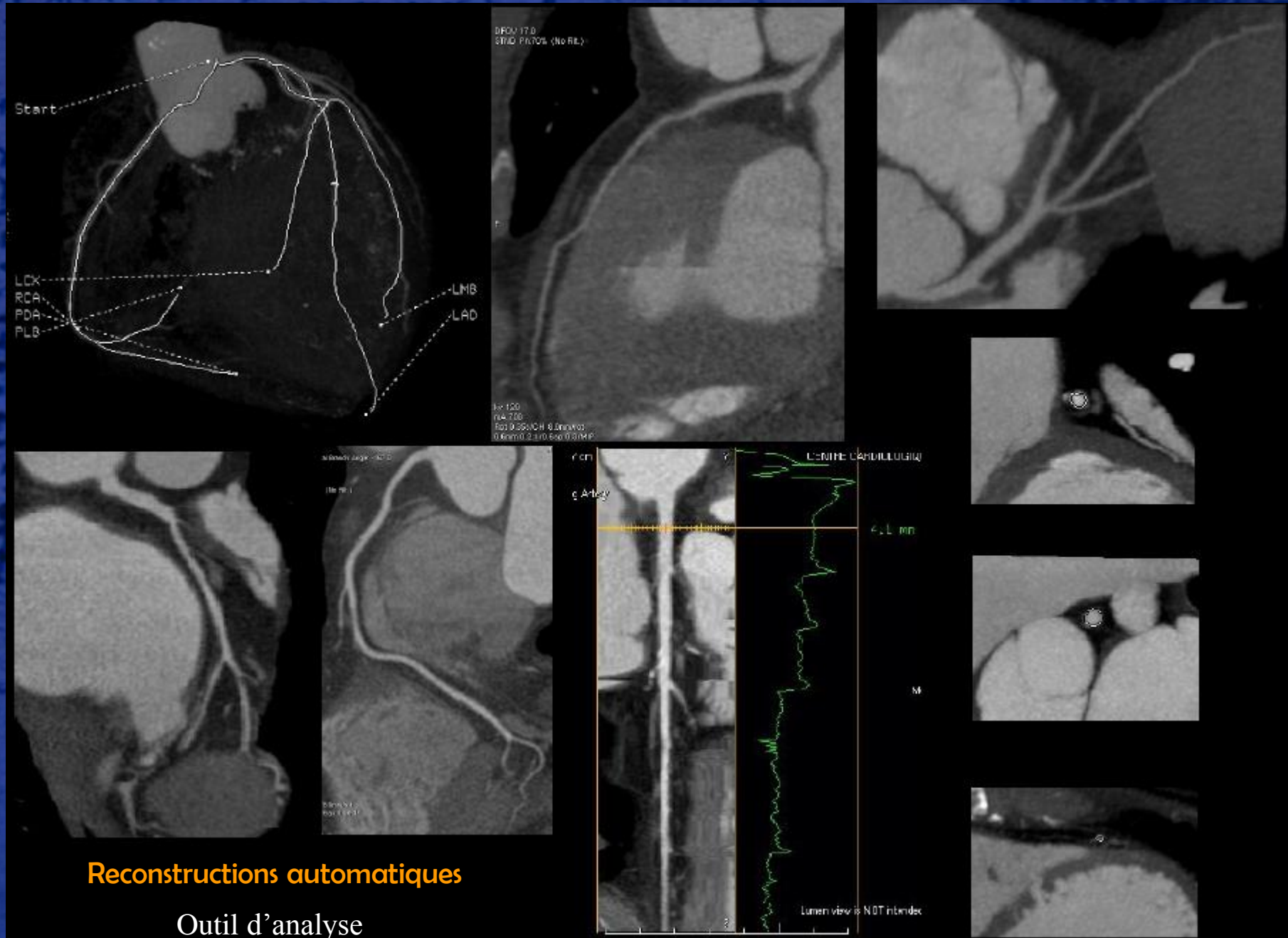


# Rendu de volume : outil de communication

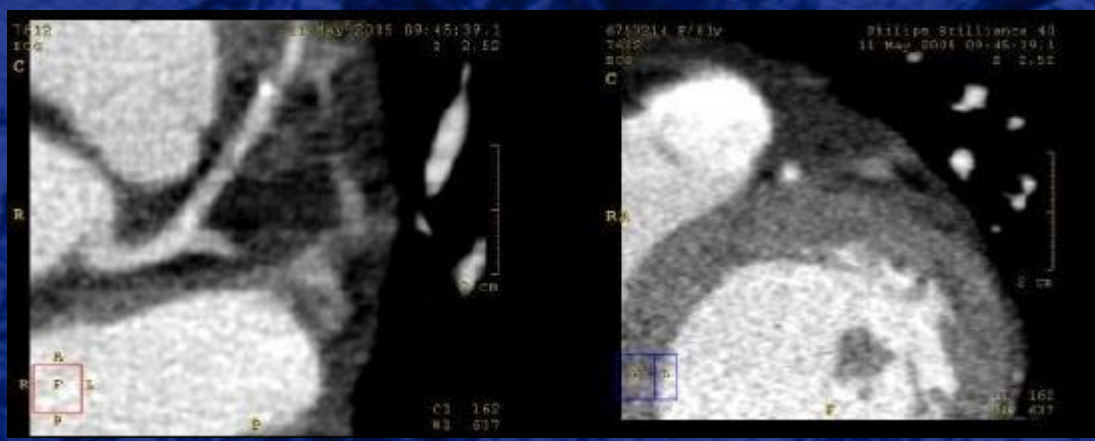
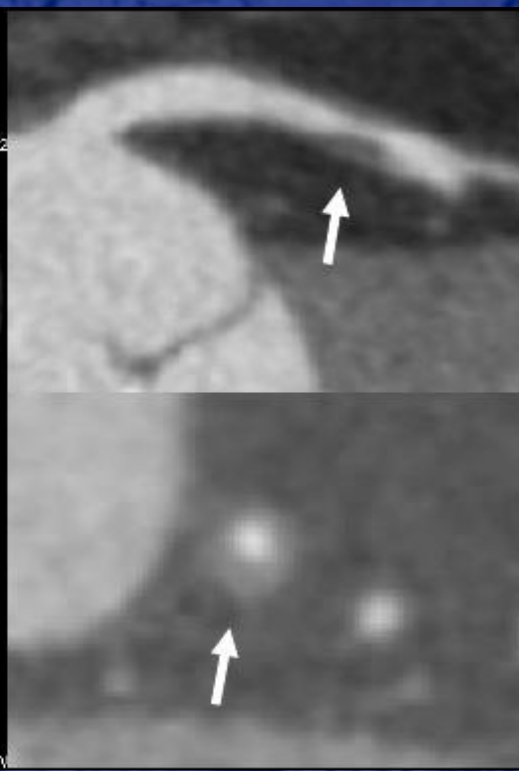
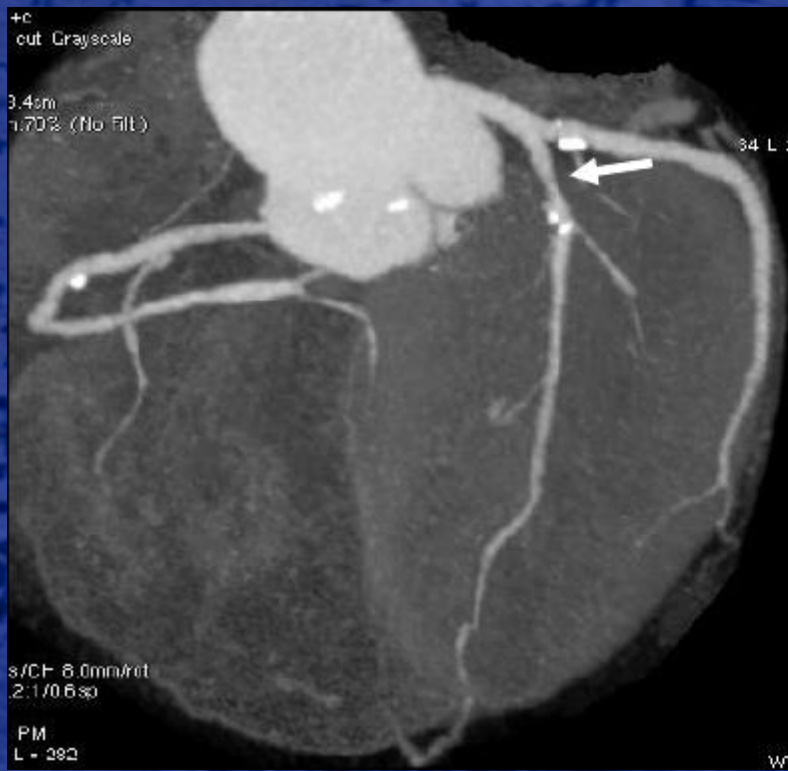




# Technique : Post Traitement



# Technique : Post Traitement



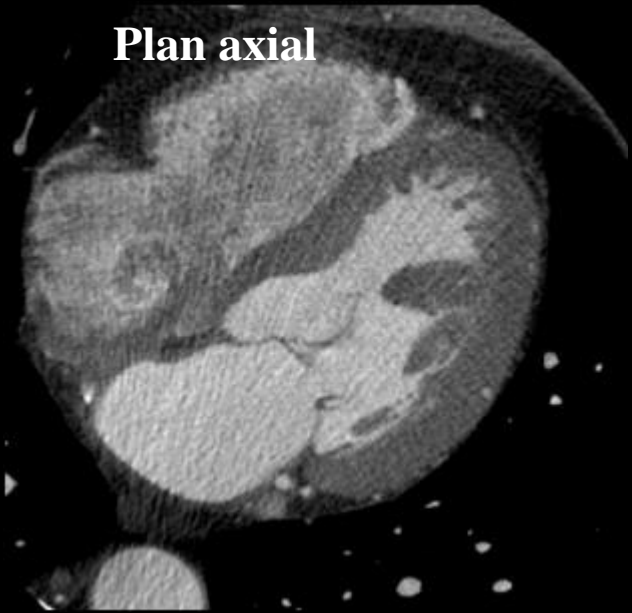
Reconstructions manuelles + +

Outil d'analyse

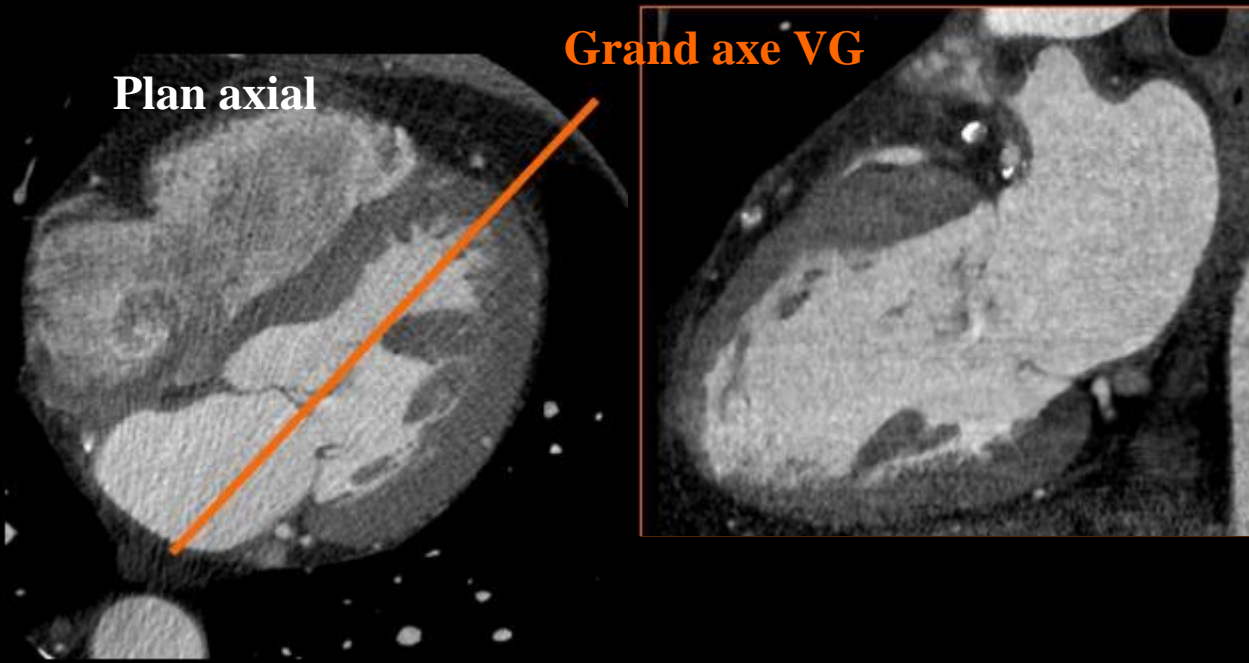


# Post Traitement des plans de coupe cardiaques

Plan axial

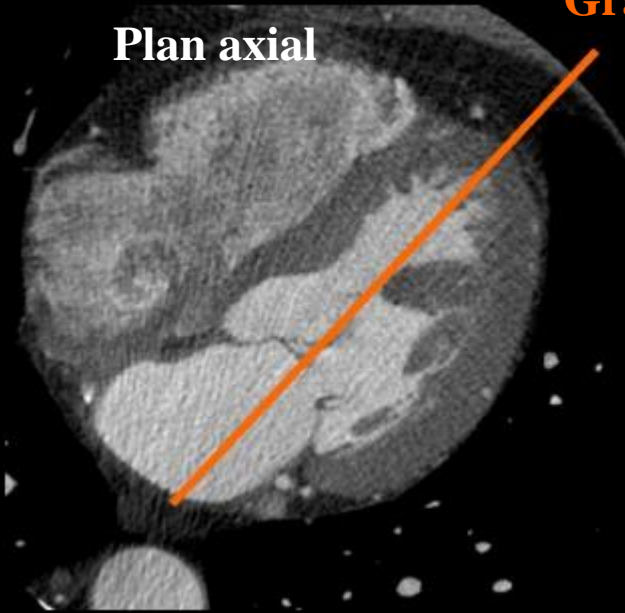


# Post Traitement des plans de coupe cardiaques

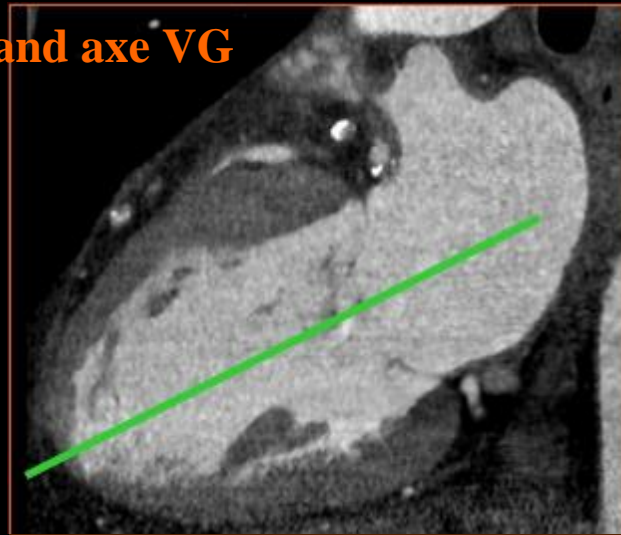




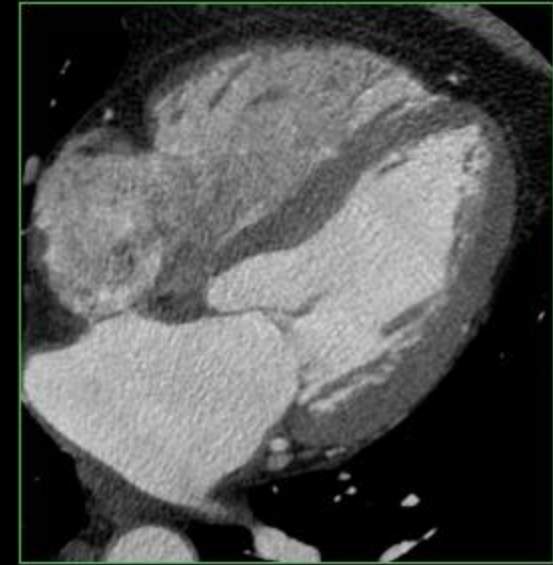
# Post Traitement des plans de coupe cardiaques



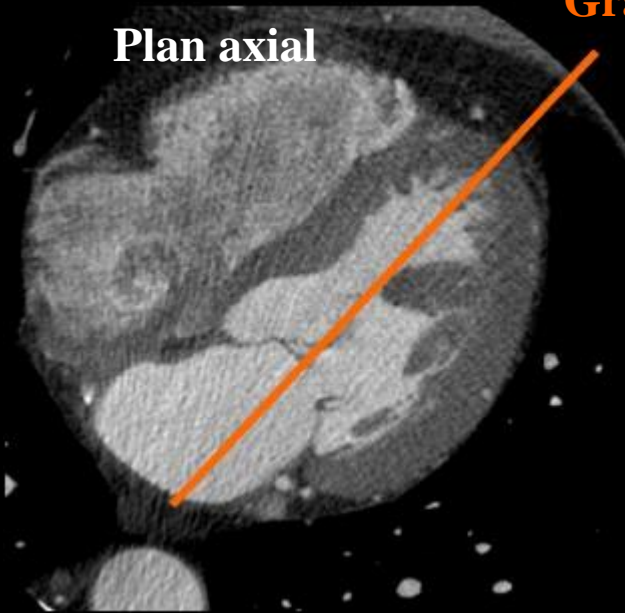
Grand axe VG



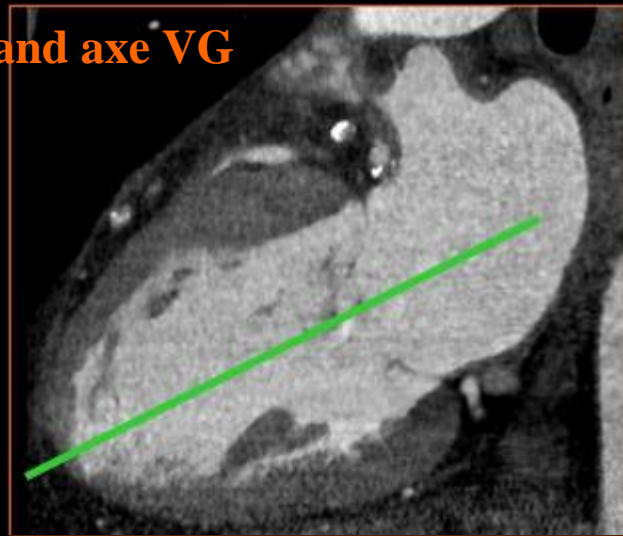
Pseudo 4 cavités



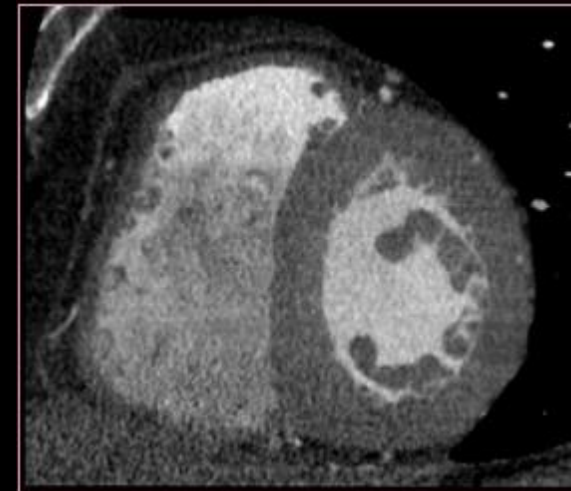
# Post Traitement des plans de coupe cardiaques



**Grand axe VG**



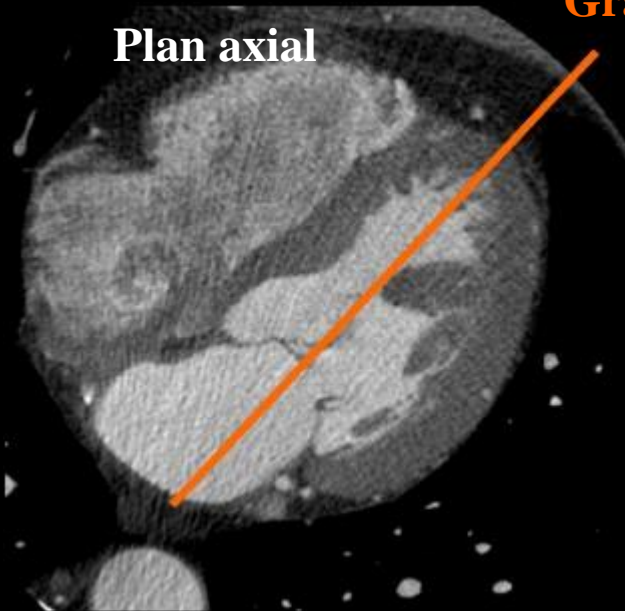
**Pseudo 4 cavités**



**Petit axe VG**



# Post Traitement des plans de coupe cardiaques



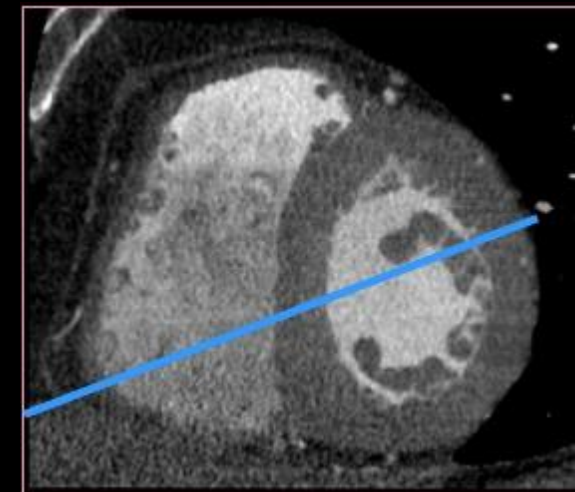
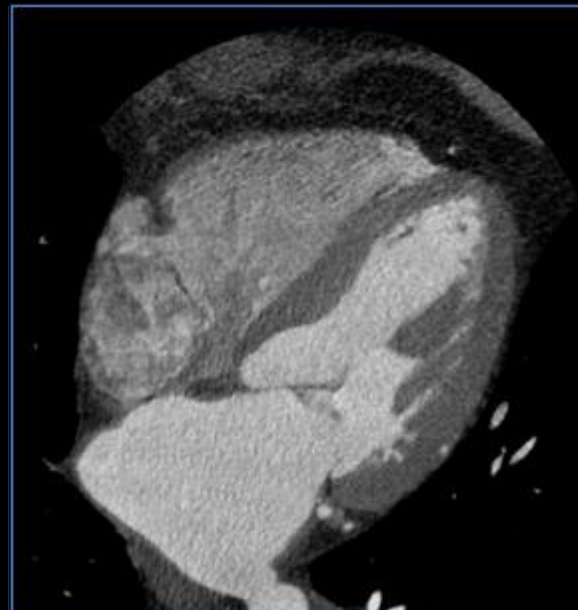
**Grand axe VG**



**Pseudo 4 cavités**

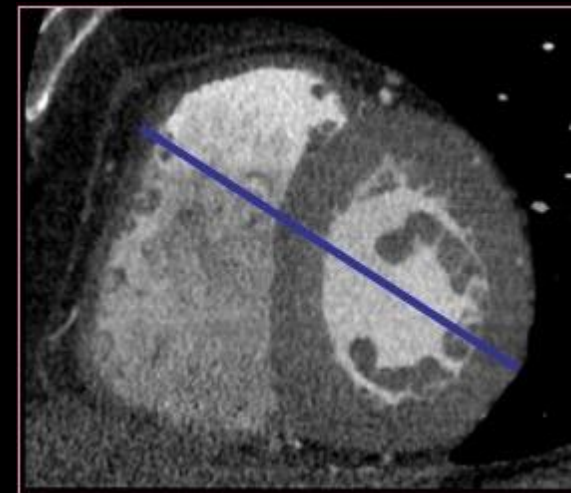
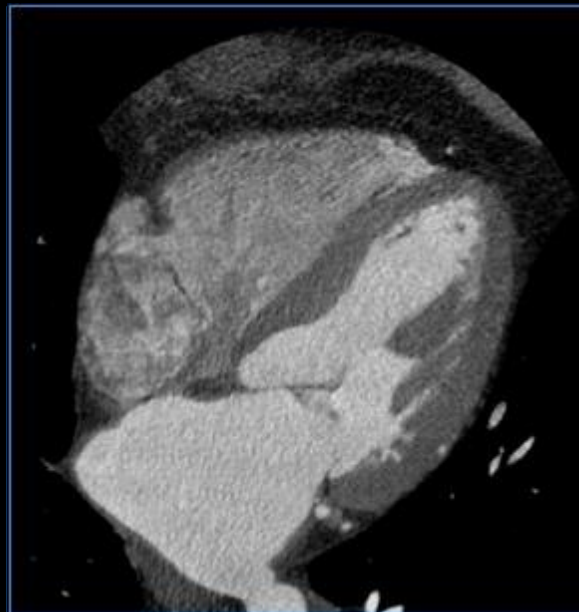
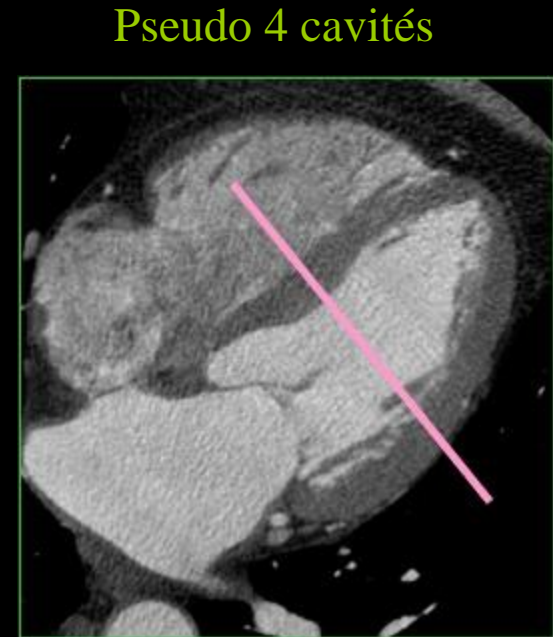
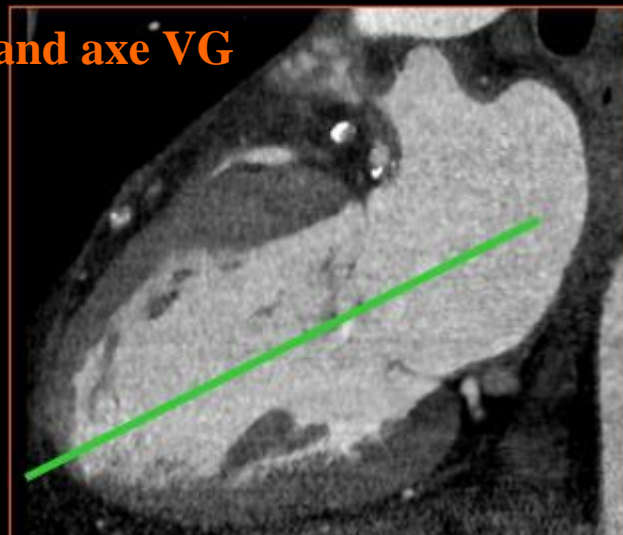
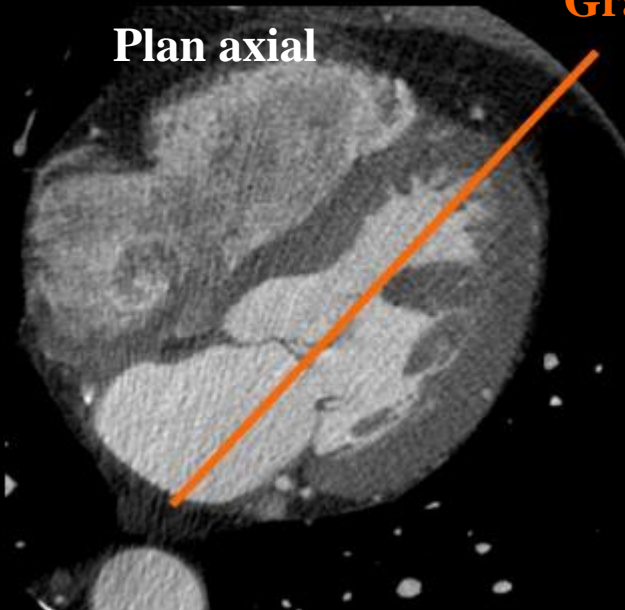


**4 cavités**



**Petit axe VG**

# Post Traitement des plans de coupe cardiaques



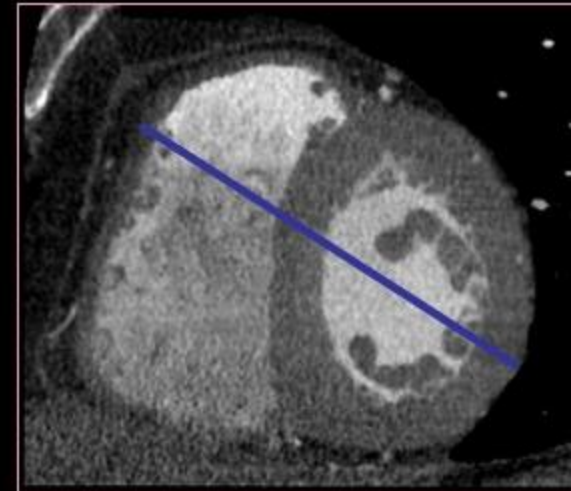
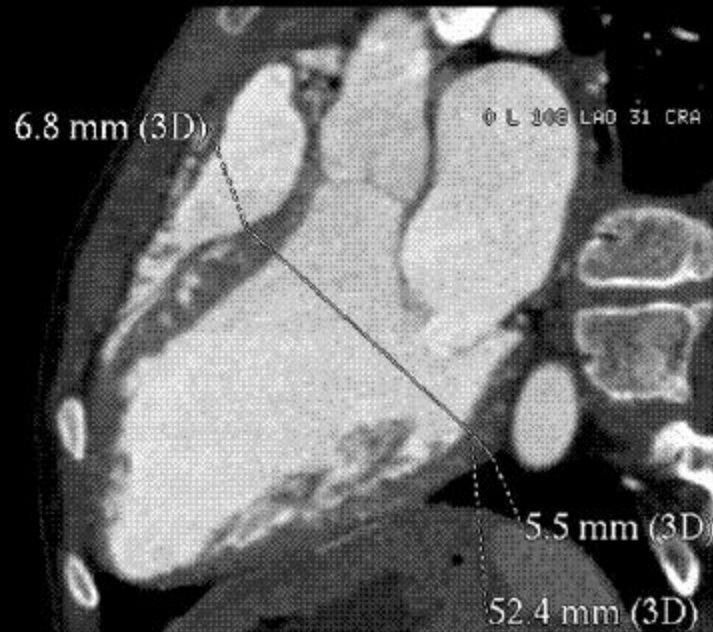
Petit axe VG



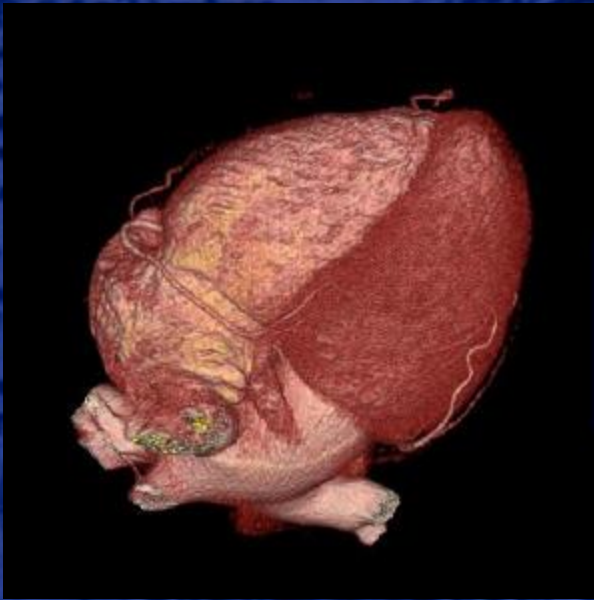
# Post Traitement des plans de coupe cardiaques

Mesures en  
télédiastole

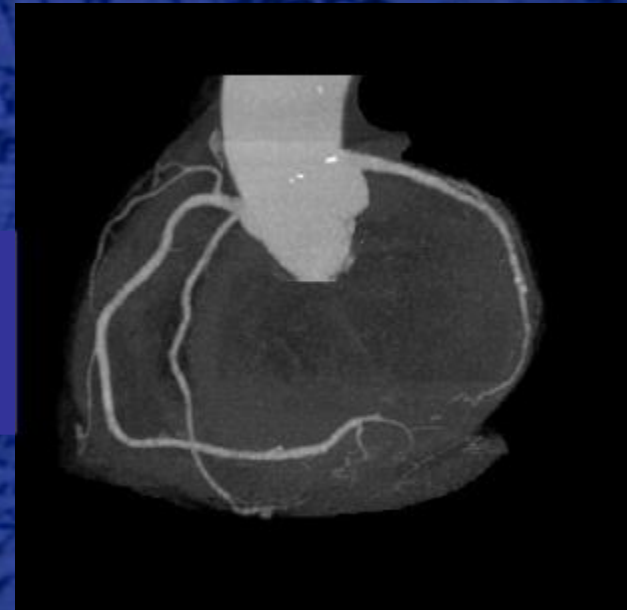
+++



# Visualisation des artères coronaires et des pontages coronaires enTDM

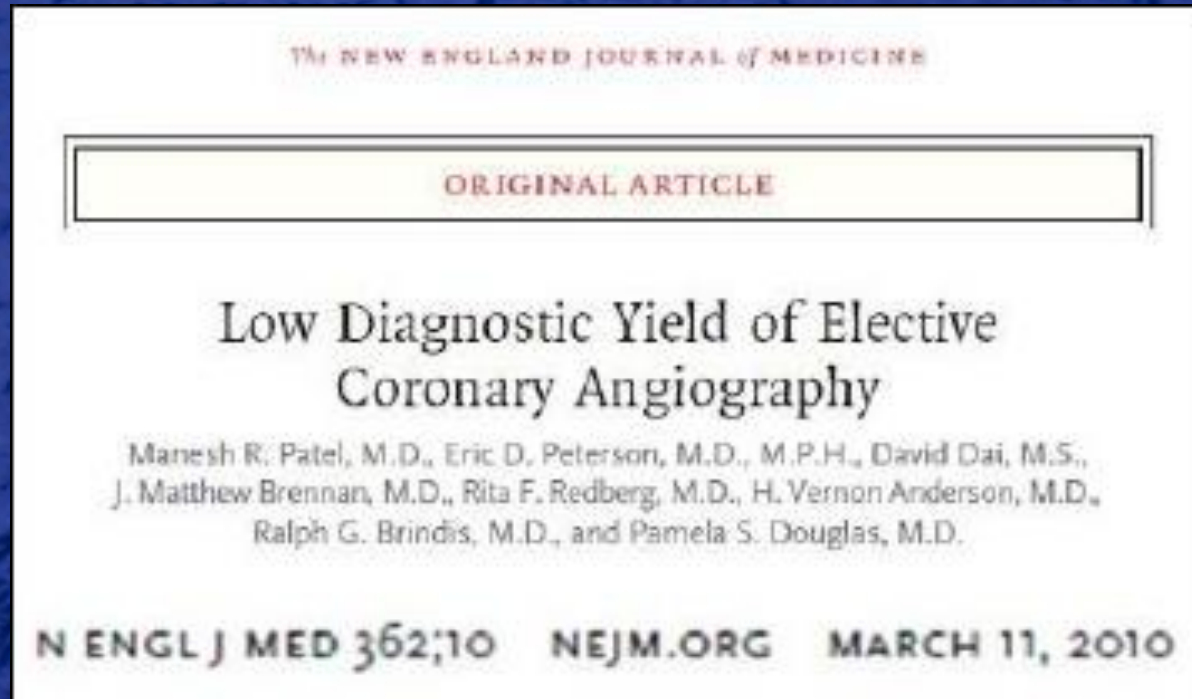


Intérêts  
potentiels





## Indications potentielles : Coronarographies blanches



400 000 coronarographies entre 2004 et 2008 (USA)      2 millions screenés

Exclusions : coronaropathie connue, greffé, valvulopathie, suspicion SCA, choc, arrêts...

84% ont eu un **ECG** ou un **test de provocation d'ischémie** (16% n'ont rien eu...)

Résultats:      Lésions > 70%      : 38%

**Pas de lésion (ou < 20%) :39%**

En France  $\approx$  **30%** (GACI)



# Indications Actuelles

## Patients sans Coronaropathie connue

CMD: ischémique ou non

Bilan d'une coronaropathie en pré-opératoire

Chirurgie non cardiaque

Chirurgie valvulaire

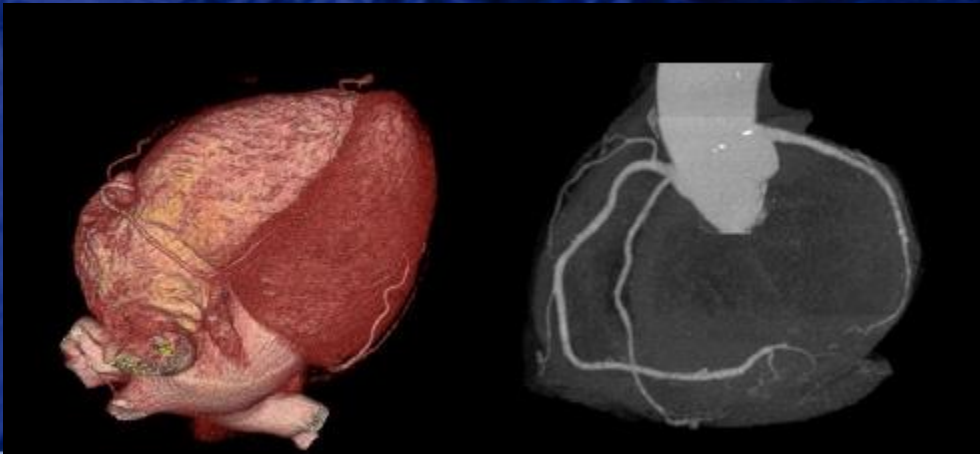
Détection d'une coronaropathie chez des patients ayant un risque faible ou intermédiaire



## Patients ayant une coronaropathie connue

– Suivi

- pontage coronaire
- Stents coronaires





# 2013 ESC guidelines on the management of stable coronary artery disease

**Table 16** Use of coronary computed tomography angiography for the diagnosis of stable coronary artery disease

Recommendations	Class <sup>a</sup>	Level <sup>b</sup>
Coronary CTA should be considered as an alternative to stress imaging techniques for ruling out SCAD in patients within the lower range of intermediate PTP for SCAD in whom good image quality can be expected.	IIa	C
Coronary CTA should be considered in patients within the lower range of intermediate PTP for SCAD after a non conclusive exercise ECG or stress imaging test or who have contraindications to stress testing in order to avoid otherwise necessary invasive coronary angiography if fully diagnostic image quality of coronary CTA can be expected.	IIa	C
Coronary calcium detection by CT is not recommended to identify individuals with coronary artery stenosis.	III	C
Coronary CTA is not recommended in patients with prior coronary revascularization.	III	C
Coronary CTA is not recommended as a 'screening' test in asymptomatic individuals without clinical suspicion of coronary artery disease.	III	C

Patients with suspected SCAD and

**Table 13** Clinical pre-test probabilities<sup>a</sup> in patients with stable chest pain symptoms<sup>108</sup>

Consi  
• Patie  
• Avail  
• Loca

Age	Typical angina		Atypical angina		Non-anginal pain	
	Men	Women	Men	Women	Men	Women
30–39	59	28	29	10	18	5
40–49	69	37	38	14	25	8
50–59	77	47	49	20	34	12
60–69	84	58	59	28	44	17
70–79	89	68	69	37	54	24
>80	93	76	78	47	65	32

ICA  
(with FFR  
when  
necessary)

↑  
patient  
tics and  
aces<sup>b</sup>

ditional CAD  
her causes

Established  
ratification  
(g. 3)

g using stress  
imaging if not done before<sup>f</sup>



# 2014 ESC/EACTS Guidelines on myocardial revascularization

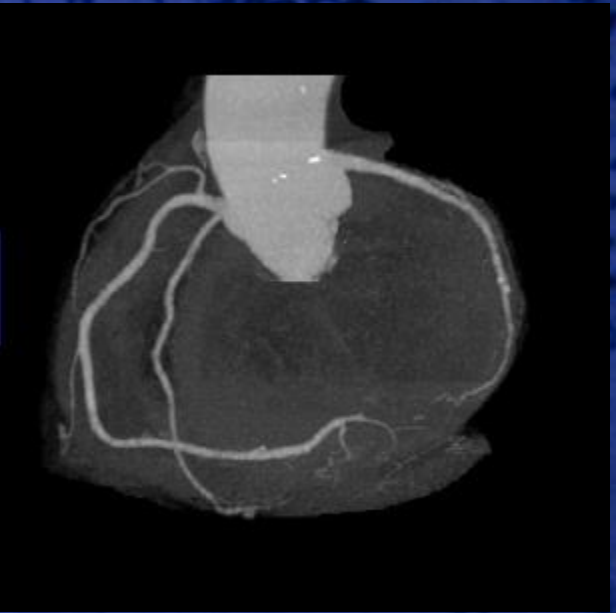
## Indications for diagnostic testing in patients with suspected CAD and stable symptoms

	Asymptomatic <sup>a</sup>		Symptomatic						Ref <sup>e</sup>
			Probability of significant disease <sup>b</sup>						
			Low (<15%)		Intermediate (15–85%)		High (>85%)		
	Class <sup>c</sup>	Level <sup>d</sup>	Class <sup>c</sup>	Level <sup>d</sup>	Class <sup>c</sup>	Level <sup>d</sup>	Class <sup>c</sup>	Level <sup>d</sup>	
<b>Anatomical detection of CAD</b>									
Invasive angiography	III	A	III	A	IIb	A	I	A	50–52,54
CT angiography <sup>f,g</sup>	III	B	III	C	IIa	A	III	B	57–62
<b>Functional test</b>									
Stress echo	III	A	III	A	I	A	III	A	63–65
Nuclear imaging	III	A	III	A	I	A	III	A	60,66–70
Stress MRI	III	B	III	C	I	A	III	B	71–75
PET perfusion	III	B	III	C	I	A	III	B	67,69,70,76,77
<b>Combined or hybrid imaging test</b>									
	III	C	III	C	IIa	B	III	B	78–83

# Visualisation des artères coronaires en TDM



Résultats





# Détection des sténoses coronaires par MSCT (16b.)

## Diagnostic Accuracy to Detect Significantly Stenosed Coronary Arteries\*

(n = 59)(diam > 2 mm)

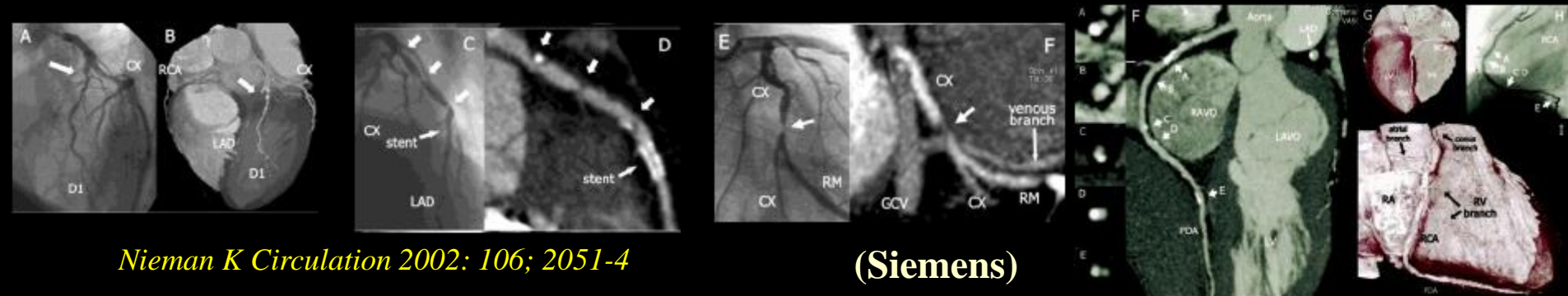
	All Branches	RCA	LM	LAD	CX
≥50% stenosed branches	86	22	3	37	24
Well assessable	160 (69)	32 (56)	52 (90)	38 (66)	38 (66)
Adequately assessable	54 (23)	18 (32)	5 (9)	15 (26)	16 (28)
Poorly assessable	17 (7)	7 (12)	1 (2)	5 (9)	4 (7)
No detectable calcium	89 (39)	23 (40)	29 (50)	9 (16)	28 (48)
Small calcified nodules	74 (32)	14 (25)	19 (33)	26 (45)	15 (26)
Marked calcification	68 (29)	20 (35)	10 (17)	23 (40)	15 (26)
Sensitivity	82/86 (95, 89–98)	22/22 (100)	3/3 (100)	37/37 (100)	20/24 (83)
Specificity	125/145 (86, 83–88)	27/35 (77)	55/55 (100)	16/21 (76)	27/34 (79)
Negative predictive value	82/102 (80, 75–83)	22/30 (73)	3/3 (100)	37/42 (88)	20/27 (74)
Positive predictive value	125/129 (97, 93–99)	27/27 (100)	55/55 (100)	16/16 (100)	27/31 (87)

Values are n (% , 95% confidence interval).

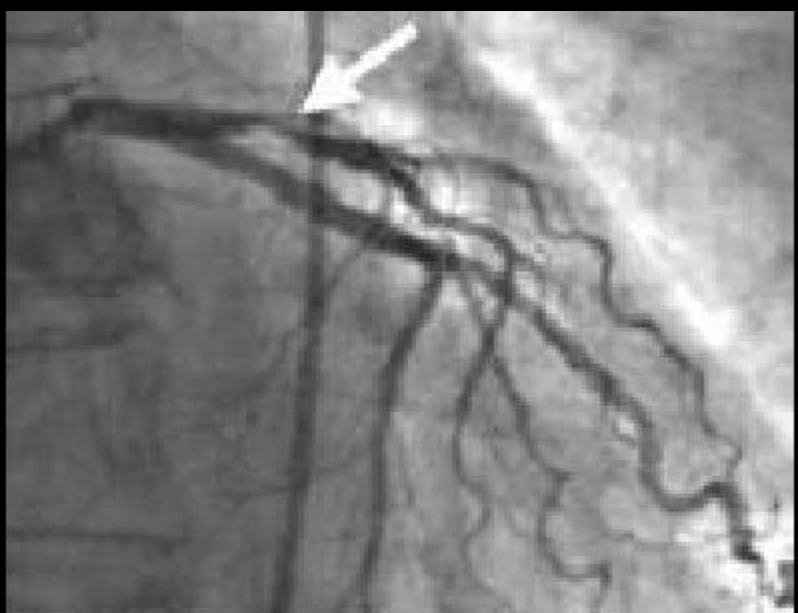
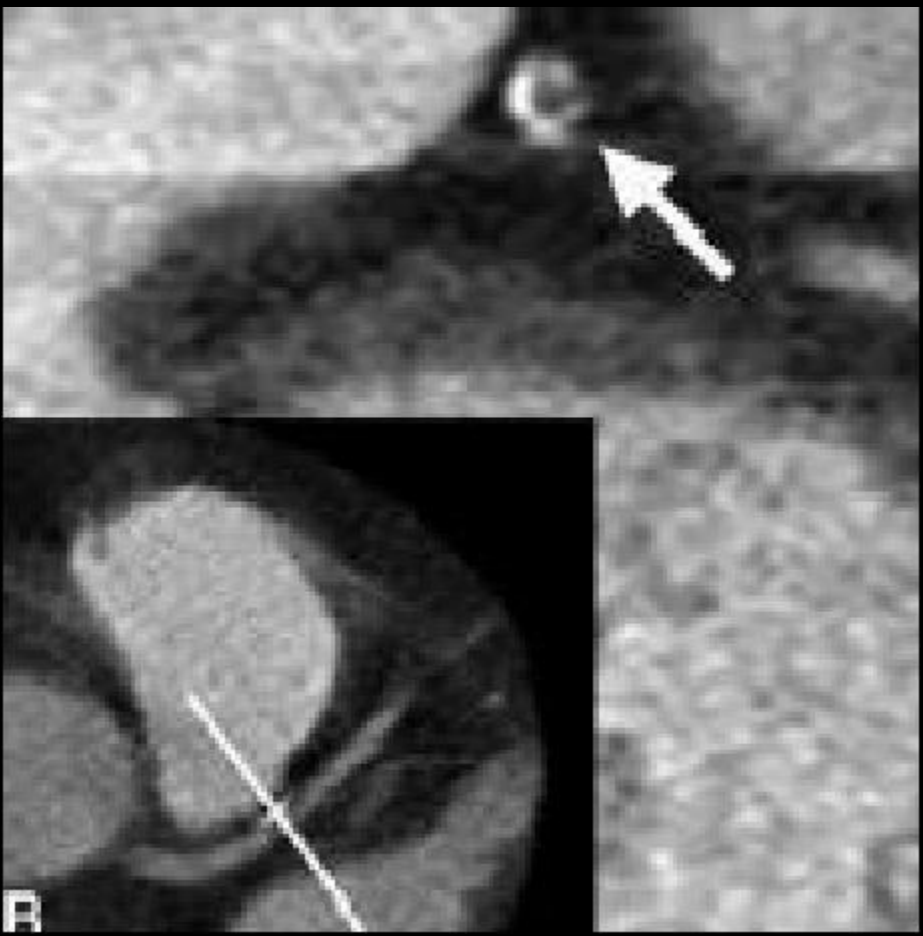
(prév coronaropathies = 37%)

RCA, LM, LAD, and LCX indicate right, left main, left anterior descending, and left circumflex coronary artery, respectively.

\*≥50% lumen diameter reduction, in ≥2.0 mm diameter vessels, consensus reading.

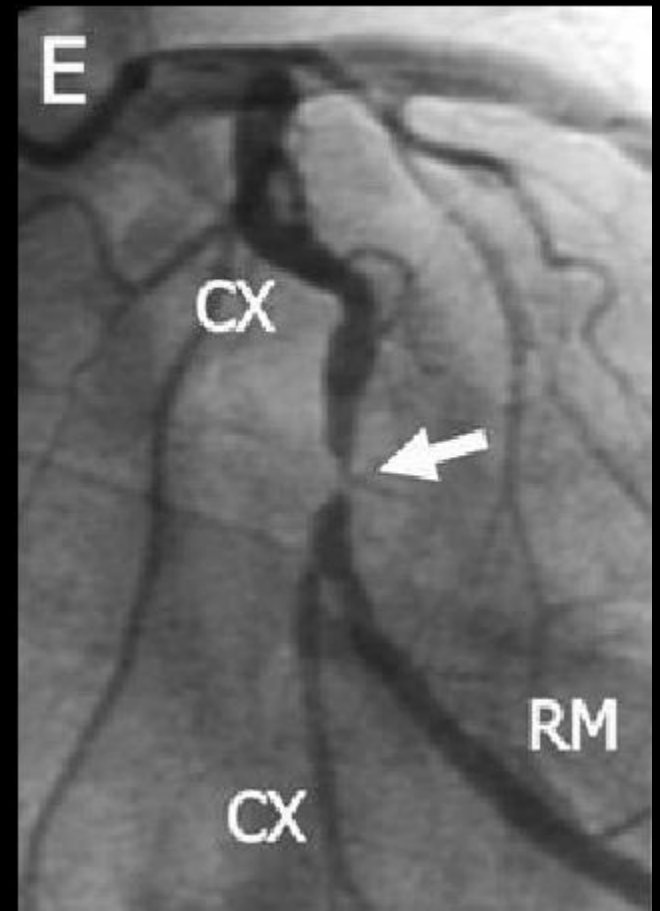
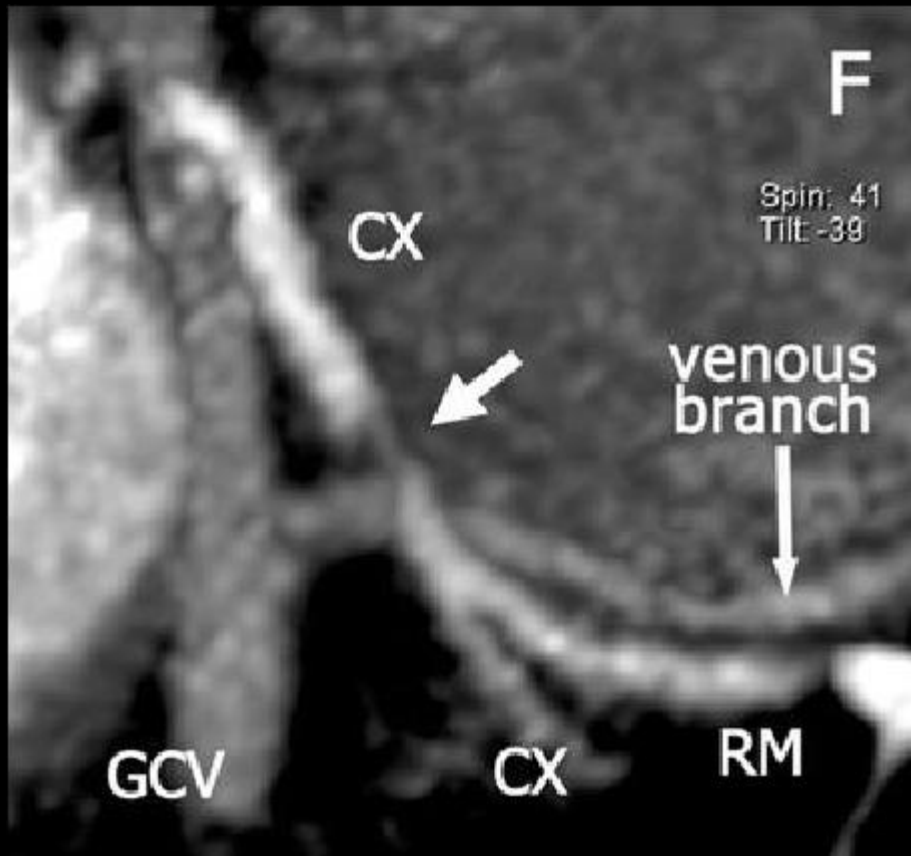


# Sténose IVA1





# Sténose Cx



## Diagnostic Performance of Coronary CT Angiography by Using Different Generations of Multisection Scanners:

	<b>4-MSCT</b>	<b>16-MSCT V1</b>	<b>16-MSCT V2</b>	<b>64-MSCT</b>	<b>256-MSCT</b>
<b>Poor quality</b>	33.1%	14.4%	6.3%	2.6%	1,5%
<b>Sensibilité</b>	57%	90%	97%	99%	96%
<b>Spécificité</b>	91%	93%	98%	96%	94%
<b>VPP</b>	60%	65%	87%	80%	79%
<b>VPN</b>	90%	99%	100%	100%	100%

Pugliese F Radiology 2008; 246:384-393

Junfu L J Comput Assist Tomogr 2018;42:54-61



# Cactus Trial

Hausleiter et al – Eur Heart J 2007

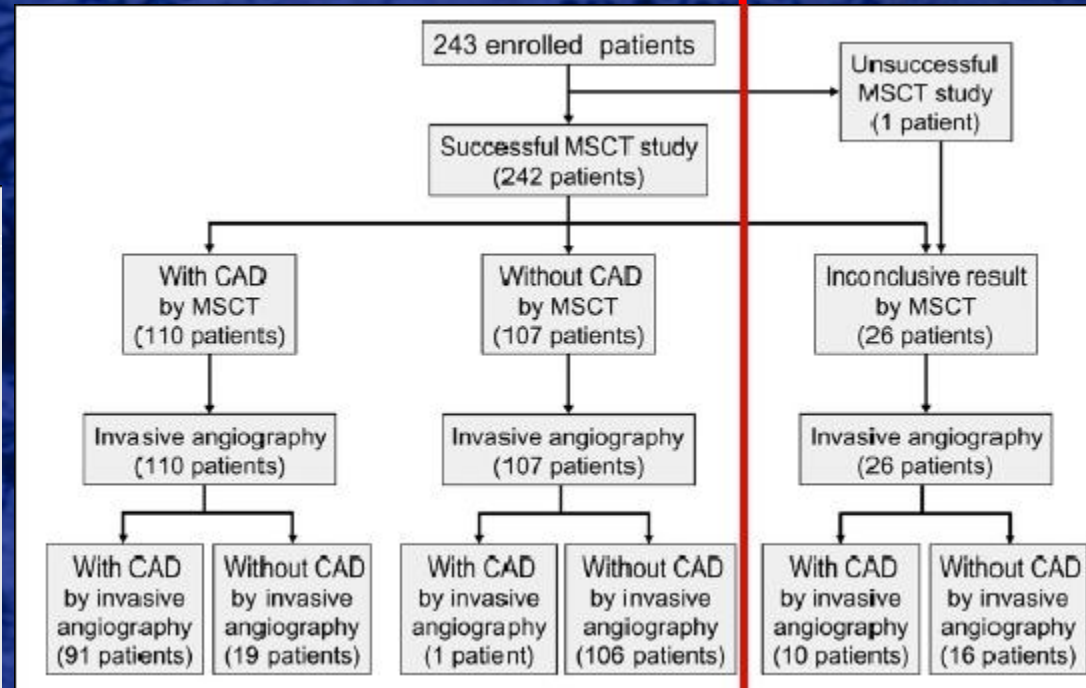


Sept 2003 – Juillet 2005

16- ou 64- MSCT (Siemens)

243 Patients	
Age, years	62.0 ± 9.9
Male sex, n (%)	158 (65.0)
Body mass index, kg/m <sup>2</sup>	26.9 ± 4.3
Total cholesterol, mg/dL	219.3 ± 43.4
LDL cholesterol, mg/dL	134.0 ± 38.0
HDL cholesterol, mg/dL	55.3 ± 15.9
Triglycerides, mg/dL	159.1 ± 108.3
Arterial hypertension, n (%)	108 (44.4)
Diabetes mellitus, n (%)	37 (15.2)
Active smoker, n (%)	38 (15.6)
Positive family history, n (%)	91 (37.4)
Framingham score	14.6 ± 10.9
Non-invasive stress testing for ischemia	
Treadmill, n (%)	129 (53.1)
Myocardial scintigraphy, n (%)	10 (4.1)
Stress echocardiography, n (%)	4 (1.6)
Indication for invasive angiography	
Chest pain, n (%)	168 (69.1)
Dyspnea, n (%)	8 (3.3)
Intermitt. arrhythmia, n (%)	21 (8.7)
Positive stress test, n (%)	46 (18.9)

- Si FC > 60 bpm, metoprolol IV 5 mg (max 20 mg)
- Iomeron 80 – 140 cc
- Exclusion des segments < 2 mm



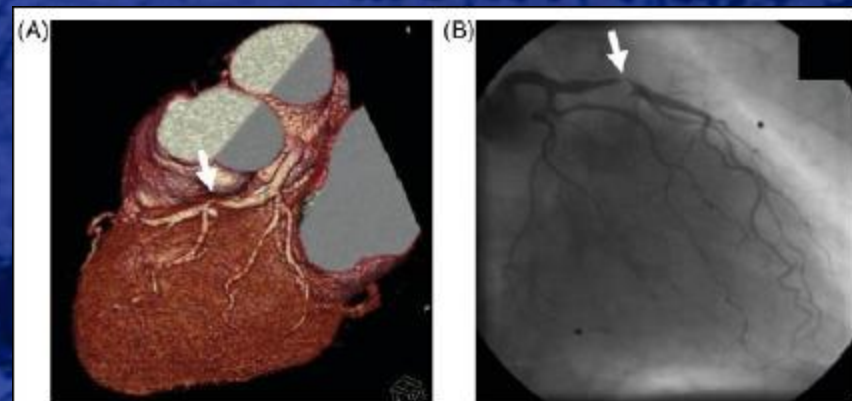
243 Patients	
16-slice CT, n (%)	129 (53.1)
64-slice CT, n (%)	114 (46.9)
Metoprolol i.v., mg	10 ± 5.5
Nitrates p.o., n (%)	239 (98.4)
Heart rate, b.p.m.	56.6 ± 6.5
Scan length, mm	125.4 ± 17.2
Agatston score equivalent (ASE)	96 [4, 398]
ASE = 0, n (%)	49 (20.2)
ASE > 1000, n (%)	24 (9.9)
MSCT radiation dose estimates	
Non-enhanced scan for calcium scoring, mSv	0.7 ± 0.4
MSCT angiography, mSv	7.4 ± 3.0
Total radiation dose, mSv	8.1 ± 3.2
Total radiation dose for 16-slice CT, mSv	5.9 ± 1.6
Total radiation dose for 64-slice CT, mSv	10.5 ± 2.8

**Table 3** Diagnostic accuracy of coronary multislice spiral computed tomography compared with invasive angiography for detection of lesions  $\geq 50\%$

	Patients (n = 243)	Arteries (n = 967)	Segments (n = 2653)
Prevalence of lesions	41.6	18.2	9.6
Sensitivity	99 (94-99)	96 (92-98)	95 (88-95)
Specificity	75 (67-82)	87 (83-90)	90 (87-92)
Positive predictive value	74 (66-81)	62 (56-69)	50 (42-57)
Negative predictive value	99 (94-99)	99 (98-100)	99 (99-100)

## Cactus Trial

Hausleiter et al – Eur Heart J 2007



**Table 4** Subgroup analysis for the diagnostic accuracy of coronary multislice spiral computed tomography compared with invasive angiography

	MSCT technology		P-value	Calcification (ASE)		P-value	Heart rate		P-value
	16-Slice (n = 1417)	64-Slice (n = 1266)		<1000 (n = 2408)	$\geq 1000$ (n = 275)		<65 b.p.m. (n = 2449)	$\geq 65$ b.p.m. (n = 234)	
Lesion prevalence (%)	10.0	8.8		7.7	25.1		9.5	9.0	
Inconclusive results (%)	11.3	7.6	<0.001	5.5	44.4	<0.001	6.7	38.0	<0.001
Sensitivity (%)	93 (87-97)	92 (87-95)	0.98	93 (88-96)	97 (88-99)	0.32	89 (84-92)	95 (59-100)	0.91
Specificity (%)	87 (83-91)	92 (89-94)	0.09	93 (90-94)	60 (49-71)	<0.001	91 (89-93)	78 (62-89)	0.022
Positive predictive value (%)	46 (36-57)	54 (46-63)	0.22	52 (43-60)	45 (33-57)	0.33	52 (44-59)	30 (13-55)	0.09
Negative predictive value (%)	99 (98-100)	99 (99-100)	0.64	99 (99-100)	98 (94-100)	0.13	99 (99-100)	99 (95-100)	0.97

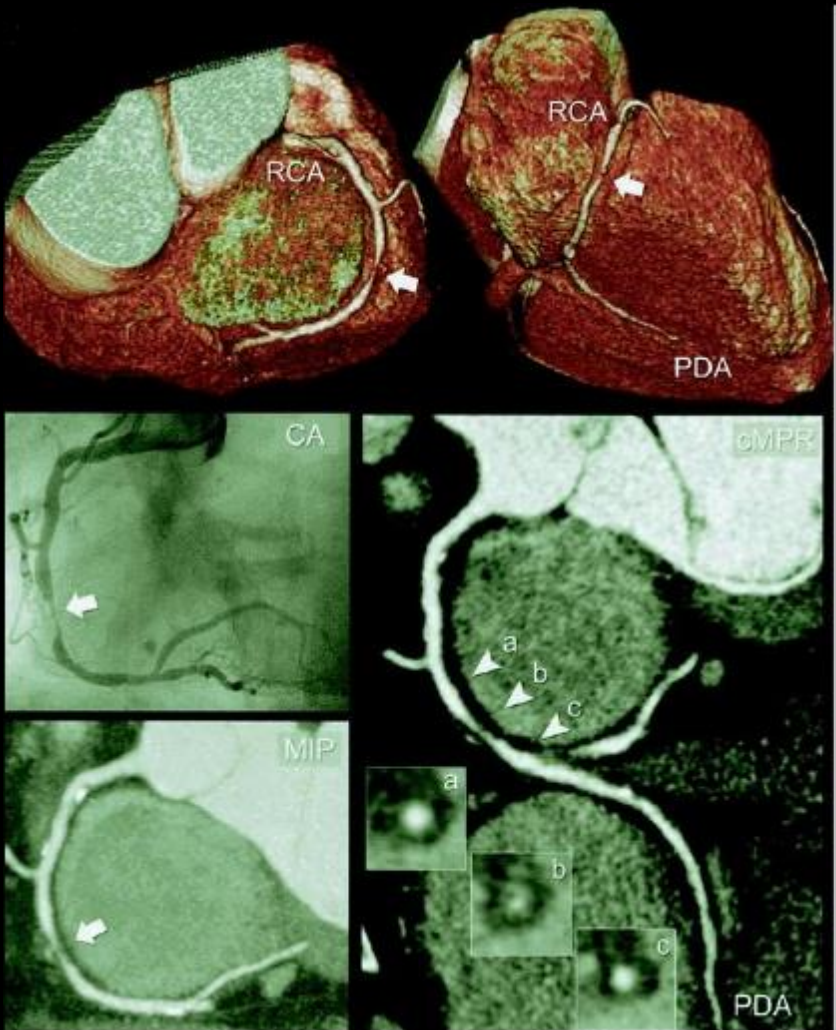
Values are percentages (95% confidence intervals). MSCT, multi-slice computed tomography; ASE, Agatston score equivalent. All coronary segments determined as inconclusive were considered significantly diseased by MSCT angiography (lumen narrowing  $\geq 50\%$ ) for the calculation of sensitivity, specificity, and positive and negative predictive values.



# Détection des sténoses coronaires par MSCT (64b)

52 pts

64-MSCT (Sensation 64, Siemens)



## Détection des sténoses coronaires par MSCT (64b)

**TABLE 2. Diagnostic Performance and Predictive Value of 64-Slice CT Coronary Angiography for the Detection of  $\geq 50\%$  Stenoses on QCA**

	n	Sensitivity, %	Specificity, %	PPV, %	NPV, %	+LR	-LR
Segment-based analysis							
All segments	725	99 (94–98)	95 (93–96)	76 (67–89)	100 (99–100)	20.81	0.01
Proximal segments	204	100 (89–100)	97 (93–98)	83 (67–97)	100 (97–100)	29.00	0.00
Mid segments	142	97 (83–99)	94 (88–97)	81 (63–96)	99 (94–99)	15.47	0.04
Distal segments	121	100 (68–100)	97 (92–99)	73 (39–98)	100 (96–100)	37.67	0.00
Side branches	258	100 (87–100)	94 (90–96)	65 (48–85)	100 (98–100)	16.57	0.00
LM	51	100 (21–100)	100 (93–100)	100 (92–100)	100 (2–100)	$\infty$	0.00
LAD	230	97 (85–100)	92 (88–95)	69 (53–86)	99 (96–99)	12.68	0.03
LCx	235	100 (88–100)	97 (94–99)	83 (66–97)	100 (98–100)	34.33	0.00
RCA	209	100 (89–100)	95 (91–97)	77 (60–95)	100 (97–100)	19.89	0.00
Patient-based analysis							
All segments	51	100 (91–100)	92 (67–99)	97 (86–99)	100 (73–100)	13.00	0.00

PPV indicates positive predictive value; NPV, negative predictive value; +LR, positive likelihood ratio; -LR, negative likelihood ratio; LM, left main coronary artery; LCx, circumflex coronary artery; and RCA, right coronary artery. For segment-based analysis, analysis of 725 segments visualized on the conventional angiogram and classified according to a 17-segment modified AHA classification was performed. Segments were further classified on the basis of their location within the coronary tree (proximal, mid, or distal segments of the main coronary artery arteries or side branches) and their location within a single vessel (LM, LAD, LCx, or RCA). For patient-based analysis, analysis of 51 patients was performed. Values in parentheses represent 95% CIs.





# TDM et Coronaropathie

Auteurs	Revue	Année	N	Se	Sp	PPV	NPV	NA
4 Nieman	Lancet	2001	35	95%	86%	81%	97%	30%
Achenbach	Circ	2001	64	91%	84%	59%	98%	32%
Nieman	Circ	2002	58	95%	86%	80%	97%	0%
16 Gilard M	AJC	2005	27	100%	93%	100%	92%	7%
Mollet	JACC	2005	51	95%	98%	87%	99%	0%
Leshka	EHJ	2005	67	94%	97%	87%	99%	0%
Raff	JACC	2005	70	91%	92%	80%	97%	1%
64 Pugliese	ER	2006	35	100%	90%	96%	100%	0%
Ehara	Circ J	2006	67	98%	86%	98%	86%	8%
Ropers	AJC	2006	84	96%	91%	83%	98%	4%
Meijboom	Heart	2007	104	100%	75%	96%	100%	0%
128 Arnoldi	Radiologe	2010	20	88%	92%	92%	100%	0%
Alkadhi	Heart	2010	61	93%	94%	89%	97%	8%
256 Chao	EHJ	2010	52	94%	87%	83%	96%	6%
Dewey	Circ	2010	30	100%	94%	92%	100%	0%
320 DeGraaf	EHJ	2010	42	100%	81%	88%	100%	6%



# 64-multislice detector computed tomography coronary angiography as potential alternative to conventional coronary angiography: a systematic review and meta-analysis

Abdulla J et al. - *European Heart Journal* 2007; 28(24):3042-50

27 études, 1740 patients

Artères coronaires natives: n = 1251 (19 études)

Pontages (CABG): n = 271 (4 études)

Stents: n = 270 (5 études)

4% des segments coronaires = non interprétables



	Natives		CABG	Stents
	<u>segment</u>	<u>patient</u>		
Sensibilité	86%	98%	99%	87%
Spécificité	96%	91%	96%	96%
VPP	83%	93%	92%	84%
VPN	97%	97%	99%	97%



## Limites des études MSCT vs Coro

Analyse statistique

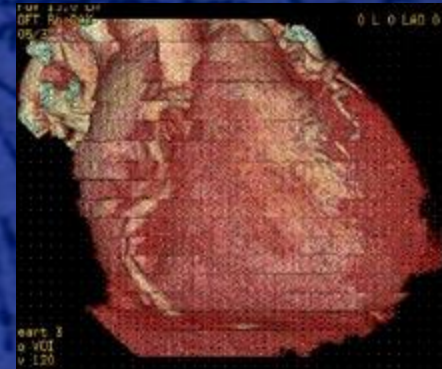
- par lésion
- par segment
- par artère
- par patient ++

Exclusion des segments non-évaluables

- artéfacts cinétiques
- calcifications
- petits vaisseaux ( $< 1,5$  ou  $2$  mm)

Reproductibilité intra- et inter-observateur

Intérêt des mesures des valeurs prédictives (VPN, VPP)





# **Intra- and interobserver variability in detection and assessment of calcified and noncalcified coronary artery plaques using 64-slice computed tomography: Variability in coronary plaque measurement using MSCT**

*Hoffmann H, Frieler K, Hamm B, Dewey M.*

*Int J Cardiovasc Imaging. 2008 Jun 28*



20 patients

64-CT \* 0.5 mm detector collimation

2 observateurs indépendants

- 1- **Détection** des plaques coronaires (n = 82 dans 262 segments coronaires)
- 2- **Classification** des plaques : calcifiées, mixtes, ou non calcifiées.
- 3- Détermination manuelle du **volume** total de plaque, refaite après 1 mois

Variabilité **inter**-observateur:

- correcte pour la détection des plaques ( $\kappa = 0.88$ , 95% CI [0.76, 0.95]).
- moyenne pour la classification des plaques ( $\kappa = 0.45$ , 95% CI [0.35, 0.61]).

Variabilité **intra**-observateur:

- correcte pour la détection des plaques ( $\kappa = 0.90$ , 95% CI [0.77, 0.96])
- modérée pour la classification des plaques ( $\kappa = 0.65$ , 95% CI [0.55, 0.80]).
- modérée pour la reproductibilité de mesure du volume total de plaque :
  - \* limites d'agrément = +/-6 mm<sup>3</sup> pour un volume moyen de 10 mm<sup>3</sup>
  - \* limites d'agrément = +/-28 mm<sup>3</sup> pour un volume moyen de 100 mm<sup>3</sup>



## Limites des études MSCT vs Coro

« La période d'évaluation et de validation de l'angioscanner des artères coronaires n'est pas encore terminée »

*M Gilard, J Boschat, SFR-SFC 2011*

En attente de la publication des recommandations **HAS** depuis 2009...

The logo for the Haute Autorité de Santé (HAS) features the letters 'HAS' in a bold, blue, sans-serif font. A red and orange swoosh underline is positioned beneath the 'A' and 'S'.

HAUTE AUTORITÉ DE SANTÉ

RAPPORT D'ÉVALUATION TECHNOLOGIQUE

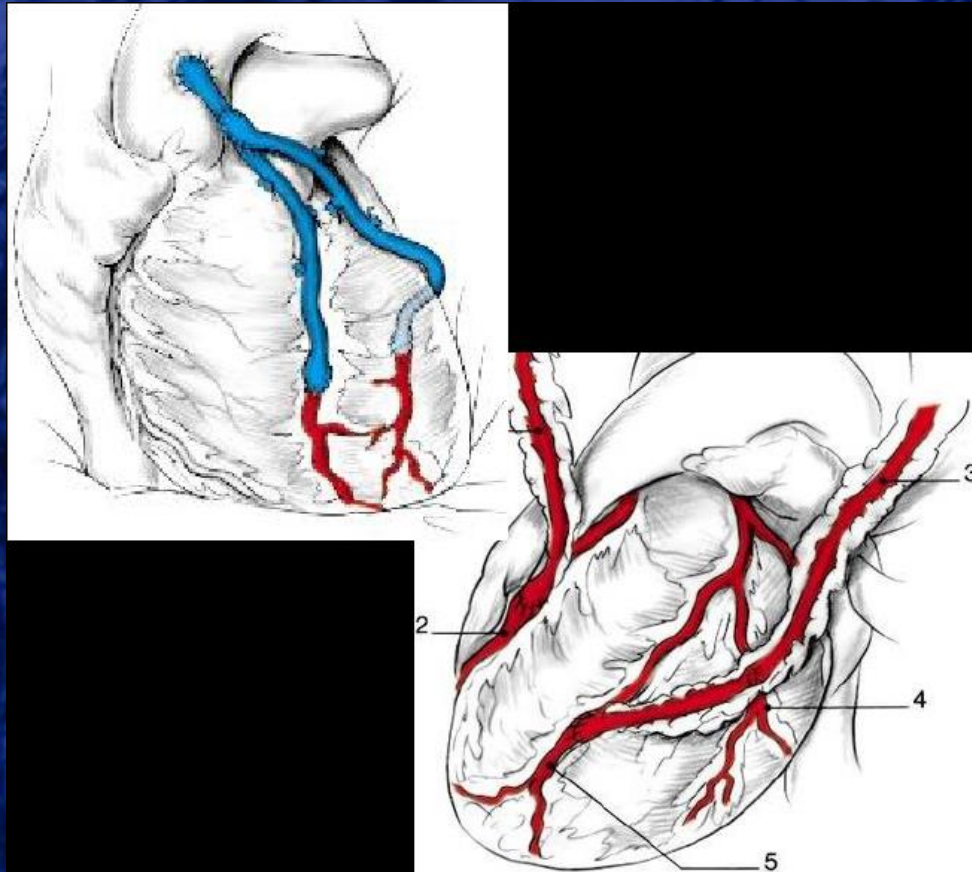
Évaluation de l'imagerie  
cardiaque non invasive dans le  
diagnostic des coronaropathies  
chroniques stables

Novembre 2016



# Visualisation des pontages coronaires en TDM

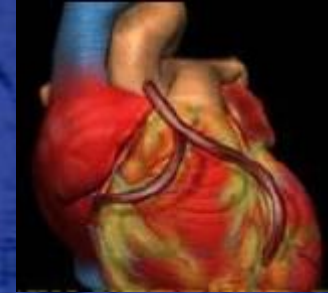
Résultats





# Imagerie des pontages : Intérêts du MSCT

- Pontages :
- relativement immobiles
  - plus gros calibre (GV)
  - moins calcifiés (MI)



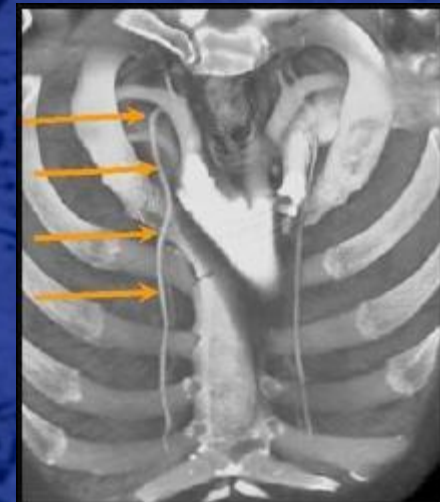
Coronarographie parfois difficile et avec un risque accru

Réduction de la quantité de produit de contraste / coronarographie

Analyse anatomique aisée (VR 3D)


Rapports anatomiques / Chir redux

CRO +++





# Imagerie des pontages : Technique

- **Sélection** des patients
  - FC < 80 bpm, pas d'arythmie (ES)
  - apnée 15" possible
- **Injection**
  - **MSD** +++ (MSG =>artéfacts AMIG – TV brachio-céphalique)
  - injecteur double corps
  - produit concentré (> 300 mg l/ml)
  - > **90 ml**
- Adapter la **volume** d'étude et l'épaisseur de coupe à la question clinique (↓ irradiation et apnée) : O, T, T du pontage  pontage AGE
- Reconstructions multiphasiques (30% → 90% ?), post-ttt ++ (3D SSD, Curviligne 2D par axe central)
- **Interprétation** prudente : perméabilité/sténose, anastomose distale ++, réseau natif ++

Auteur	Publication	CT	n pts	n PAC	Type PAC	Perméabilité		Sténose	
						Sens	Spé	Sens	Spé
Schlosser	JACC 2004	16-MSCT	48	131	40 A 91 V	100 %	100 %	96 %	95 %
Martuscelli	Circulation 2004	16-MSCT	84	251	85 A 166 V	100 %	100 %	90 %	100 %
Song	Zhonghua Xin Xue Guan Bing Za Zhi 2005	16-MSCT	56	152	48 A 104 V	100%	100%	94%	95%
Salm	Am Heart J 2005	16-MSCT	25	67	14 A 53 V	100%	100%	100%	94%
Chiurlia	Am J Cardiol 2005	16-MSCT	52	166		100%	100%	96%	100%
<b>TOTAL</b>		<b>16-MSCT</b>	<b>265</b>	<b>767</b>					
Ropers	Circulation 2006	64-MSCT	50	138	37 A 101 V			100 %	94 %
Onuma	Am Heart J 2007	64-MSCT	53	146				100 %	91 %
Jabara	Am J Cardiol 2007	64-MSCT	50	147	47 A 100 V	93 %	100 %	100 %	100 %
JONES (méta analyse)	Ann Thorac Surg 2007	8 à 64-MSCT				97,6 %	98,5 %	88,7 %	97,4



Radiology 2008; 247:679-686

## Diagnostic Performance of 16- and 64-Section Spiral CT for Coronary Artery Bypass Graft Assessment: Meta-Analysis

*Michèle Hamon, MD, Olivier Lepage, MD, Patrizia Malagutti, MD, John W. Riddell, MD, Rémy Morello, MD, Denis Agostini, MD, PhD, and Martial Hamon, MD*



158 articles => 15 articles = 723 patients = 2023 CABGs

Pontages (et anastomoses) analysables:

78% à 100%

Moyenne = 92.4%

Moyenne = 90% avec 16-CT

Moyenne = 96% avec 64-CT

Occlusion et sténose >50% :

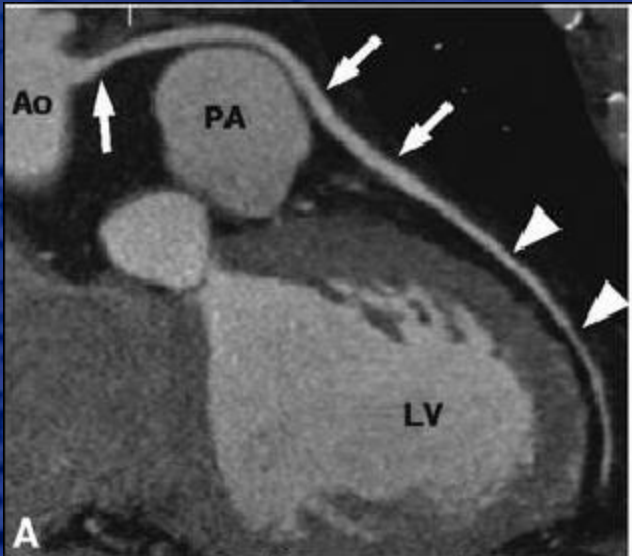
SENS = 97.6% (95% CI: 96%, 98.6%)

SPE = 96.7% (95% CI: 95.6%, 97.5%)

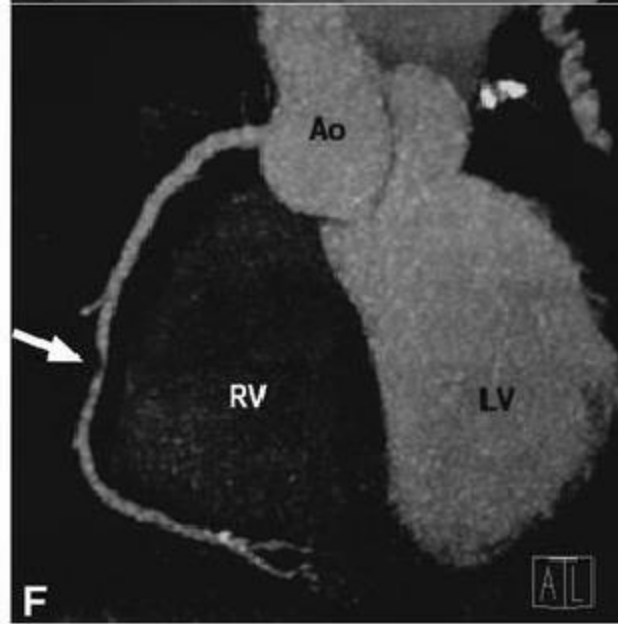
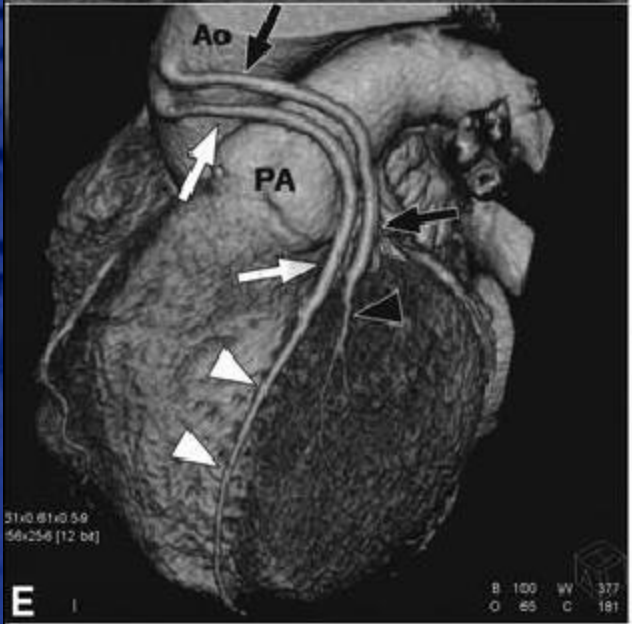
VPP = 92.7% (95% CI: 90.5%, 94.6%)

VPN = 98.9% (95% CI: 98.2%, 99.4%)

# Imagerie des pontages : MSCT vs Coro



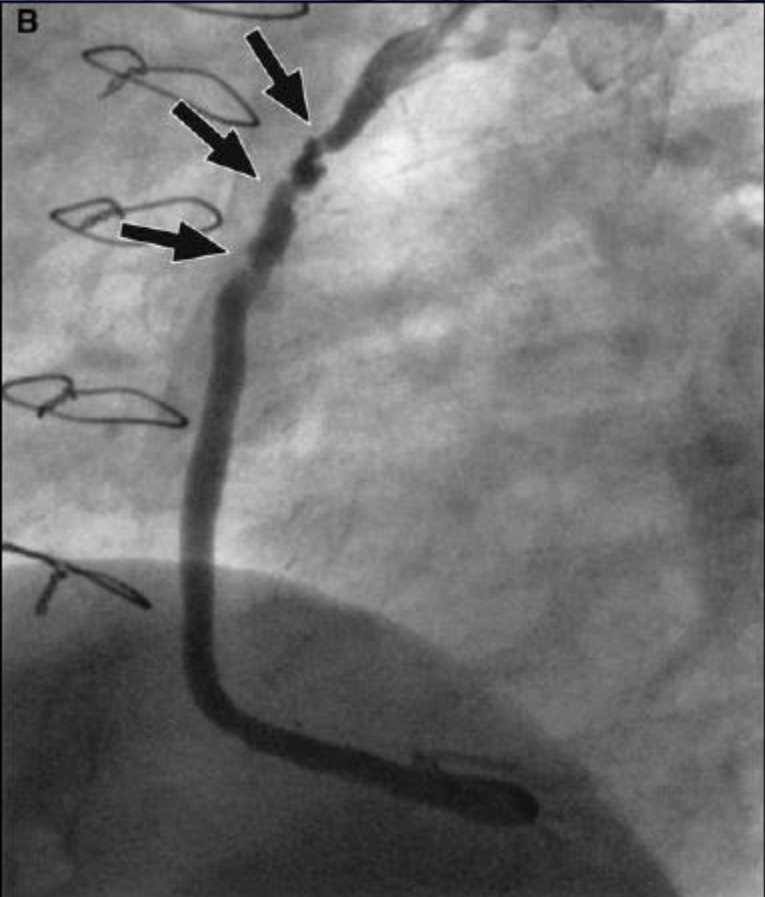
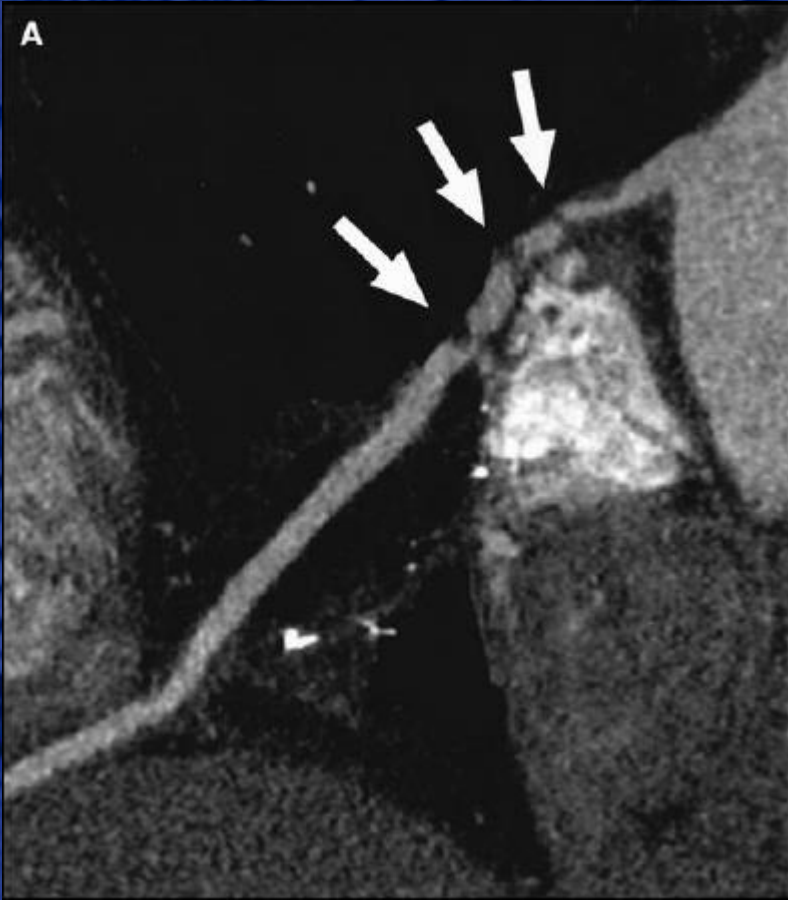
GV / IVA  
GV / diag



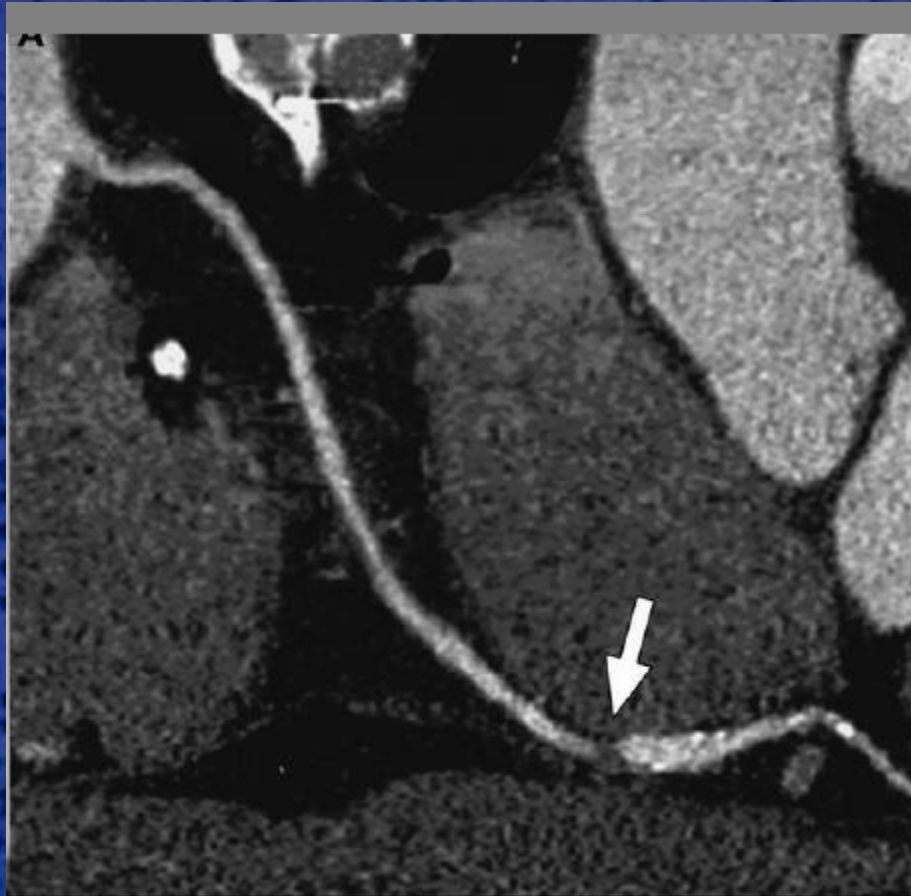


# Imagerie des pontages : MSCT vs Coro

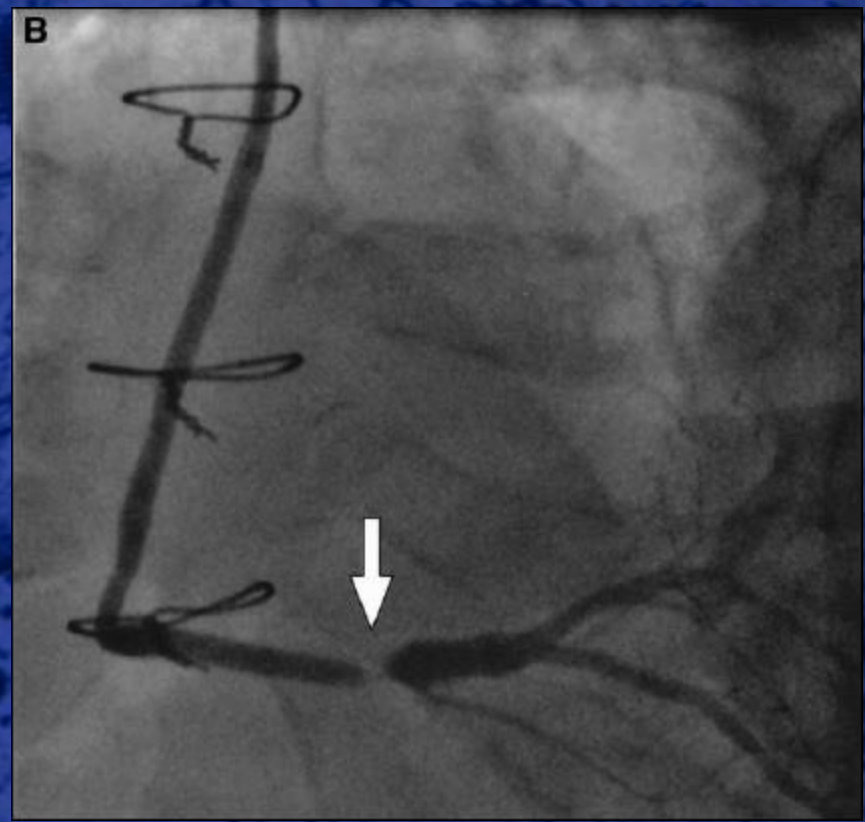
GV/CD à J7



# Imagerie des pontages : MSCT vs Coro

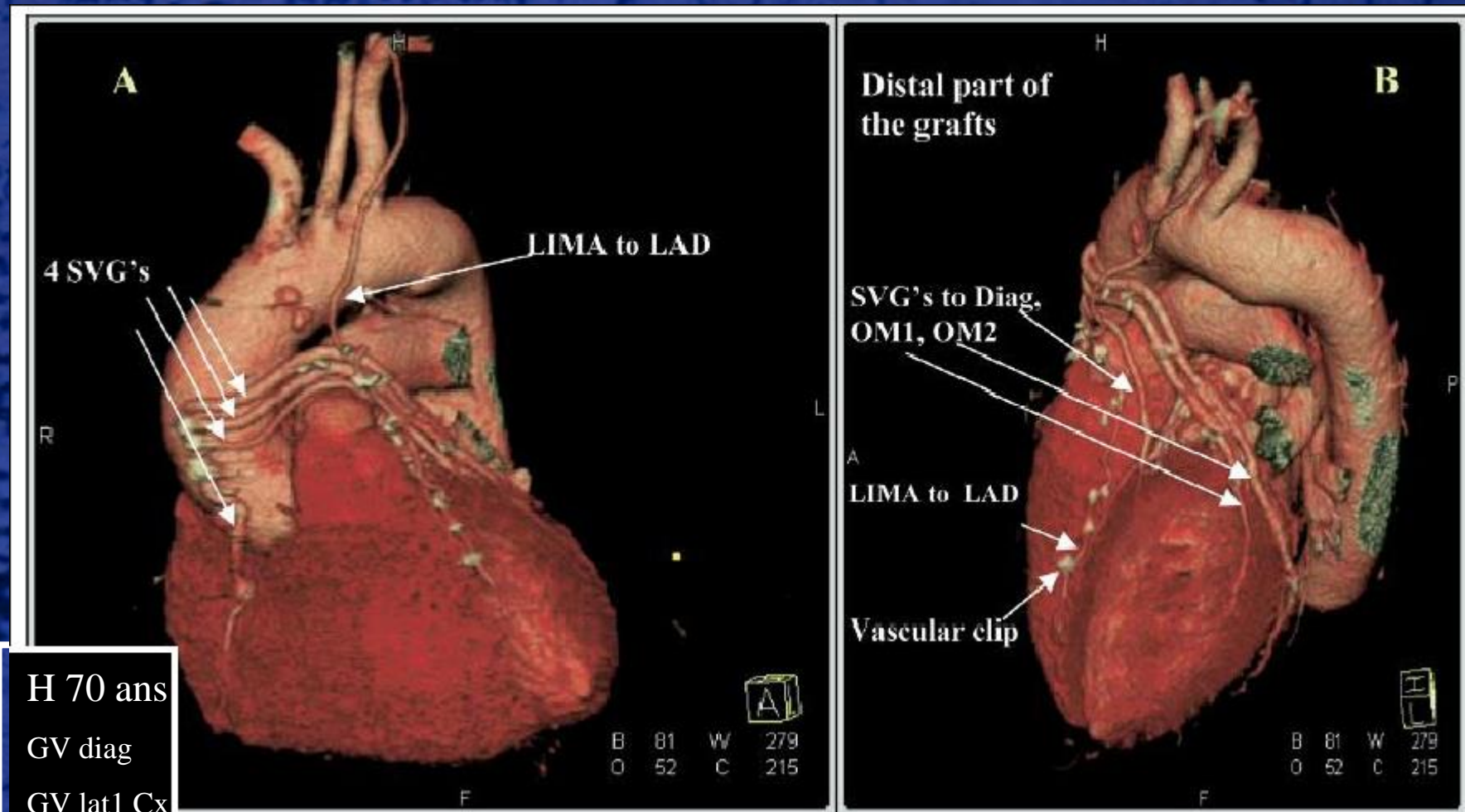


**GV / CD à 4 ans**





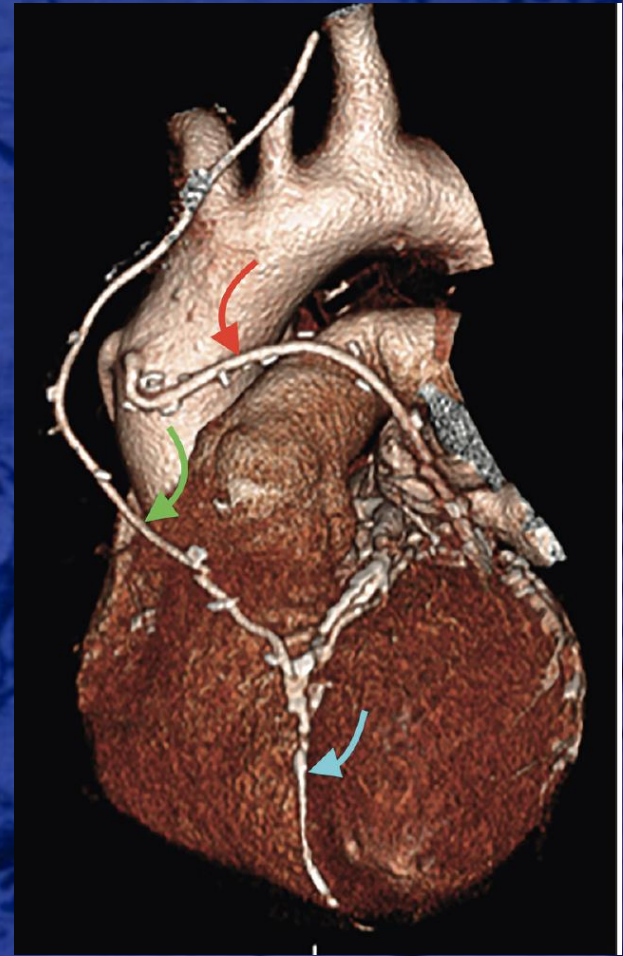
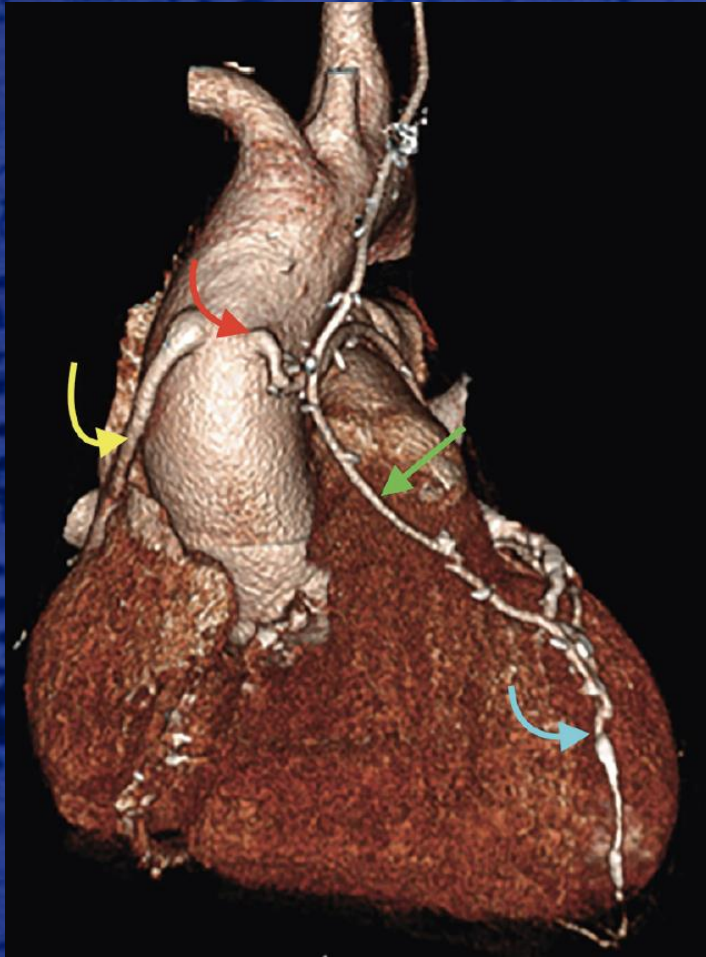
# Imagerie des pontages : MSCT vs Coro



- H 70 ans
- GV diag
- GV lat1 Cx
- GV lat2 Cx
- GV CD3
- MIG IVA



# Imagerie des pontages : MSCT vs Coro





# Imagerie des coronaires et des pontages: Limites du MSCT

- Techniques
- Calcifications
- Clips et anastomoses
- Stent

Irradiation 9-21mSv

Résolution spatiale insuffisante (anastomose distale)





# Imagerie des coronaires et des pontages : Limites du MSCT

- Mouvements
- Calcifications
- Clips et anastomoses
- Stent





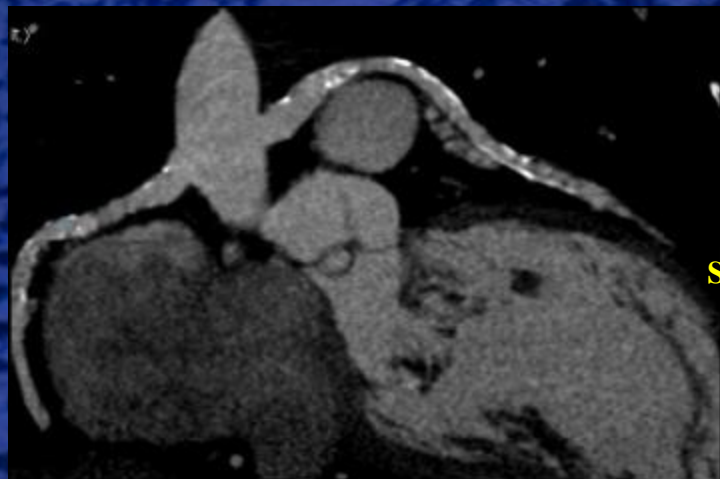
# Imagerie des coronaires et des pontages: Limites du MSCT

Mme UNG... 34 ans

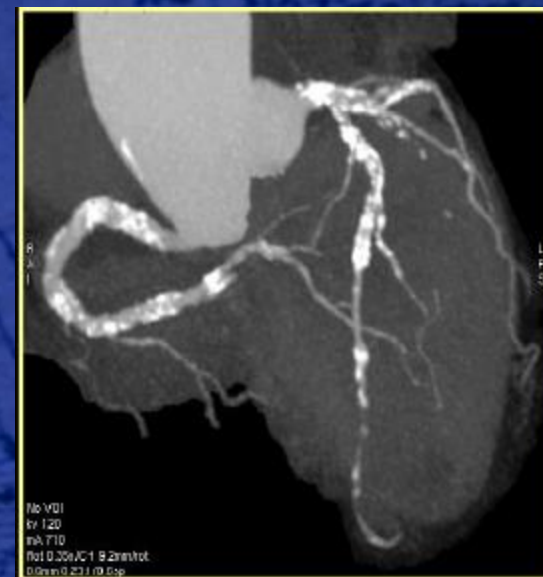
Pseudoxanthomatose élastique

GV/CD et GV/IVA à l'âge de 12 ans

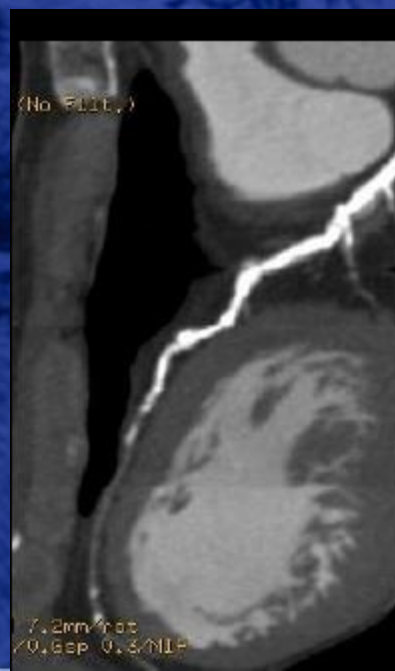
Scintigraphie myocardique litigieuse



Mme UNG... 34 ans  
Pseudoxanthomatose élastique  
GV/CD et GV/IVA à l'âge de 12 ans  
Scintigraphie myocardique litigieuse



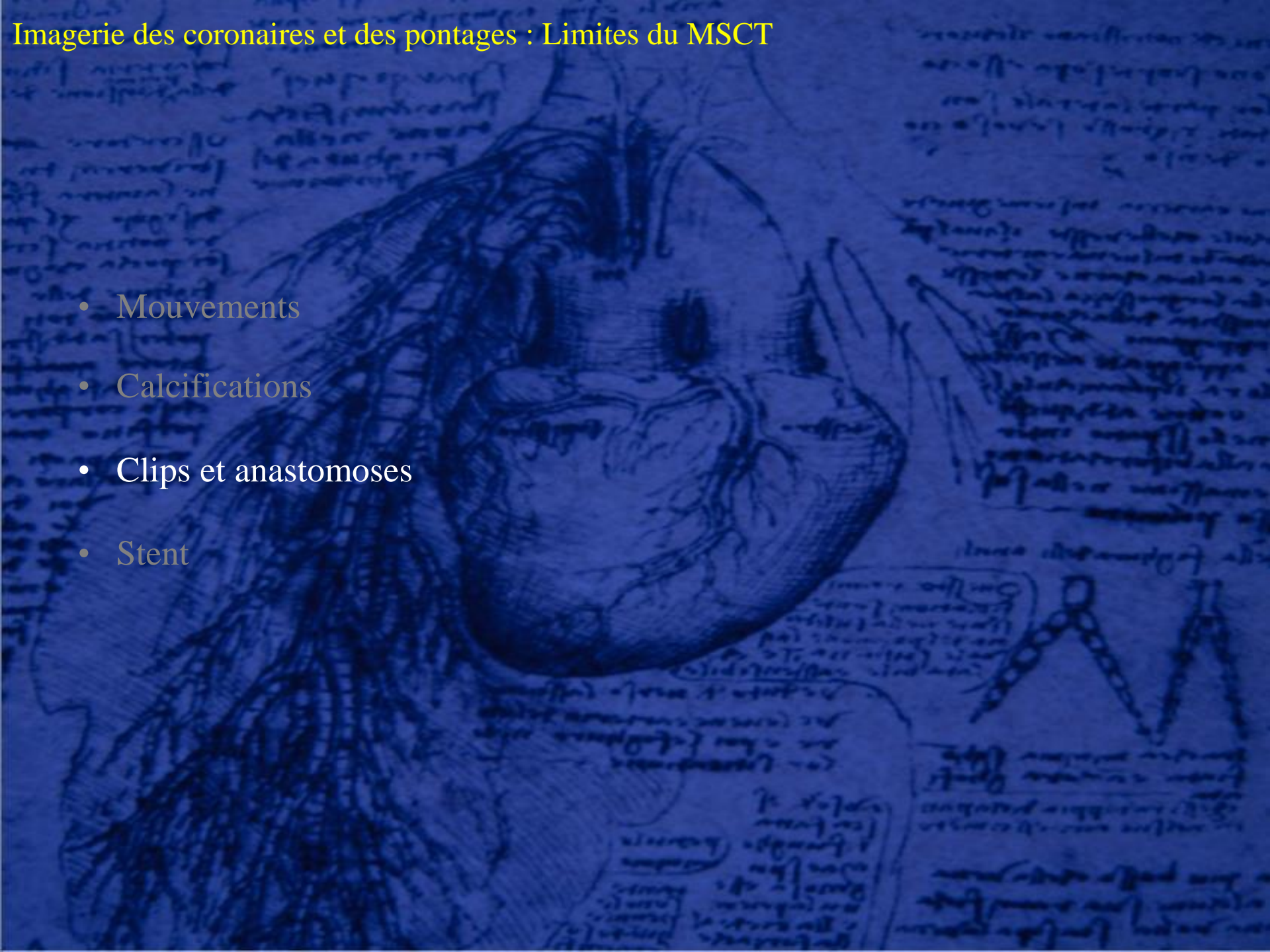
M LEC... 53 ans  
AOMI, tritronculaire



Ca++ (maladie du greffon)  
Anastomoses

# Imagerie des coronaires et des pontages : Limites du MSCT

- Mouvements
- Calcifications
- Clips et anastomoses
- Stent



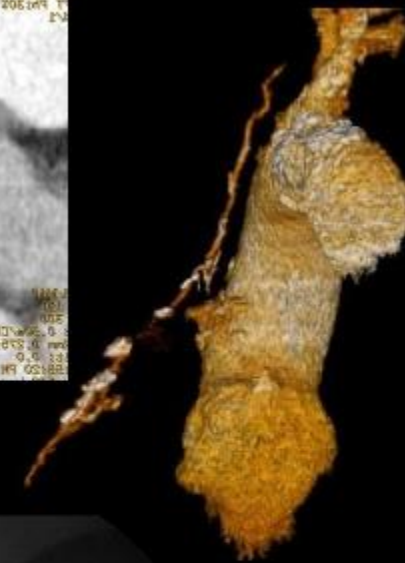
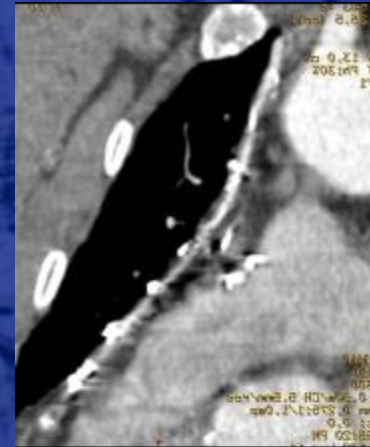
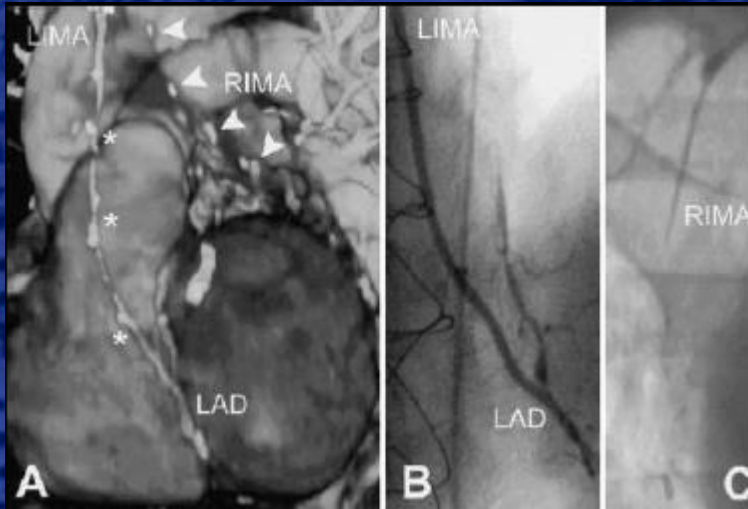
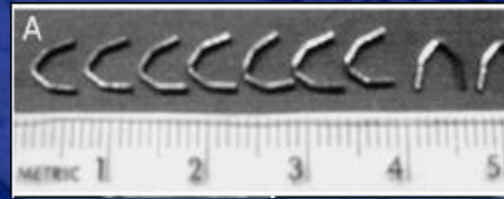


# Imagerie des coronaires et des pontages: Limites du MSCT

## Clips

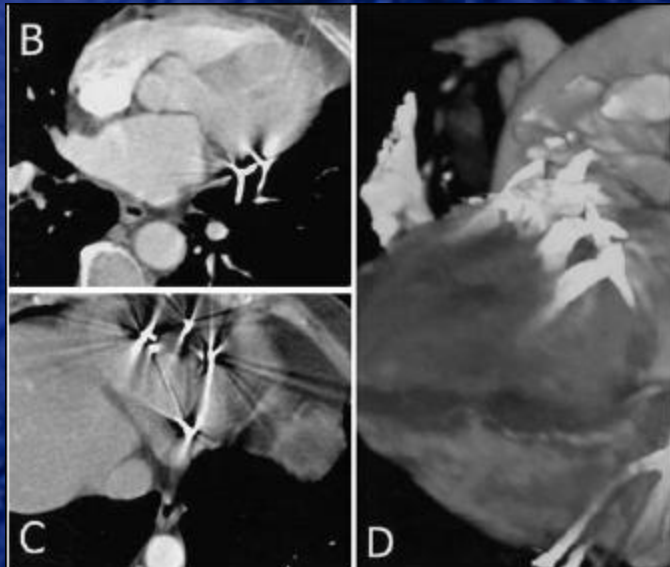
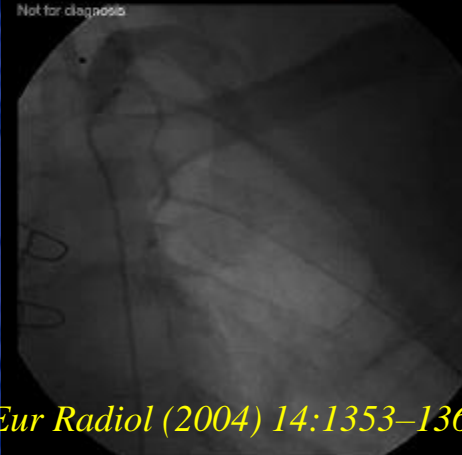
**MIG/IVA ( clips)**

**MID/lat Cx (occlus)**

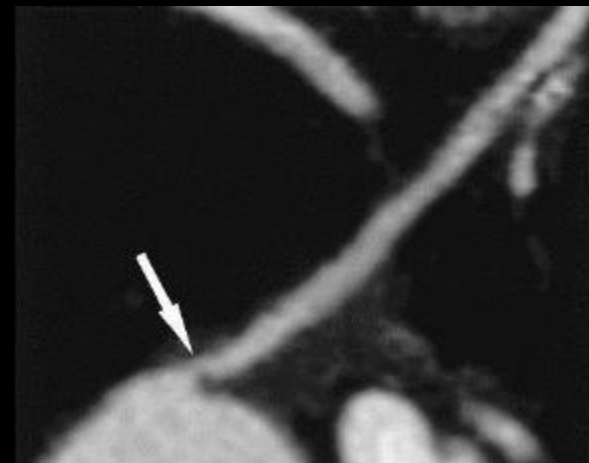


**MIG/IVA**

Not for diagnosis



# Anastomose proximale







# ACCF/AHA/ASE/ASNC/HFSA/HRS/SCAI/SCCT/SCMR/STS 2013 Multimodality Appropriate Use Criteria for the Detection and Risk Assessment of Stable Ischemic Heart Disease

## Section 2.2. Post-Revascularization (PCI or CABG)

Table 2.4. Symptomatic (Ischemic Equivalent)

Indication Text		Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
64.	<ul style="list-style-type: none"> <li>Evaluation of ischemic equivalent</li> </ul>	M	A	A	A	R	M	A

A = Appropriate; CCTA = coronary computed tomography angiography; CMR = cardiac magnetic resonance; ECG = electrocardiogram; Echo = echocardiography; M = May Be Appropriate; R = Rarely Appropriate; RNI = radionuclide imaging.

Table 2.5. Asymptomatic (Without Ischemic Equivalent)

Indication Text		Exercise ECG	Stress RNI	Stress Echo	Stress CMR	Calcium Scoring	CCTA	Invasive Coronary Angiography
65.	<ul style="list-style-type: none"> <li>Incomplete revascularization</li> <li>Additional revascularization feasible</li> </ul>	M	A	A	M	R	R	R
66.	<ul style="list-style-type: none"> <li>Prior left main coronary stent</li> </ul>	M	M	M	M	R	M	M
67.	<ul style="list-style-type: none"> <li>&lt;5 years after CABG</li> </ul>	R	R	R	R	R	R	R
68.	<ul style="list-style-type: none"> <li>≥5 years after CABG</li> </ul>	M	M	M	M	R	R	R
69.	<ul style="list-style-type: none"> <li>&lt;2 years after PCI</li> </ul>	R	R	R	R	R	R	R
70.	<ul style="list-style-type: none"> <li>≥2 years after PCI</li> </ul>	M	M	M	M	R	R	R



# Imagerie des pontages en MSCT : CONCLUSIONS

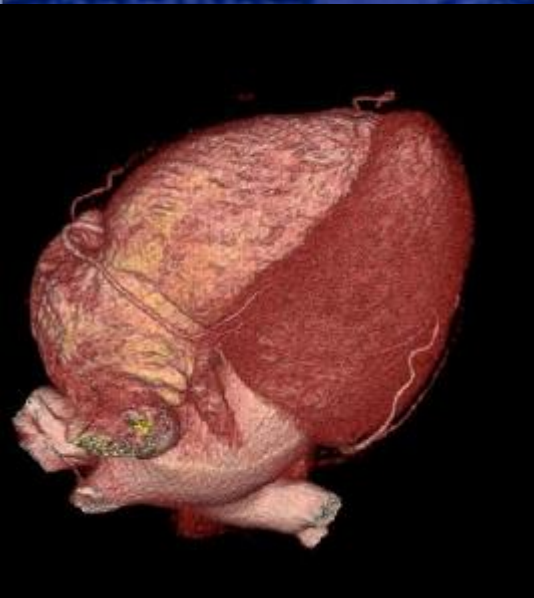
Précision diagnostique satisfaisante, mais peu d'études...

Reproductibilité ? (expérience ++)

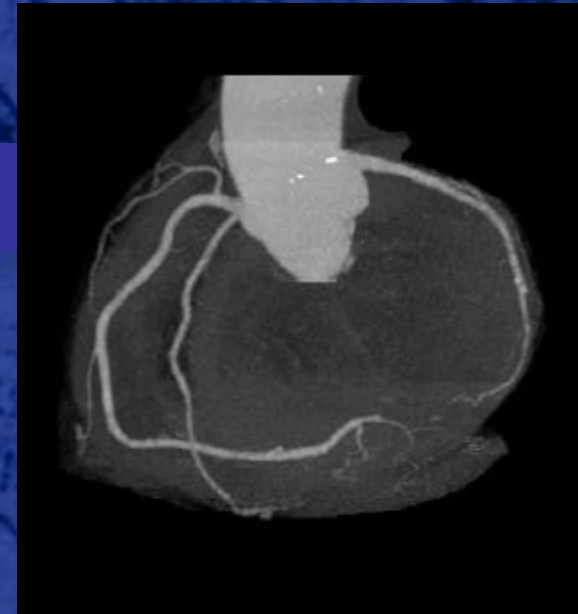
Bien connaître les limites (irradiation, apnée, arythmie, tachycardie...) afin de bien sélectionner les patients

Imagerie séduisante mais pertinence clinique ? (analyse difficile du réseau natif ++)

# Visualisation des artères coronaires et des pontages coronaires en TDM



Perspectives

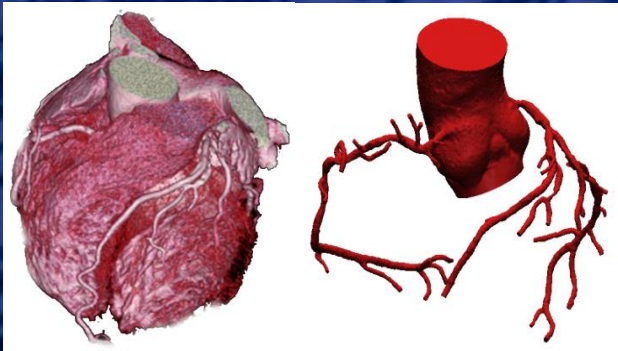




# FFR CT

## Traitement à partir du scanner coronaire

Analyse 3-D à partir du scanner



### Models physiologiques:

- Myocardique
- Analyse morphométriques basée sur les conditions de repos et extrêmes.
- Effet de l'adénosine sur la micro-circulation

## Analyse du flux sanguin

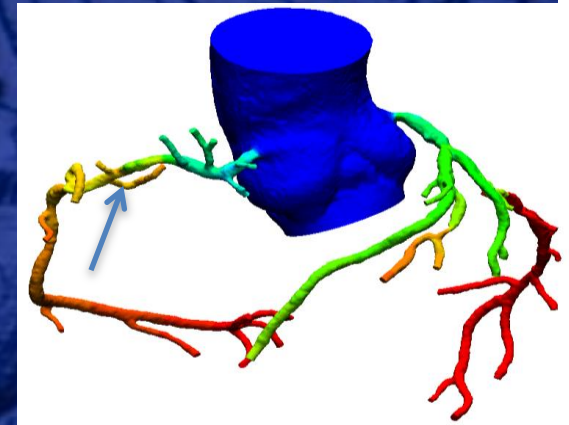
Equations de flux  
résolues par ordinateurs

$$\rho \bar{v}_{,t} + \rho \bar{v} \cdot \nabla \bar{v} = -\nabla p + \nabla \cdot \bar{\tau}$$
$$\nabla \cdot \bar{v} = 0$$



## Calcul de FFR<sub>CT</sub>

FFR<sub>CT</sub> 3D



FFR<sub>CT</sub> = 0.72

(on peut la calculer sur tous les trajets coronaires)



# FFR CT

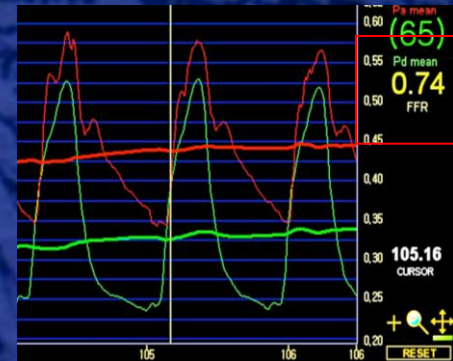
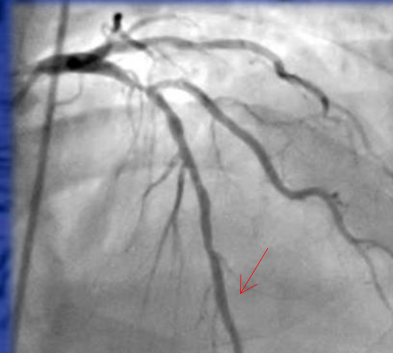
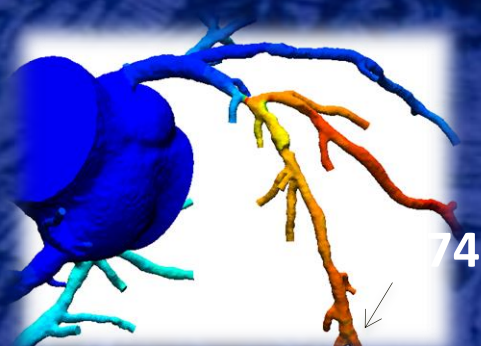
# Angio FFR

Scanner

FFR-CT

Coronarographie

FFR

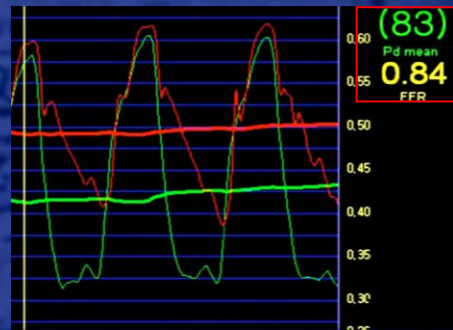
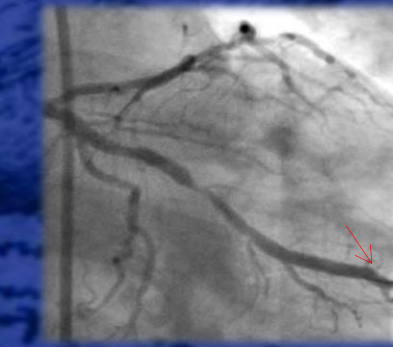
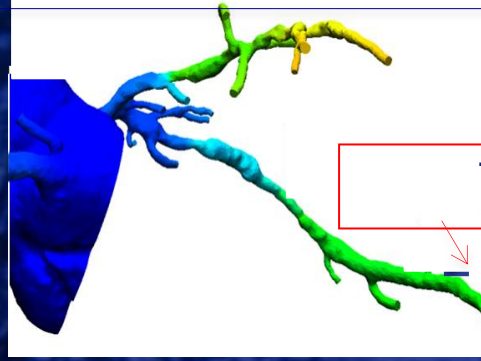
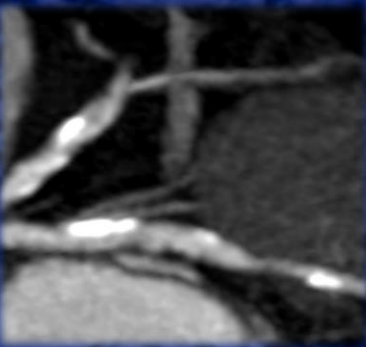


Sténose >50%

FFR<sub>CT</sub> 0.74 → ischemie

Sténose >50%

FFR 0.74 → ischemie



Sténose >50%

FFR<sub>CT</sub> 0.85 → pas d' ischemie

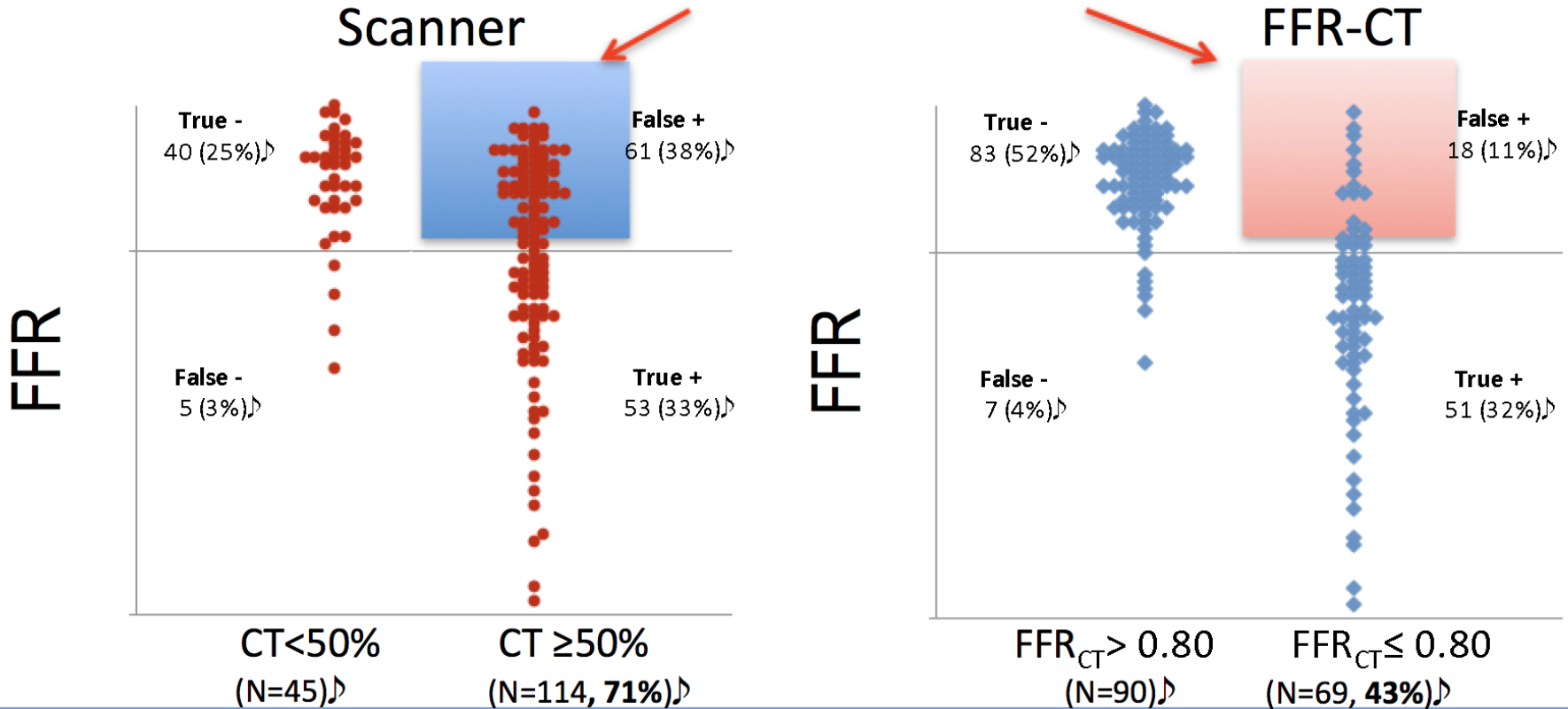
Sténose >50%

FFR 0.84 → pas d'ischemie



# FFR CT

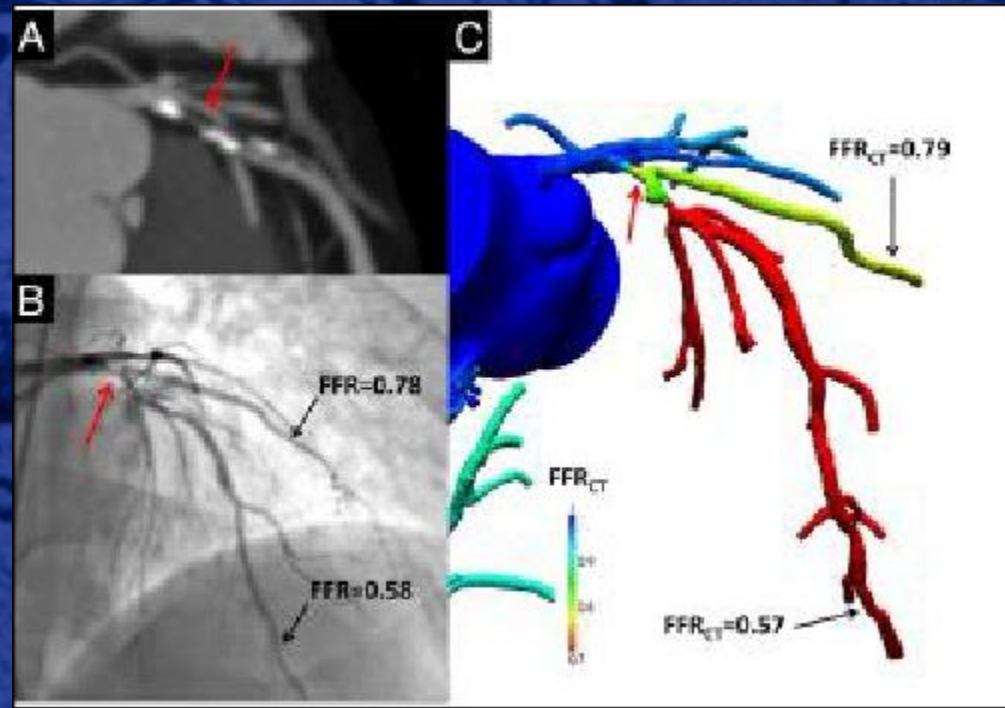
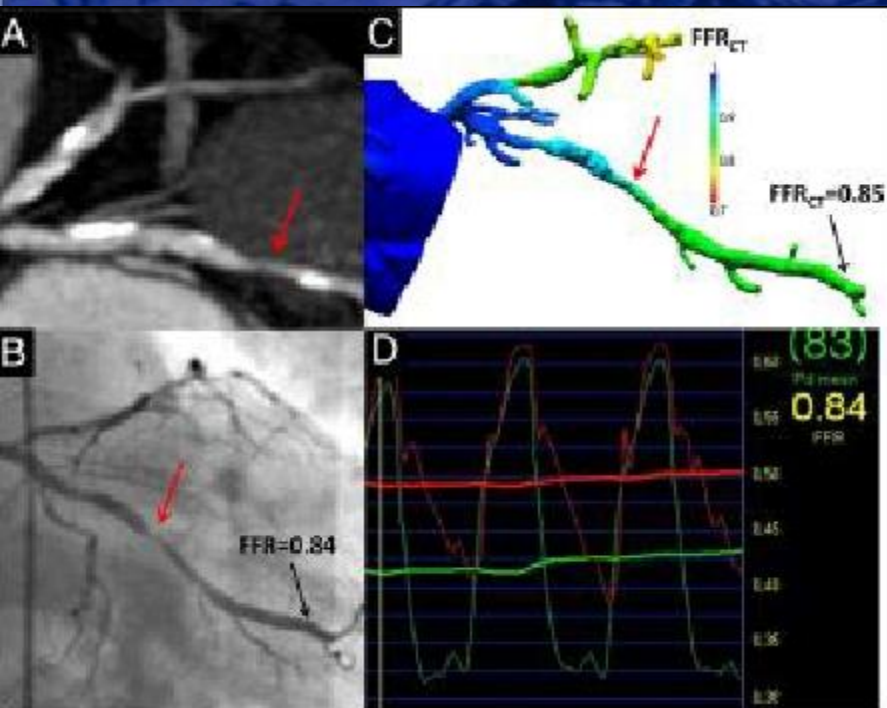
**Réduction des faux positifs: 70%**



# TDM cardiaque : examen fonctionnel ?

## Diagnosis of Ischemia-Causing Coronary Stenoses by Noninvasive Fractional Flow Reserve Computed From Coronary Computed Tomographic Angiograms

Results From the Prospective Multicenter DISCOVER-FLOW (Diagnosis of Ischemia-Causing Stenoses Obtained Via Noninvasive Fractional Flow Reserve) Study



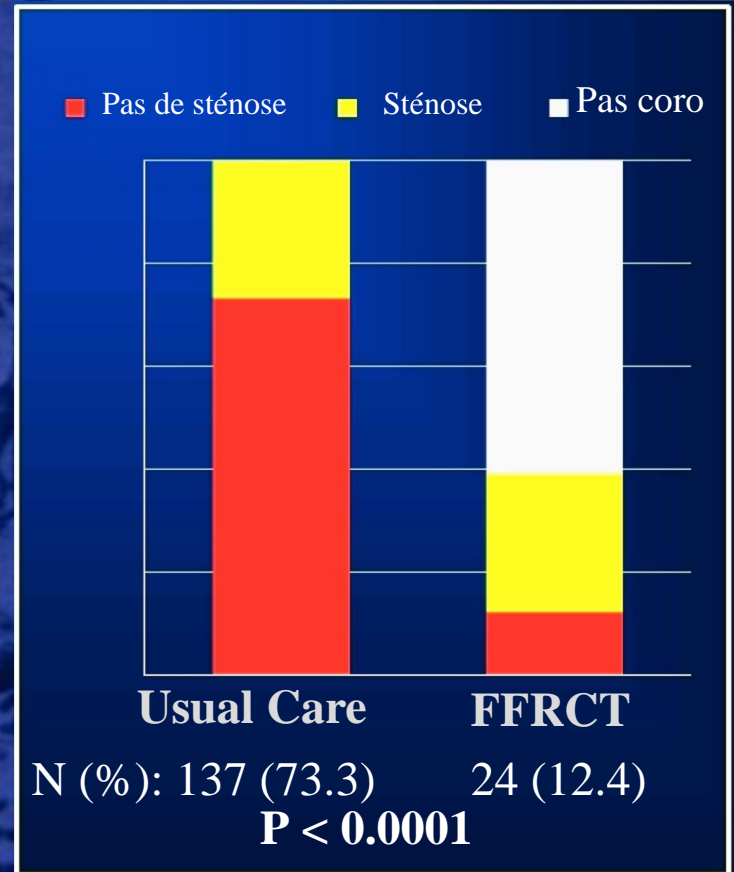
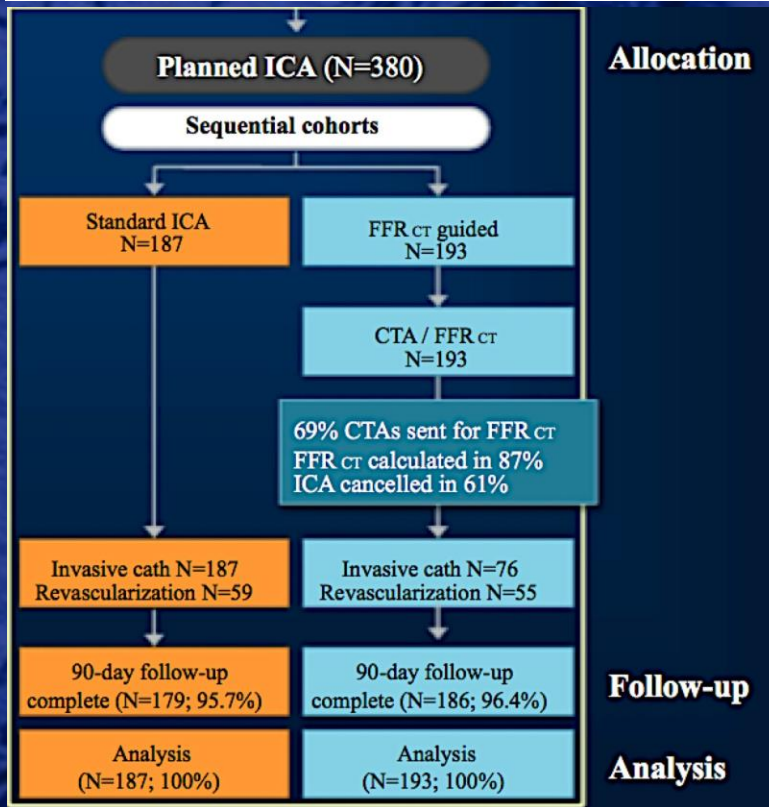


# FFR CT



## Prospective Longitudinal Trial of FFR<sub>CT</sub> Outcome and Resource Impacts

Clinical outcomes of FFR<sub>CT</sub>-guided diagnostic strategies versus usual care in patients with suspected coronary artery disease



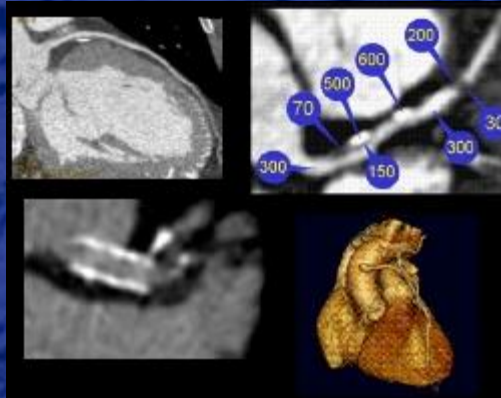
Résultats identiques dans tous les sous groupes  
Score de propension

# Perspectives

## Anatomie et fonction cardiaque

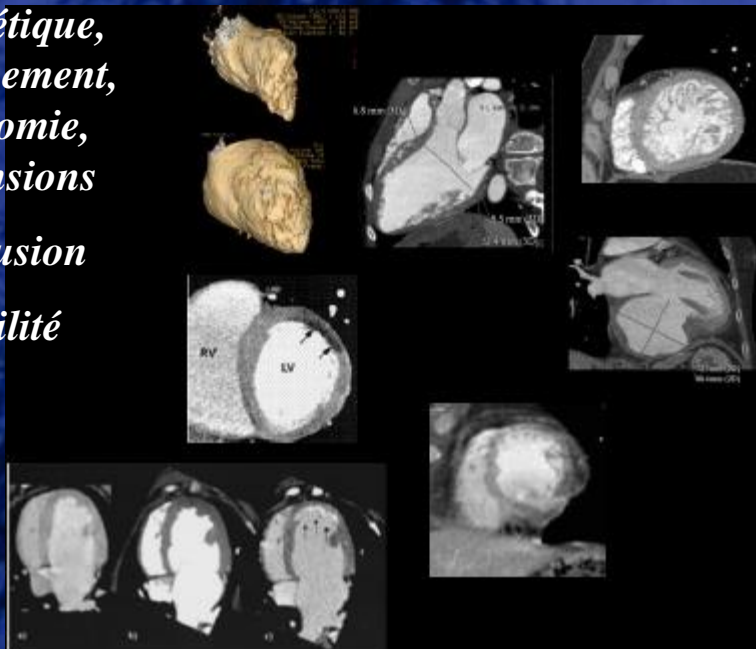
### Artères coronaires

Sténose, anatomie,  
plaques instables  
stent, pontage,  
fistule, anévrisme,  
naissance  
anormale



### Fonction VG

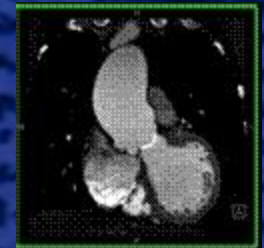
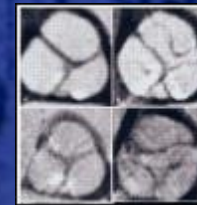
- Cinétique,  
épaissement,  
anatomie,  
dimensions
- Perfusion
- Viabilité



### Veines coronaires



### Valves



### Autres

péricarde, gros vaisseaux,  
EP, pathologie  
extracardiaque, ...

