Progres en Imagerie cardiaque

Bernhard Gerber, MD, PhD
Pôle de Recherche Cardiovasculaire
Institut de Recherche Expérimentale et Clinique
Université catholique de Louvain

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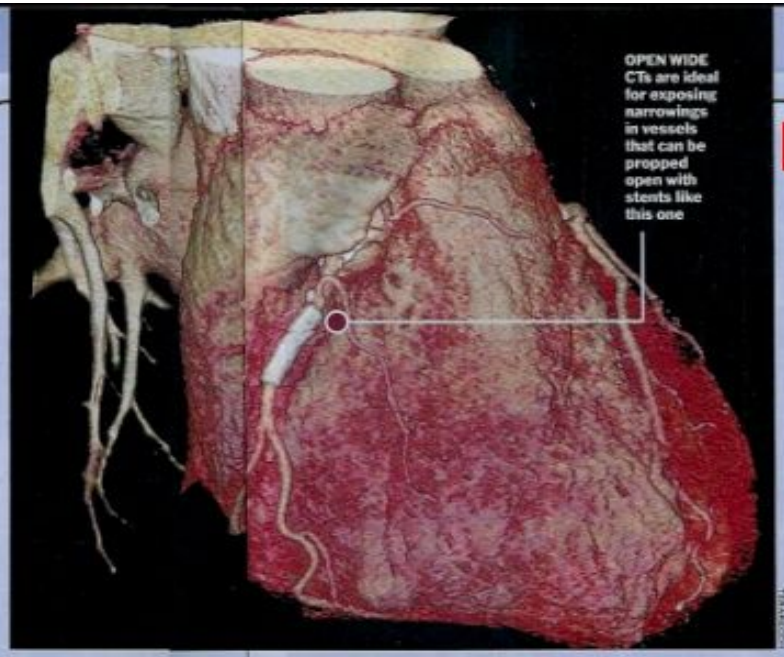
A READER'S GUIDE

Your Choices in Heart Scans

Once the stethoscope was the only tool doctors had for diagnosing heart trouble. Today, using the latest X-ray, magnetic and ultrasound scanners, they can take detailed, three-dimensional and even moving pictures of that vital organ. Here's a guide to the many choices available. —By Alice Park and Cristina Scalet



OPEN WIDE CTs are ideal for exposing narrowings in vessels that can be propped open with stents like this one

CT SCAN

■ **How it works** This test combines rapid X-ray scanning with multiple computed tomography (CT) to produce the most detailed images available of the heart's arteries without surgery. Patients receive an injection of contrast dye to highlight the blood vessels, and X rays create images of the heart in slices. A computer assembles the slices into an image of the heart that reveals calcium and fat-filled plaques lodged in the arteries.

■ **Limitations** CT scans involve radiation exposure, a particular concern for children. Those who are overweight or have stents or extensive calcium deposits won't generate useful images, since fat can distort X rays and the beams cannot penetrate metal or calcium.

CALCIUM PLUG Bulging regions along the arteries (circled) indicate sequestered calcium plaques that stand out on CT scans

BYPASS A powerful CT scanner provides a detailed look at two vein grafts (at arrows) inserted to detour blood around arterial blockages

ELECTROCARDIOGRAM (EKG)

■ **How it works** This oldest and most basic heart scan records the electrical impulses that regulate your heart's pumping action. It may seem unsophisticated, but any deviation from the normal rhythm pattern can alert doctors to the likelihood of damaged heart tissue and reduced blood flow.

■ **Limitations** While it can indicate signs of trouble, an EKG provides no visual map of the heart and cannot identify precisely what ails the organ or where in the heart the problem lies.

NUCLEAR STRESS TESTING

■ **How it works** Doctors inject a radioactive substance into the blood, then use gamma-ray cameras to see how the blood moves through the heart. The test shows how well the heart is doing at keeping itself saturated with oxygen-rich blood. The test is often done twice, to check cardiac performance at rest and under physical stress.

■ **Limitations** Carrying out two scans can take as long as five hours. The test also exposes the patient to small amounts of radiation.

FLOW CHART The heart at left is getting enough blood; dark spots on the heart at right indicate inadequate fluid

BLOCKED BLOOD: A constricted stretch of artery (arrow) that could reduce blood flow to the rest of the heart

CORONARY ANGIOGRAM

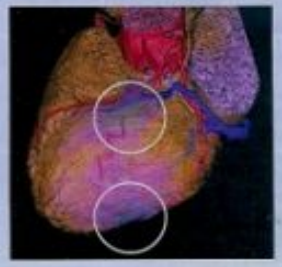
■ **How it works** This procedure is the gold standard for viewing the arteries that nourish the heart. Doctors insert a catheter through an artery in the leg and snake it up toward the heart. They then send a special dye through the tube that highlights the arteries under X rays and exposes any blockages.

■ **Limitations** Because they're invasive, angiograms have some risks: catheters can tear artery walls, requiring surgical repair. (In 1% of cases, serious complications, including death, may occur.) Afterward, patients need to lie still for four to six hours until the blood vessel in the leg seals.

PET/CT SCAN

■ **How it works** A hybrid of positron emission tomography and CT, this scan provides structural and functional information about the heart in a single scan. Doctors use the CT to physically locate narrowed regions along arteries, then apply PET to isolate parts of the heart muscle, such as the areas circled, that are deprived of blood flow as a result.

■ **Limitations** PET technology is expensive, and the hybrid machines are not widely available. The test also involves some radiation exposure.



ECHOCARDIOGRAM (ECHO)

■ **How it works** Harmless ultrasound waves, similar to the ones used to take sonograms of a fetus, are directed at the chest and bounce off the heart's walls and valves. A computer analyzes these rebounding waves and calculates the size, shape and movement of structures inside the heart. Doctors often take two echoes—one of the heart at rest and another of the heart under stress (e.g., after the patient exercises on a treadmill or after technicians have injected a drug to make the heart race). Comparison of the two images helps pinpoint abnormal valves or areas that are not receiving enough blood.

■ **Limitations** Ultrasound does not produce images with high enough resolution to see heart arteries and can highlight only the biggest changes in structures like the heart chambers.

LEAKY SEAL An echo detects a valve (arrow) that doesn't properly isolate the chambers of the heart

MAGNETIC RESONANCE IMAGING (MRI)

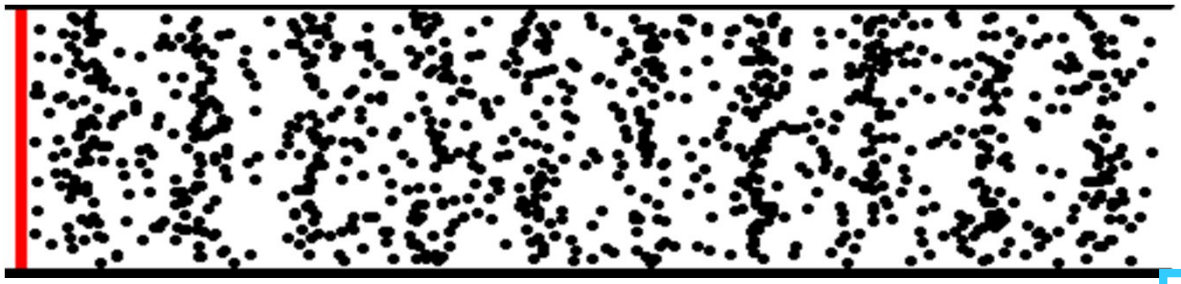
■ **How it works** Powerful magnets create a field that sets the nuclei of atoms in heart cells vibrating. The oscillating atoms emit radio signals, which are converted by a computer into either still or moving 3-D images. The arrow at left points to a plaque-filled spot in the artery; the scan also reveals the layer of fat that envelops most hearts.

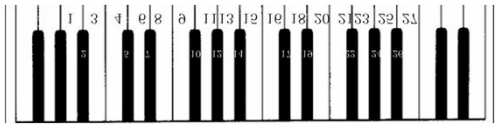
■ **Limitations** Because of the intense magnetic field, patients with pacemakers, stents or other metal implants can't get an MRI. These scans cannot pick up calcium deposits, which could signal dangerously narrowed vessels.

SUITE...

Cardiac Imaing
Physical Principles (1)

Mechanical Waves





Audible Sound

Ultrasound

20 Hz

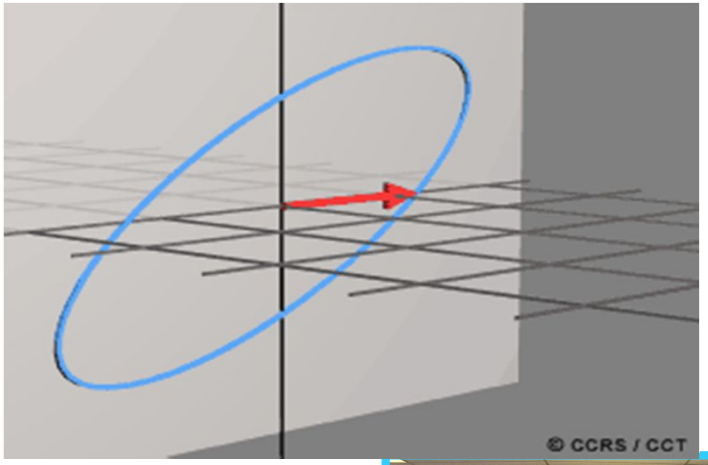
20000 Hz

1.5 MHz

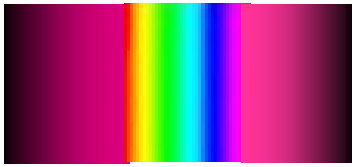
10 Mhz

Cardiac Imaging
Physical Principles (2)

Electromagnetic Waves



Magnetic Resonance



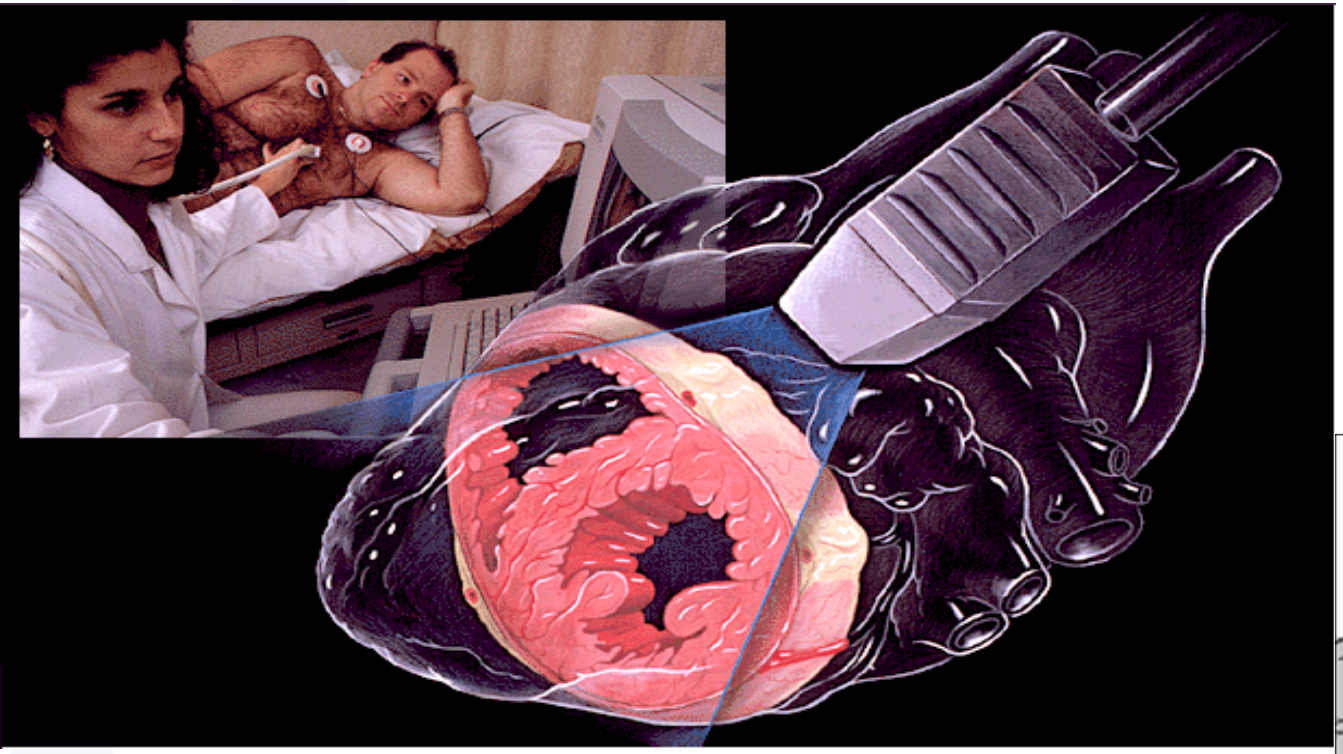
CT

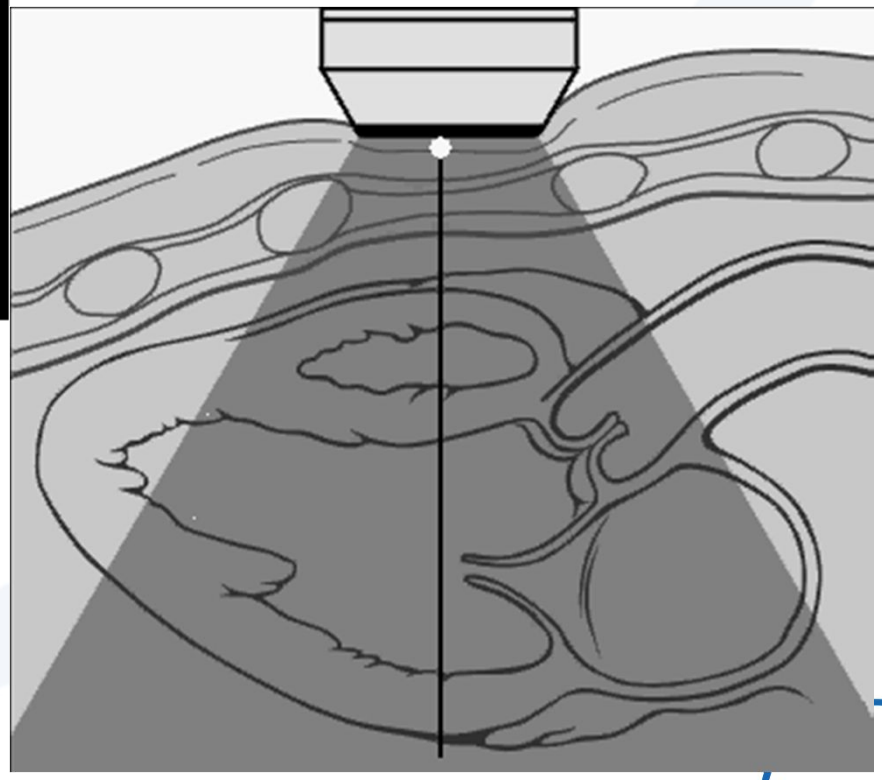
SPECT

PET

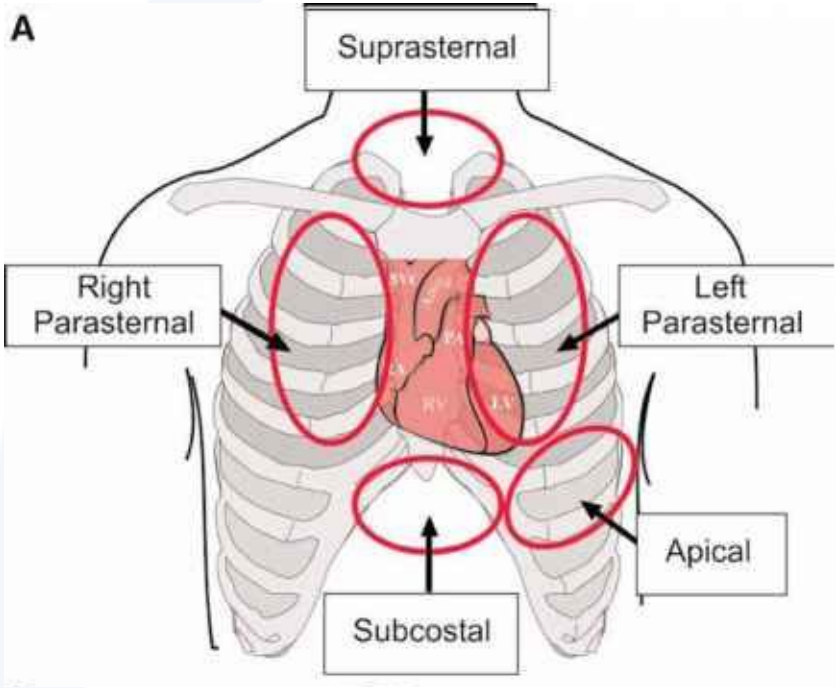
Radio Radar IR Visible Light UV X-Ray gamma

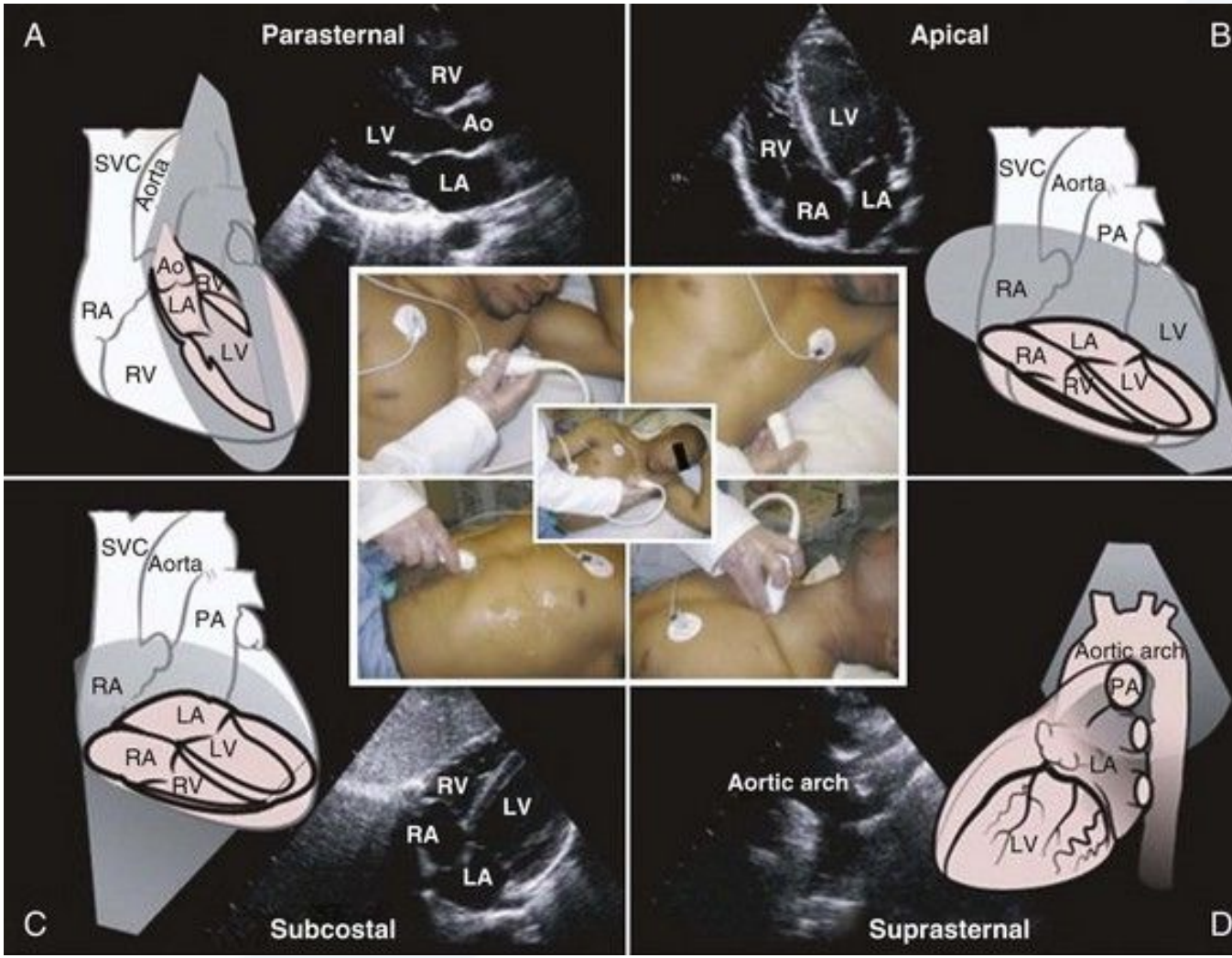
Echocardiographie transthoracique
Principles



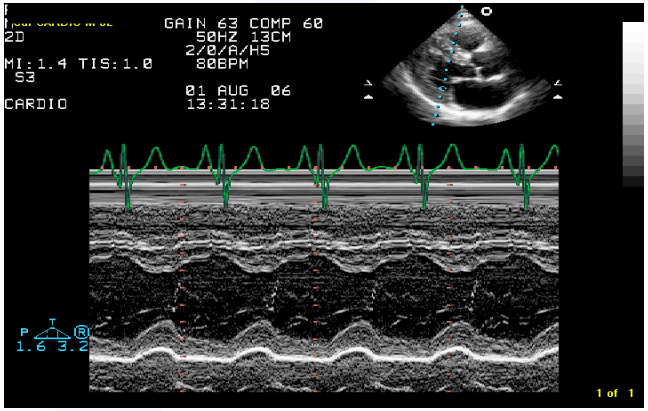


Transthoracic echocardiography

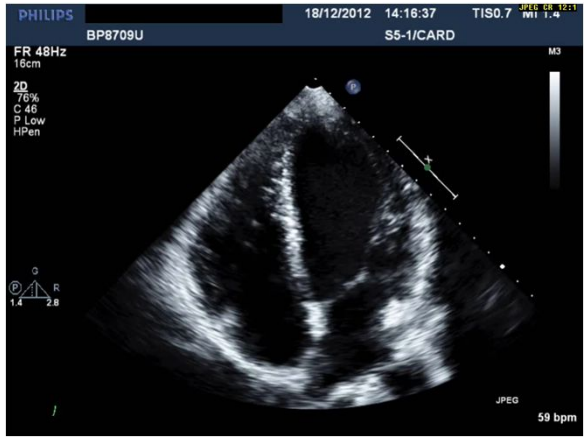




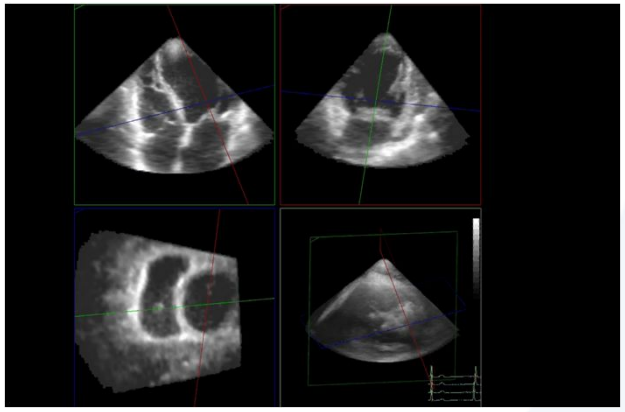
Echocardiography Imaging Modalities



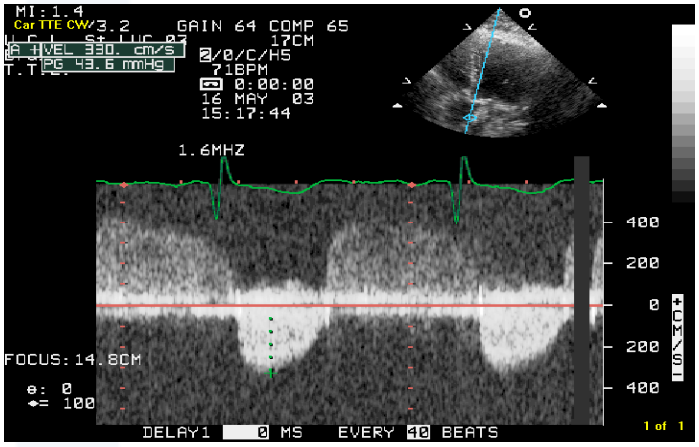
M-Mode



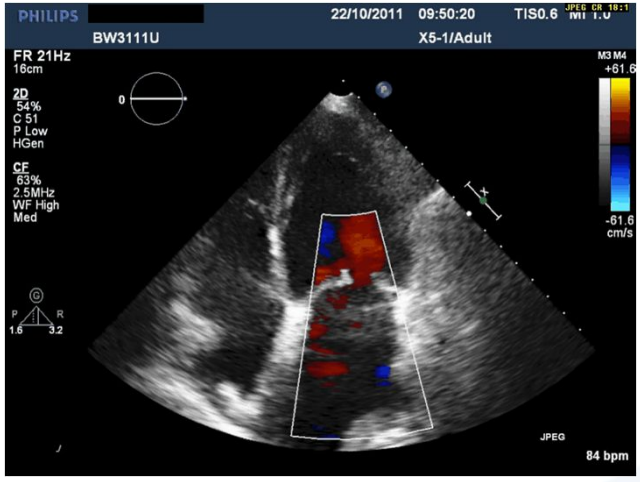
2D-Imaging



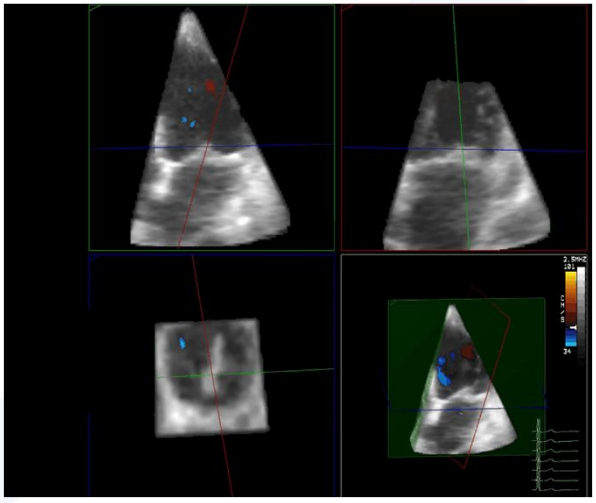
3D



Doppler

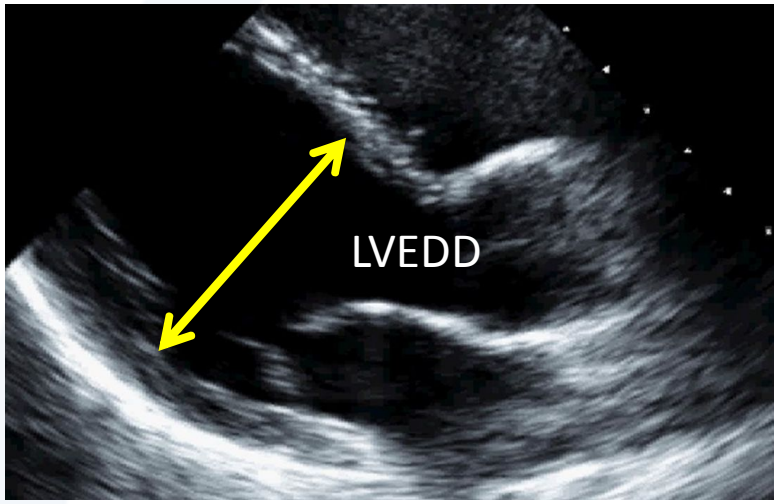


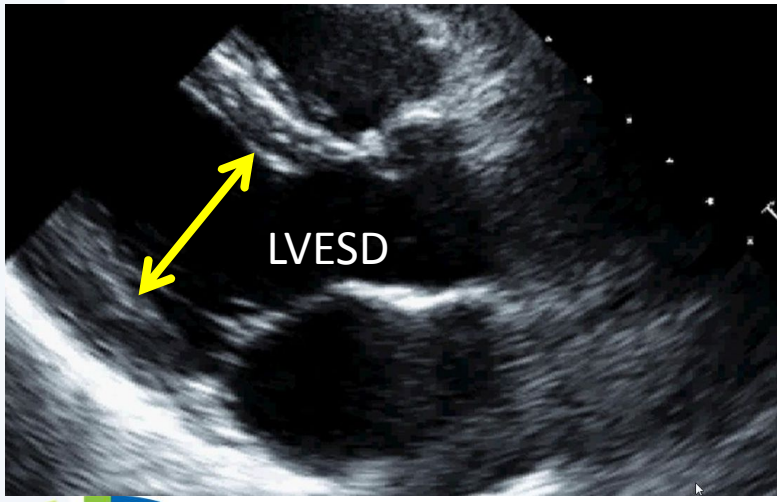
Color Doppler

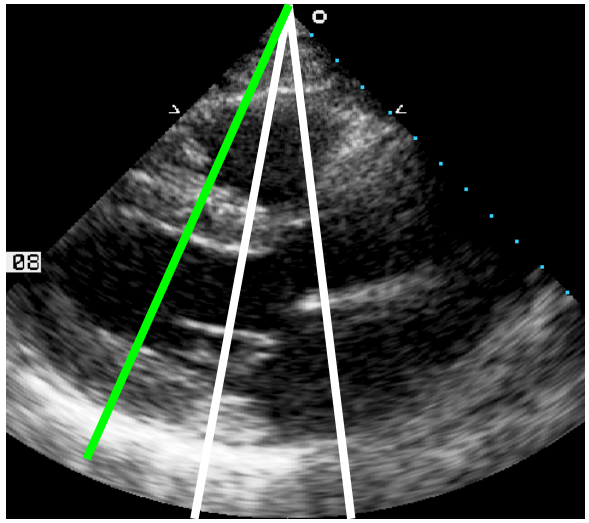


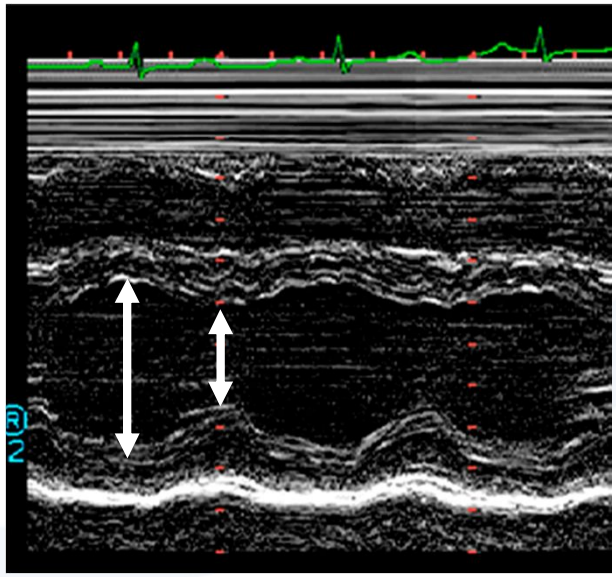
3D Couleur

Echocardiographie: Dimensions et Fonction VG





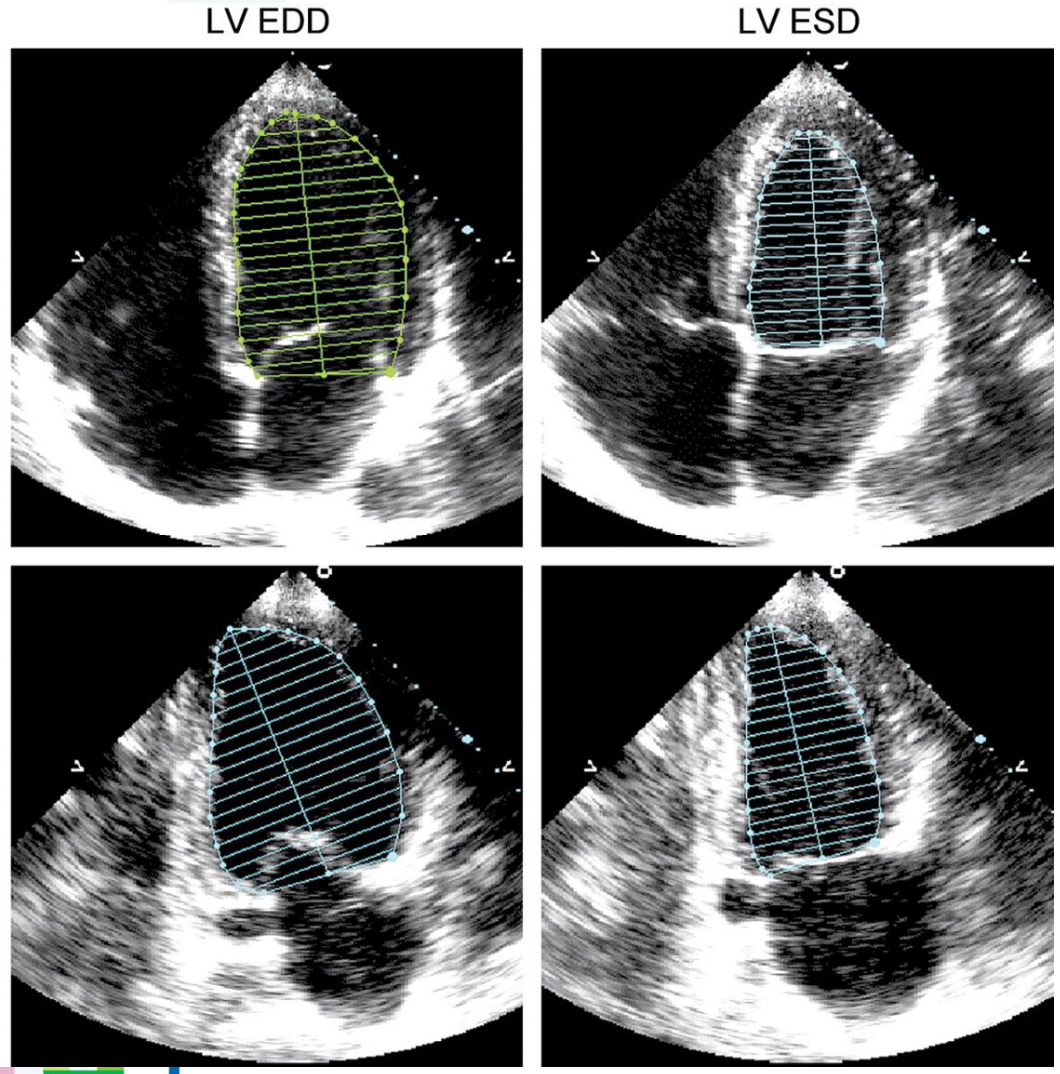


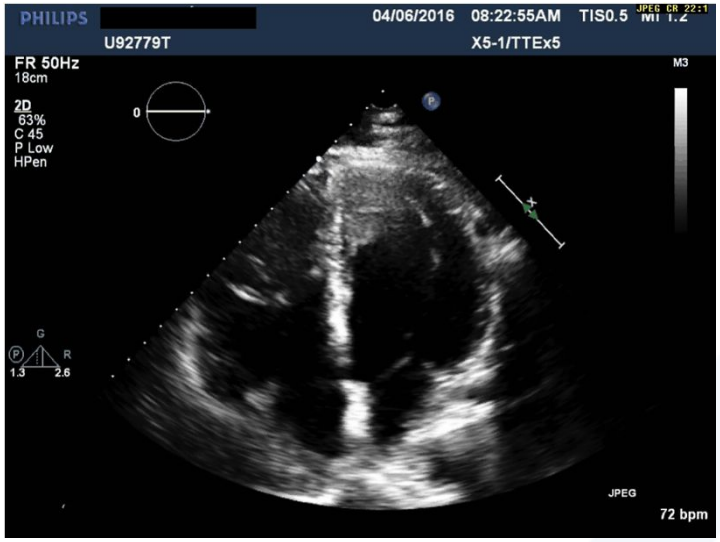


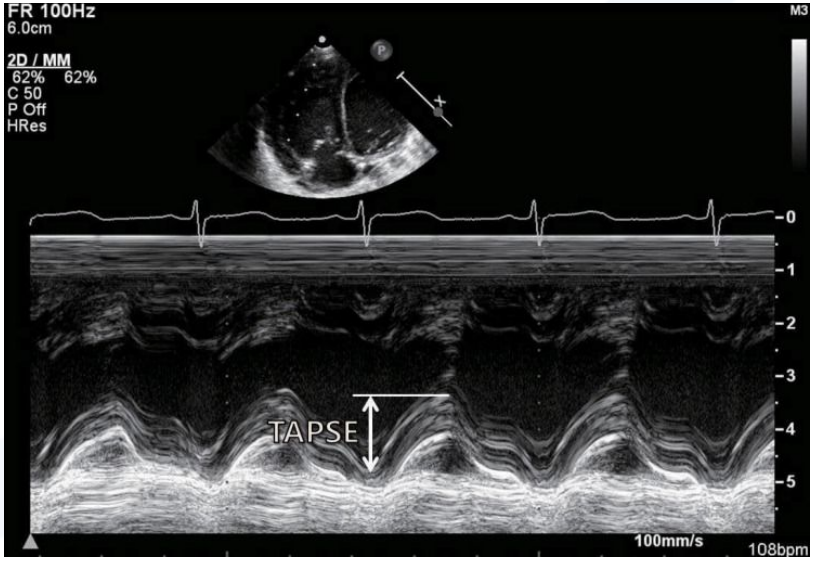
$$FS: \frac{LVDD - LVDS}{LVDD} = \%$$

FS < 25 %
abnormal

Echocardiographie: Global function VG VD



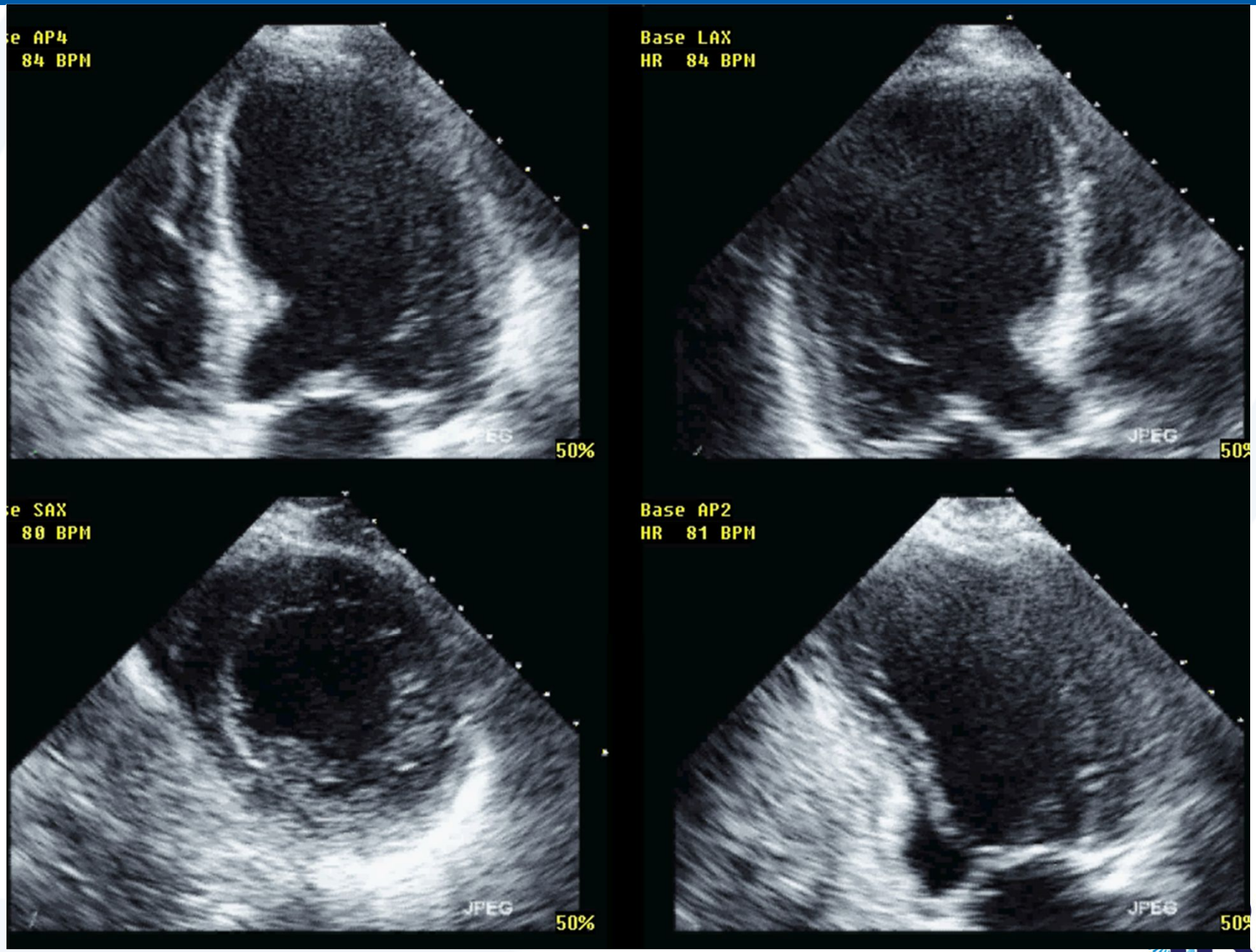




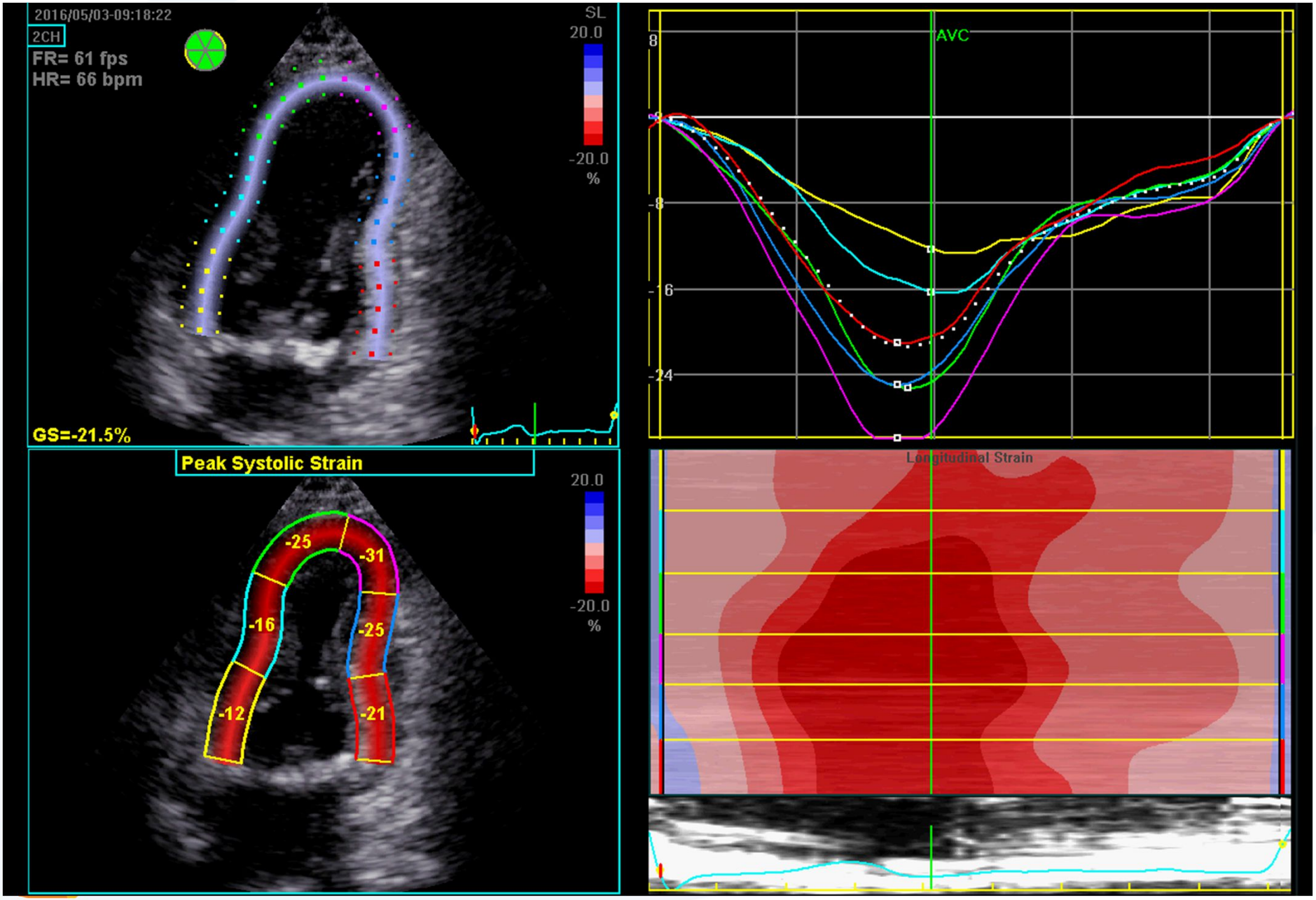
Imagerie de cardiaque : Global function

EF by 3 D method:

Imagerie cardiaque : Regional function

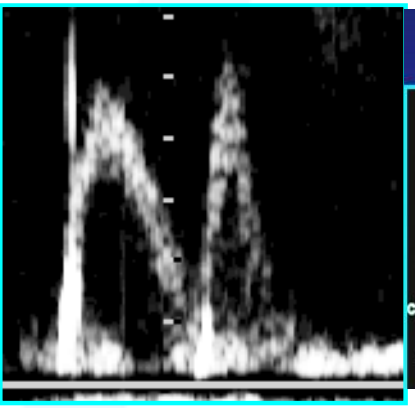


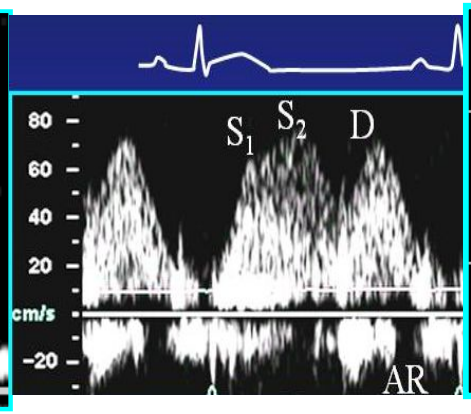
Echocardiographie Strain

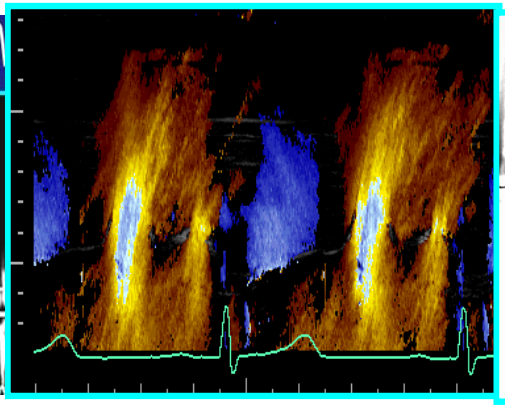


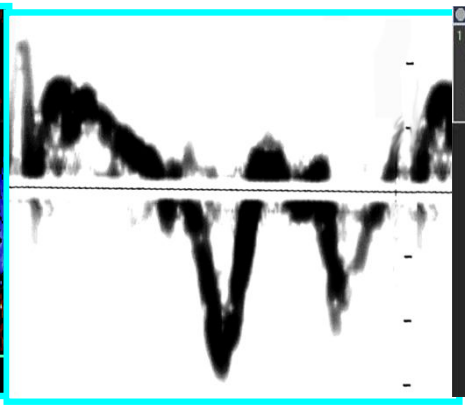
Echocardiography: diastolic function / Pulmonary hypertension

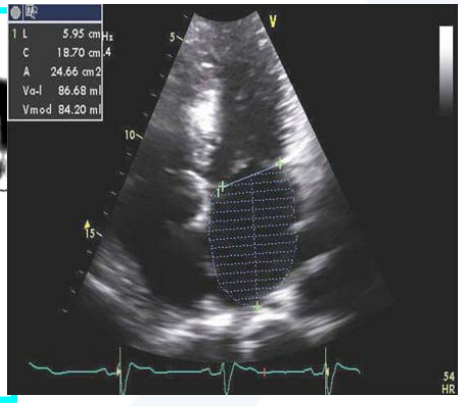
Mitral flow | Pulm v flow | Color M Mode | TDI | LA size

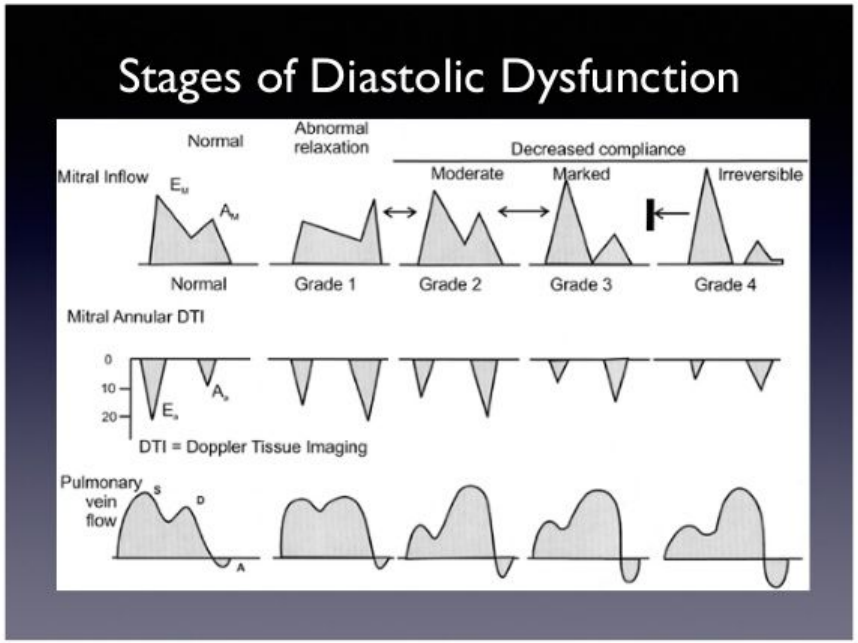


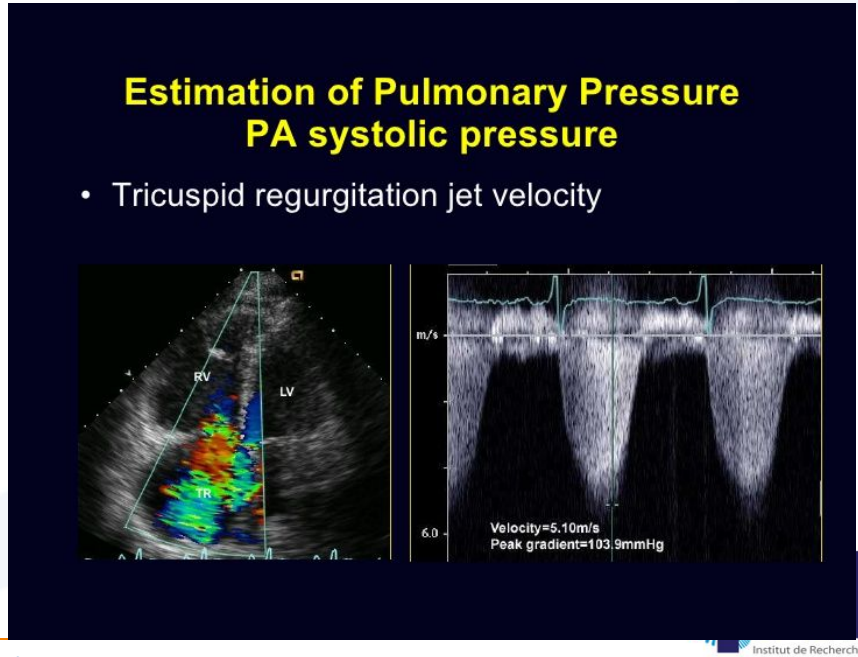












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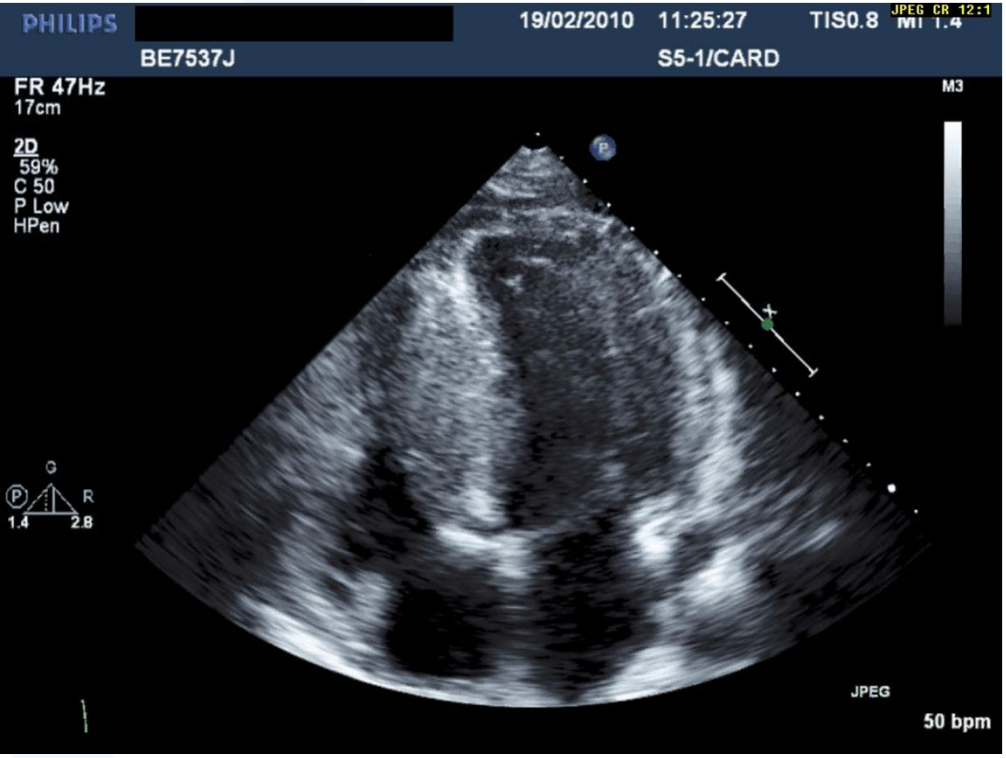
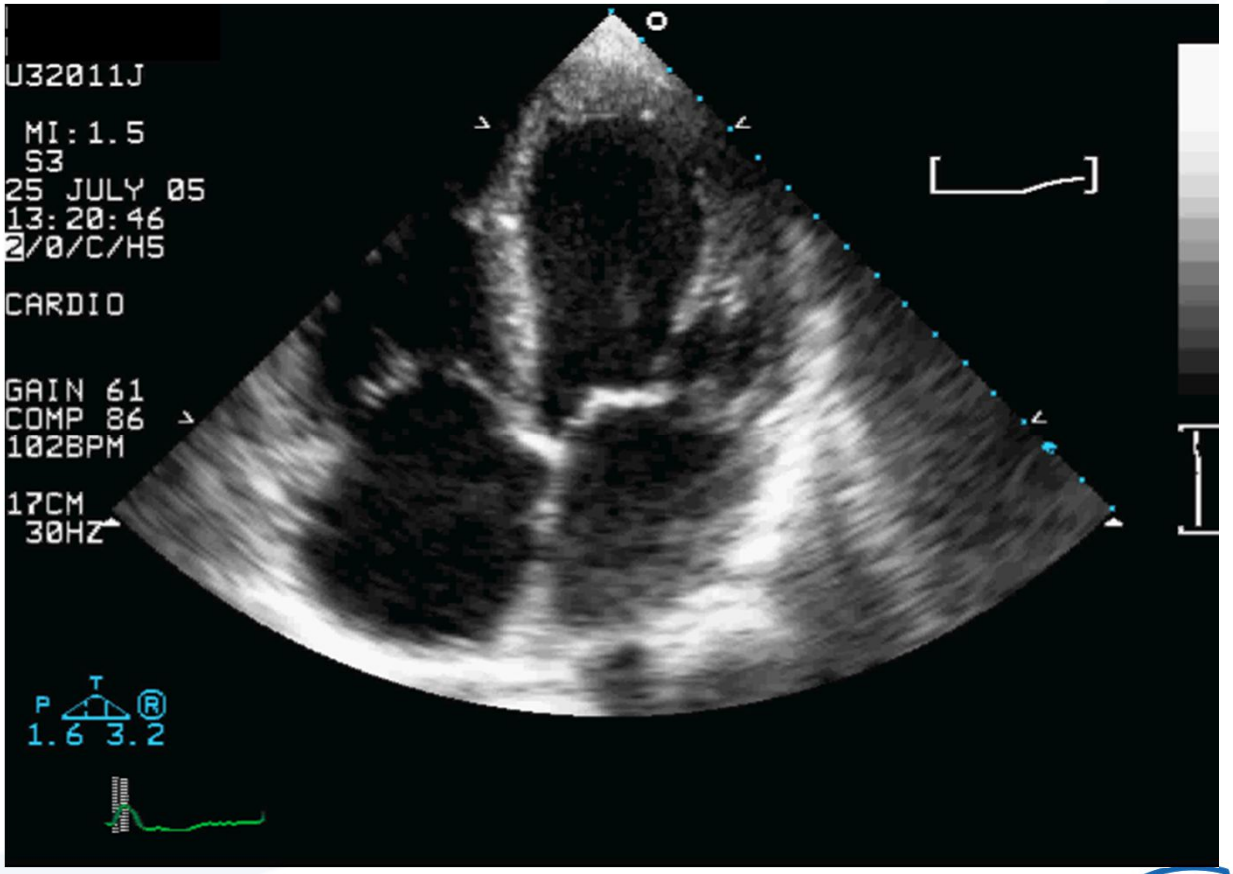
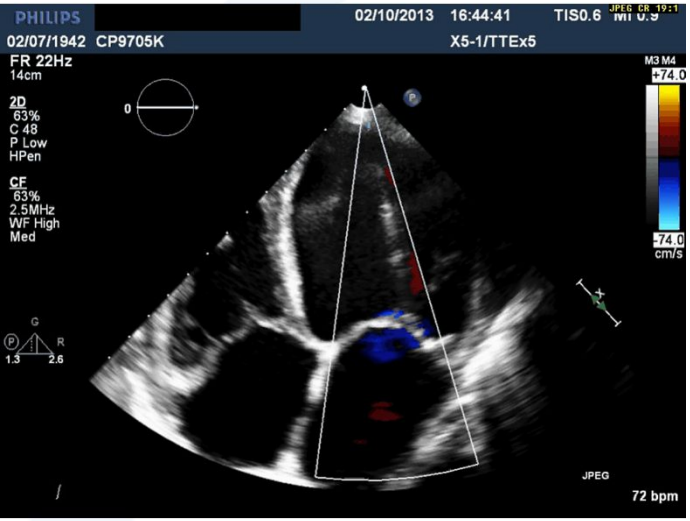
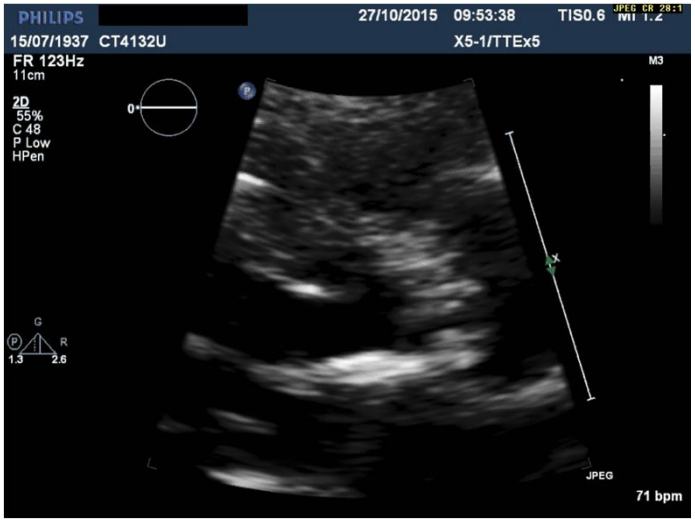
Echocardiographie: cardiomyopathies

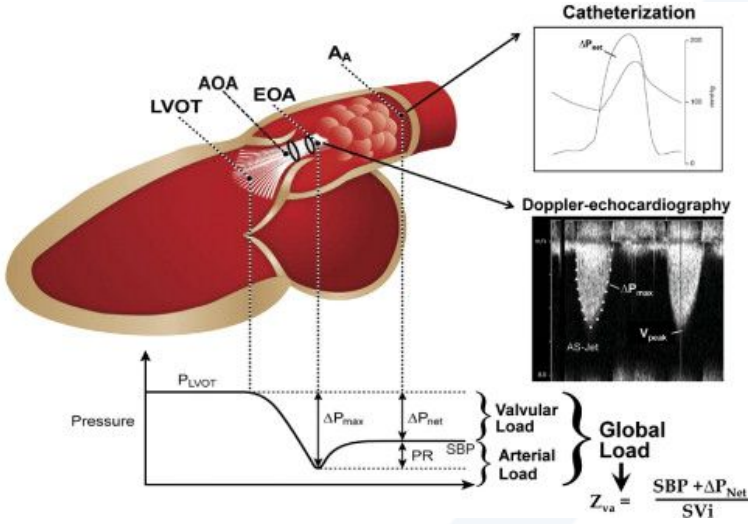


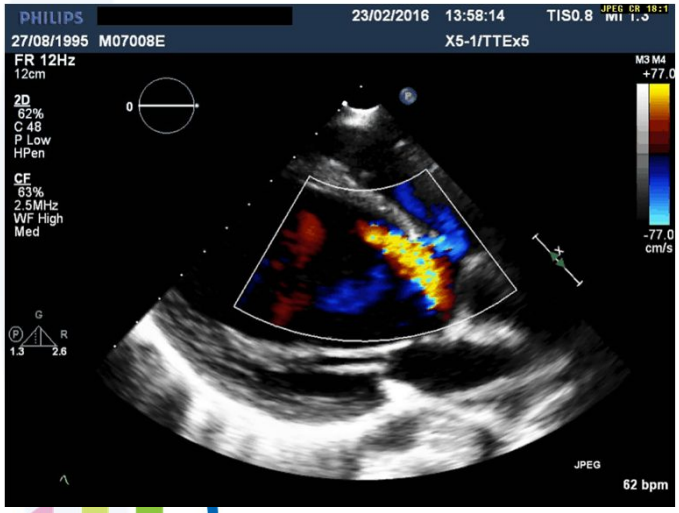


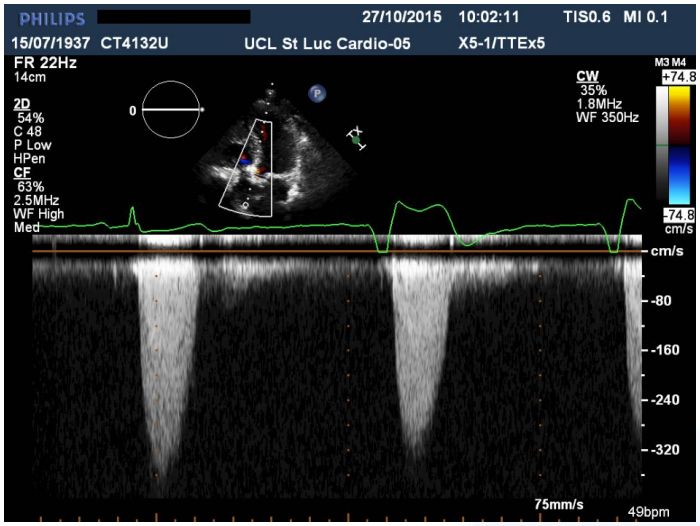
Fonction Valvulaire

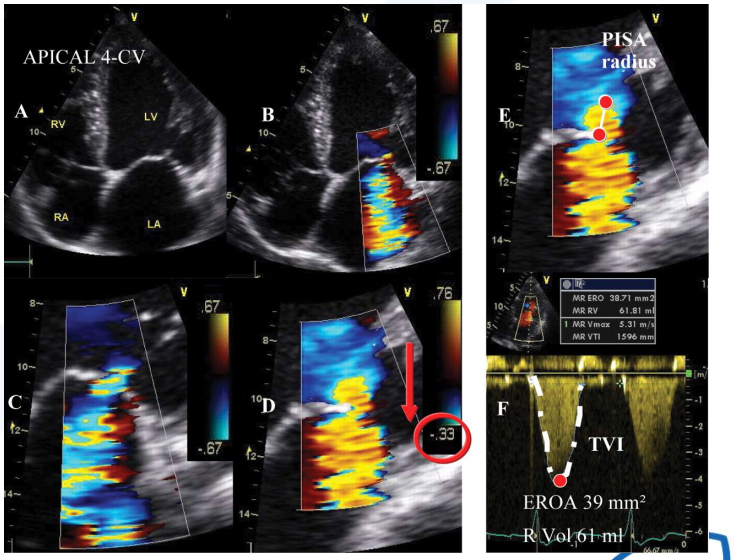












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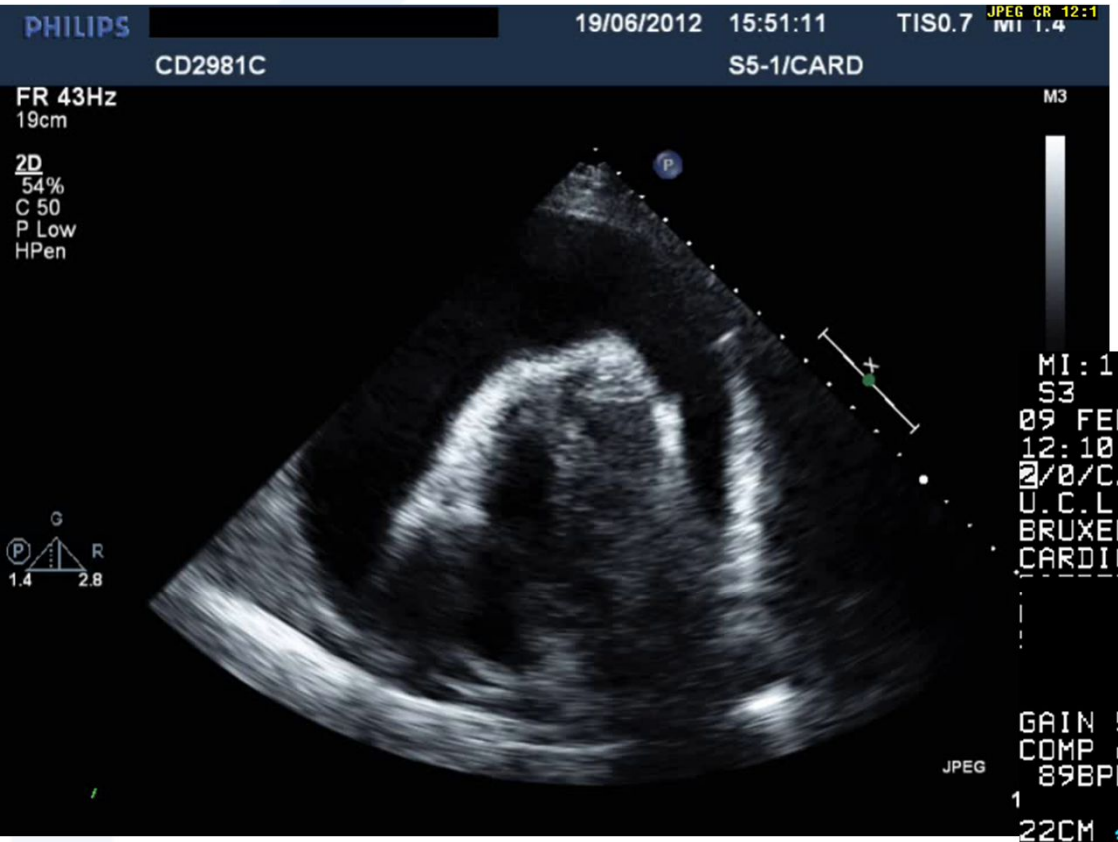
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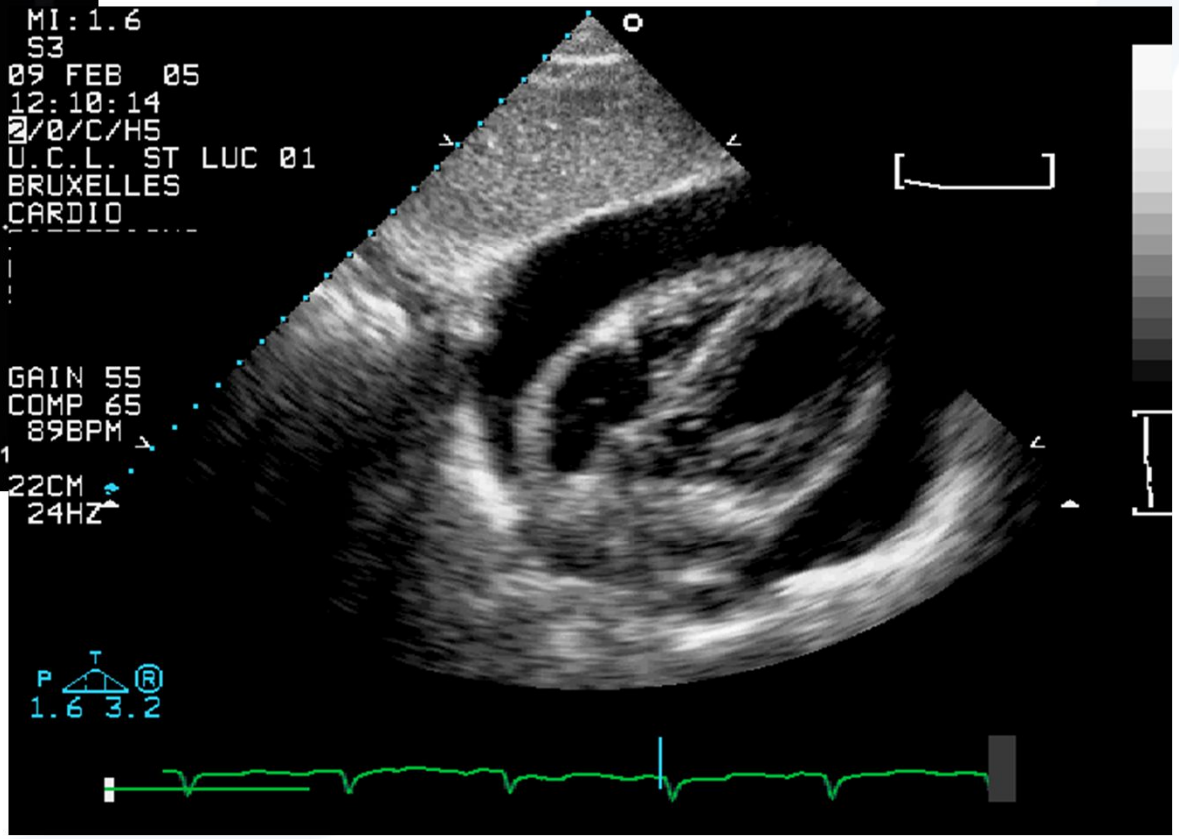
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COMP 65
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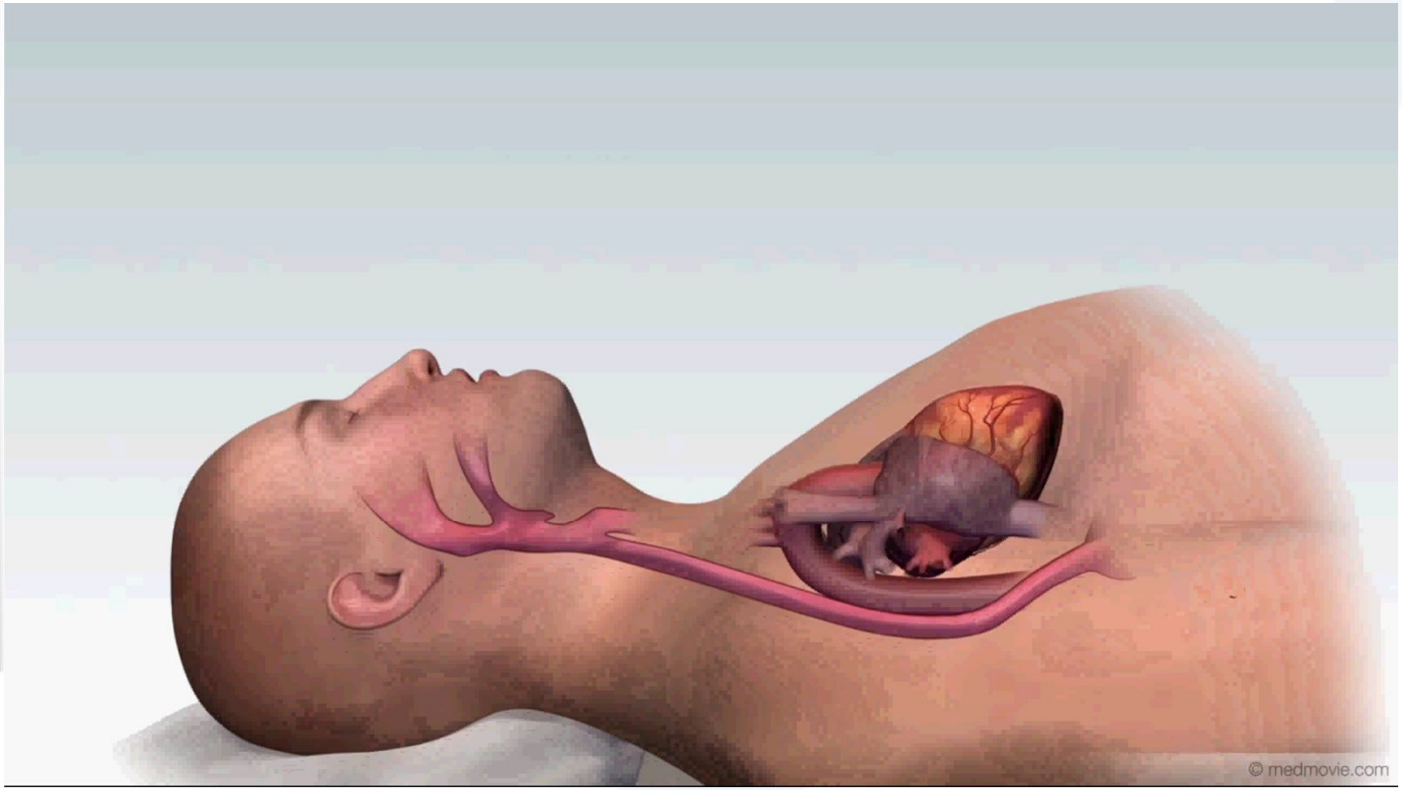
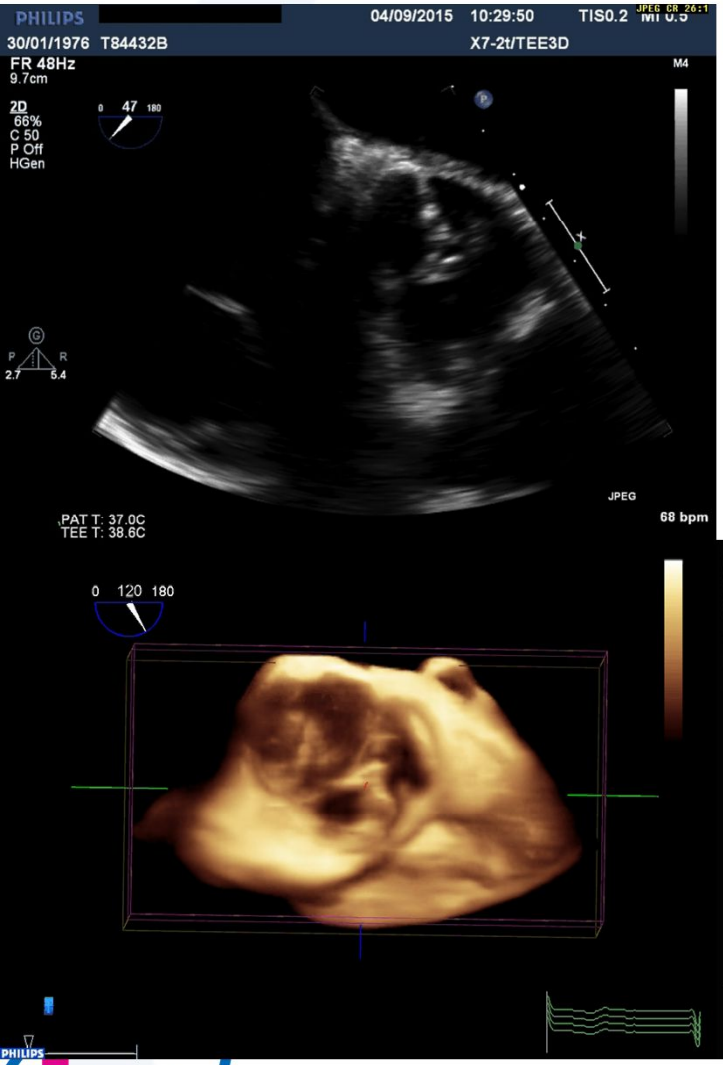
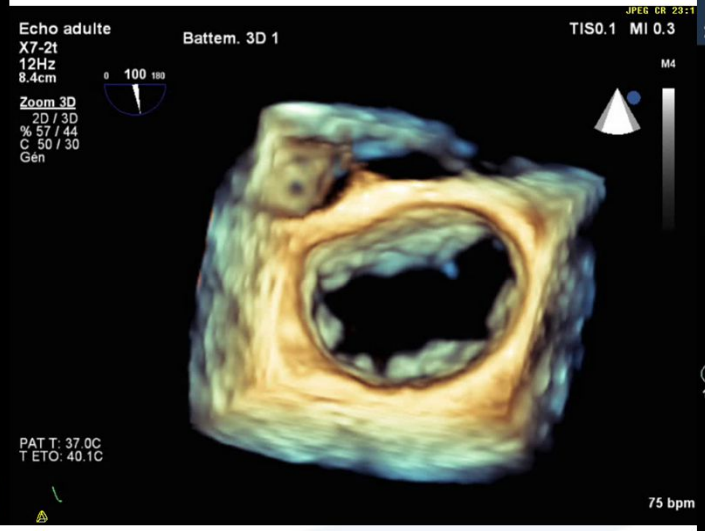
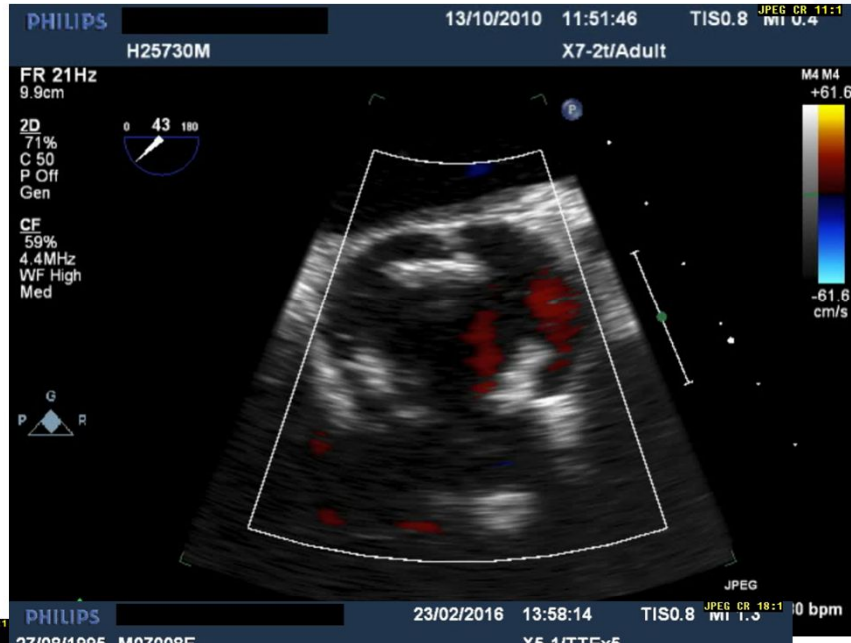
Echocardiographie transoesophagenne

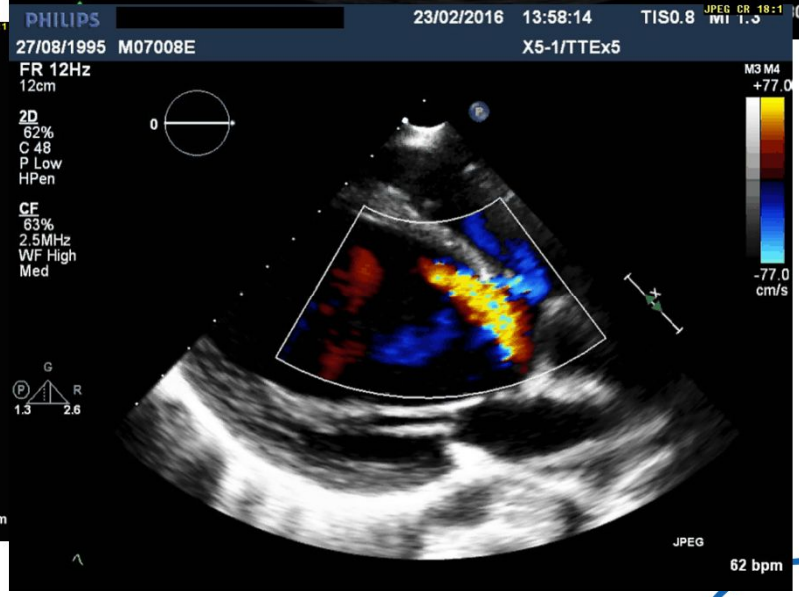


Echocardiographie transoesophagienne
Evaluation des Valves et Prothèses

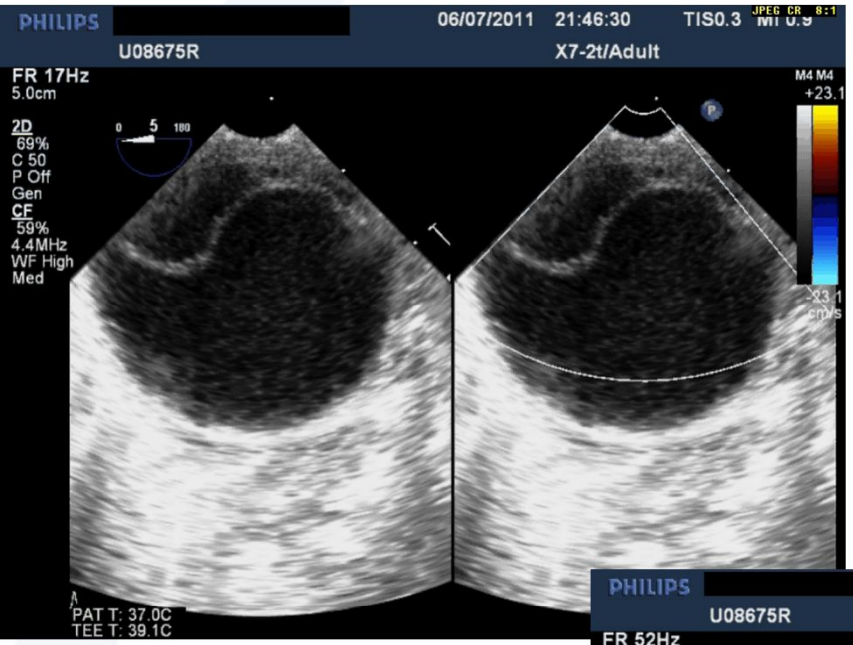


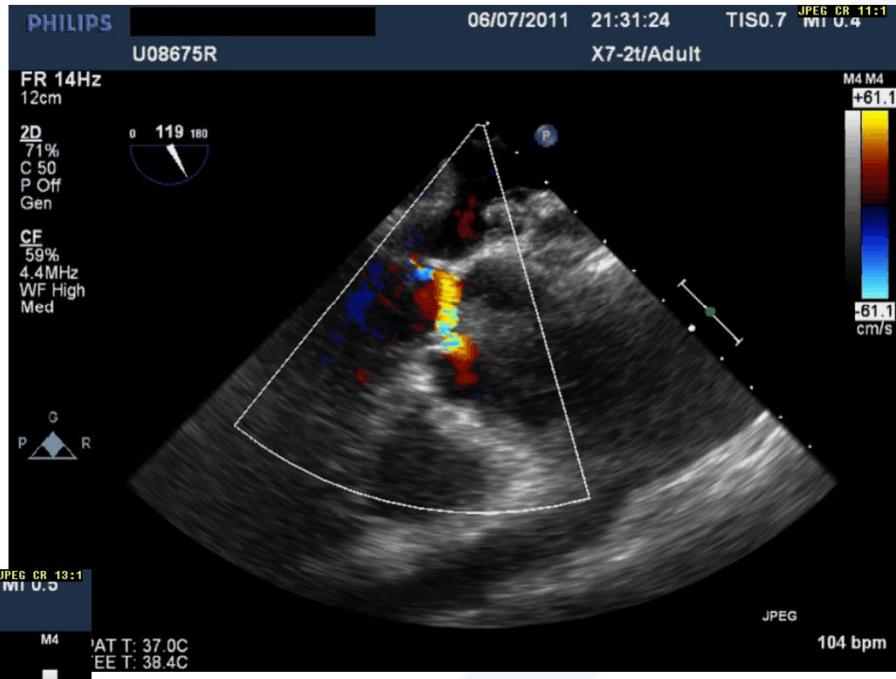


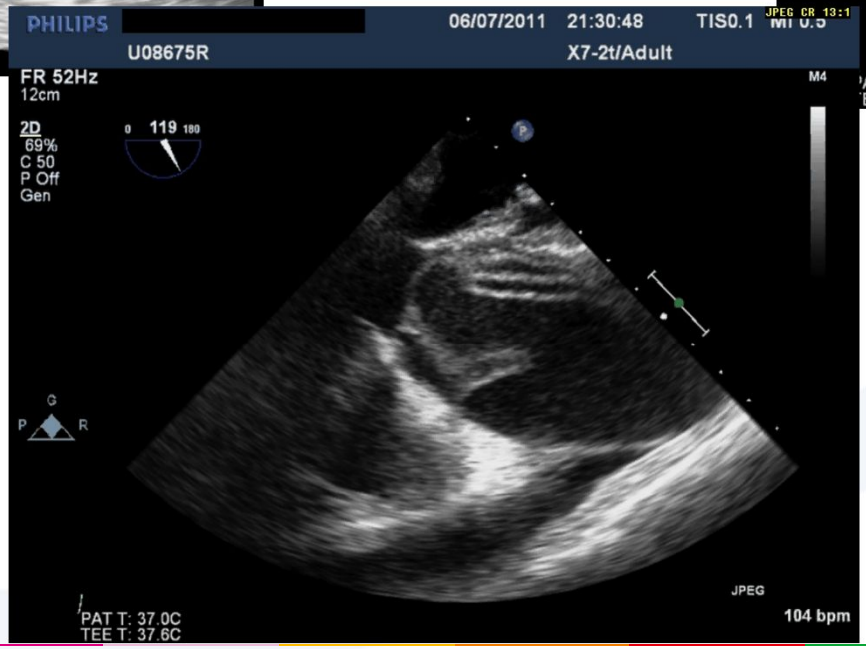




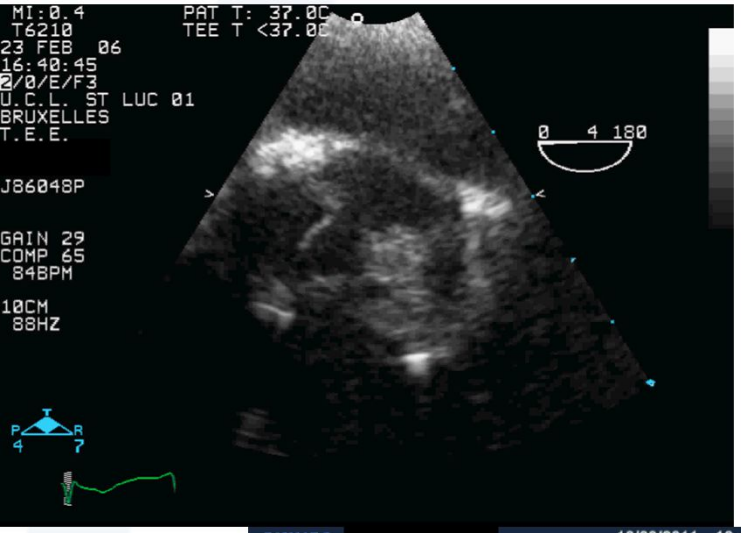
Echocardiographie Transoesophagenne
Dissection Aortique

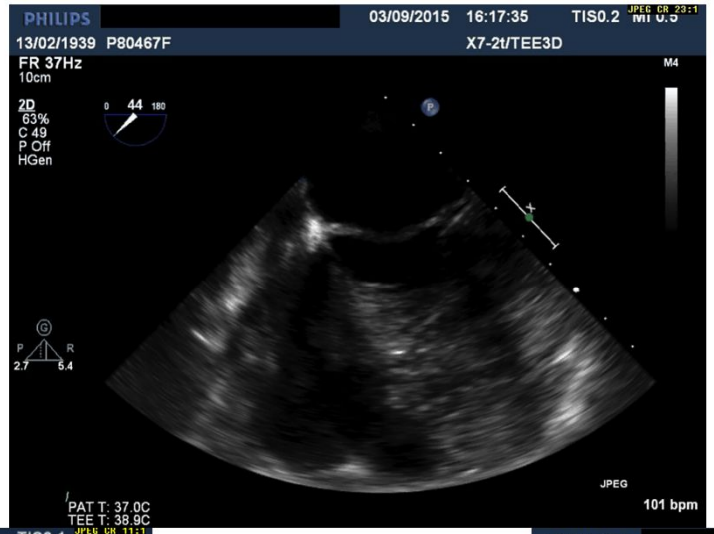


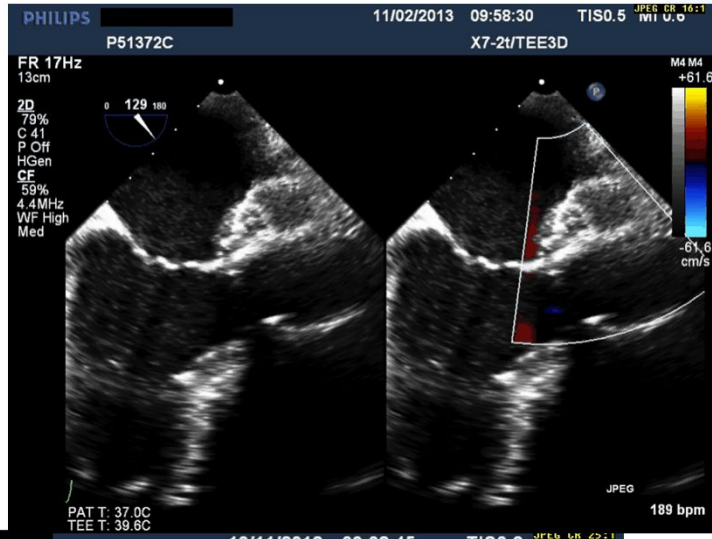


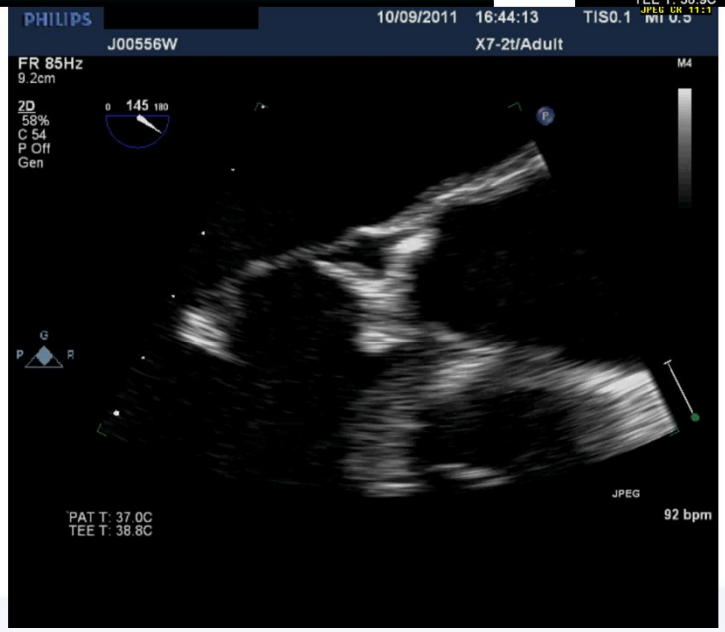


Echocardiographie Transoesophagenne
Endocardite

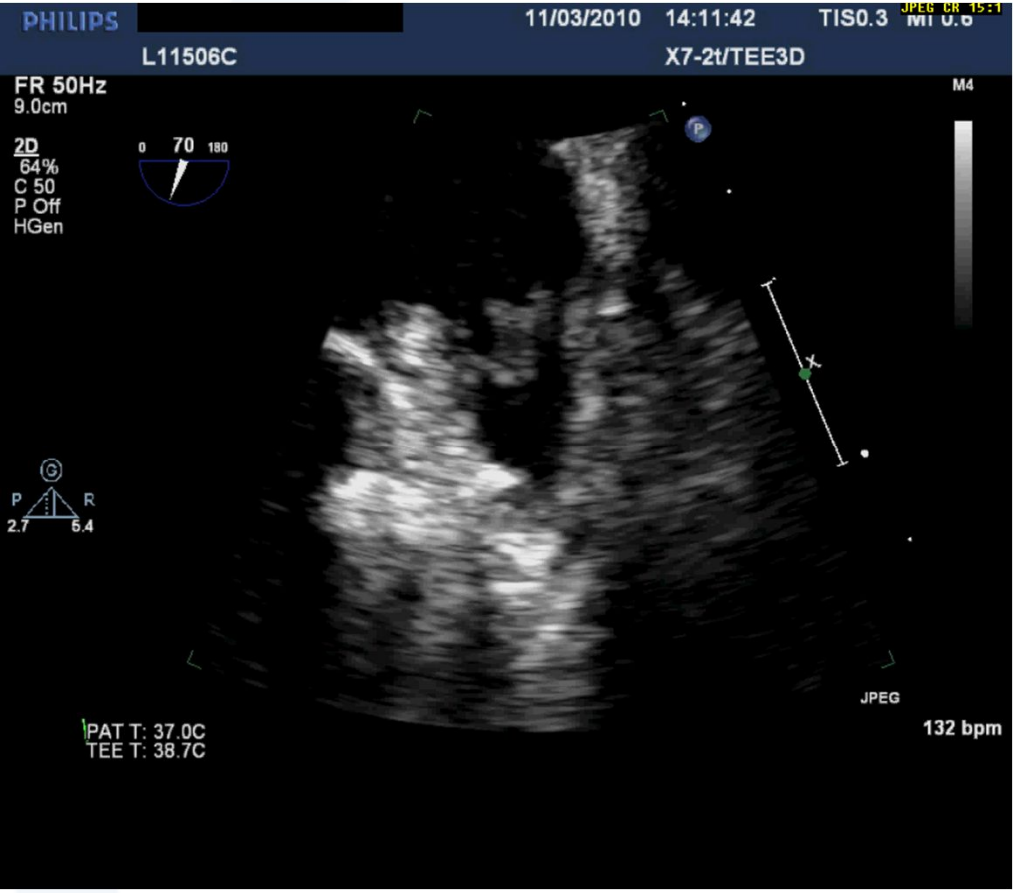


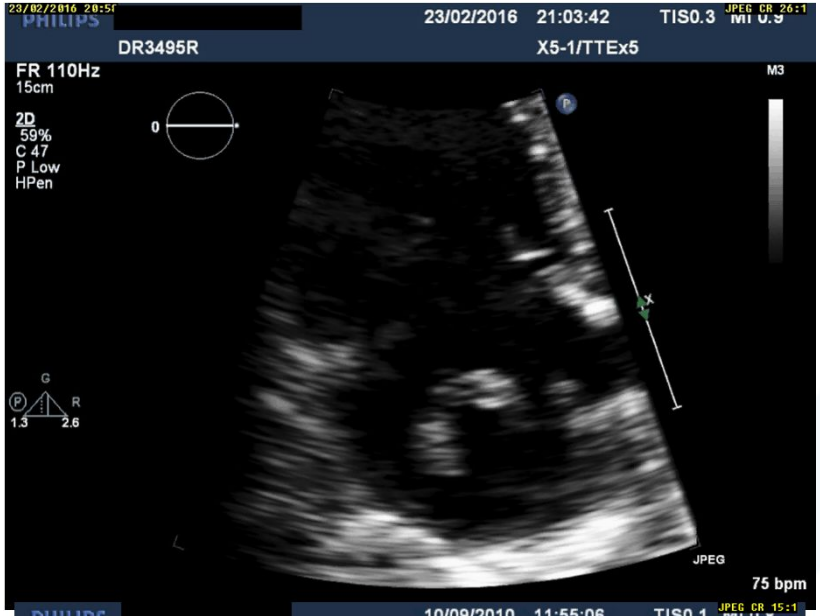


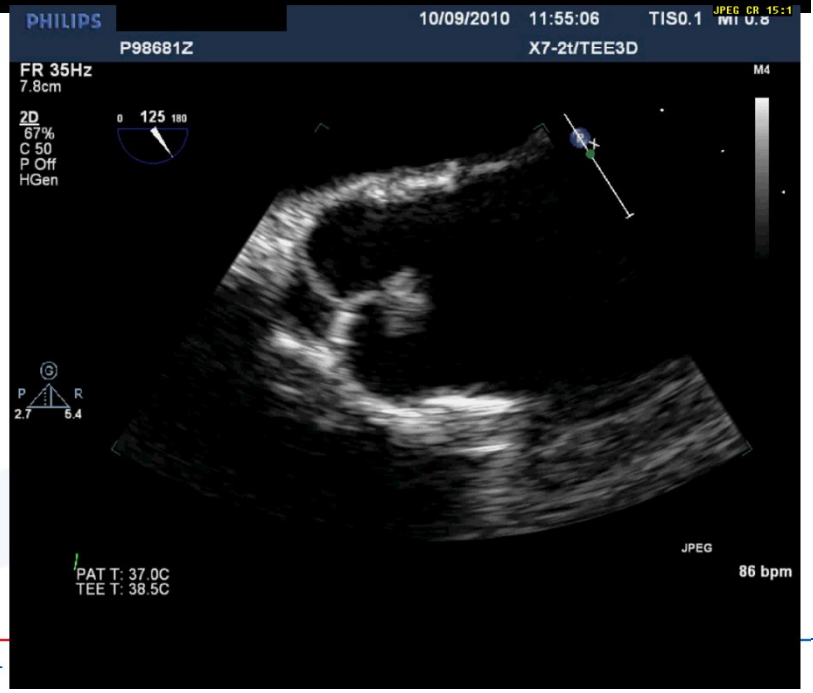




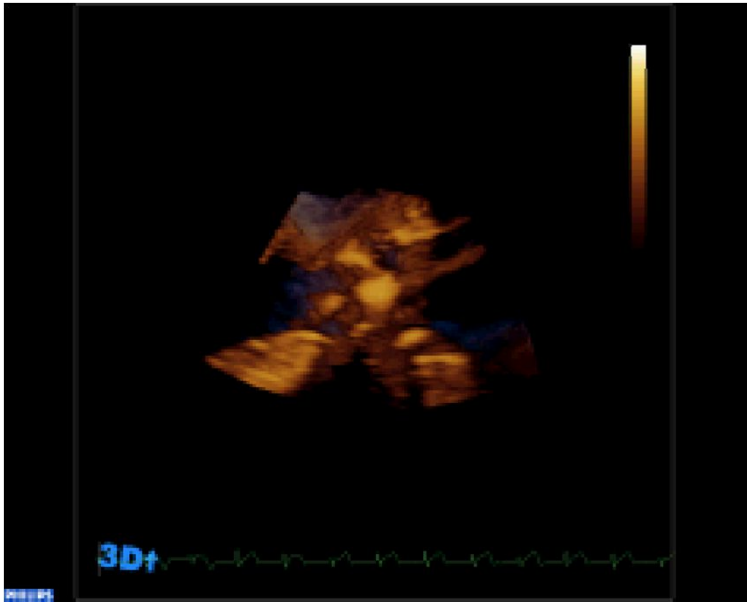
Echocardiographie Transoesophagenne
Evaluation AVC – Thrombi / Tumeurs

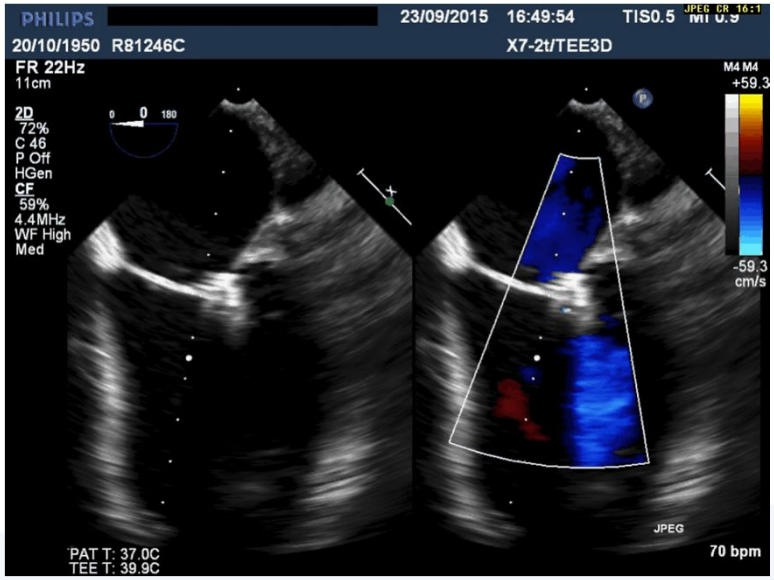


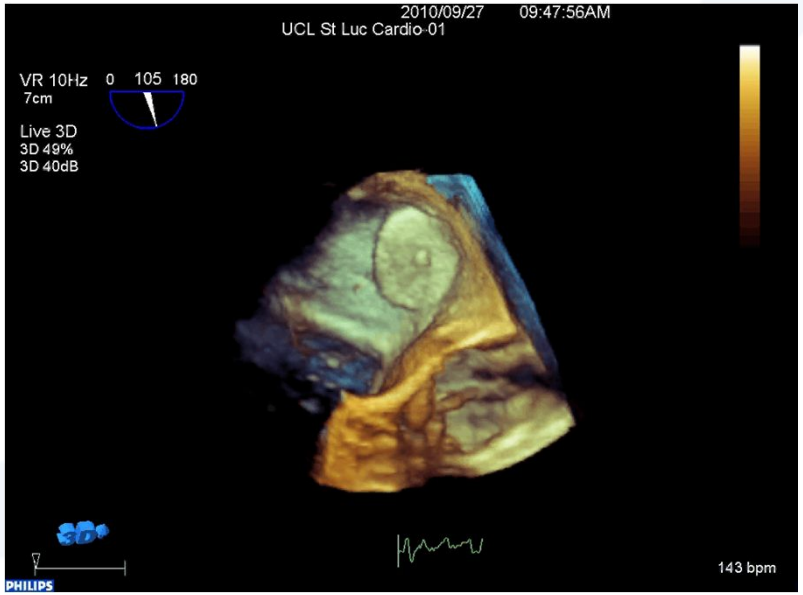




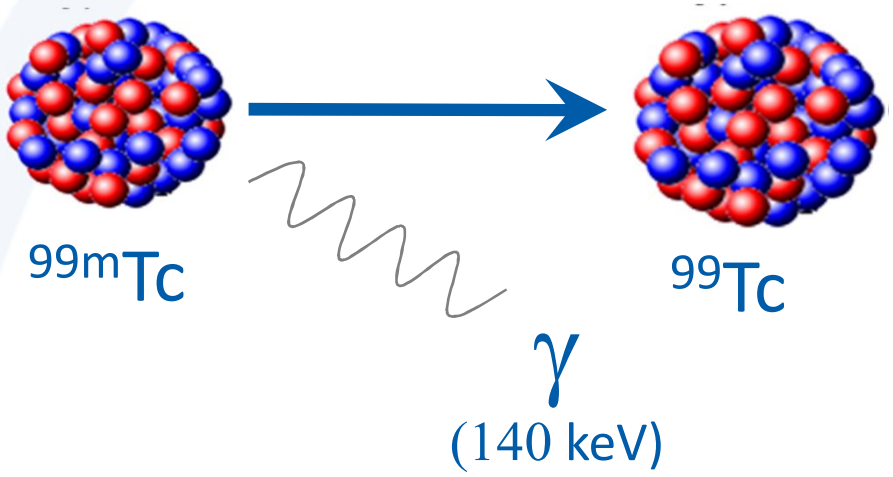
Echocardiographie transoesophagenne
Procedures





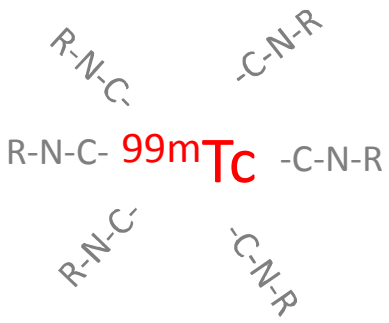


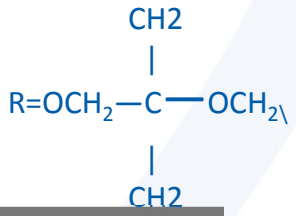
Nuclear Medicine (SPECT)
Principles

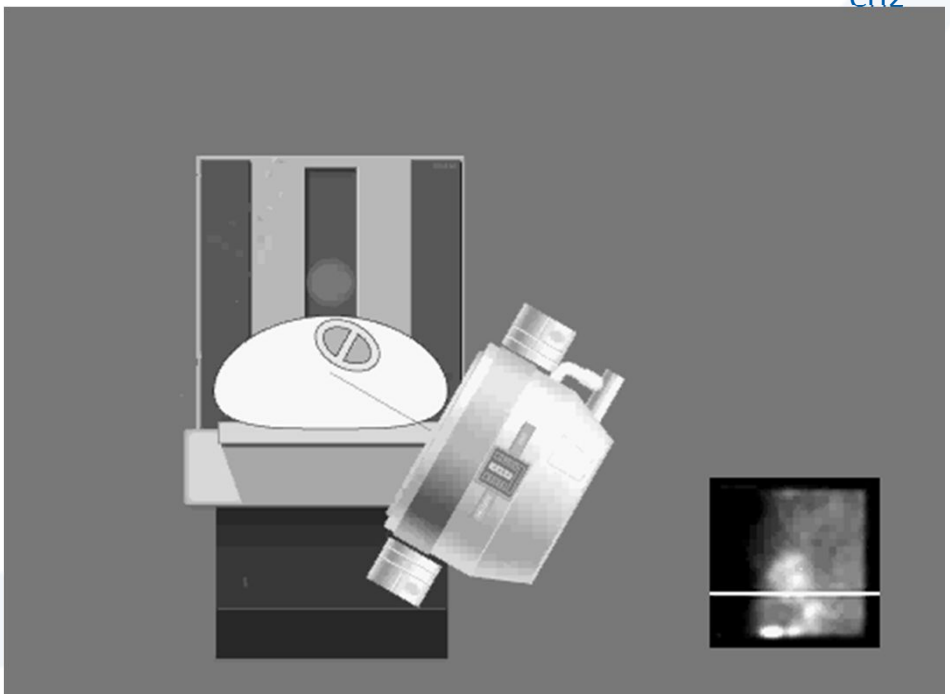


^{99}Tc Sesta-MIBI

Metabolized
$T_{1/2}$=6 hours
140 keV





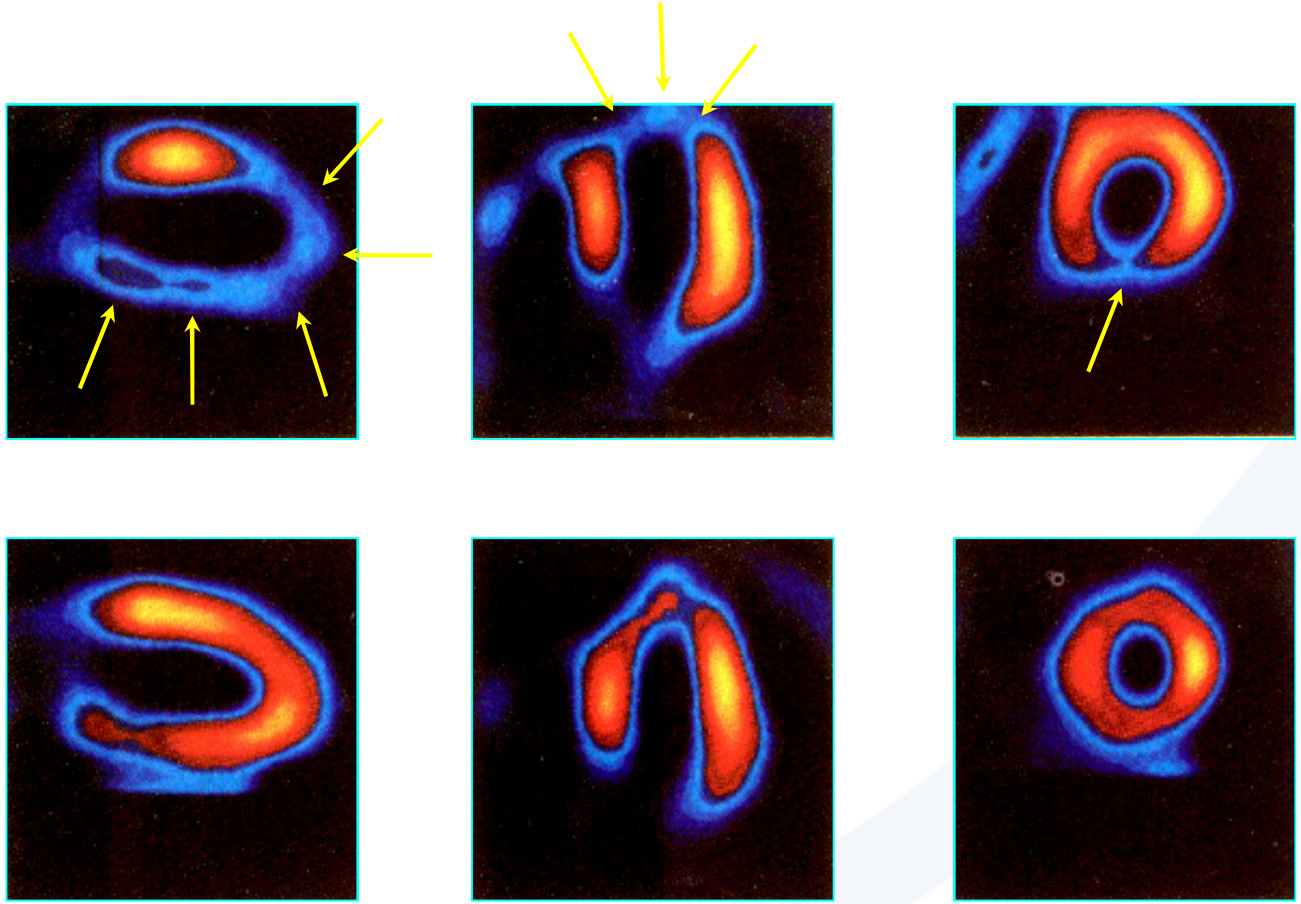


Classical Nuclear Cardiology

Perfusion Imaging

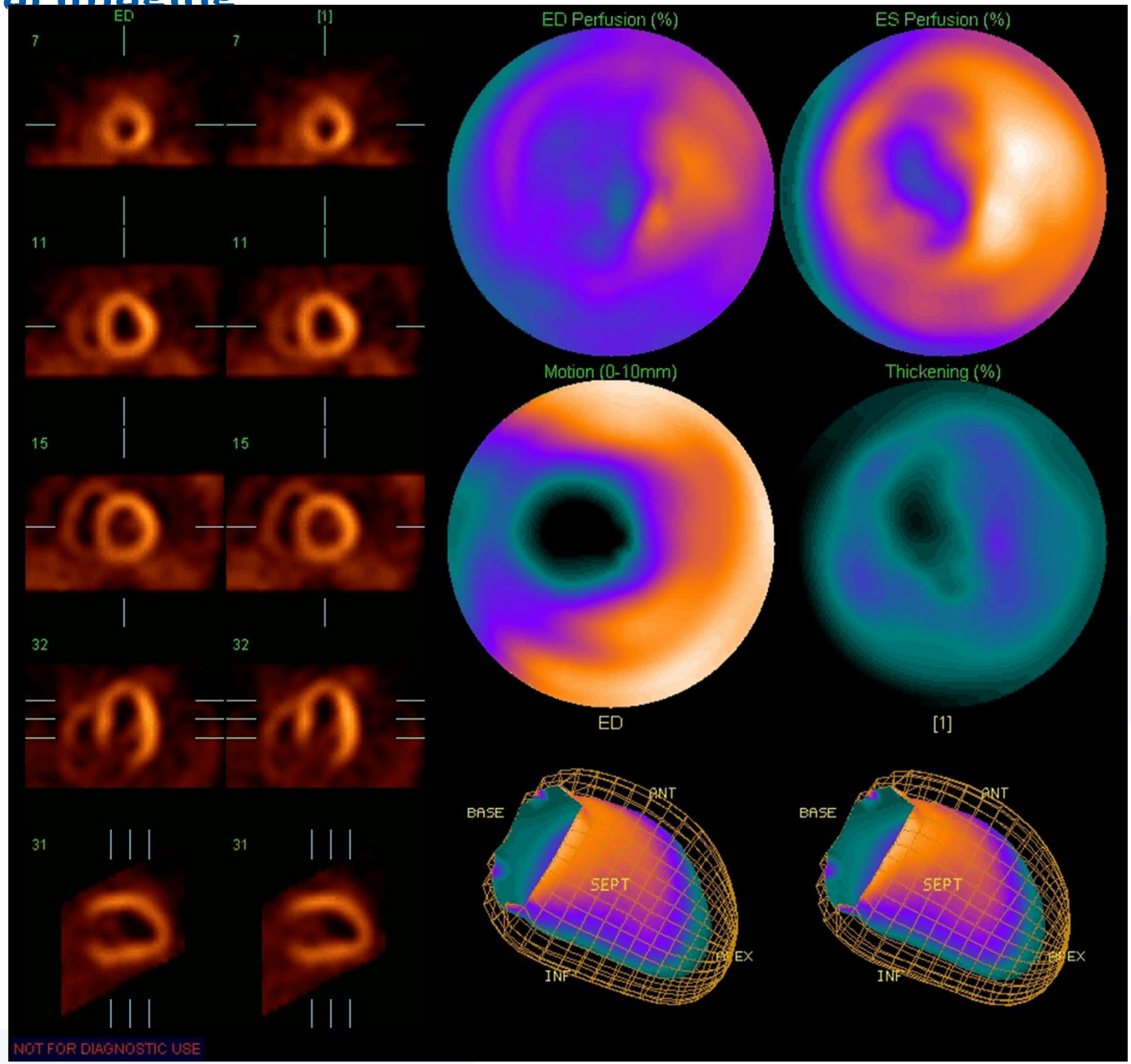
Effort

Repos



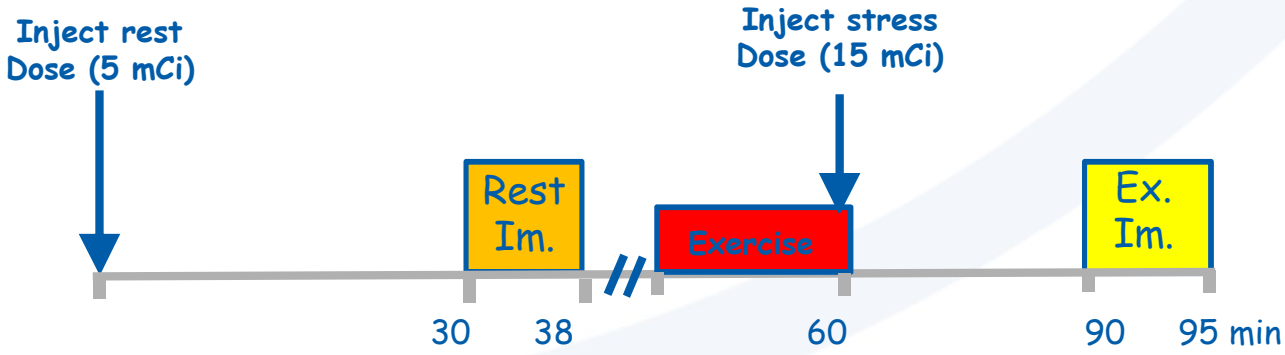
Sagittal Transverse Coronal

Classical Nuclear Cardiology
SPECT: Functional Imaging



New High speed SPECT protocols
CZT detectors

One day Mibi Stress-Rest Protocol



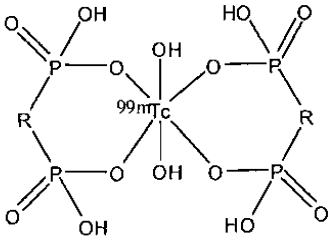
Duvall J Nucl Cardiol 2011;18:847-57
Berman JACC: Cv Imag 2(3) 2009:273-82

TTR-Amyloidosis detection by Nuclear Imaging: ^{99}Tc-DCD and ^{99}Tc-PYP

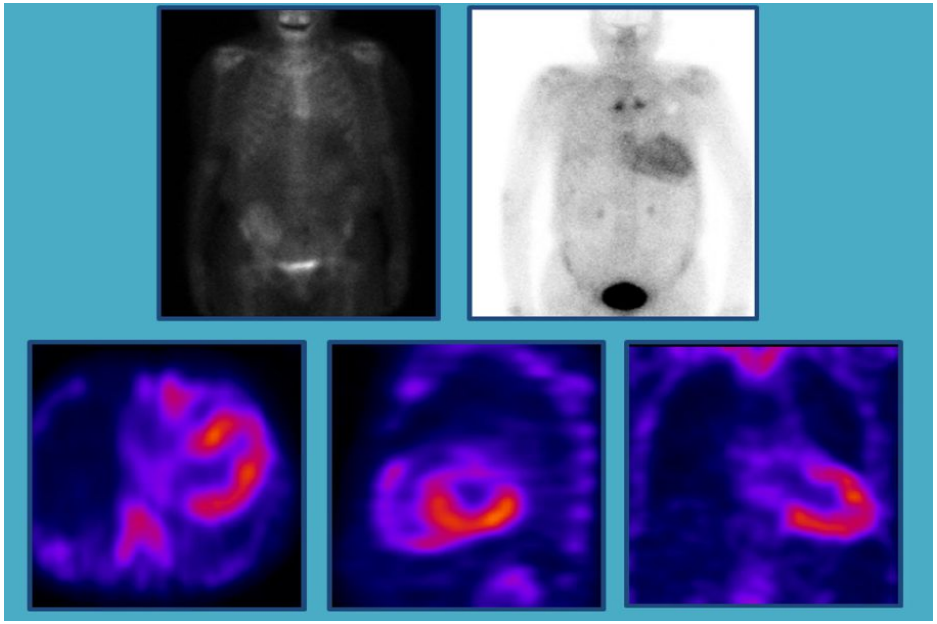
Tc-DCD

^{99}mTc-3,3-diphosphono-1,2-propanodicarboxylic acid

Europe - Not in USA



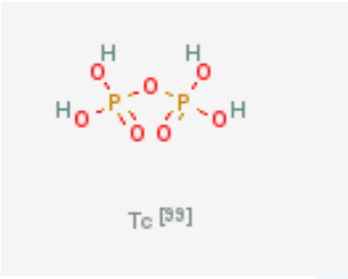
740 mBq,
imaging 3 h later



99mTc-PYP

99m-technetium pyrophosphate)

Europe and USA



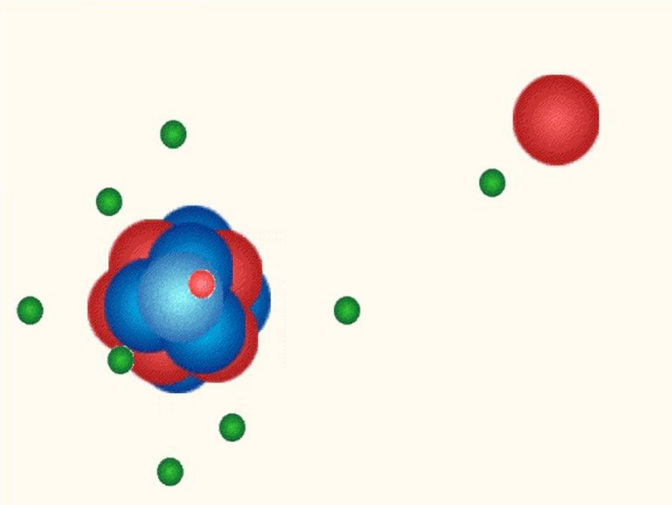
20-25 mC
imaging 1 h later

Works for **TTR-Amyloidosis** (senile and familiar) but **not AL amyloidosis**

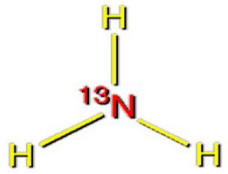
Mechanisms unknown:

high calcium levels in amyloidosis bind to phospate in the radiotracers

PET



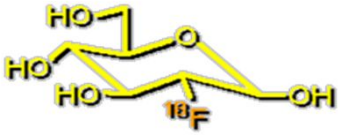
A) Perfusion Tracers:



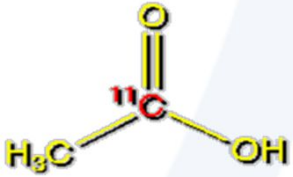
^{13}N-Ammonia

^{15}O-Water

B) Metabolic Tracers:

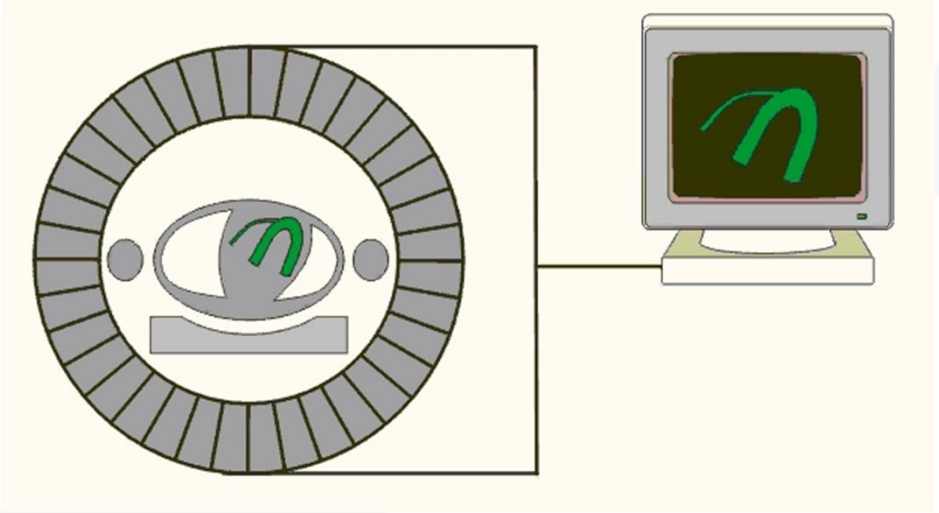


^{18}F-Desoxyglucose

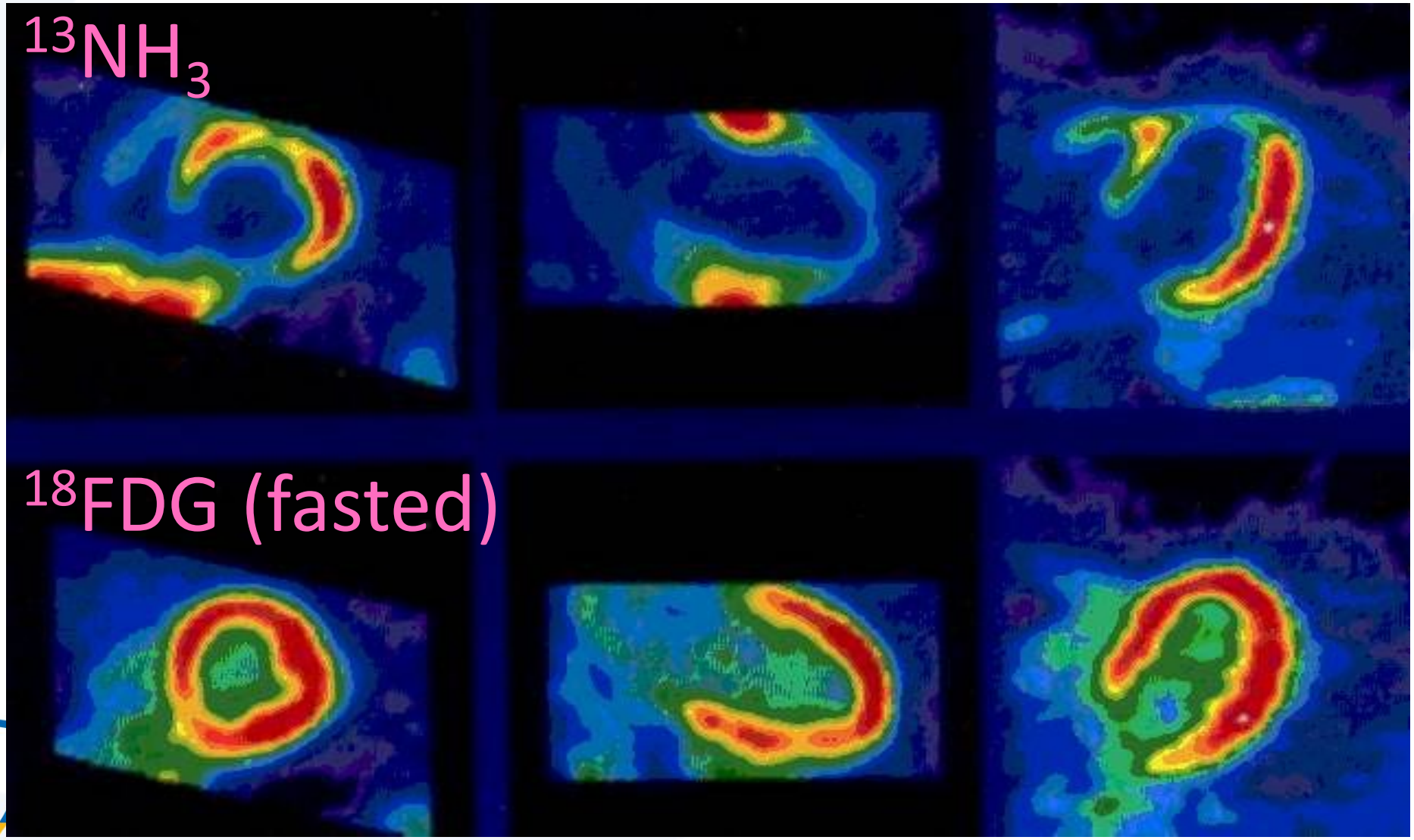


^{11}C-Acetate

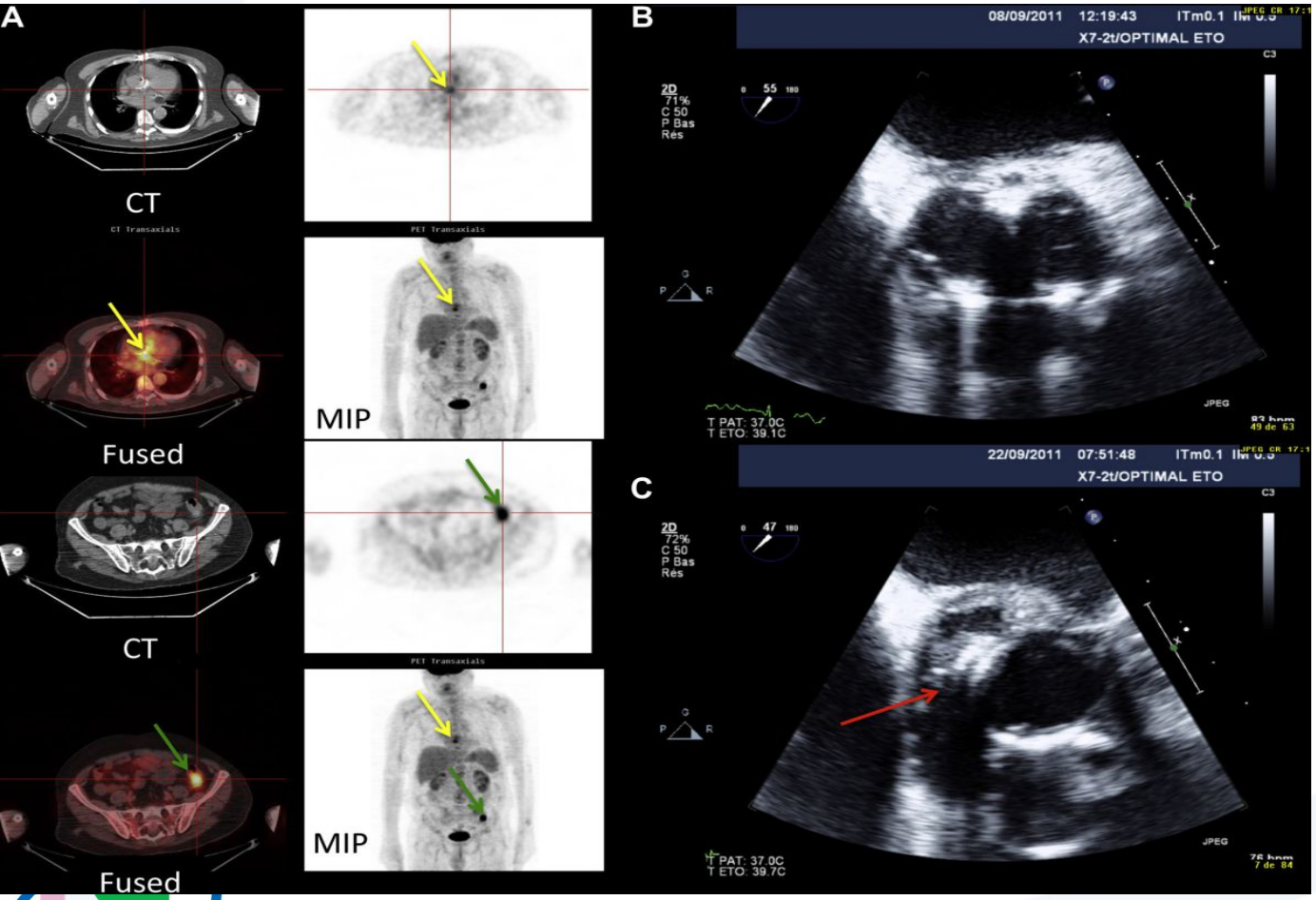
^{11}C-Palmitate



PET:
Viability



PET-CT for detection of perivacular abces in prosthetic valves



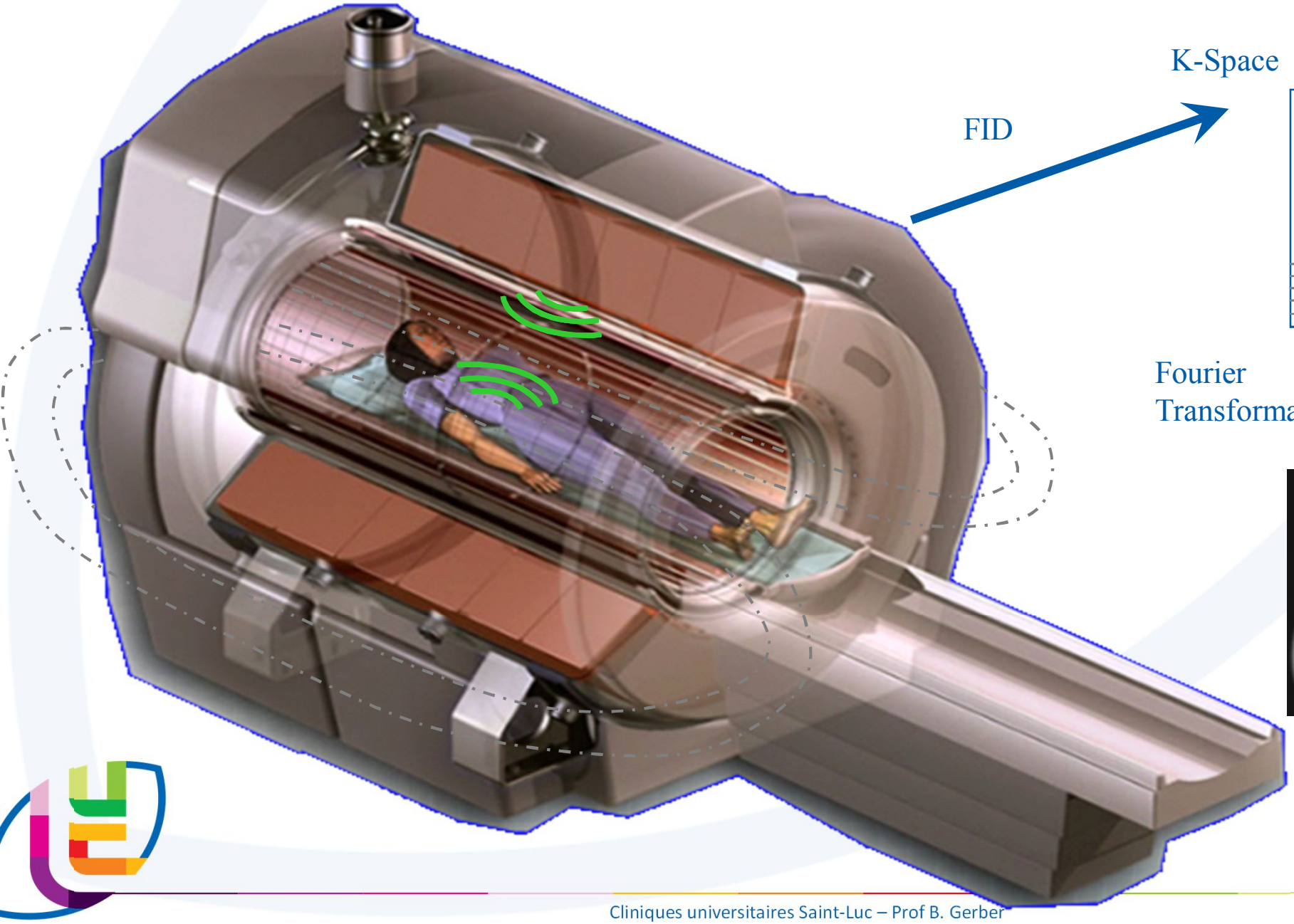
	Final Diagnosis		
	Definite PVE	*Possible* PVE	*Rejected* PVE
Duke			
Definite PVE	21 (70)	0 (0)	0 (0)
Possible PVE	8 (27)	22 (100)	10 (50)
Rejected PVE	1 (3)	0 (0)	10 (50)
Duke-PET/CT			
Definite PVE	29 (97)	10 (45)	2 (10)
Possible PVE	1 (3)	12 (55)	10 (50)
Rejected PVE	0	0	8 (40)

Sens 73 [54-87] %
Spec 80 [56-93] %
PPV 85 [64-95] %
NPV 67 [45-85] %
ACC 76 [63-86]%

Adding PET as major criterion increased sensitivity from 70 [52-83]% to 97 [83-93]% p=0.008 and decreased # of possible PVE from 40(56%) to 23 (32%)

Saby J Am Coll Cardiol 2013;61:2374–82

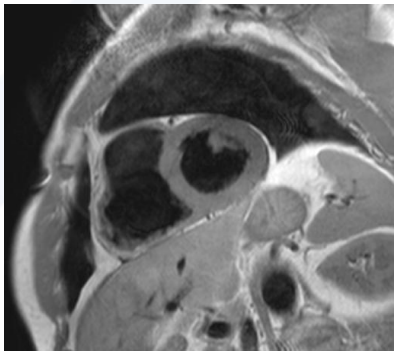
IRM Principes



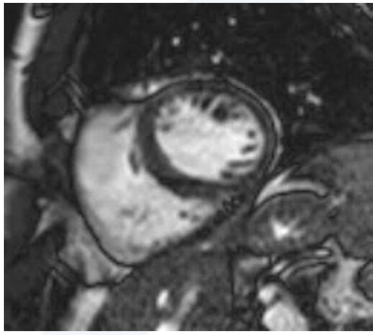
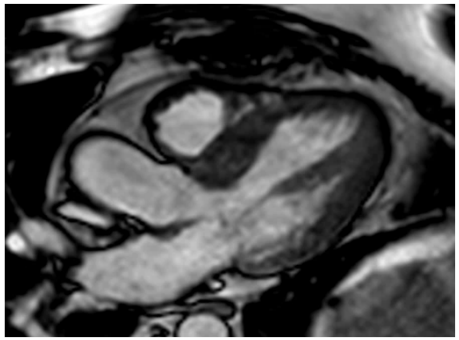
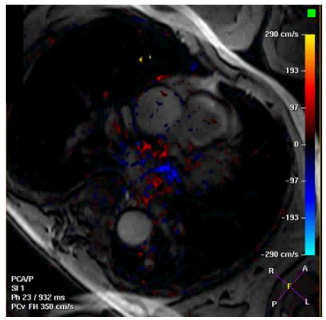
K-Space

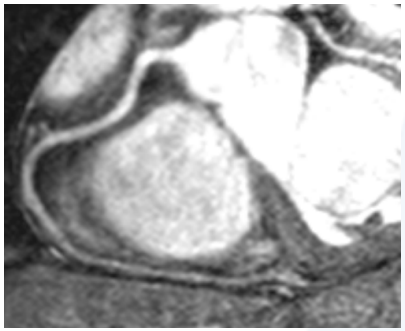
FID

Fourier
Transformation

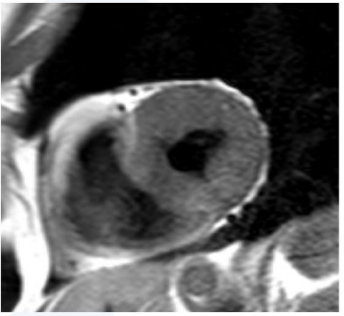
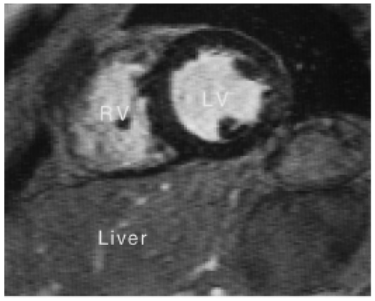


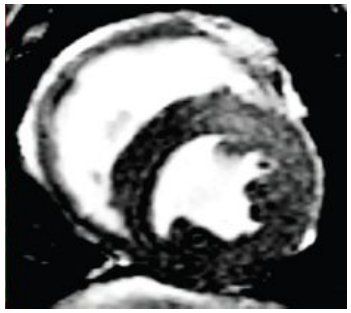
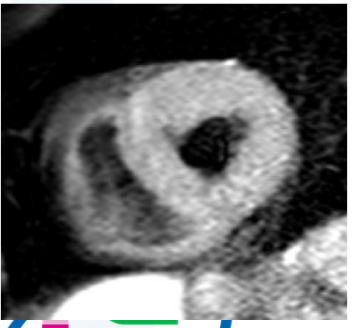
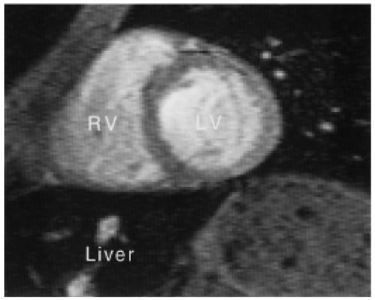
MRI of the heart
Technical Possibilities

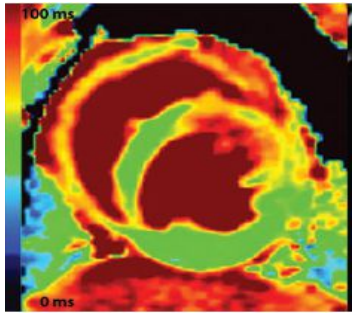




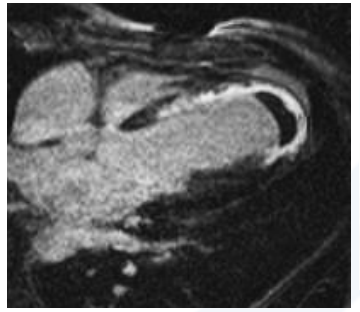
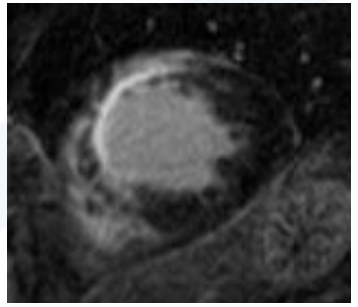
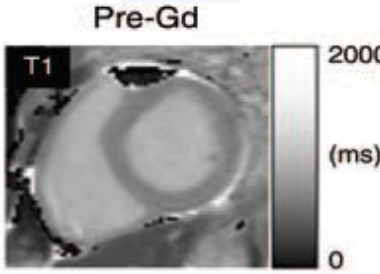



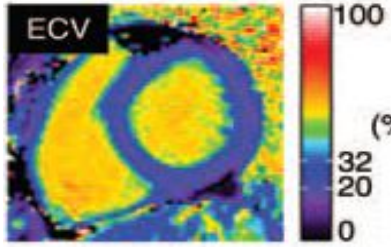
Anatomy and Function

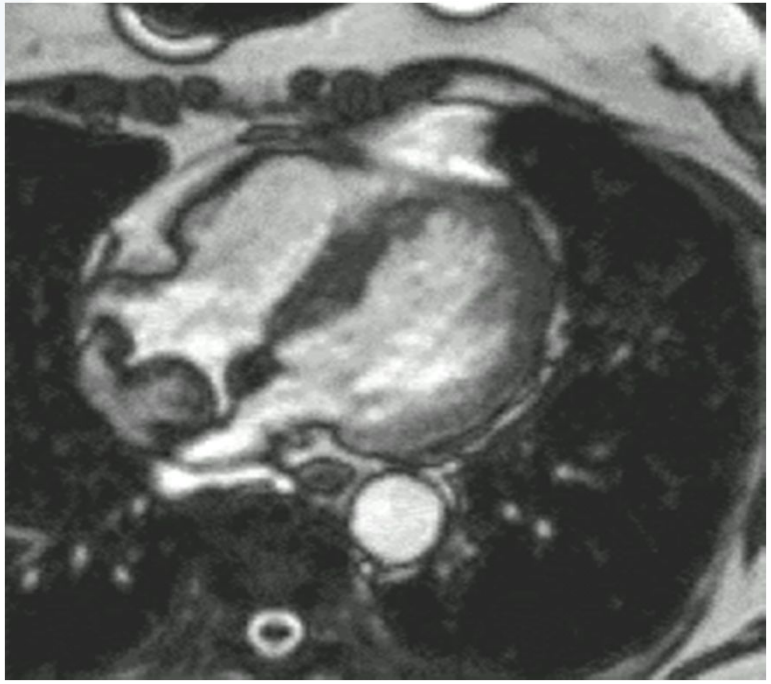


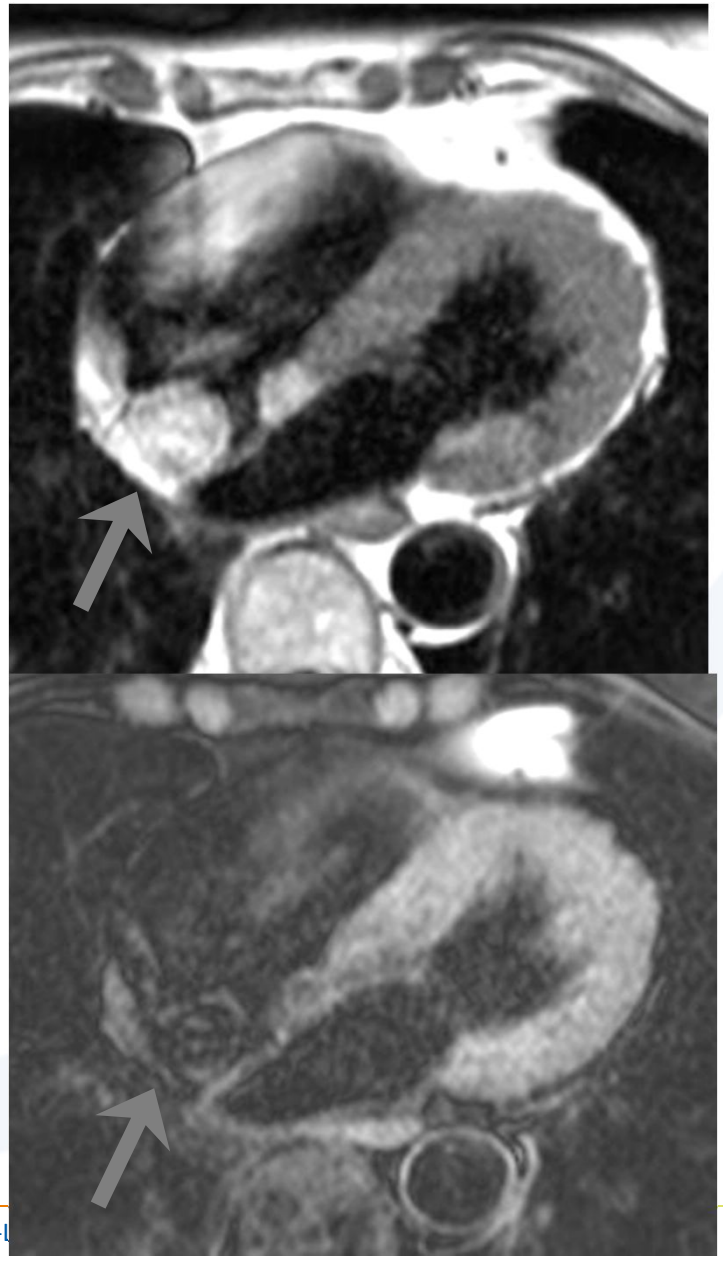







T1: FAT | T2*: IRON | T2 Edema | Perfusion | LGE/Fibrosis

Charactérisation des tumeurs
Lipome de l'oreillette droite



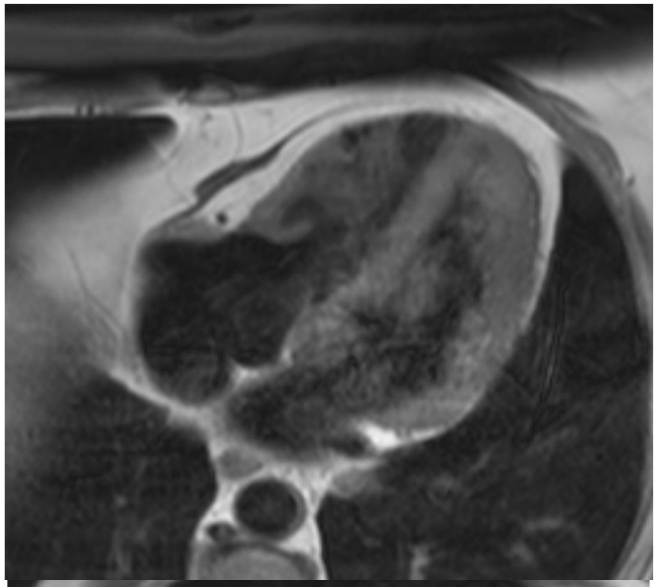


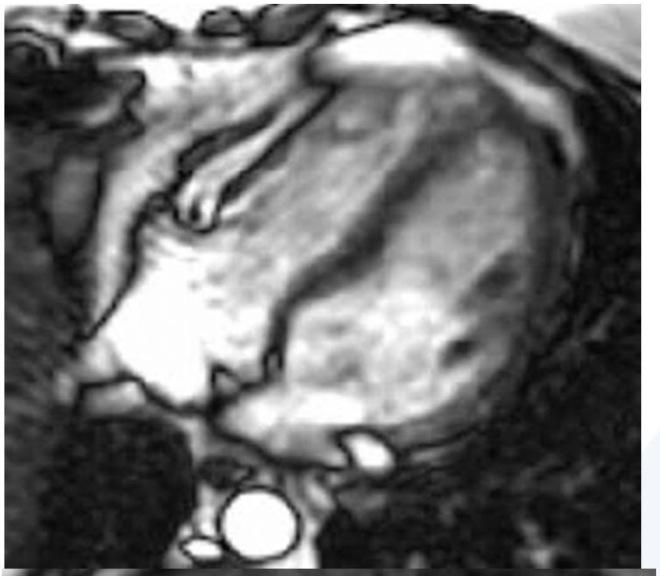
T1w

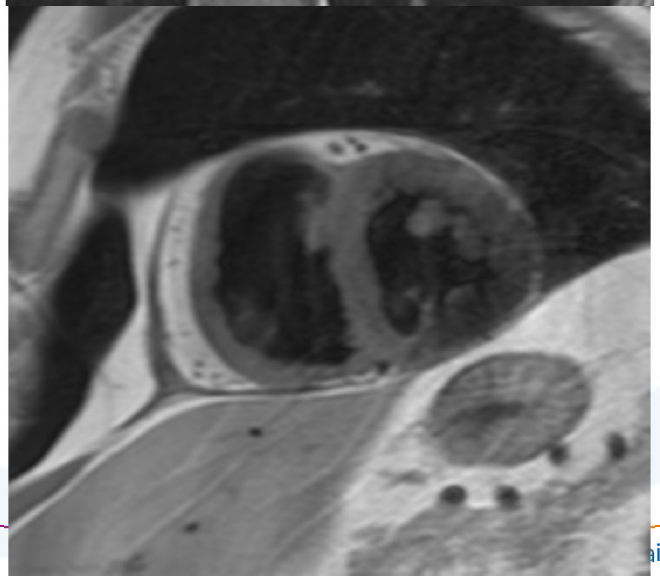
FS

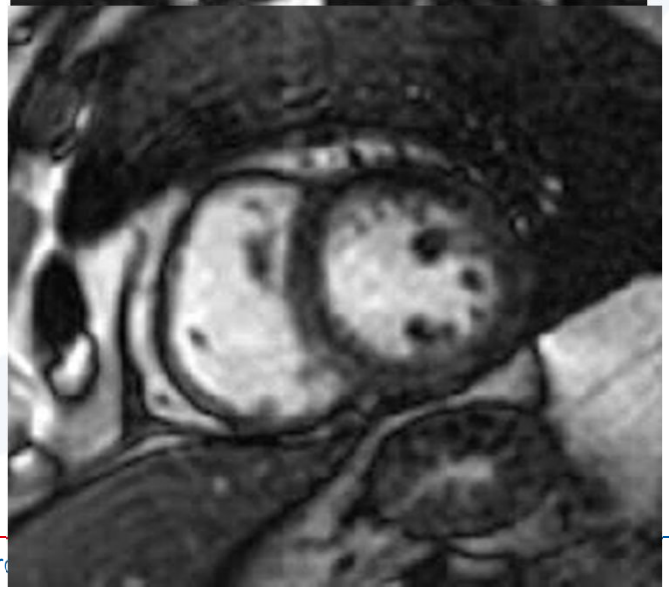
Pericardite Constrictive

Hémodynamique





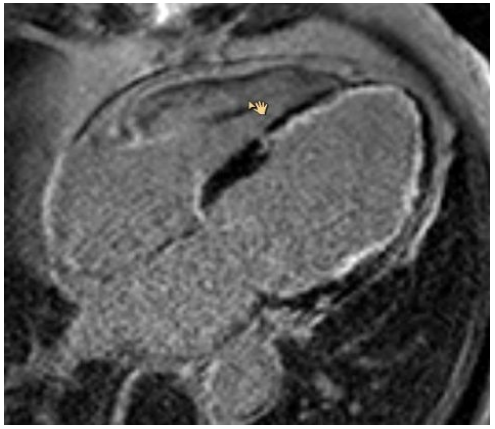




cMR Viability. Principle

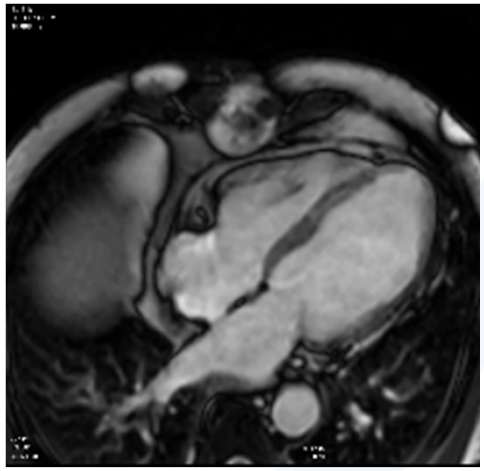
A) TRANSMURAL INFARCT: NON-VIABLE

DE



pre-CABG: EF 28%

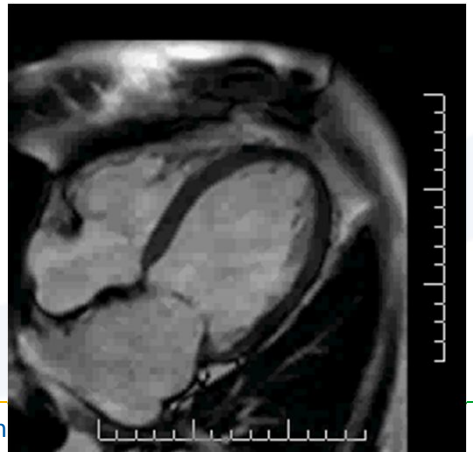
post-CABG: EF 30%



B) DYSFUNCTIONAL NON INFARCTED: VIABLE (HIBERNATING, STUNNING)

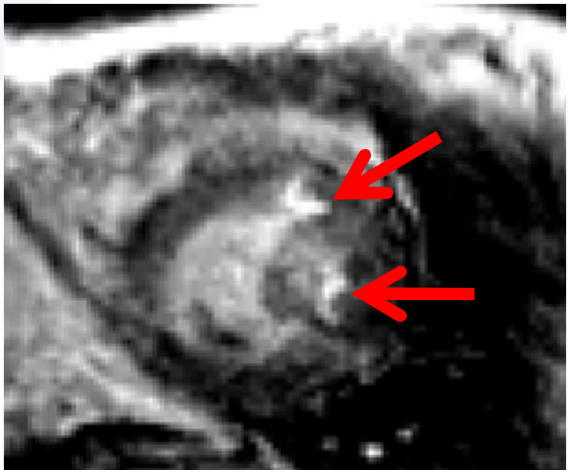
NO DE

pre-CABG: EF 23%

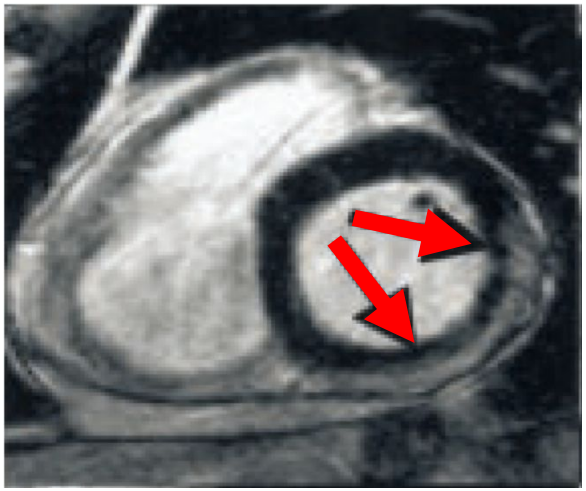


6 mo post-CABG: EF 36%

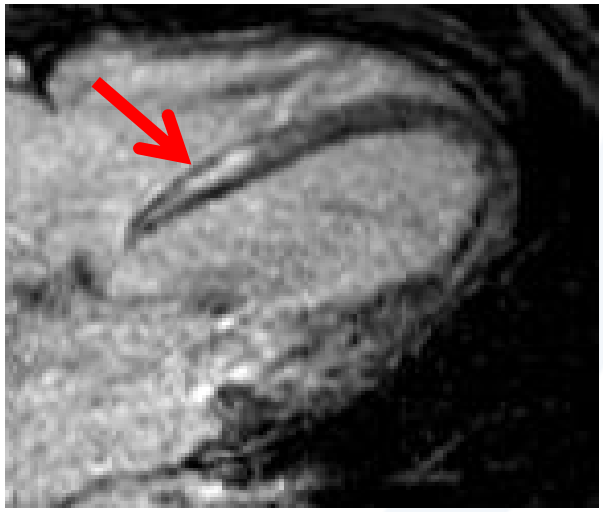
Differentiation of Non-ischemic Cardiomyopathies



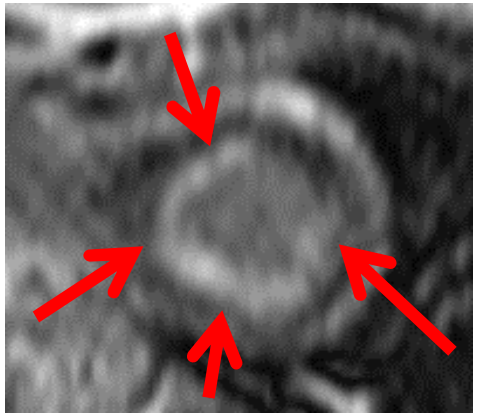
Hypertrophic



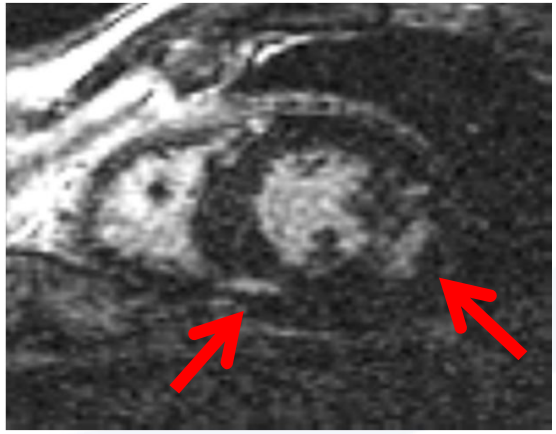
Myocarditis



Non-ischemic



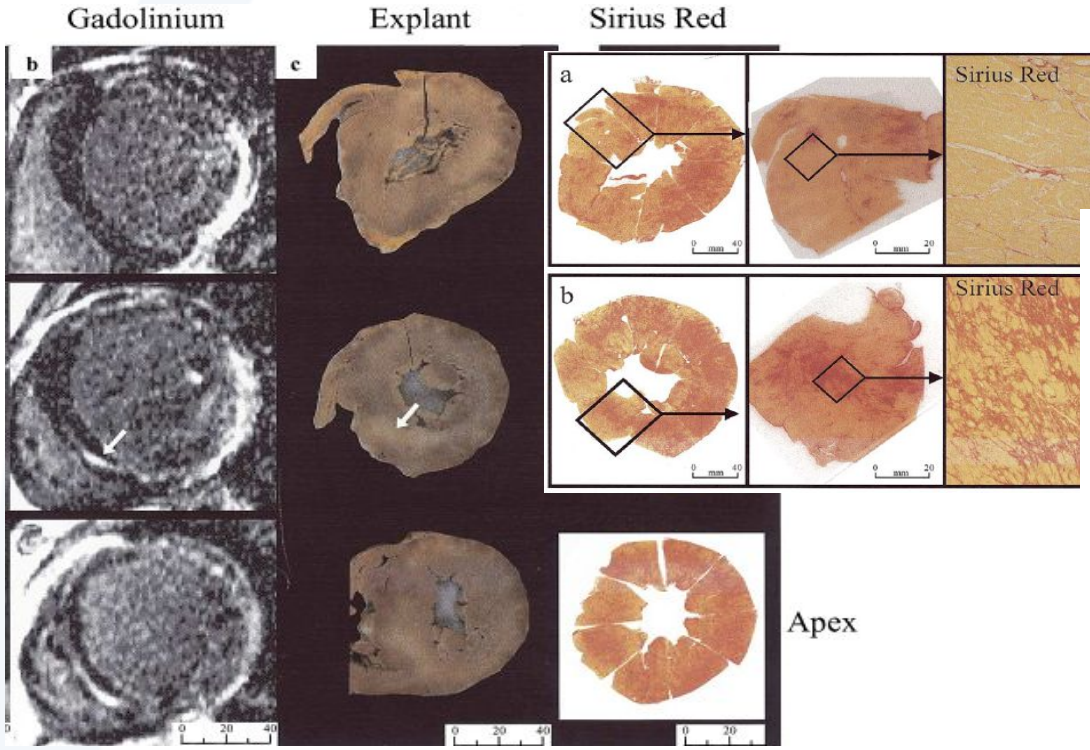
Amyloidosis



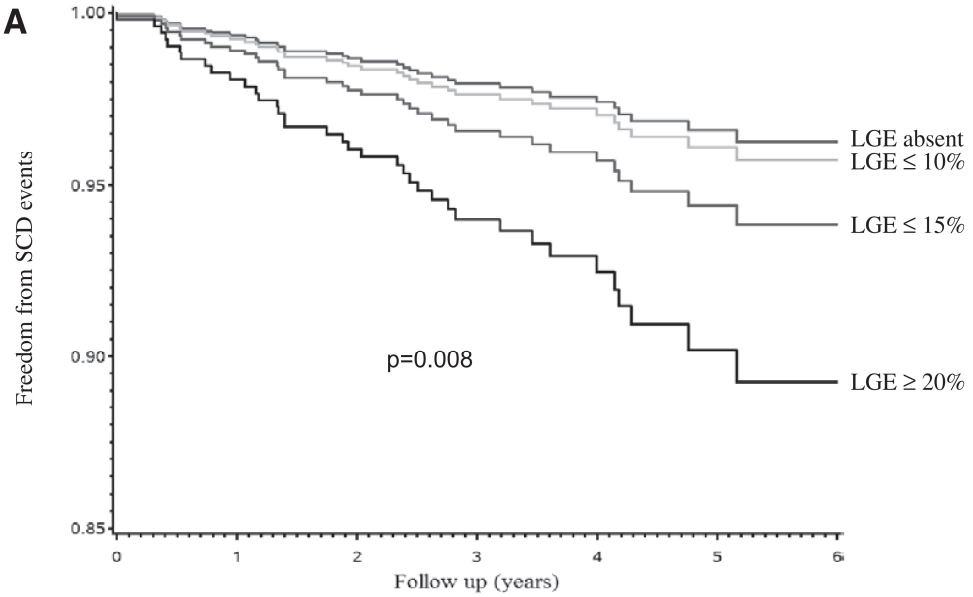
Chagas

Mc Cohon, *Circulation 2003*
Moon, *JACC* 2003
Maceira *Circulation* 2004
Marhold *Circulation* 2004

DE-cMR detects myocardial fibrosis in CMH



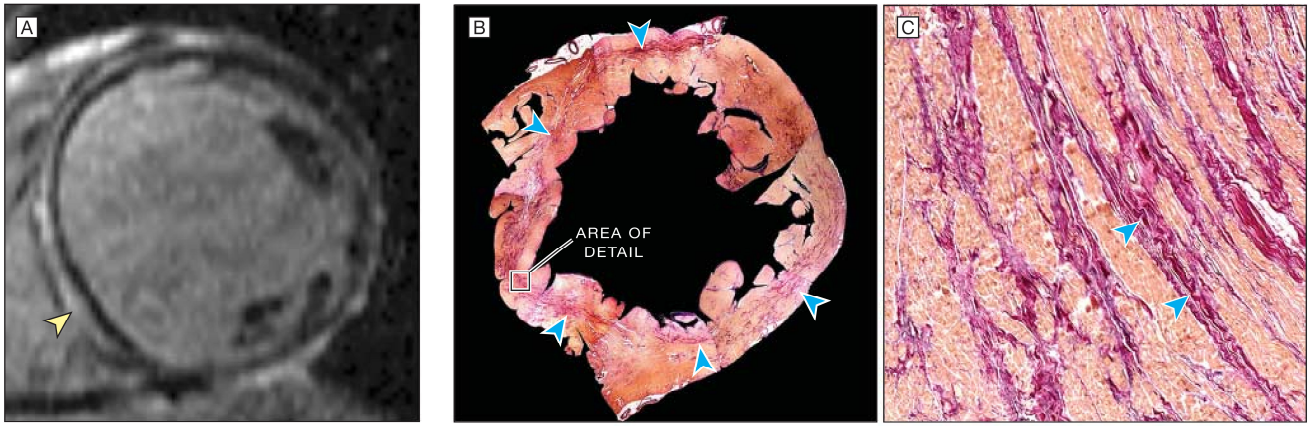
Moon J Am Coll Cardiol 2004;43:2260–4

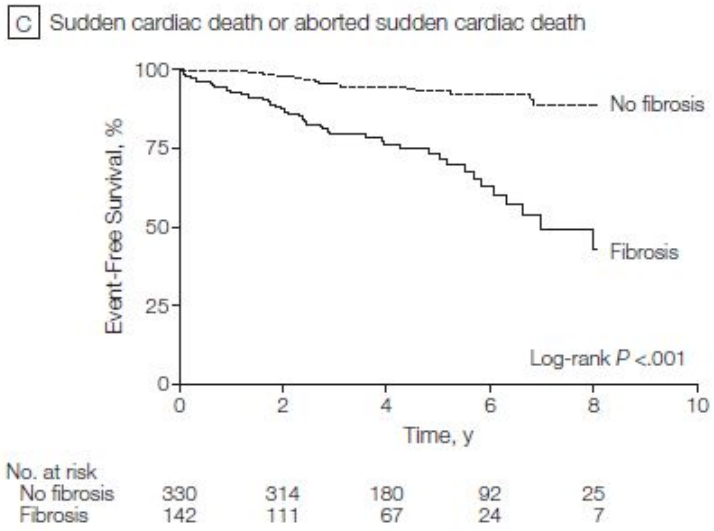


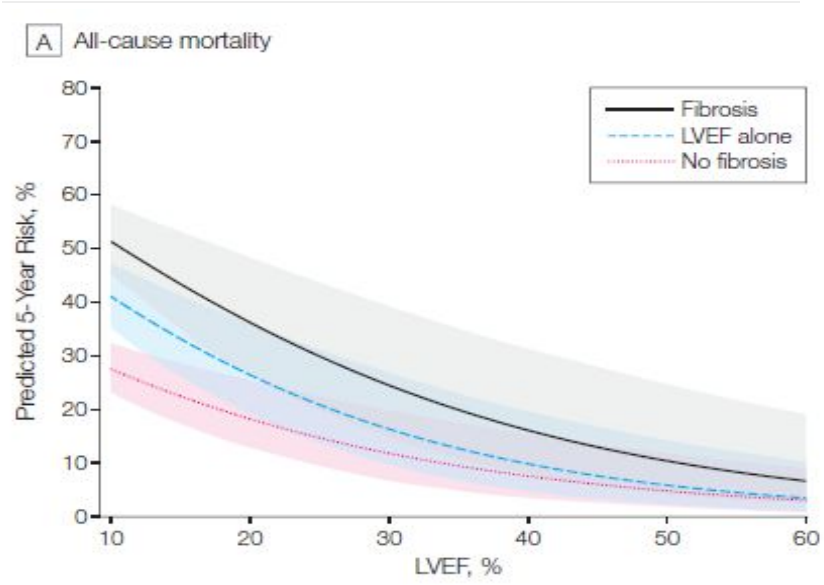
Chan Circ 2014

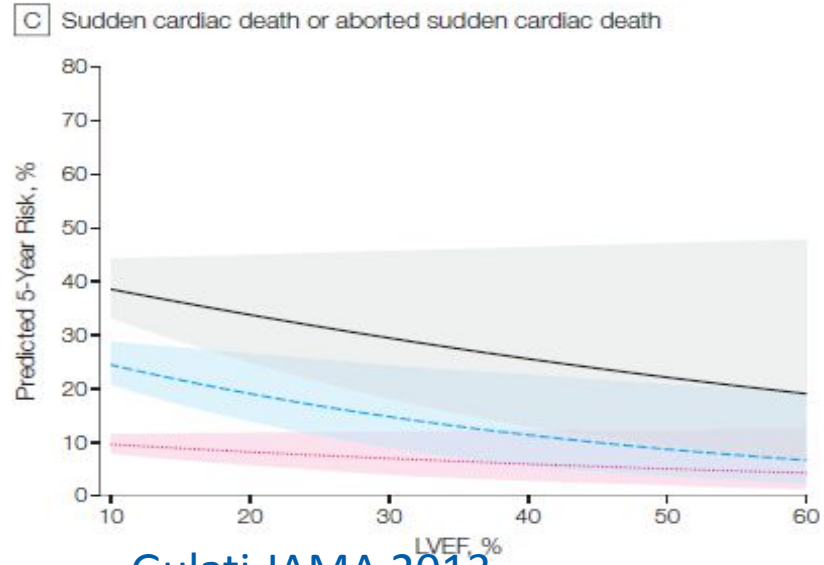
Risk prediction in Dilated CMP

Patient with midwall fibrosis



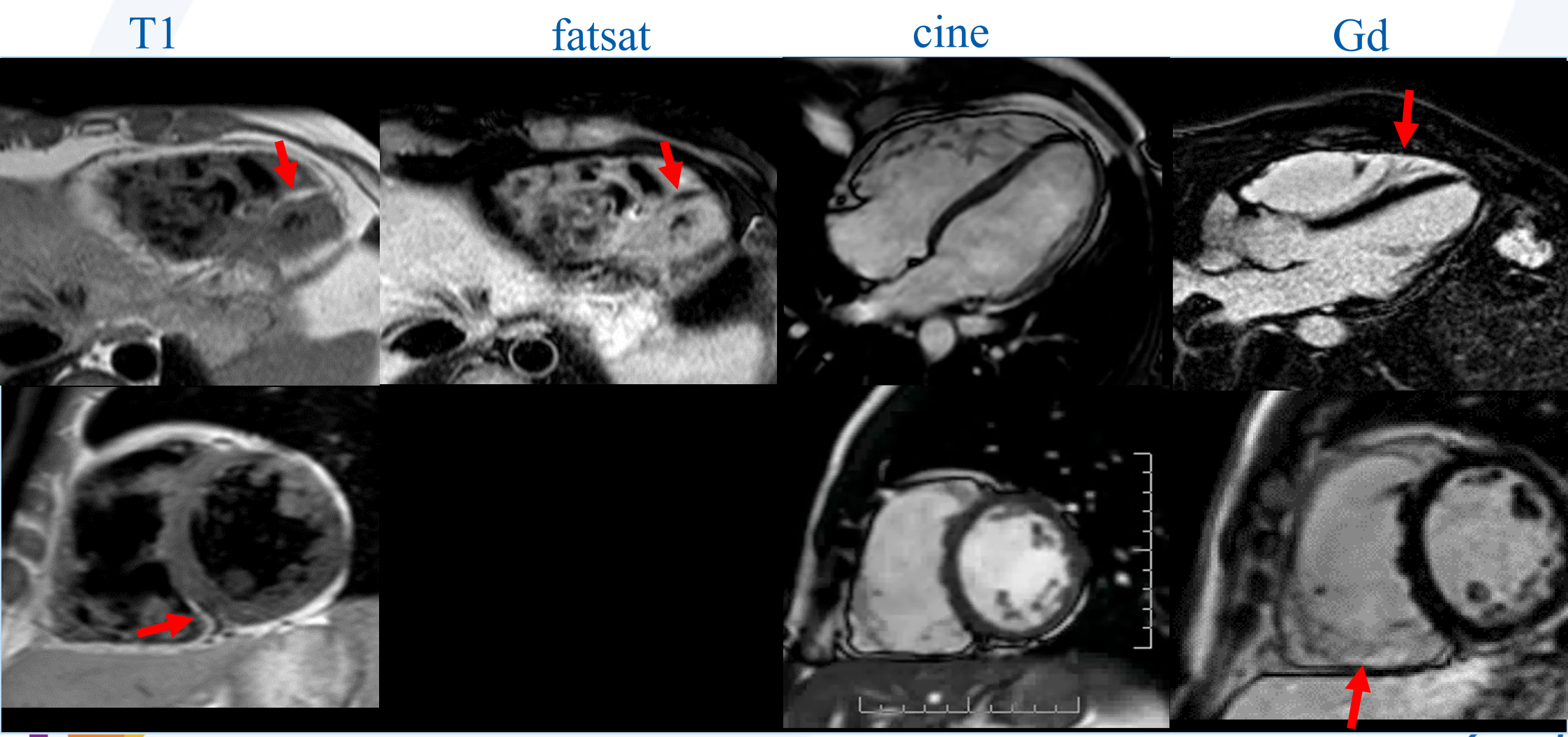




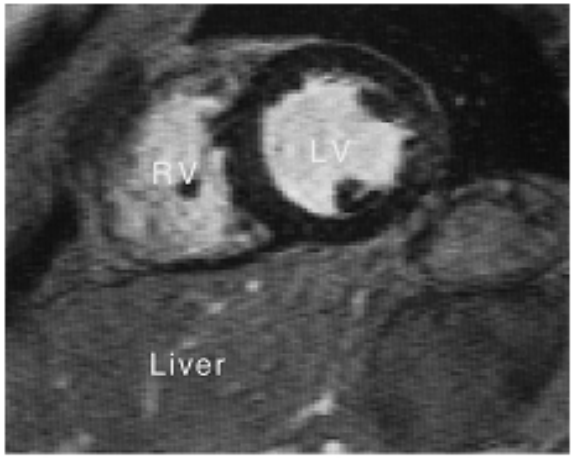


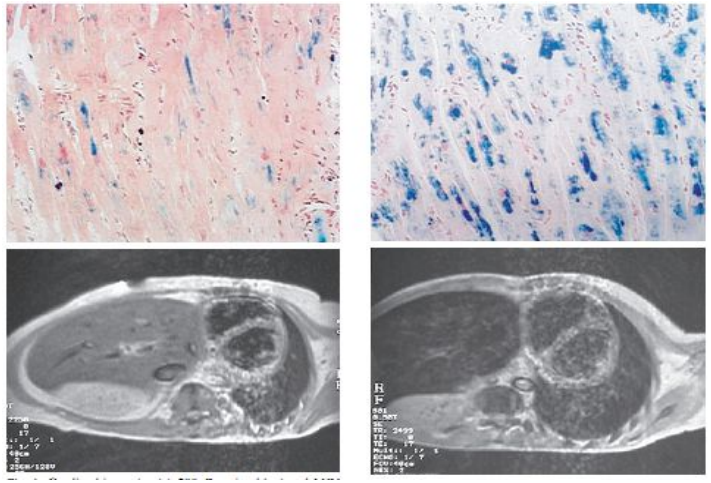
Gulati JAMA 2013

ARVD: cMR ♂ 39 ans

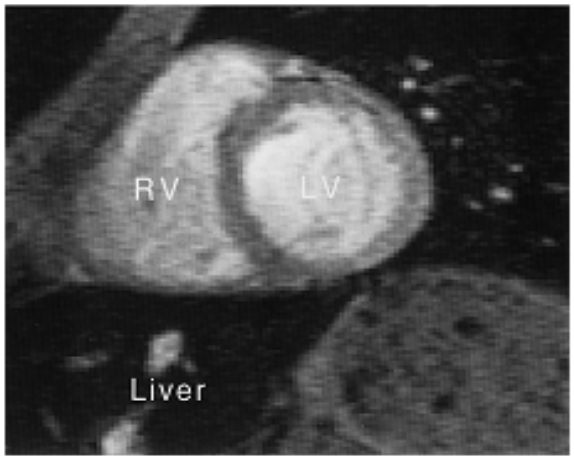


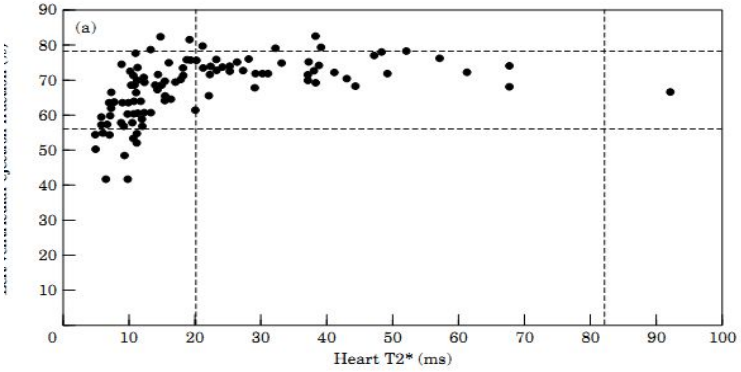
Mesure de la quantité de fer dans les hémochromatoses



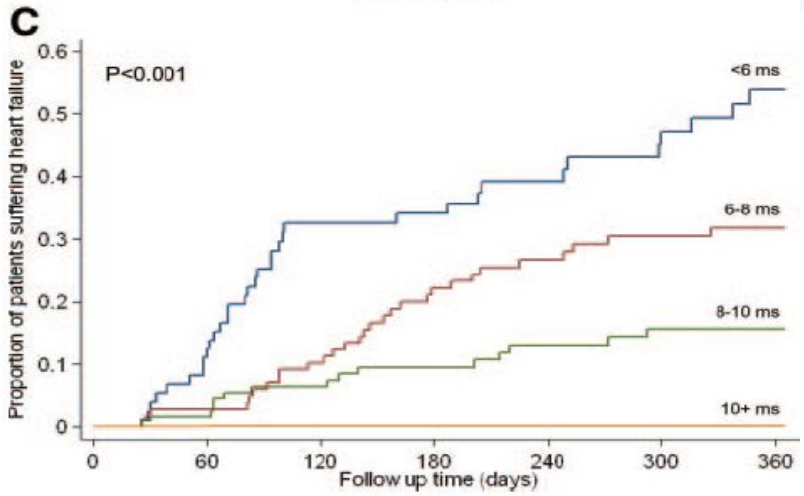


Mavrogeni Eur J Haematol 2005: 75: 241–247



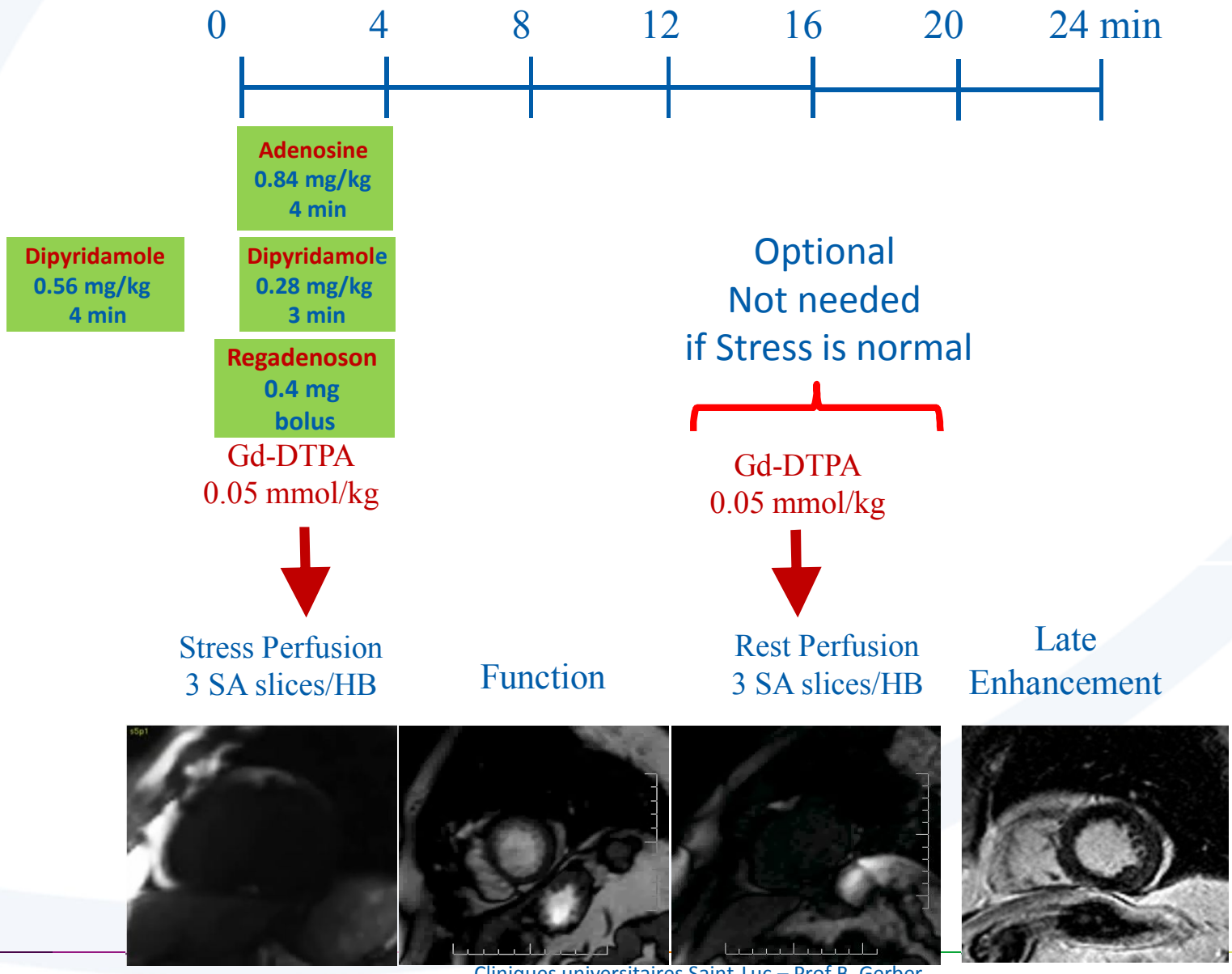


Anderson Eur Heart J 2001; 22: 2171–2179



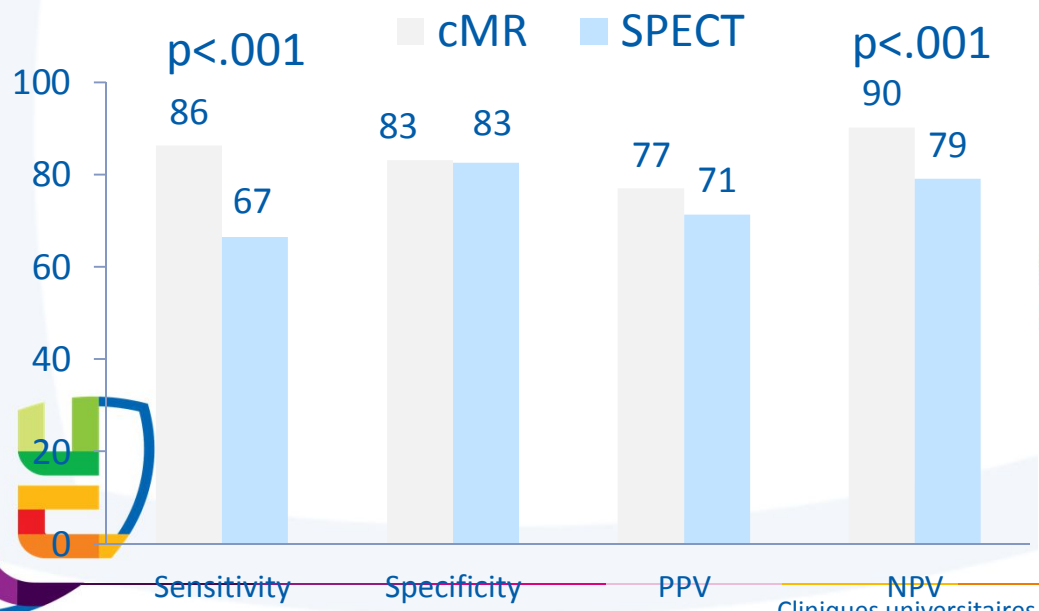
Kirk, Circulation 2009

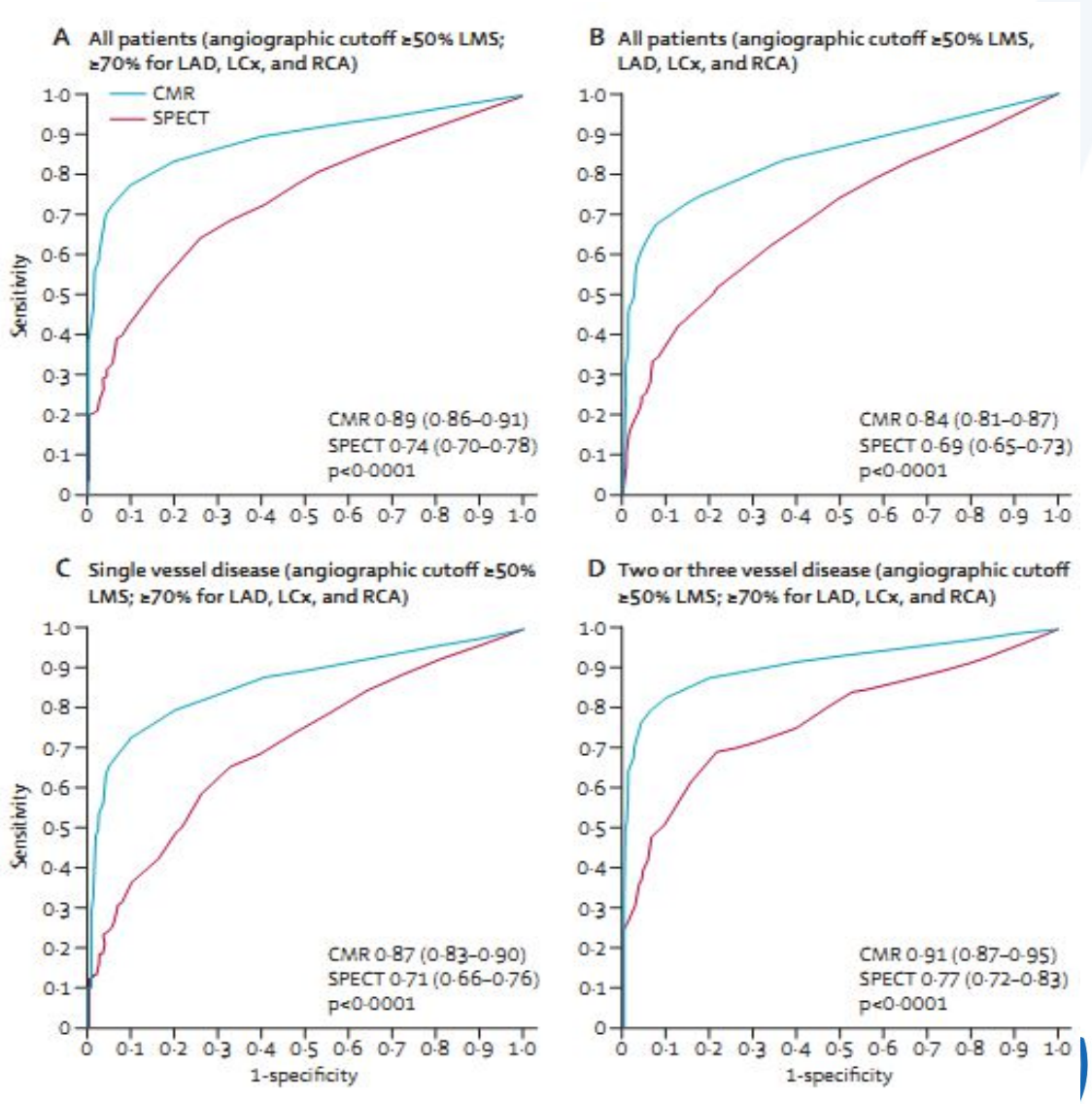
CMR: Stress Perfusion



Head to head comparison of cMR and SPECT
CE-MARC Study

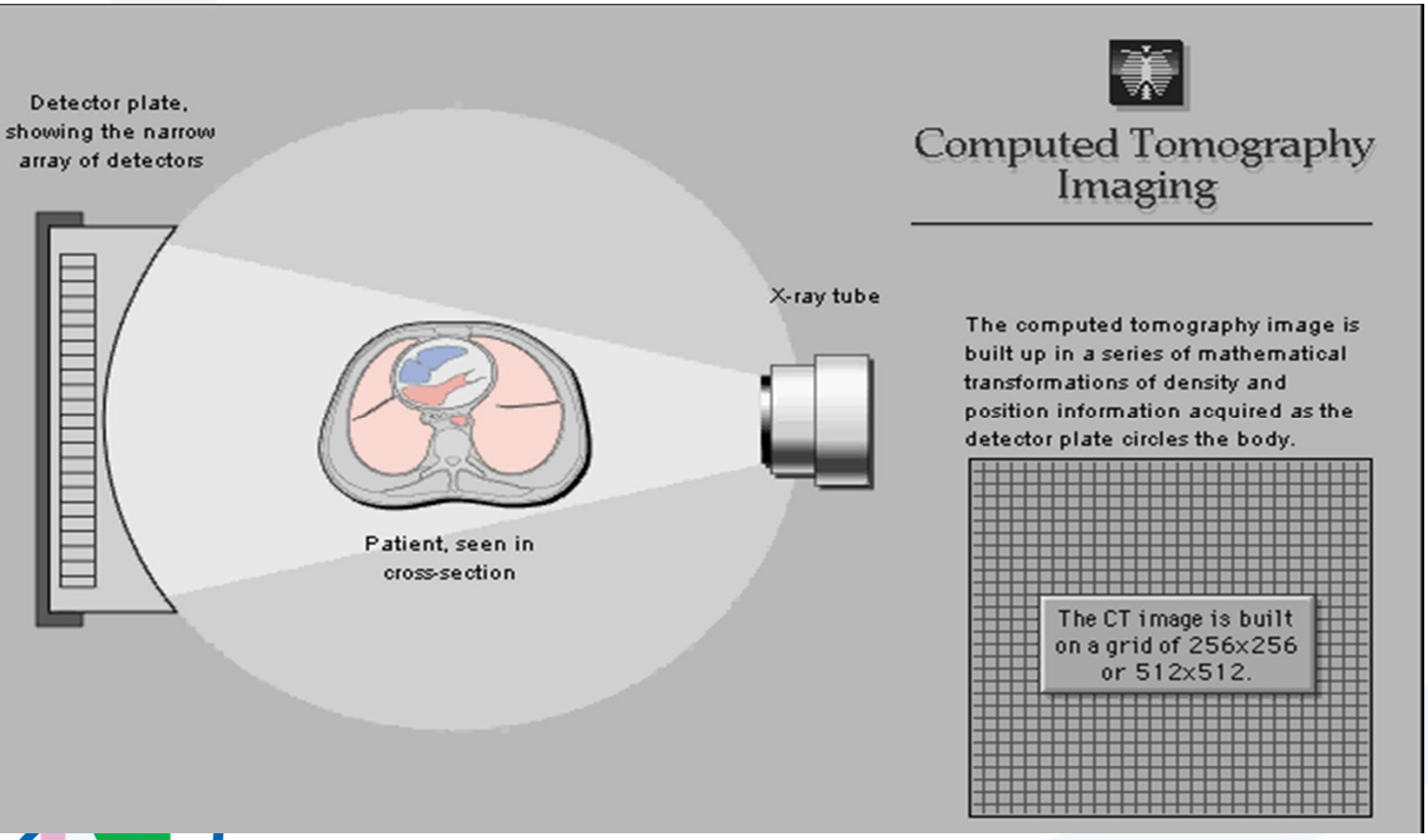
- Two center trial: 752 pts undergoing CAD
  733 completed 3 all tests
  (628 evaluable)
- Adenosine stress-rest cMR and DE
  One vendor 1.5 T Philips
  0.05 mmol/kg Magnevist
- Adenosine stress-rest ^{99}Tc MIBI 2 day protocol
  gated in all patients
- Endpoint: CAD (70% diameter stenosis by QCA)
- Prevalence of CAD: 39%



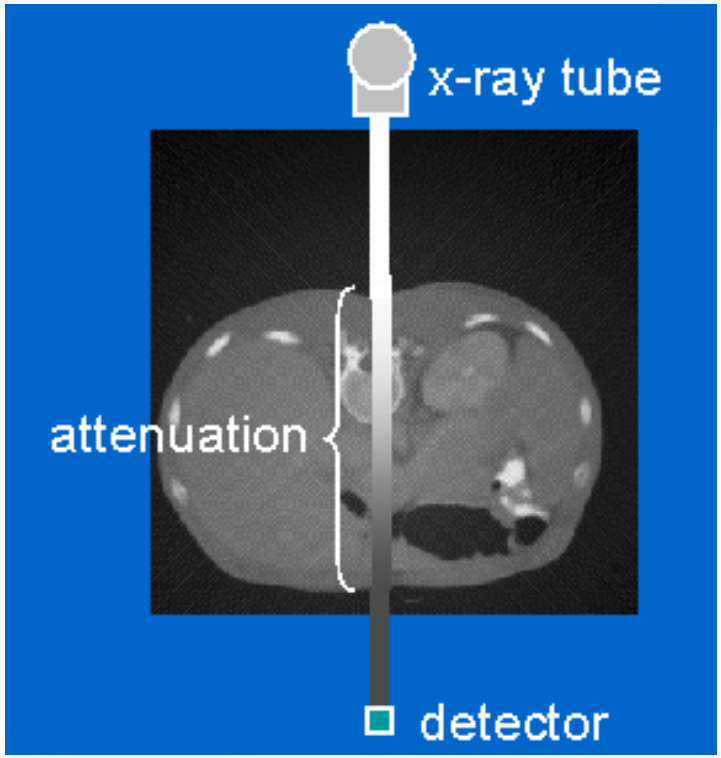


Greenwood, Lancet 2012 ;379(9814):453-60

CT
Principles



Qu'est ce qu'on mesure?

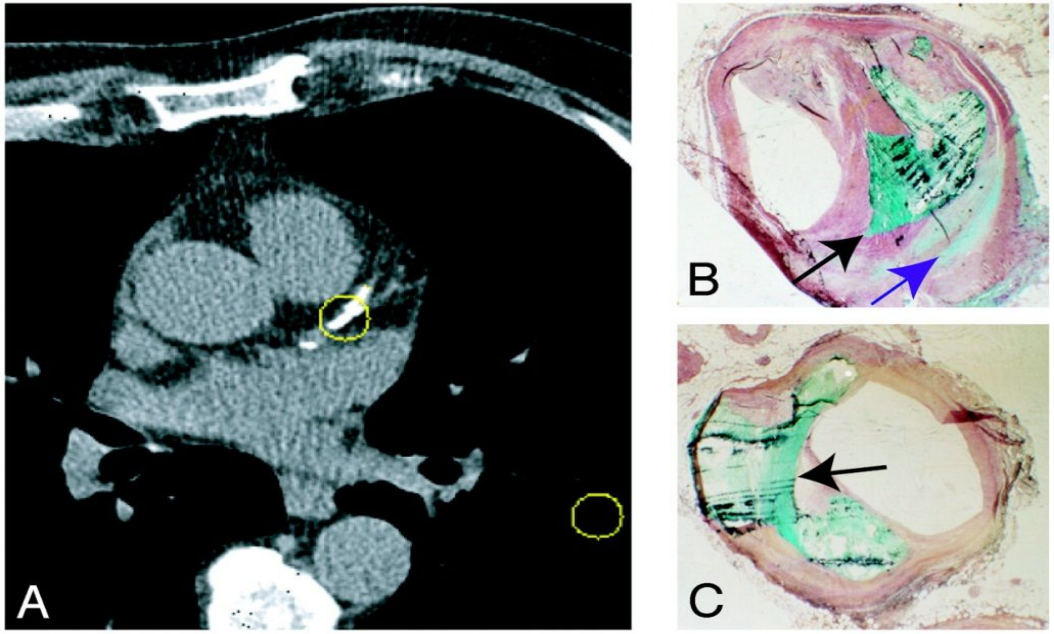


Le coefficient d'attenuation μ reflechit le dégré d'attenuation des RX par le corps.

Principles of Calcium Scoring

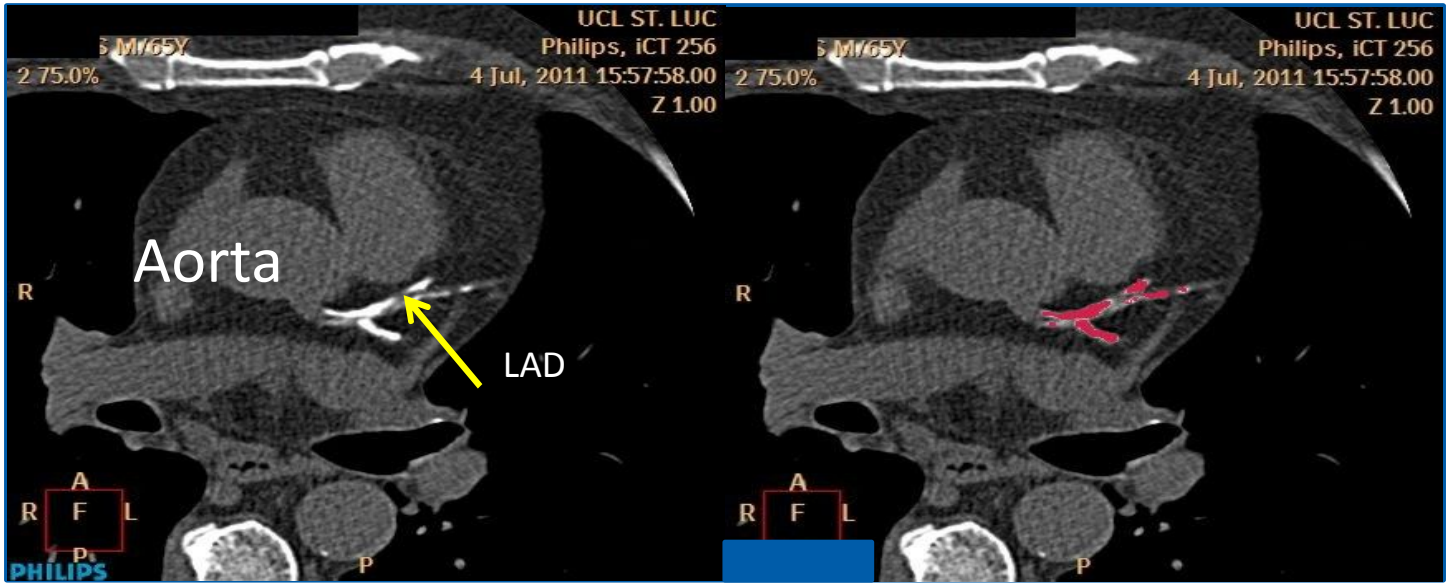
- Coronary artery calcium (CAC)
  - Calcium does not occur in normal blood vessel walls, so calcification = atherosclerosis

- CT Coronary Calcium score
  - CT can quantify Coronary Calcium
  - CAC score parallels total plaque burden
  - High CAC scores suggest increased risk of future CV events



Doherty T M et al. PNAS 2003;100:11201-11206

CT
Measurement of Calcium Score



$$Agaston\ Score = \sum_{i=0}^{n} Area_i\ \omega_i$$

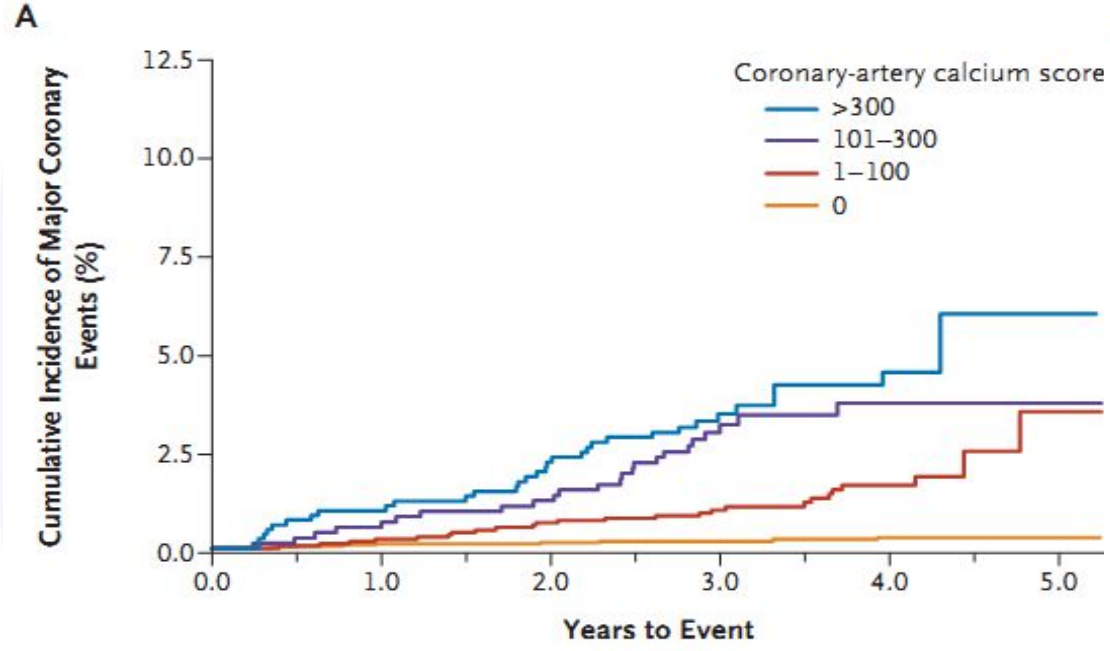
Density	Factor ω
130-199 HU	1
200-299 HU	2
300-399 HU	3
>400 HU	4

Agaston Score	Interpretation
0	Very low CVD risk
1-10	Low CVD risk
11-100	Moderate CVD risk
101-400	High CVD risk
>400	Very High CVD risk

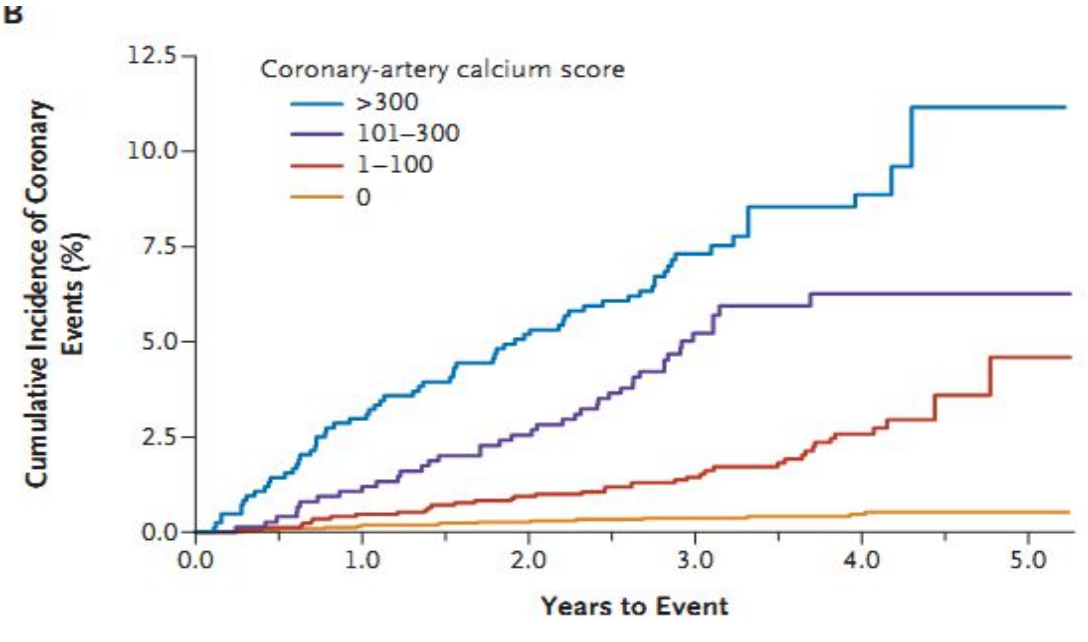
Calcium score prediction of events: MESA Study

Population based study: 6720 participants without cardiovascular disease
45-85 years: (mean 62±10). 47% male. 4 ethnic groups

Infarct or Death



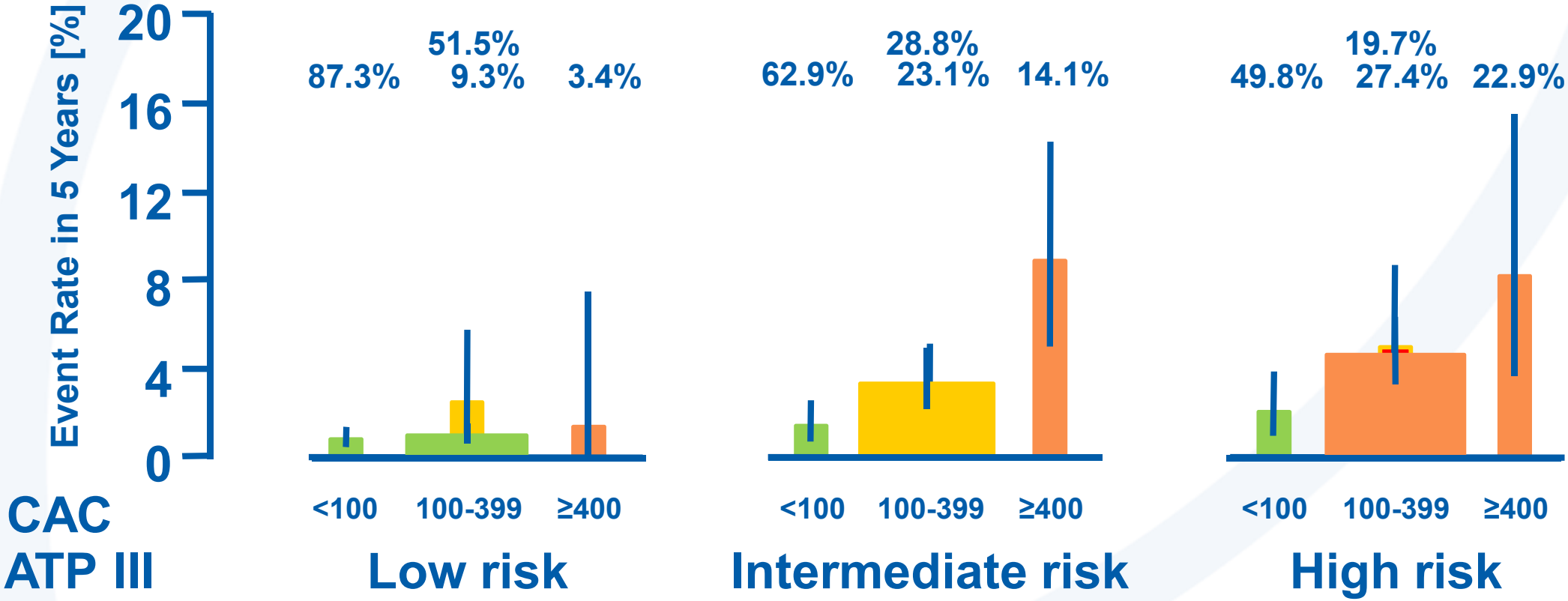
Any coronary event



Detrano N Engl J Med 2008;358:1336-45

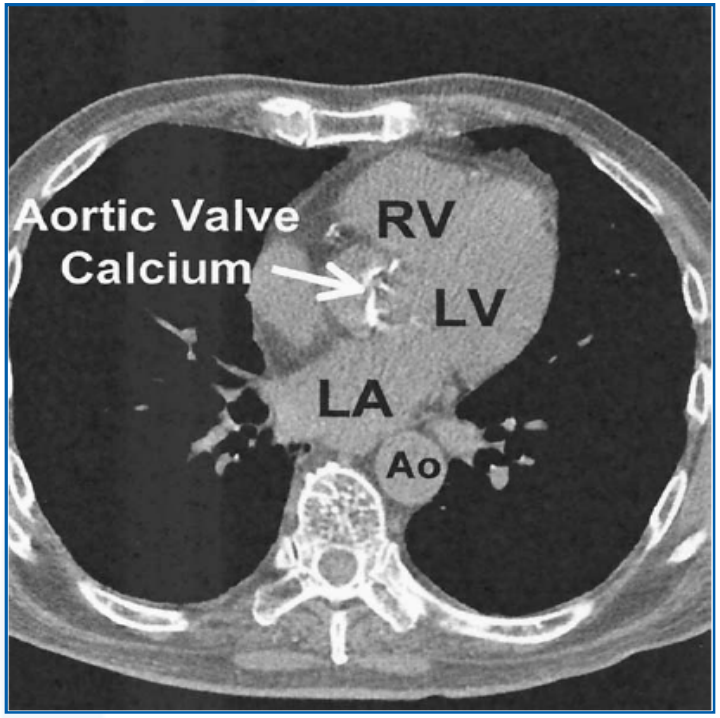
Events Stratified by ATP III & CAC Categories

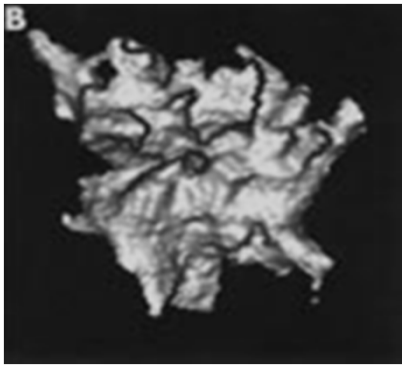
All Subjects

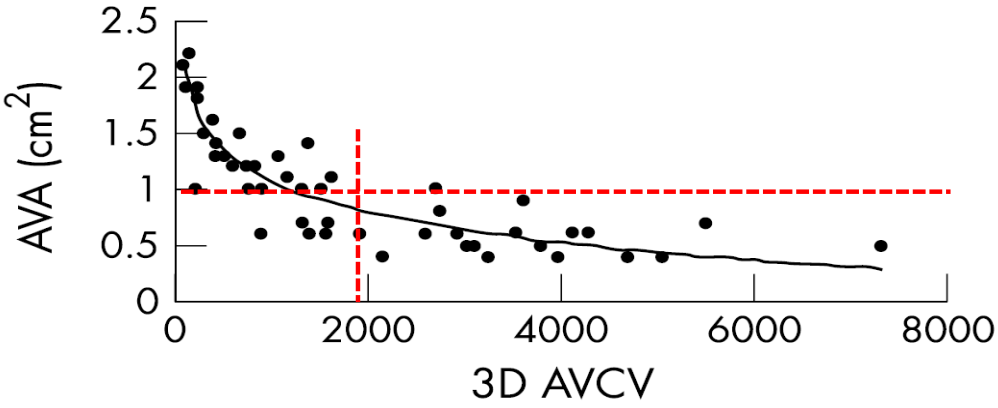


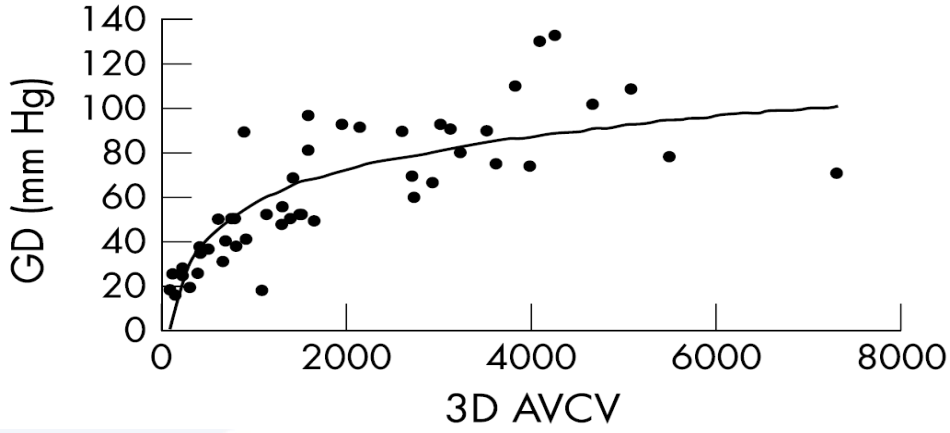
Data = Event Rates (95%CI)

CT:
Evaluation du Calcium dans la sténose aortique.









EBCT:

Mac Millan *Am Heart J* 1988; 115: 655-671

Kiezer *J Heart Valve Dis 2001;10:361–366*

Budoff *Acad Radiol 2002;9:1122–1127.*

MDCT:

Willmann *Radiology* 2002; 225:120–128

Cowell *Clin Radiol.* 2004; 59(2):208

Morgan-Hughes Heart 2003: 89;1191

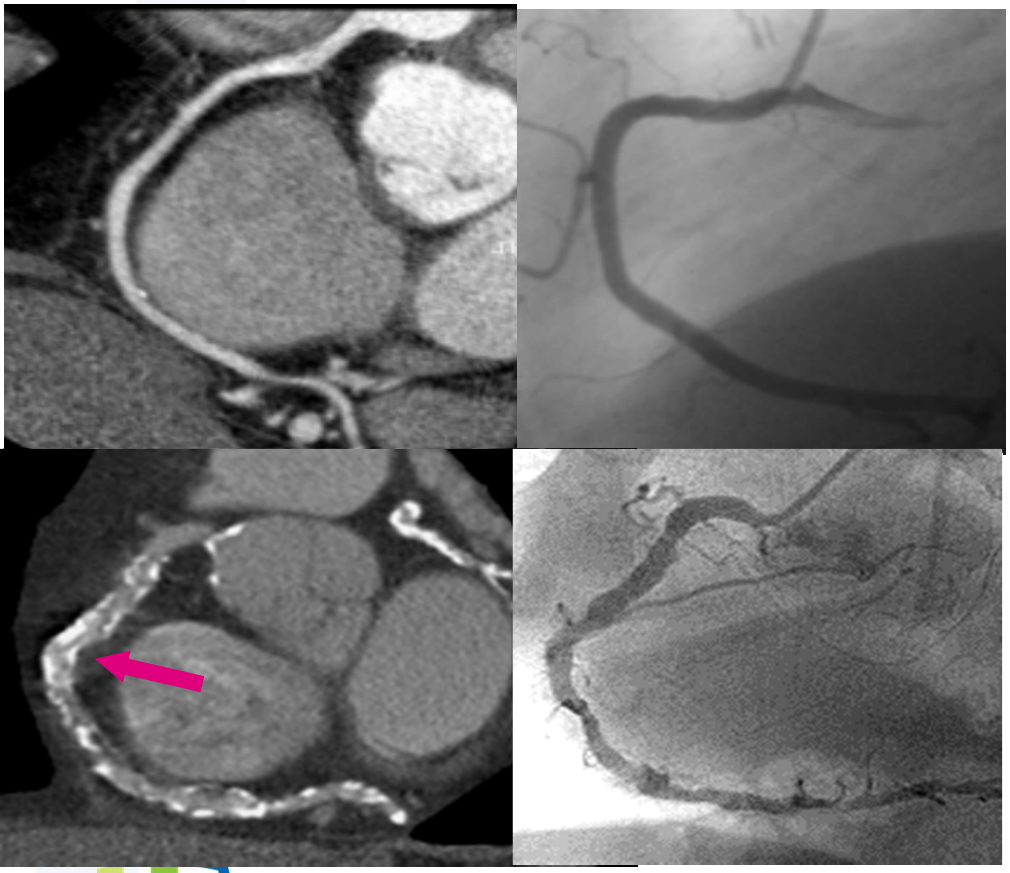
Contrast-Enhanced MDCT

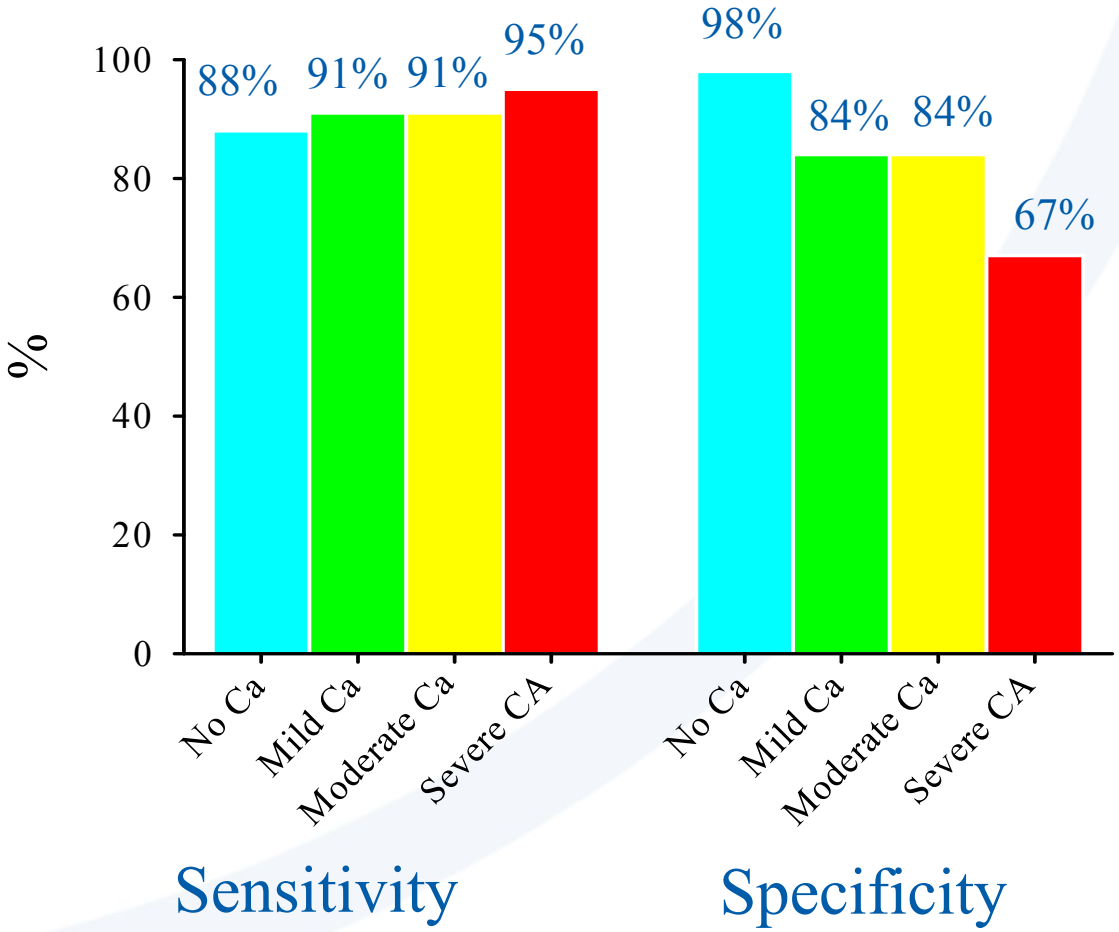
64 slice MDCT: Detection of CAD. Diagnostic Accuracy per-patient

Type of analysis	Number of studies	Number of patients	Number of segments	Number of unassessable segments%	Prevalence of coronary stenosis%	Sensitivity% (95% CI)	Specificity% (95% CI)	PPV%	NPV%	Overall accuracy%
Per-segment analysis of native coronary arteries	19	1251	17 695	747 (4)	19	86 (85–87)	96 (95.5–96.5)	83	96.5	94
Per-patient analysis of native coronary arteries	13	875	–	–	57.5	97.5 (96–99)	91 (87.5–94)	93.5	96.5	95

Abdullah Eur Heart Journal (2007) 28, 3042–3050

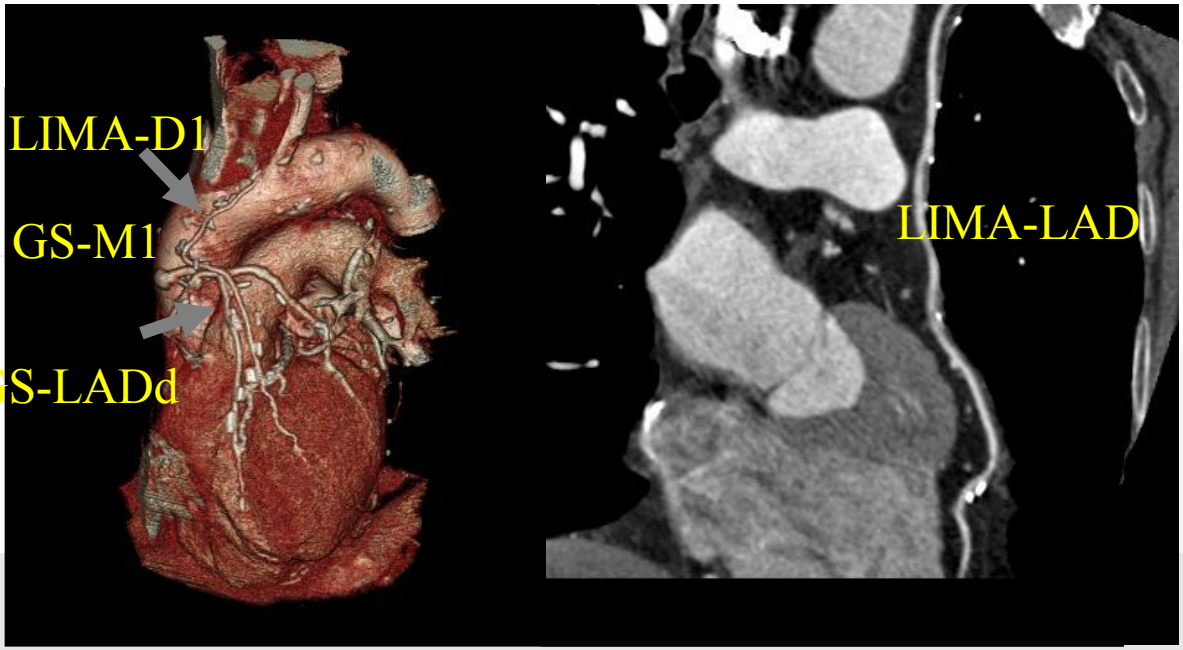
MDCT Limitations
Calcium





Raff, *JACC* 2005;46:552–7

Diagnostic Accuracy
Bypass Grafts



Pooled Summary Results

Analysis Type and No. of Studies (n = 15)	No. of Grafts	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)	Negative Predictive Value (%)
Graft obstruction, 15	2023	97.6 (96.0, 98.6)	96.7 (95.6, 97.5)	92.7 (90.5, 94.6)	98.9 (98.2, 99.4)
16-section, nine	1047	96.9 (94.2, 98.6)	96.4 (94.8, 97.6)	91.3 (87.6, 94.2)	98.8 (97.7, 99.4)
64-section, six	976	98.1 (96.0, 99.3)	96.9 (95.3, 98.1)	94.1 (91.0, 96.3)	99.1 (98.0, 99.7)
Occlusion, 10	1308	99.3 (97.3, 99.9)	98.7 (97.9, 99.3)	95.4 (92.2, 97.5)	99.8 (99.3, 100)
Stenosis, nine	871	94.4 (87.5, 98.2)	98.0 (96.7, 98.8)	84.2 (75.6, 90.7)	99.4 (98.5, 99.8)

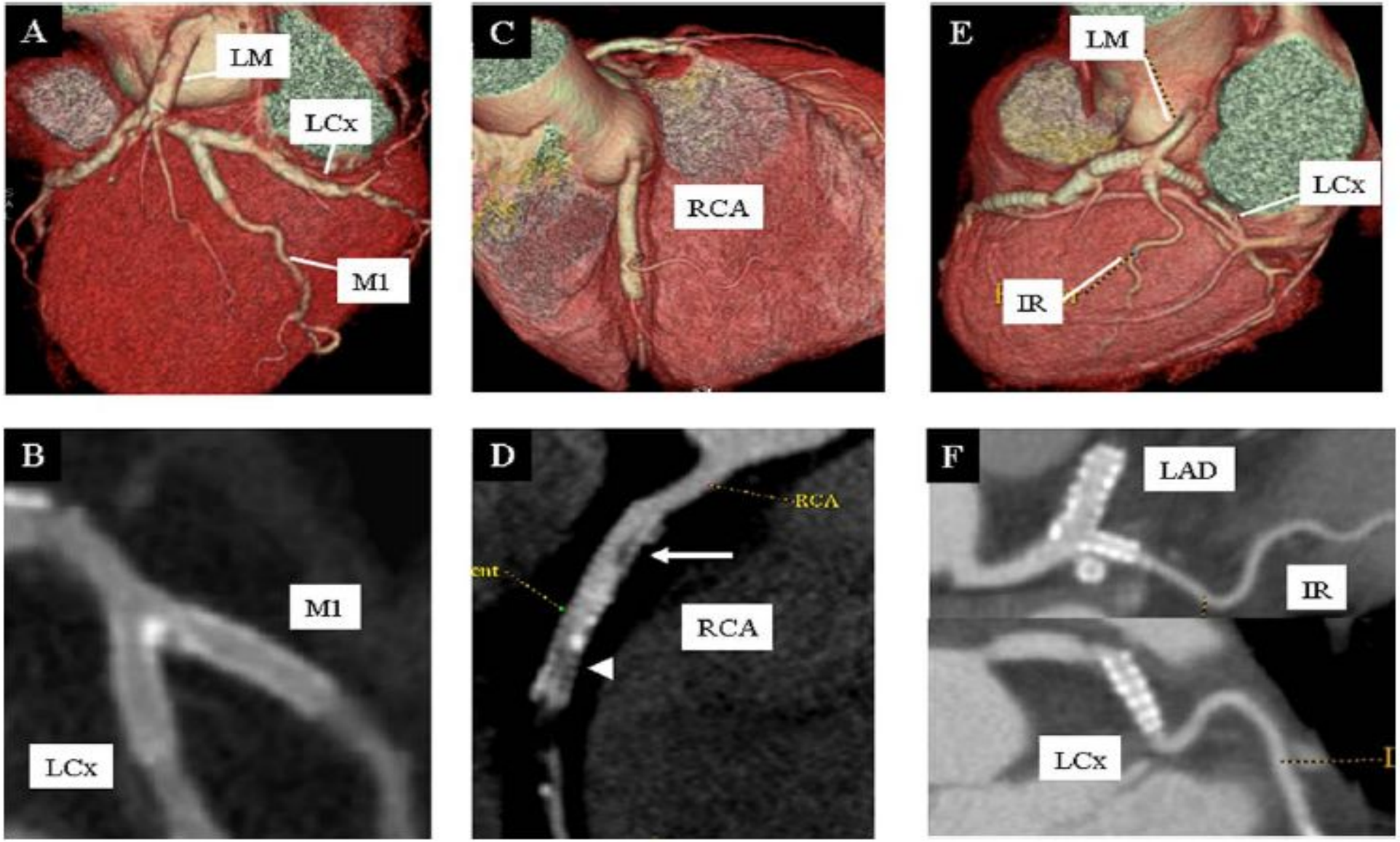
Note.—Numbers in parentheses are 95% CIs.

None of the studies assessed **completeness of revascularization** (ie. bypass patency cfr. patency of native vessels)

Heavy calcification of native vessels does not allow to appreciate completeness of revacsularization.

Radiology 2008

CT Stents



Adreini, Am J Cardiol 2010;105:645– 655)

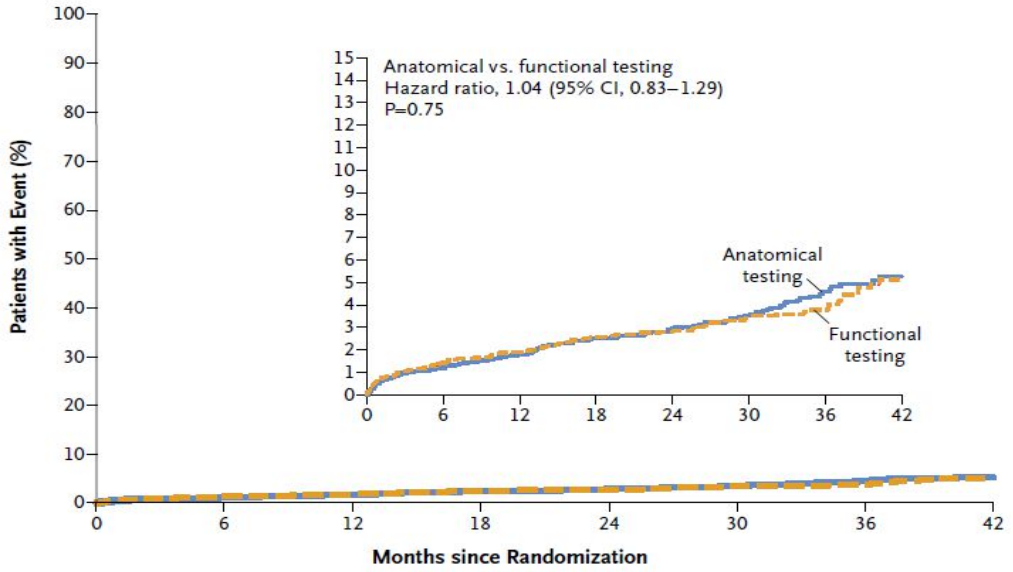
MDCT:
Diagnostic Accuracy Stents

Study	Journal	No. of Patients/No. of Stents	Not Evaluable (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Rixe et al (2006)[17]	*EHJ*	64/102	42 (43/102)	86 (6/7)	98 (51/52)	86 (6/7)	98 (51/52)	97 (57/59)
Van Mieghem et al (2006)[18]	*Circ*	70/162	—	100 (10/10)	91 (55/60)	67 (10/15)	100 (55/55)	93 (65/70)
Rist et al (2007)[5]	*AR*	25/46	2 (1/46)	75 (6/8)	92 (34/37)	67 (6/9)	94 (34/36)	89 (40/45)
Oncel et al (2007)[19]	*Rad*	30/39	0 (0/39)	89 (17/19)	95 (19/20)	94 (17/18)	90 (19/21)	92 (36/39)
Ehara et al (2007)[20]	*JACC*	81/125	12 (15/125)	91 (20/22)	93 (82/88)	77 (20/26)	98 (82/84)	93 (102/110)
Cademartiri et al (2007)[21]	*JACC*	182/192	7 (14/192)	95 (19/20)	93 (147/158)	63 (19/30)	99 (147/148)	93 (166/178)
Carrabba et al (2007)[22]	*AJC*	41/87	0 (0/87)	84 (11/13)	97 (73/74)	92 (11/12)	97 (73/75)	96 (84/87)
Das et al (2007)[23]	*Rad*	53/110	2.7 (3/110)	97 (31/32)	88 (66/75)	77 (31/40)	98 (66/67)	91 (96/107)
Schuijf et al (2007)[8]	*Rad*	50/76	14 (11/76)	100 (6/6)	100 (52/52)	100 (6/6)	100 (52/52)	100 (58/58)
Pugliese et al (2008)[24]	*Heart*	100/178	5 (9/178)	94 (37/39)	92 (128/130)	77 (37/48)	98 (128/130)	98 (165/169)
Oncel et al (2008)[25]	*AJR*	35/48	15 (7/48)	100 (17/17)	94 (29/31)	89 (17/19)	100 (29/29)	96 (46/48)
Carbone et al (2008)[26]	*ER*	41/74	19.5 (21/74)	75 (12/16)	86 (32/37)	71 (11/14)	89 (32/36)	83 (44/53)
Manghat et al (2008)[27]	*AJC*	40/114	9.6 (11/114)	85 (17/20)	86 (68/79)	61 (17/28)	96 (68/71)	83 (85/103)
Hecht et al (2008)[6]	*AJC*	67/132	0 (0/132)	94 (16/17)	74 (85/115)	39 (16/46)	99 (85/86)	77 (101/132)
Nakamura et al (2008)[7]	*IJC*	49/75	14.6 (11/75)	67 (2/3)	92 (56/61)	29 (2/7)	98 (56/57)	91 (58/64)
Andreini et al (2009)[28]	*AJC*	100/179	5 (9/179)	87 (34/39)	98 (128/131)	92 (35/38)	96 (128/133)	95 (162/170)
Pontone et al (2009)[29]	*JACC*	80/48* 80/66†	8 (4/48) 6 (4/66)	92 (11/12) 73 (8/11)	94 (30/32) 96 (49/51)	85 (11/13) 80 (8/10)	97 (30/31) 94 (49/52)	93 (41/44) 92 (57/62)
Pflederer et al (2009)[30]	*AJC*	112/150	10 (15/150)	84 (16/19)	95 (110/116)	73 (16/22)	97 (110/113)	93 (126/135)
Total		1,300/2,003	9.6 (178/1,841)	89.7 (296/330)	92.2 (1,294/1,399)	72.5 (296/408)	97.4 (1,294/1,328)	91.9 (1,590/1,729)

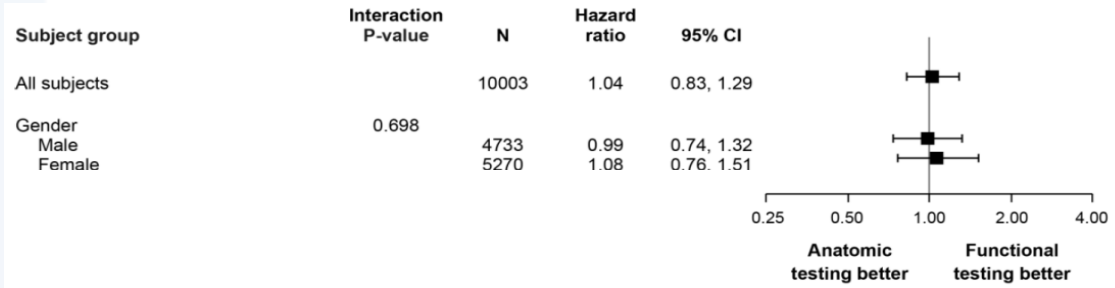
Adreini, Am J Cardiol 2010;105:645– 655)

Anatomical imaging vs Functional Testing in CAD: Promise trial

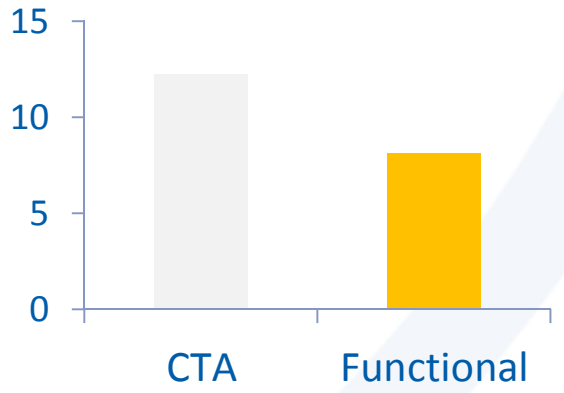
10003 symptomatic pts randomized to CT vs functional testing



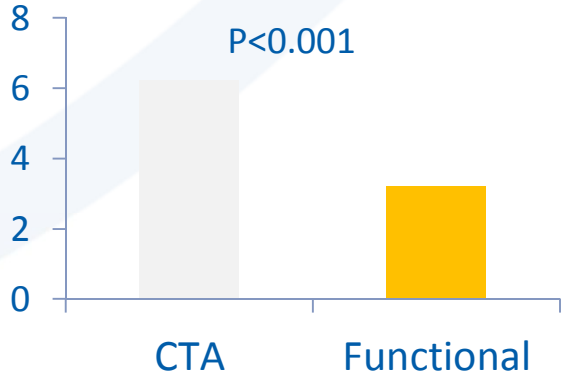
No. at Risk								
Anatomical testing	4996	4703	4362	3551	2652	1705	902	269
Functional testing	5007	4536	4115	3331	2388	1518	832	258



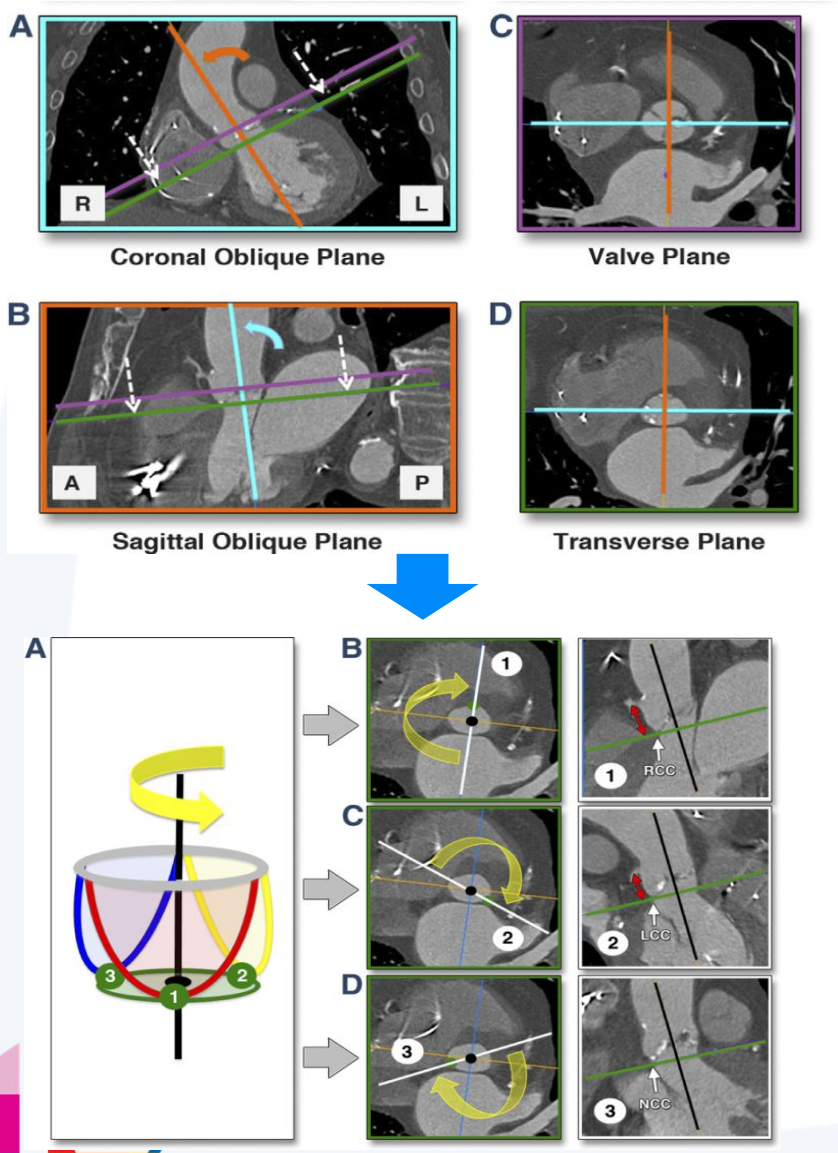
% receiving cath within 90 days

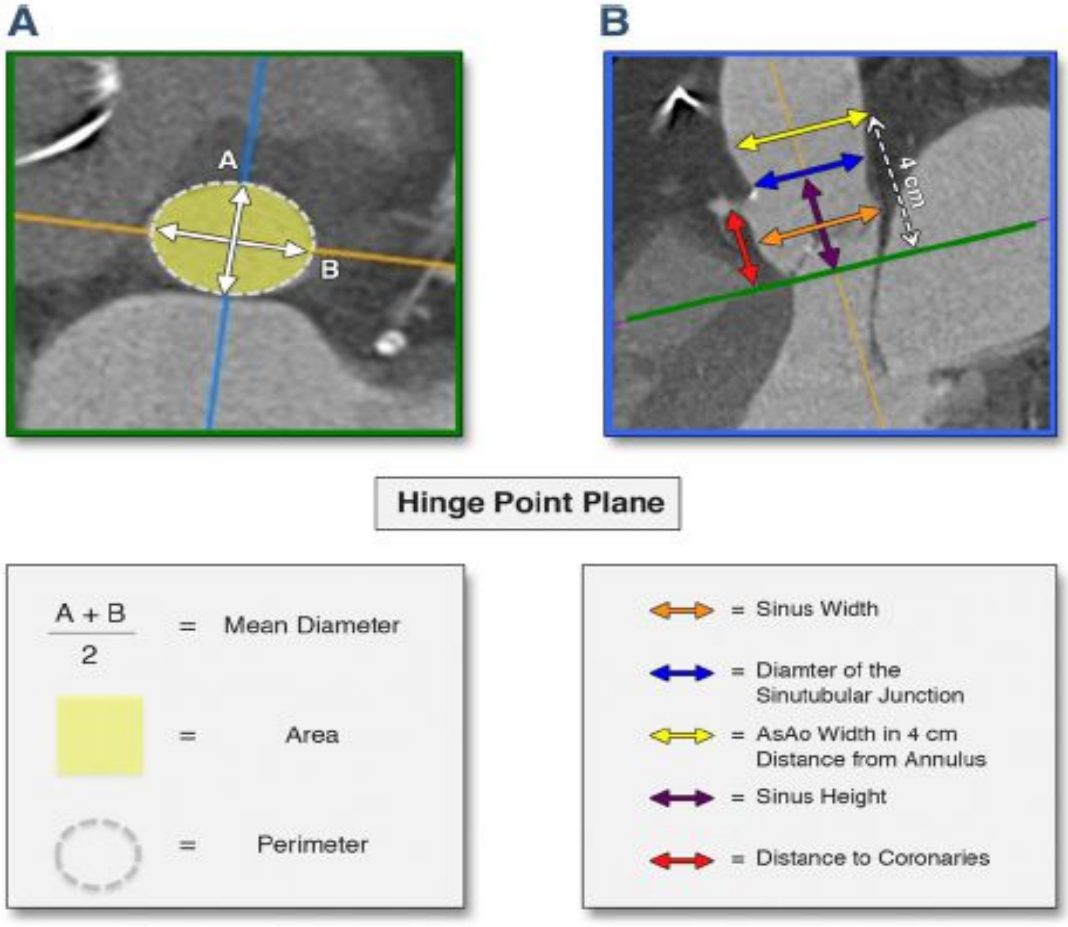


revascularization within 90 days



CT TAVI Sizing





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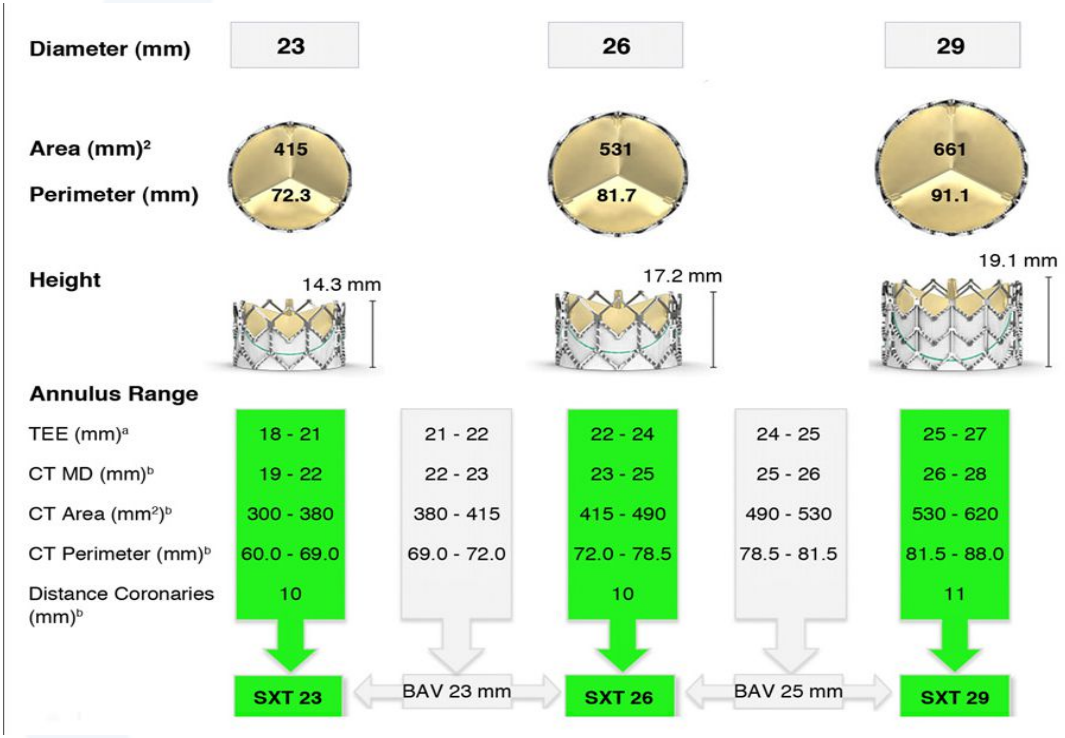
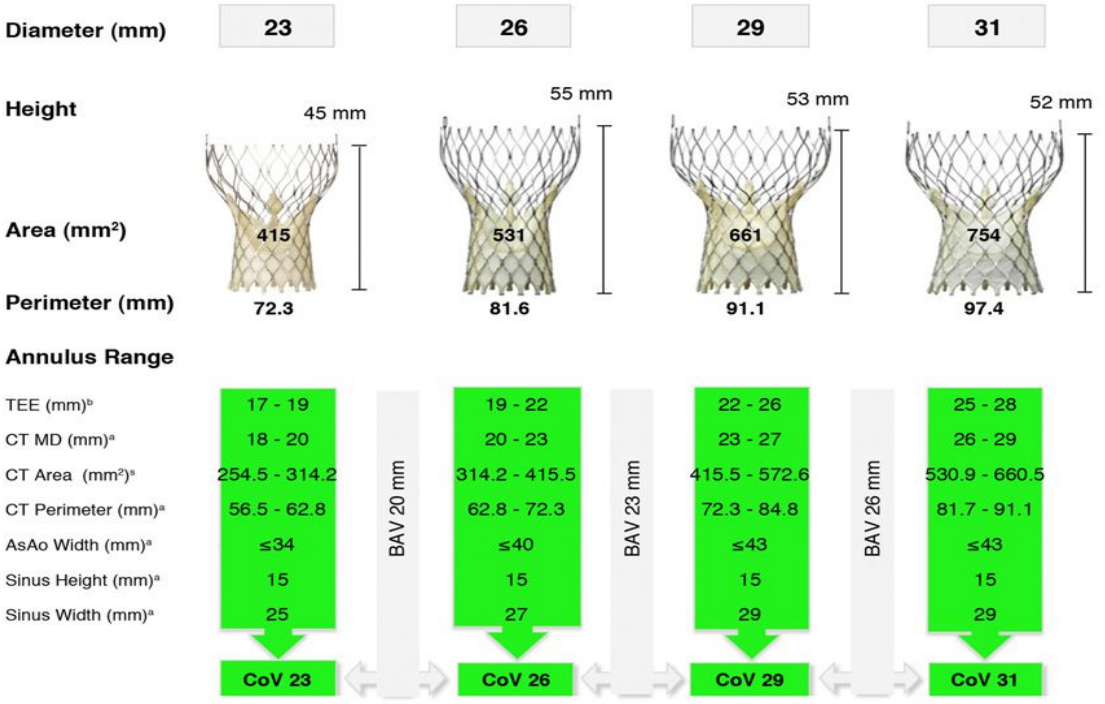
TAVR Device Selection

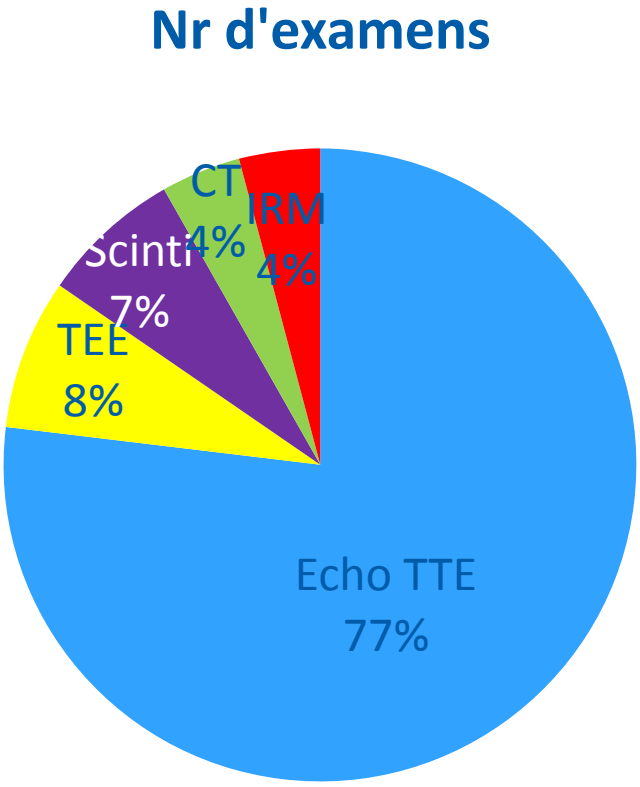
Carpentier-Edwards



Corevalve (St.Jude)



Conclusions



L'echocardiographie Transthoracique

reste la technique de 1e choix pour le diagnositic des insuffisances cardiaques, des valvulopathies

L'échocardiographie Transoesophageenne

Permet un diagnostic des AVC, des endocardites, des dissections aortiques et des réparations valvulaires.

La scintigraphie

Reste le 1e choix pour la détection de l'ischémie

L'IRM Cardiaque

Est la technique d'appoint pour le diagnostic des tumeurs, ARVD et des cardiomyopathies

Le CT coronaire

Permet l'évaluation du risque CV et l'exclusion de la maladie coronaire

Est indispenable dans la planification TAVI

Imagerie cardiaque :

Merci pour votre attention