Updates in Myocardial Perfusion SPECT

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Myocardial Perfusion SPECT

- Radiopharmarceutial reflecting coronary blood flow
- Stress – rest images
- Non-invasive, quantitative
- Most commonly performed nuclear cardiology imaging

Contents

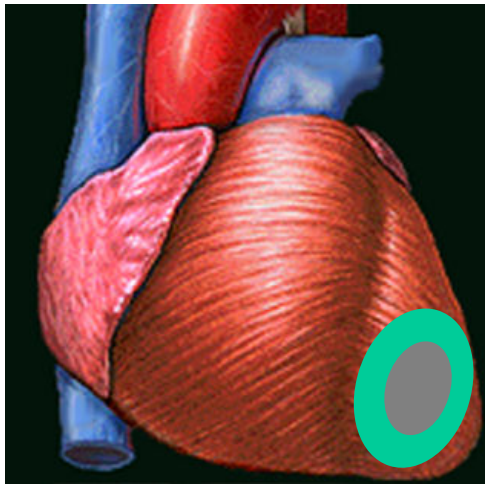
- Quantitative MPS
- Current clinical indication of MPS
- Comparison with multi-slice cardiac CT
- MPS in patients with DM

Quantitative MPS

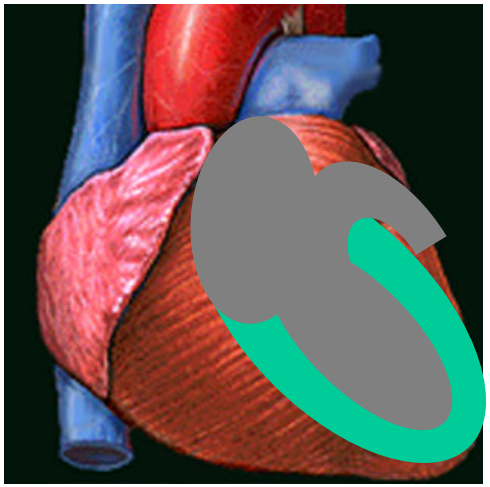
SPECT Image Analysis

- SPECT: 3-demensional image data
- Short axis, vertical long axis, horizontal long axis views
- Polar map, reversibility map, defect extent
- Comparison with normal database
- 3D rendered image display

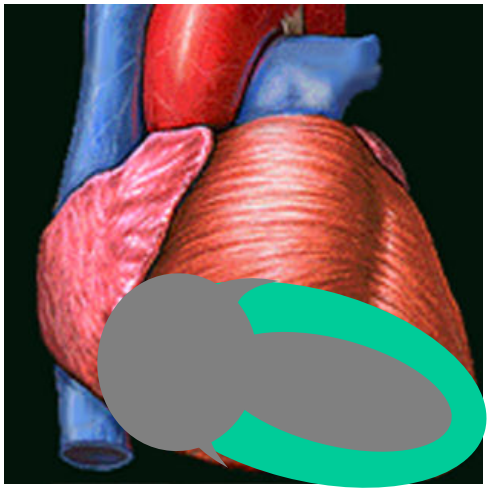
3 Basic Views of MPS



Short axis

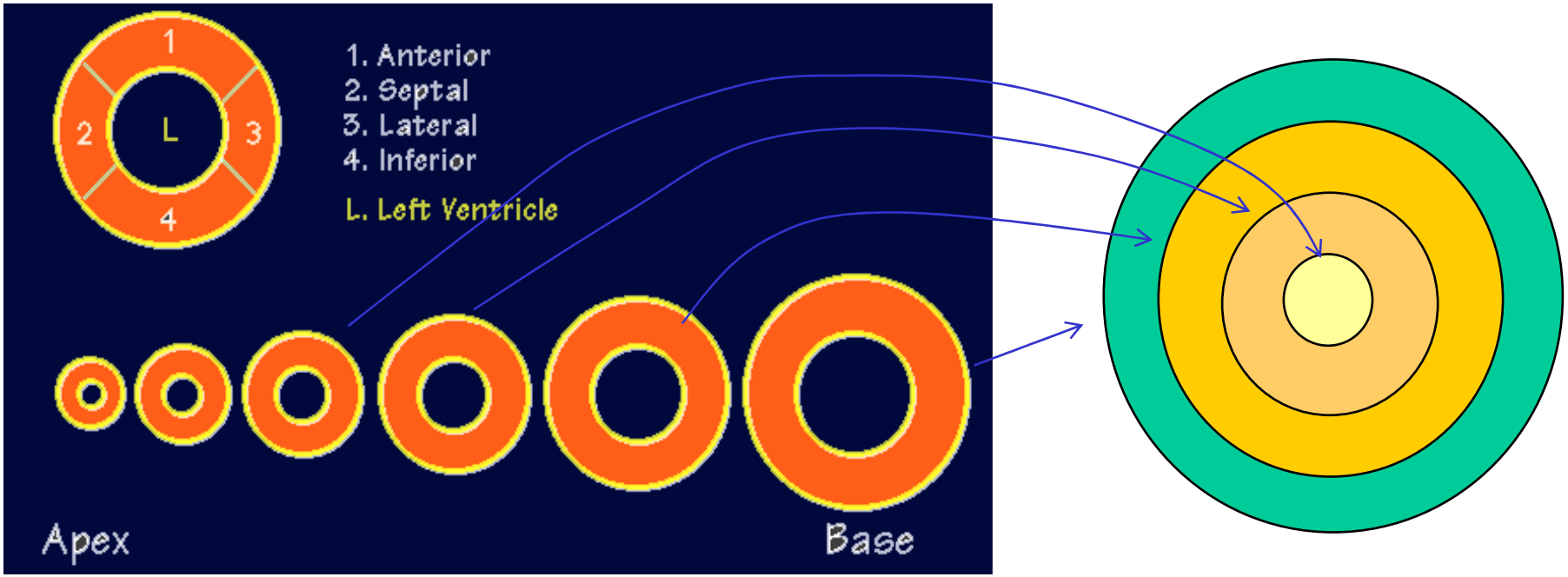


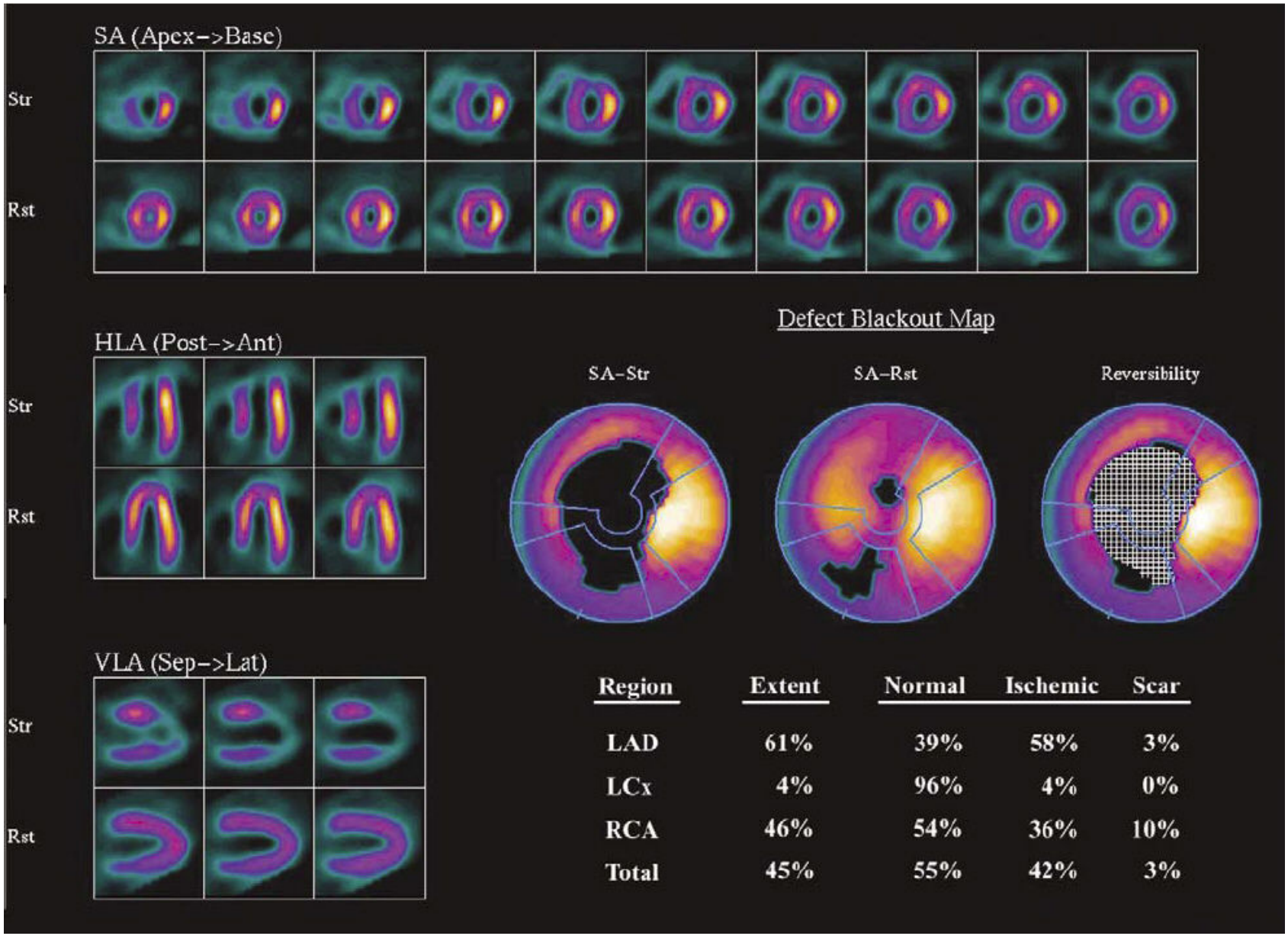
Vertical long axis



Horizontal long axis

Polar Map


1
2
L
3
4
1. Anterior
2. Septal
3. Lateral
4. Inferior
L. Left Ventricle
Apex
Base



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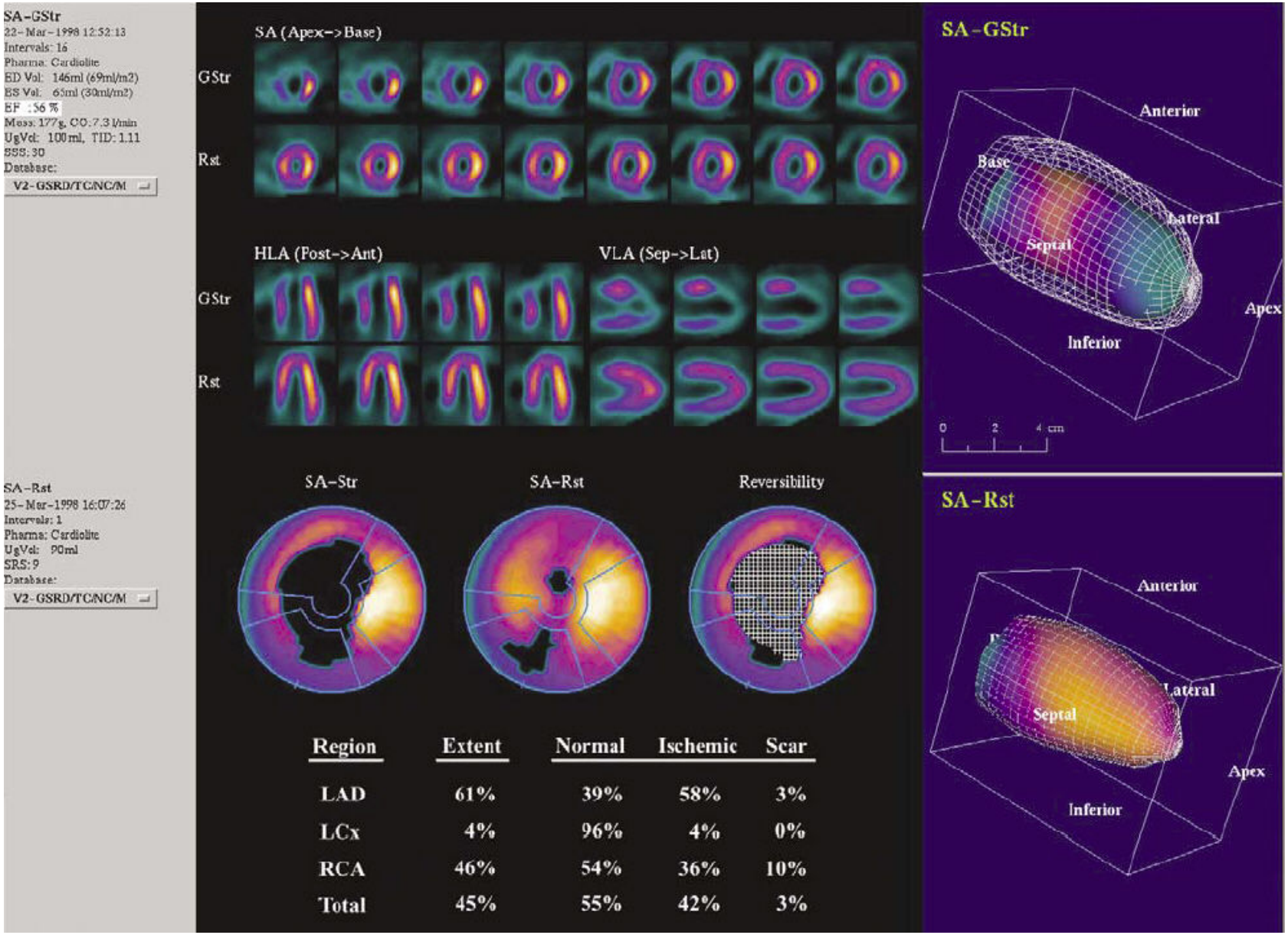

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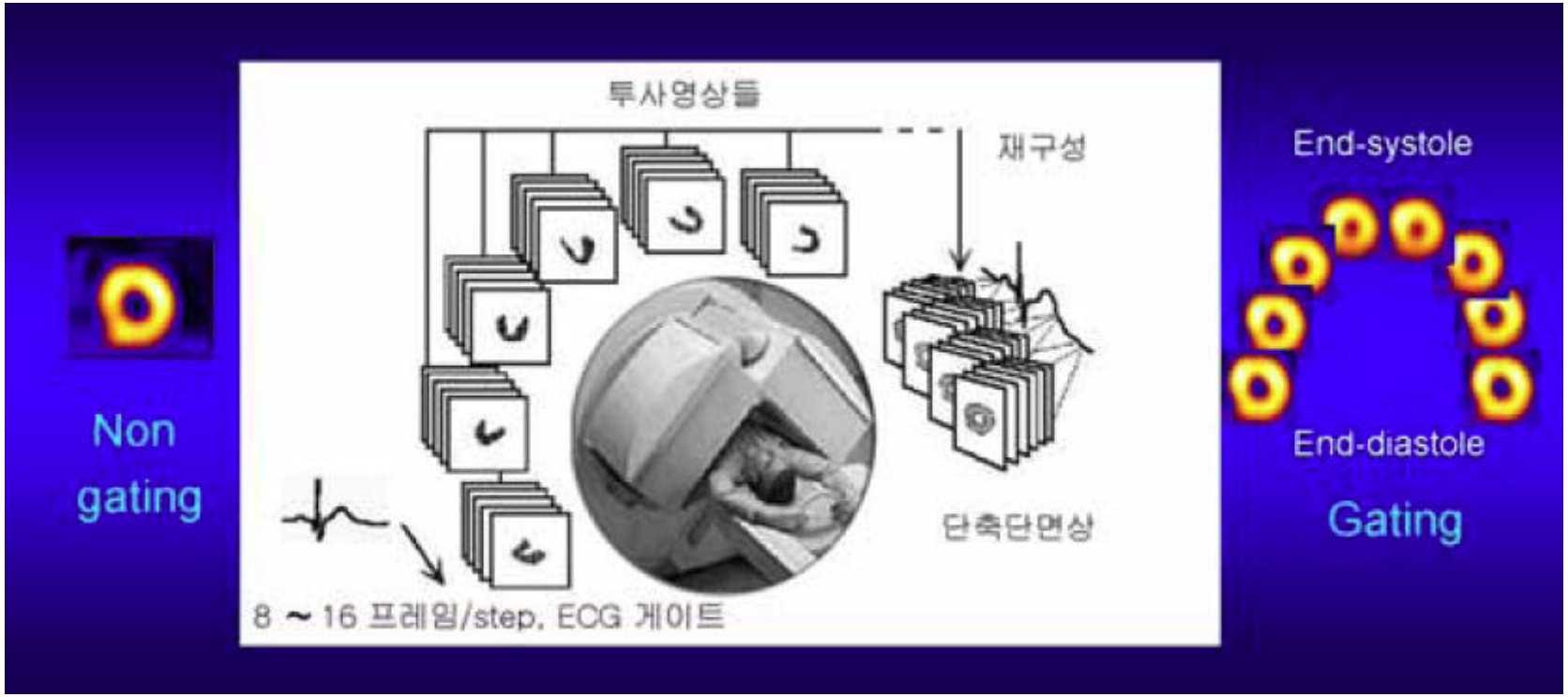
ECG-Gated MPS

- Combined assessment of mycocardial perfusion & function
- Regional myocardial perfusion
- Volumetric parameter: LVEF, LV mass, LV EDV, LV ESV
- Regional function: regional wall motion & thickening

Gated Image Acquisition



Korean J Nucl Med 2003

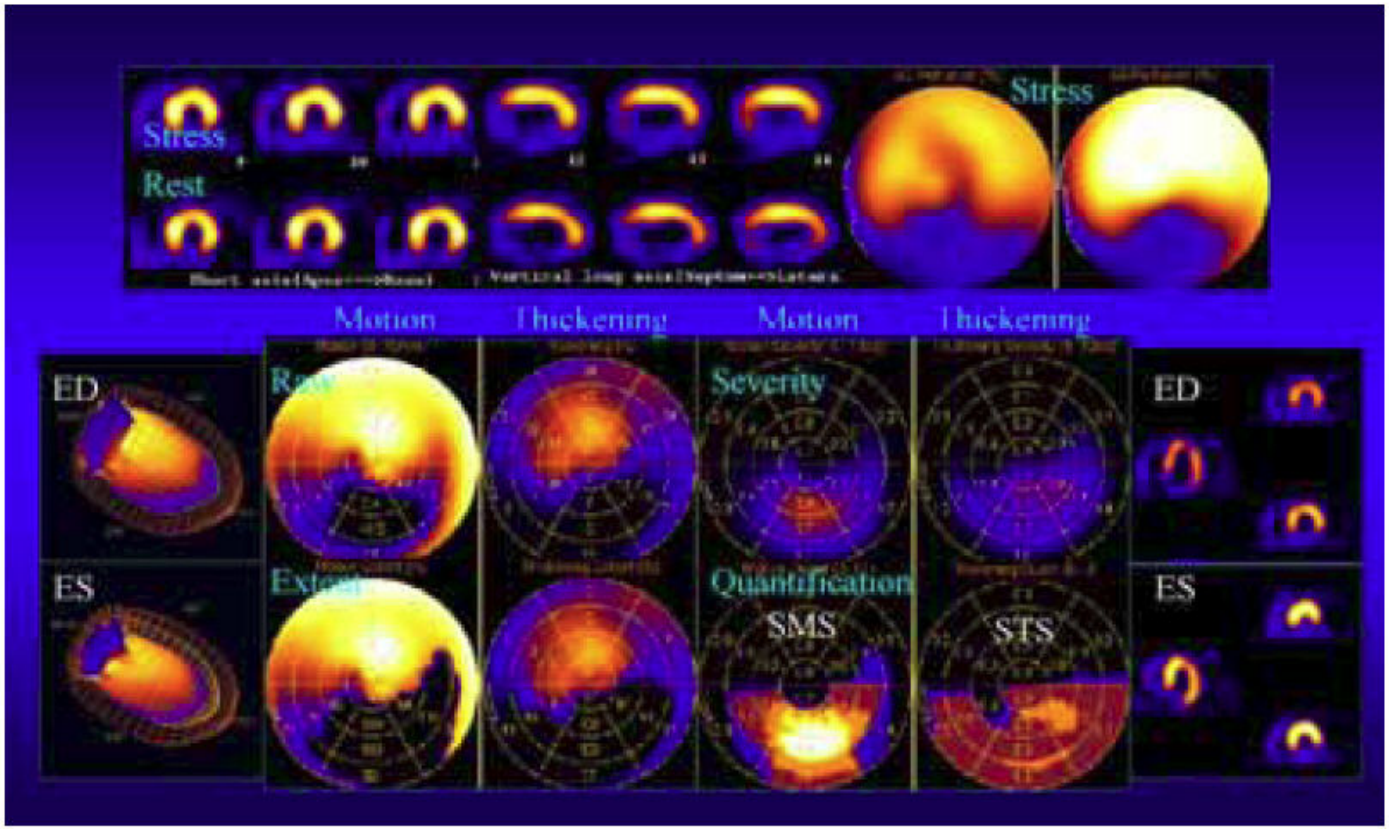


Fig. 4. Regional wall motion and wall thickening analysis using AutoQUANT™. ED; end-diastole, ES; end-systole, SMS; summed stress score, STS; summed thickening score. Stress and rest myocardial perfusion images show fixed perfusion defect in inferior left ventricular wall. Motion and thickening analyses show normal motion and thickening in anterior wall and decreased motion and thickening in inferior wall.

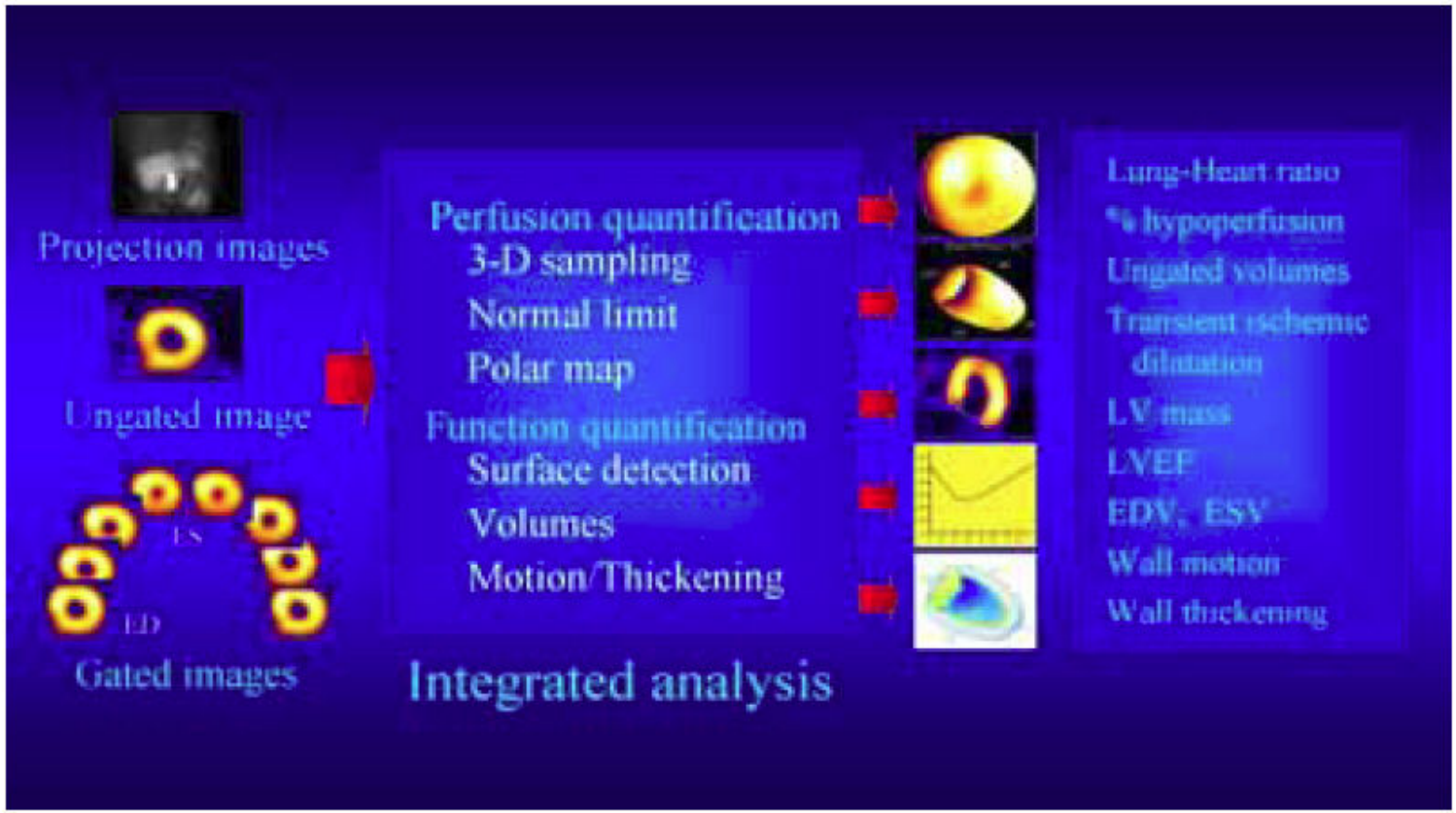


Fig. 3. Cardiac functional parameters that are derived from a gated myocardial perfusion SPECT. ES; end-systole, ED; end-diastole, LV; left ventricle, LVEF; LV ejection fraction, EDV; end-diastolic volume, ESV; end-systolic volume.

Validation of Quantitative Measurements of LVEF by Different Software Programs for Gated Myocardial Perfusion SPECT

Authors	Year	Software	Gold standard	No. of patients	*r*	Isotope	Reference
Ioannidis et al.	2002	QGS	MRI		0.89		*62*
Baba et al.	2002	QGS	Contrast ventriculography	20	0.80	^{201}Tl	*63*
Itti et al.	2001	QGS	ERNA	50	0.88–0.92	^{201}Tl	*64*
Vourvouri et al.	2001	QGS	2D Echo	32	0.83		*65*
Higuchi et al.	2001	QGS	ERNA		0.90		*66*
Germano et al.	1995	QGS	FPRNA	65	0.90	^{99m}Tc-Sestamibi	*10*
Faber et al.	1999	ECTb	MRI	10	0.88	^{99m}Tc-Sestamibi	*67*
			FPRNA	79	0.82		
Vallejo et al.	2000	QGS	MRI	16 (canine)	0.51	^{99m}Tc-Sestamibi	*13*
Tadamura et al.	1999	QGS	MRI	20	0.92	^{201}Tl	*68*
					0.94	^{99m}Tc-Sestamibi	
Yoshioka et al.	1999	QGS	FPRNA	21	0.91	^{99m}Tc-Tetrofosmin	*69*
					0.87		
Vallejo et al.	2000	QGS	FPRNA	400	0.66		*14*
Nichols et al.	1998		LV angiography	58	0.86	^{99m}Tc-Sestamibi	*70*
Nichols et al.	1997		FPRNA	22	0.90	^{99m}Tc-Sestamibi	*71*
Atsma et al.	2000	QGS	Contrast ventriculography	74	0.84	^{99m}Tc-Tetrofosmin	*72*
Wright et al.	2000	QGS	ERNA	70	0.70–0.71	^{201}Tl (low dose)	*73*
Bax et al.	2000	QGS	MRI	22	0.90	^{99m}Tc-Tetrofosmin	*74*
Bavelaar-Croon et al.	2000	QGS	MRI	21	0.85		*75*
Cwajg et al.	2000		2D Echo	109	≥0.68	^{201}Tl ^{99m}Tc	*76*
Nichols et al.	2000	SPECT EF QGS ECTb	2D Echo	33	0.92 overall 0.82 SPECT EF 0.75 QGS 0.72 ECTb		*77*
He et al.	1999		FPRNA	63	0.84–0.85	^{99m}Tc-Sestamibi ^{201}Tl	*78*
Vaduganathan et al.	1999		MRI	25	0.93	^{99m}Tc	*79*
Inubushi et al.	1999	QGS	FPRNA	44	0.919	^{99m}Tc-Sestamibi	*80*
Nichols et al.	1996		ERNA	75	0.87	^{99m}Tc-Sestamibi	*81*
			FPRNA	65	0.87		
Nakajima et al.	2001	QGS ECTb 4D-MSPECT pFAST*	ERNA	30	0.82 QGS 0.78 ECTb 0.69 4D-MSPECT 0.84 pFAST*		*18*
Everaert et al.	1997	QGS Stanford	ERNA	40	0.89 QGS 0.93 SU	^{99m}Tc-Tetrofosmin	*82*
Chua et al.	2000	QGS	ERNA	62	0.94	^{99m}Tc	*83*
Abe et al.	2000	QGS	Contrast ventriculography	229	0.78	^{99m}Tc-Tetrofosmin	*84*
Manrique et al.	2000	QGS	ERNA	55	0.71–0.94	^{201}Tl	*85*
Williams and Taillon	1996	University of Chicago image inversion	FPRNA	38	0.83	^{99m}Tc-Sestamibi	*86*
			Contrast ventriculography	54	0.93		

Improved Normalcy Rate

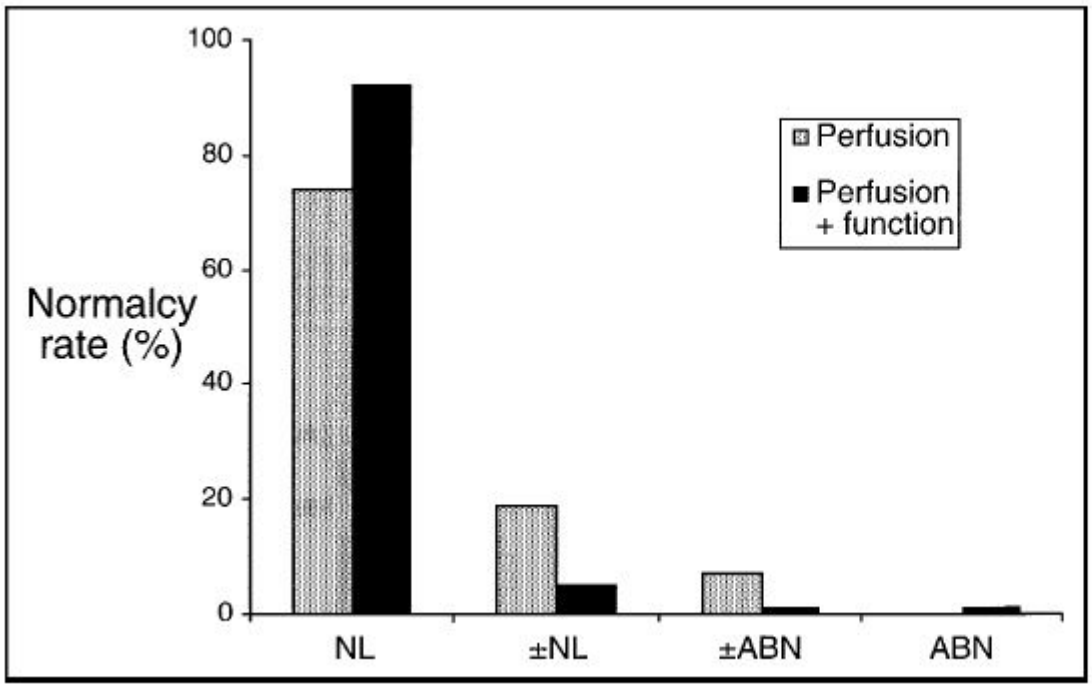
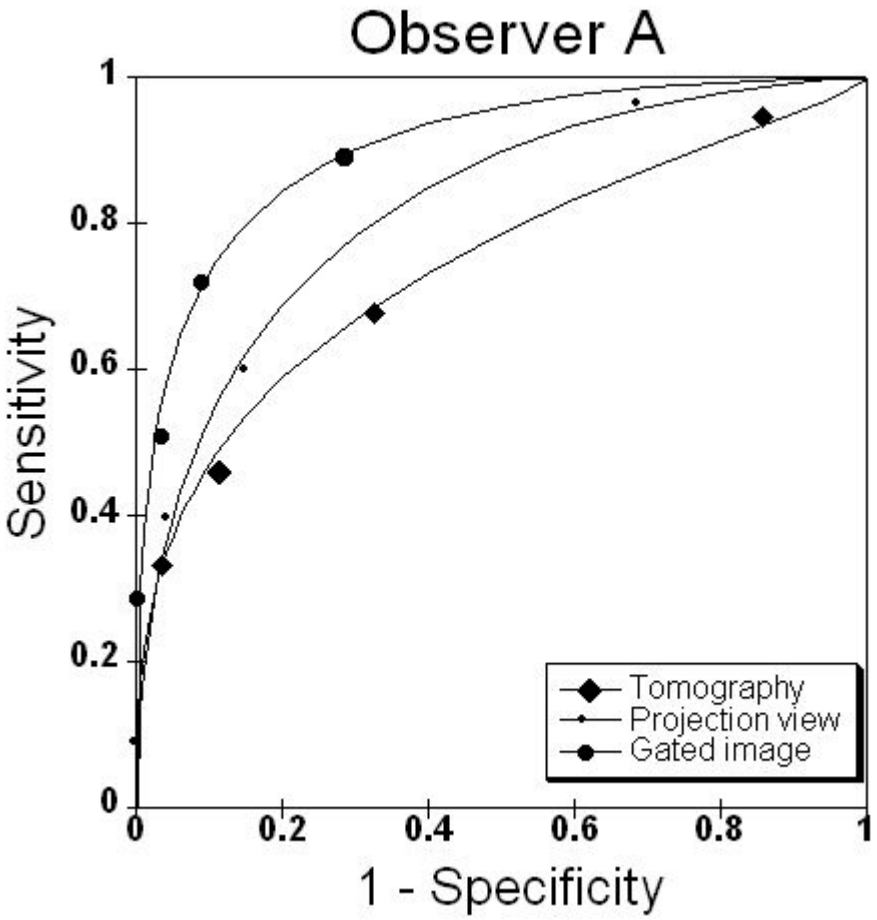
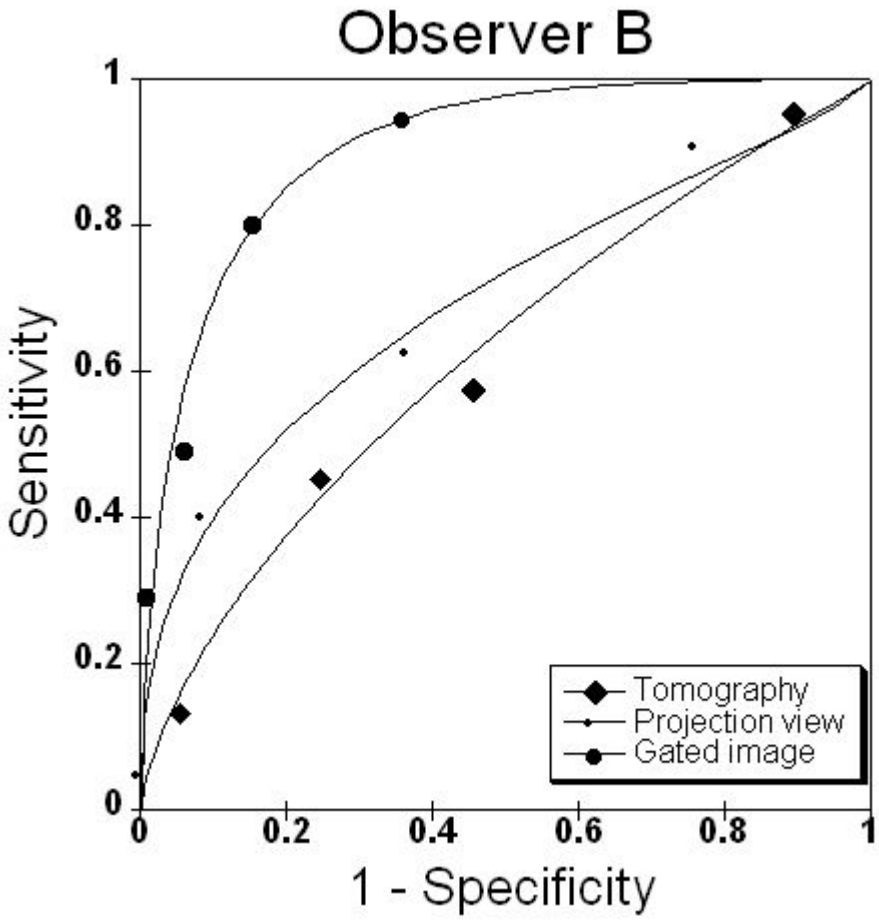


FIGURE 3. In patients with low likelihood of CAD, normalcy rate increased from 74% to 93%, and borderline readings decreased from 32% to 10% when functional data from gating are incorporated into study interpretation. NL = normal; ±NL = borderline normal; ±ABN = borderline abnormal; ABN = abnormal. (Modified and reprinted with permission of (22).)

J Am Coll Cardiol 1997

Improved Diagnostic Accuracy





J Nucl Cardiol 1998

Gated MPS as a Prognostic Factor

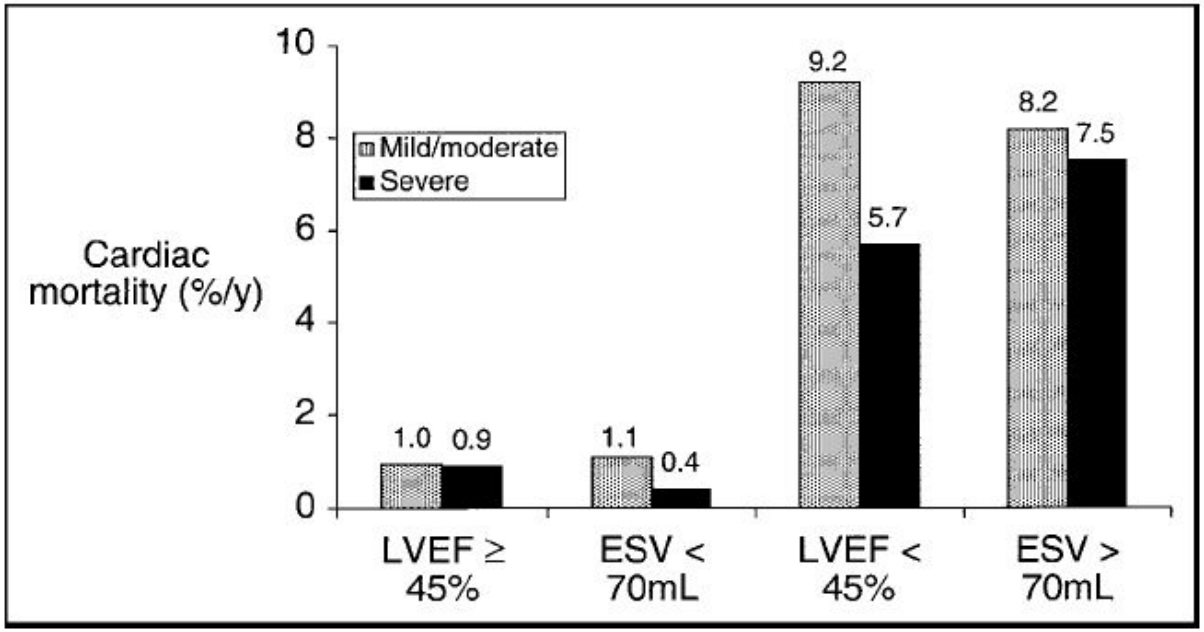


FIGURE 4. Annual cardiac death rates stratified by LV volume and EF. Patients with LVEF of ≥45% or end-systolic volume (ESV) of <70 mL have low mortality rate regardless of severity of perfusion defects. Similar findings are noted for patients with low EF (<45%). (Modified and reprinted with permission of (32).)

Circulation 1999

Attenuation-Corrected MPS

- Tissue attenuation of photon
  - Attenuation artifact
  - False positive on MPS
- Attenuation correction
  - Transmission scan
  - CT scan: SPECT/CT camera

Attenuation Correction

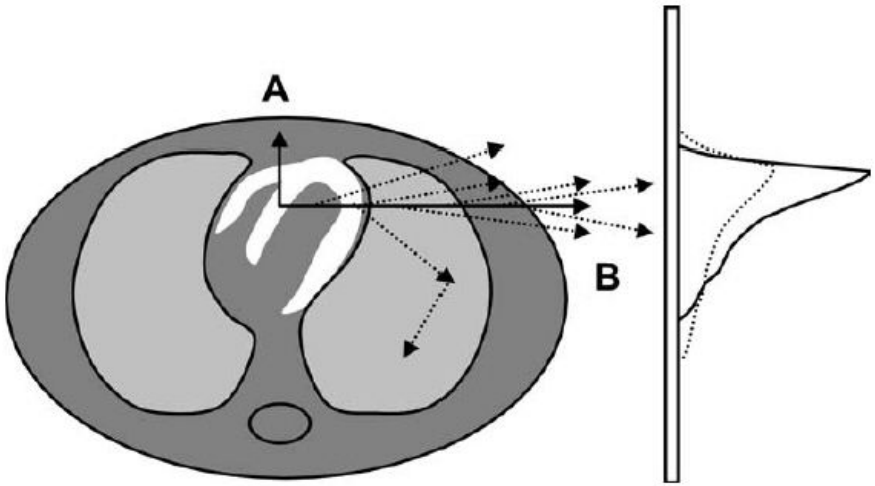


Figure 1 Attenuation of photons and impact on measured projections. (A) photoelectric absorption. (B) Compton scattering illustrating multiple possible paths. Attenuation causes quantitative errors as well as distortions in the projection profiles that are propagated into the reconstructed images. Knowledge of the attenuating distribution is required for attenuation correction. Solid lines depict true profile; dotted lines depict attenuated profile.

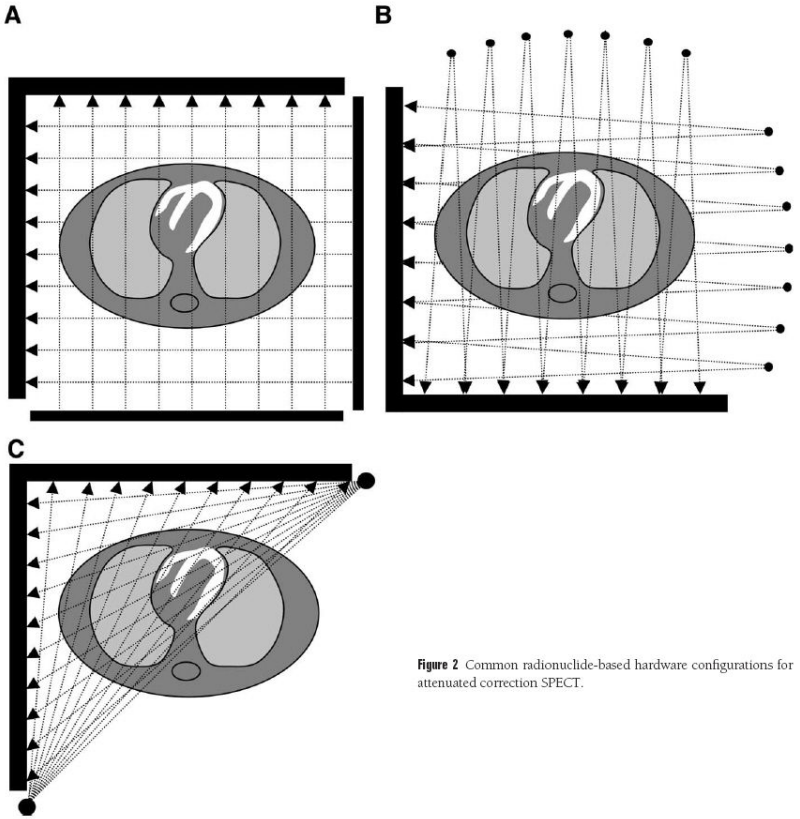


Figure 2 Common radionuclide-based hardware configurations for attenuated correction SPECT.

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Advantages of AC MPS

Table 1 Sensitivity and Specificity of Corrected and Noncorrected ^{99m}Tc Sestamibi SPECT in Nonobese (BMI <30) and Obese (BMI >30) Patients (Adapted from Bateman et al[82])

	Sensitivity (%)		Specificity (%)	
	Non-AC	AC	Non-AC	AC
All patients	88	86	50*	79
BMI <30	90	90	64	82
BMI >30	87	82	41*	76

*$P < 0.05$.

- Improve diagnostic confidence
- Improved normalcy rate & specificity
- Sensitivity: similar or slightly improved

Circulation 2003

Inferior Wall Attenuation Artifact

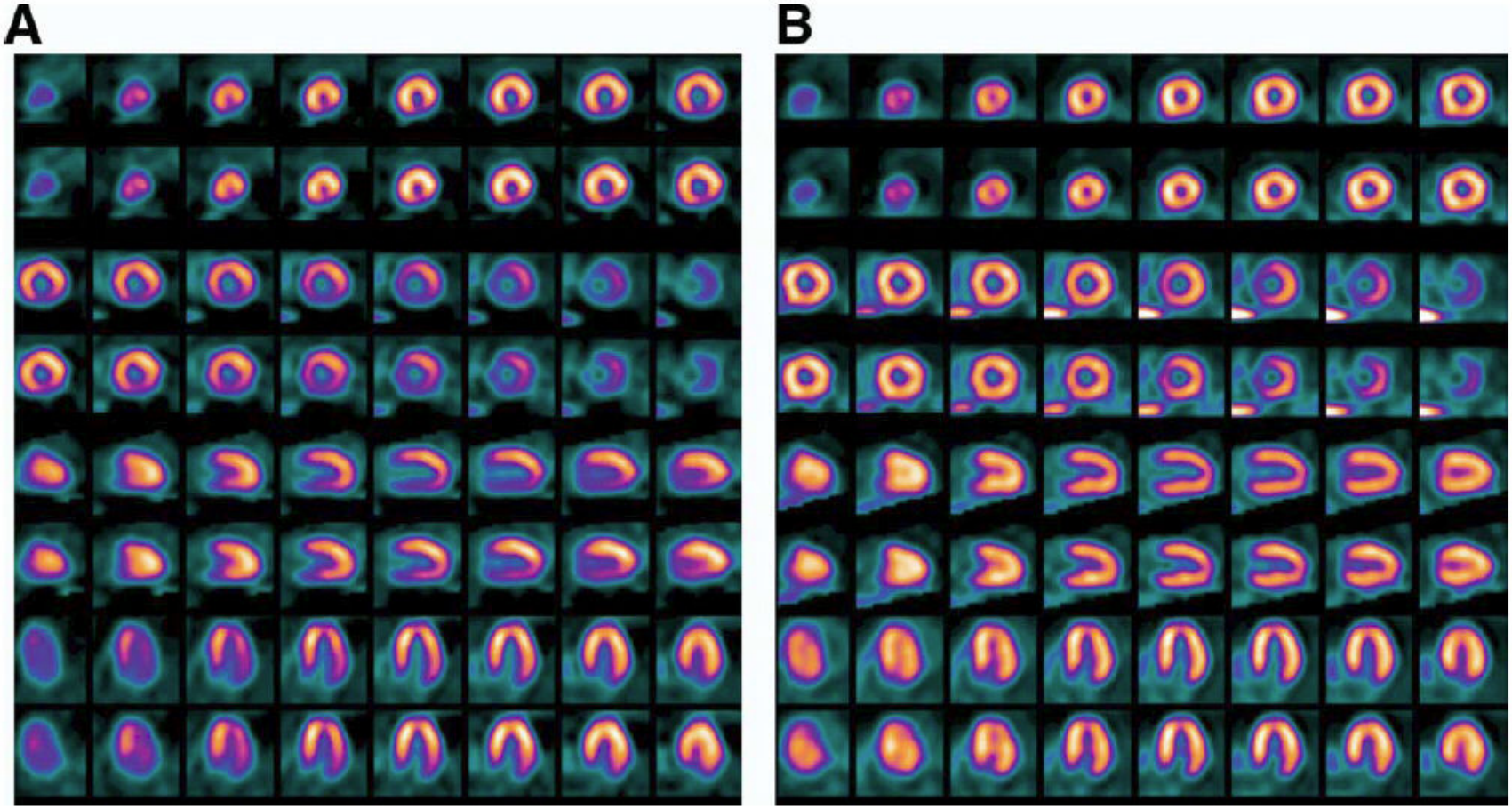

Figure 7 Large male patient with an apparent perfusion defect of the inferior wall in the nonattenuation-corrected images (A) and uniform count distribution after attenuation correction (B). He exercised for 7 min on the Bruce treadmill with no chest pain and no ST segment changes.

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Image Fusion

- Mental integration from several different imaging modalities by the physician → difficult & inaccurate
- Automatic Image Fusion
  - Provide complementary information from different modalities to be combined
  - Draw additional useful clinical conclusions
  - Accurate comparisons between images from the same modality
  - Best profitable between functional and anatomical imaging methods

Image Fusion between MPS & CTA

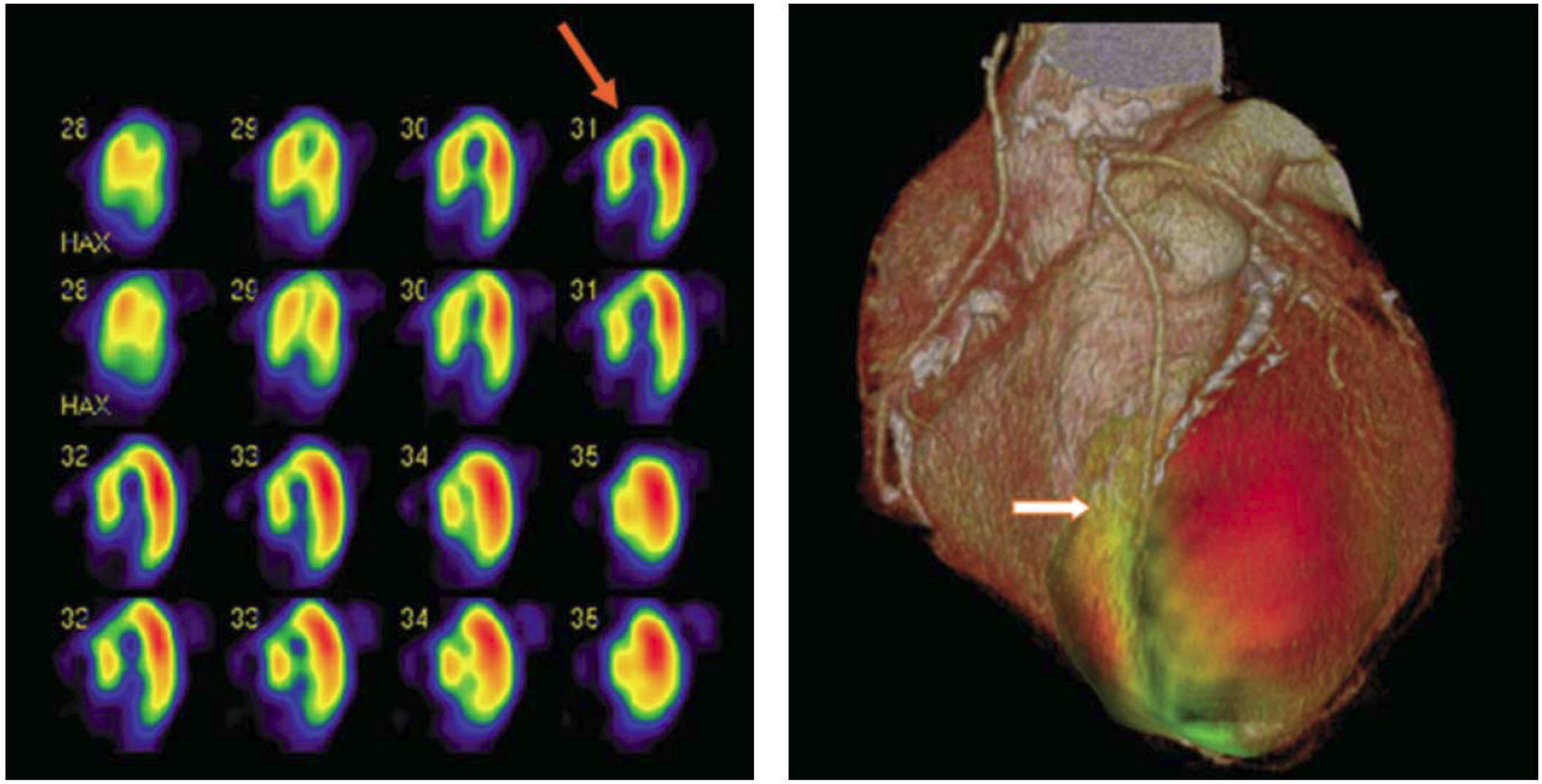

Fig. 1—62-year-old man who underwent coronary artery bypass grafting.
A, Myocardial perfusion SPECT (horizontal long-axis) stress images in first and third panels show perfusion defect in anterior and septal wall (*arrow*). Redistribution images in second and fourth panels show reverse redistribution.
B, On volume-rendering fused images, patency of left internal thoracic artery-to-left anterior descending coronary artery bypass graft and myocardial perfusion defect around left anterior descending coronary artery are clearly depicted (*arrow*).

AJR 2005

Current Clinical

Indication of MPS

ACCF/ASNC
Appropriate Criteria of MPS

Table 1. Detection of CAD: Symptomatic

	Indication	Appropriateness Criteria (Median Score)
	Evaluation of Chest Pain Syndrome	
1.	• Low pre-test probability of CAD • ECG interpretable AND able to exercise	I (2.0)
2.	• Low pre-test probability of CAD • ECG uninterpretable OR unable to exercise	U* (6.5)
3.	• Intermediate pre-test probability of CAD • ECG interpretable AND able to exercise	A (7.0)
4.	• Intermediate pre-test probability of CAD • ECG uninterpretable OR unable to exercise	A (9.0)
5.	• High pre-test probability of CAD • ECG interpretable AND able to exercise	A (8.0)
6.	• High pre-test probability of CAD • ECG uninterpretable OR unable to exercise	A (9.0)
	Acute Chest Pain (in Reference to Rest Perfusion Imaging)	
7.	• Intermediate pre-test probability of CAD • ECG – no ST elevation AND initial cardiac enzymes negative	A (9.0)
8.	• High pre-test probability of CAD • ECG – ST elevation	I (1.0)
	New-Onset/Diagnosed Heart Failure With Chest Pain Syndrome	
9.	• Intermediate pre-test probability of CAD	A (8.0)

*Median scores of 3.5 and 6.5 are rounded to the middle (Uncertain). Note: I (Inappropriate), U (Uncertain), and A (Appropriate).

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ACCF/ASNC
Appropriate Criteria of MPS

Table 2. Detection of CAD: Asymptomatic (Without Chest Pain Syndrome)

Indication		Appropriateness Criteria (Median Score)
Asymptomatic		
10.	• Low CHD risk (Framingham risk criteria)	I (1.0)
11.	• Moderate CHD risk (Framingham)	U (5.5)
New-Onset or Diagnosed Heart Failure or LV Systolic Dysfunction Without Chest Pain Syndrome		
12.	• Moderate CHD risk (Framingham) • No prior CAD evaluation AND no planned cardiac catheterization	A (7.5)
Valvular Heart Disease Without Chest Pain Syndrome		
13.	• Moderate CHD risk (Framingham) • To help guide decision for invasive studies	U (5.5)
New-Onset Atrial Fibrillation		
14.	• Low CHD risk (Framingham) • Part of the evaluation	U* (3.5)
15.	• High CHD risk (Framingham) • Part of the evaluation	A (8.0)
Ventricular Tachycardia		
16.	• Moderate to high CHD risk (Framingham)	A (9.0)

*Median scores of 3.5 and 6.5 are rounded to the middle (Uncertain). Note: I (Inappropriate), U (Uncertain), and A (Appropriate).

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Table 3. Risk Assessment: General and Specific Patient Populations

Indication		Appropriateness Criteria (Median Score)
Asymptomatic		
17.	• Low CHD risk (Framingham)	I (1.0)
18.	• Moderate CHD risk (Framingham)	U (4.0)
19.	• Moderate to high CHD risk (Framingham) • High-risk occupation (e.g., airline pilot)	A (8.0)
20.	• High CHD risk (Framingham)	A (7.5)

Note: I (Inappropriate), U (Uncertain), and A (Appropriate).

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Table 4. Risk Assessment With Prior Test Results

Indication		Appropriateness Criteria (Median Score)
Asymptomatic OR Stable Symptoms Normal Prior SPECT MPI Study		
21.	• Normal initial RNI study • High CHD risk (Framingham) • Annual SPECT MPI study	I (3.0)
22.	• Normal initial RNI study • High CHD risk (Framingham) • Repeat SPECT MPI study after 2 years or greater	A (7.0)

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Appropriate Criteria of MPS

Table 5. Risk Assessment: Preoperative Evaluation for Non-Cardiac Surgery

Indication		Appropriateness Criteria (Median Score)
Low-Risk Surgery		
31.	• Preoperative evaluation for non-cardiac surgery risk assessment	**I (1.0)**
Intermediate-Risk Surgery		
32.	• Minor to intermediate perioperative risk predictor • Normal exercise tolerance (greater than or equal to 4 METS)	**I (3.0)**
33.	• Intermediate perioperative risk predictor OR • Poor exercise tolerance (less than 4 METS)	**A (8.0)**
High-Risk Surgery		
34.	• Minor perioperative risk predictor • Normal exercise tolerance (greater than or equal to 4 METS)	**U (4.0)**
35.	• Minor perioperative risk predictor • Poor exercise tolerance (less than 4 METS)	**A (8.0)**
36.	• Asymptomatic up to 1 year post normal catheterization, non-invasive test, or previous revascularization	**I (3.0)**

Note: I (Inappropriate), U (Uncertain), and A (Appropriate).

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Comparison with

Multi-Slice Coronary CT

MSCT vs. MPS

- MSCT
  - CTA, calcium score
  - Atherosclerotic coronary artery
  - Risk stratification of CAD
- Normal CTA: ~90% normal MPS
- Abnormal CTA (Ø < 50%): 29-50% abnormal MPS
- Calcium score

  < 100: abnormal MPS in < 20%

  > 400: abnormal MPS in 40-50%

Prognostic Value of Calcium Score & MPS

Table 1: Interaction between CAC scores and the extent of myocardial perfusion abnormality for prediction of 24-month event-free survival (P = 0.003). Interaction P = 0.003 (unadjusted) and < 0.0001 (adjusted for UKPDS risk score). Event-free survival estimates are from a stratified Cox model.

(Adapted from Anand DV, Lim E, Hopkins D, Corder R, Shaw LJ, Sharp P, Lipkin D, Lahiri A. *Risk stratification in uncomplicated type 2 diabetes: prospective evaluation of the combined use of coronary artery calcium imaging and selective myocardial perfusion scintigraphy.* European Heart Journal 2006;27(6):713-21.)

% Myocardium	CAC 0–100	CAC 101–400	CAC 401–1000	CAC > 1000
0%	100%	98%	96%	90%
1–5%	100%	92%	83%	77% RR = 9.20 (1.48, 57.19) P = 0.017
> 5%	100%	80% RR = 8.30 (1.35, 50.99) P = 0.022	64% RR = 12.64 (2.97, 53.84) P = 0.001	48% RR = 24.43 (5.59, > 100) P < 0.0001

MPS in DM

Survival of DM Patients vs. MPS

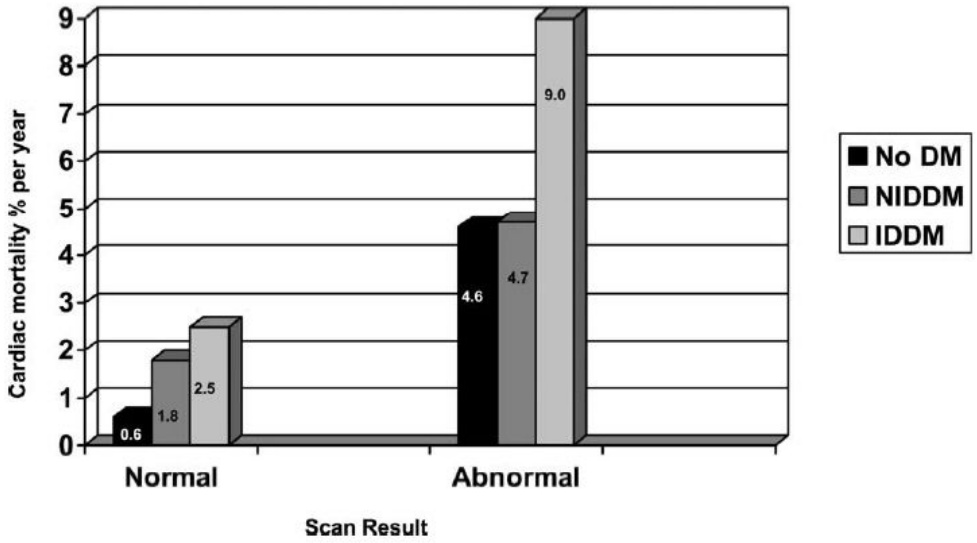

Figure 4 Cardiac mortality in patients without diabetes mellitus, noninsulin-dependent diabetes mellitus, and insulin diabetes mellitus. (Reprinted from Berman DS, Kang X, Hayes SW, et al: Adenosine myocardial perfusion single-photon emission computed tomography in women compared with men. Impact of diabetes mellitus on incremental prognostic value and effect on patient management. J Am Coll Cardiol 41:1125-1133, 2003, with permission from the American College of Cardiology Foundation.)

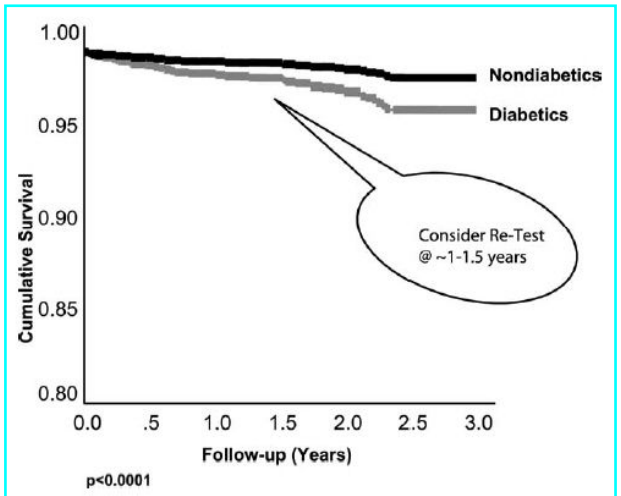

Figure 5 Kaplan–Meier survival curves comparing the subset of diabetic and nondiabetic patients with a normal stress. (Source: Giri S, Shaw LJ, Murthy DR, et al: Impact of diabetes on the risk stratification using stress single-photon emission computed tomography myocardial perfusion imaging in patients with symptoms suggestive of coronary artery disease. Circulation 105:32-40, 2002.)

Pre Test Probability of CAD

Table B1. Pre-Test Probability of CAD by Age, Gender, and Symptoms

Age (yrs)	Gender	Typical/Definite Angina Pectoris	Atypical/Probable Angina Pectoris	Nonanginal Chest Pain	Asymptomatic
30–39	Men	Intermediate	Intermediate	Low	Very low
	Women	Intermediate	Very low	Very low	Very low
40–49	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Low	Very low	Very low
50–59	Men	High	Intermediate	Intermediate	Low
	Women	Intermediate	Intermediate	Low	Very low
60–59	Men	High	Intermediate	Intermediate	Low
	Women	High	Intermediate	Intermediate	Low

High: Greater than 90% pre-test probability; **Intermediate:** Between 10% and 90% pre-test probability; **Low:** Between 5% and 10% pre-test probability; **Very Low:** Less than 5% pre-test probability.
Reproduced with permission from ACC/AHA 2002 Guideline Update for Exercise Testing (8).

Coronary heart disease (CHD) risk.*

- **CHD risk—low.** Defined by the age-specific risk level that is below average. In general, low risk will correlate with a 10-year absolute CHD risk less than 10%.
- **CHD risk—moderate.** Defined by the age-specific risk level that is average or above average. In general, moderate risk will correlate with a 10-year absolute CHD risk between 10% to 20%.
- **CHD risk—high.** Defined as the presence of diabetes mellitus or the 10-year absolute CHD risk of greater than 20%.

Perioperative risk predictors.†

- **Major risk predictors.** Unstable coronary syndromes, decompensated heart failure (HF), significant arrhythmias, and severe valve disease.
- **Intermediate risk predictors.** Mild angina, prior myocardial infarction (MI), compensated or prior HF, diabetes, or renal insufficiency.
- **Minor risk predictors.** Advanced age, abnormal electrocardiogram (ECG), rhythm other than sinus, low functional capacity, history of cardiovascular accident (CVA), and uncontrolled hypertension.

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Asymptomatic DM

Table 2 Myocardial perfusion imaging studies

References	Number of patients	Patient characteristics and age (years)	Mean follow-up (months)	Abnormal MPI (%)	Stress type and tracer	Annual event rates (death + myocardial infarction) (%)
Retrospective studies						
Felsher *et al.*[37]	123	Suspected CAD, 56 ± 8	36	56	Exercise, thallium	Normal MPI: 1.25 Abnormal MPI: 4.8
Vanzetto *et al.*[38]	158	High-risk patients with known or suspected CAD, 63 ± 9	23 ± 17	Abn MPI: 56 moderate/severe Abn MPI: 11	Exercise or dipyridamole, thallium	Normal/mild Abn MPI: 5.2 Moderate/severe Abn MPI: 23.3
Kang *et al.*[39]	1271 DM 5862 non-DM	Known or suspected CAD, 67 ± 11	24 ± 8	Multi-vessel disease: DM—25; non-DM—16	Exercise or adenosine, ^{201}Tl + ^{99m}Tc-MIBI	DM: 4.3 (Normal MPI: 1–2; moderate/severe Abn MPI >7); Non-DM: 2.3
Schinkel *et al.*[41]	207	Known or suspected CAD, 61 ± 10	4.1 ± 2.4 years	Abn MPI: 64	Dobutamine, ^{99m}Tc-MIBI	Normal MPI: 0.7[a] Abn MPI: 6.6[a]
Giri *et al.*[40]	929 DM 3826 non-DM	Known or suspected CAD, 65 ± 11	2.5 ± 1.5 years	Abn MPI: DM—48; Non-DM—42	Exercise/adenosine, ^{201}Tl + ^{99m}Tc-MIBI	DM: 3.4 (Normal MPI: 3; multi-vessel ischaemia: 8.9) Non-DM: 1.8
DeLorenzo *et al.*[42]	180	Asymptomatic with no previous CAD, 61 ± 10	36 ± 18	Abn MPI: 26	Exercise/dipyridamole, ^{99m}Tc-MIBI	Normal MPI: 2 Abn MPI: 9
Cosson *et al.*[45]	362	Asymptomatic, no previous CAD, 58 ± 9	41 ± 24	Abn MPI: 33.4	Exercise/dipyridamole/ ^{201}Tl	Normal MPI: 1.2 Abn MPI: 9.4
Zellweger *et al.*[43]	1737	No previous CAD; 47% asymptomatic; 44%; angina; 9% SOB; 60 ± 13	24	Abn MPI: asymptomatic—39, angina—44, SOB—51	Exercise/adenosine, ^{201}Tl + ^{99m}Tc-MIBI	Asymptomatic: normal MPI—2.2; Abn MPI—3.4 Angina: normal MPI—3.2; Abn MPI—5.6 SOB: normal—7.7; Abn—13.2
Miller *et al.*[10]	4736 DM 22 429 non-DM	No previous CAD DM (Symptomatic: 63%)	70 ± 42	DM Asymptomatic: 58.6; Symptomatic: 59.5	Exercise or pharmacologic stress	Low risk MPI: 3.6 Intermediate risk MPI: 5 High-risk MPI: 5.9
Rajagopalan *et al.*[44]		Non-DM (Symptomatic: 72%) 60 ± 14		Non-DM Asymptomatic: 46.2; Symptomatic: 44.4.	^{201}Tl or ^{99m}Tc-MIBI	
Completed/ongoing prospective studies						
MiSAD 2004[59]	925	Asymptomatic low-risk, 54 ± 6	60	Abn MPI: 6.4	Exercise	Abn MPI: 0.2
DIAD 2004[47]	522	Asymptomatic low-risk, 61 ± 7	Ongoing	Abn MPI: 22 Moderate/severe Abn: 6	Exercise + adenosine ^{99m}Tc-MIBI	NA
Anand *et al.* 2004[60]	400	Asymptomatic low-risk, 53 ± 8	Ongoing	EBCT data (%) CAC ≤ 10: 55 CAC 11–100: 20 CAC >100: 25 MPI data (%) (CAC > 100) Abn MPI: 48 Markedly Abn MPI: 20	Exercise + dipyridamole ^{99m}Tc-MIBI	NA

MPI, myocardial perfusion imaging; Abn, abnormality; DM, diabetes mellitus; MIBI, sestamibi; SOB, shortness of breath on exertion; EBCT, electron beam computed tomography; MiSAD, Milan study of atherosclerosis in diabetes.
[a]Mortality rate only.

Recommendations of MPS in DM (1)

- Chest pain including typical & atypical: Do MPS!
- New-onset AF: Do MPS!
- Ventricular tachycardia → Do MPS!
- [Stable symptoms or Sx(-)] & previous normal MPS

  → Do MPS with an interval of > 2 yrs!
- Pre-operative evaluation of non-cardiac surgery

  - Intermediate-risk surgery: Do MPS!

Recommendations of MPS in DM (2)

- Asymptomatic DM

1) Useful in high-risk DM patients

- Additional major risk factor of CAD

- Complicated DM: abnormal MPS in > 50%

cf. Uncomplicated DM: abnormal MPS in ~20%

2) Abnormal MPS: associated with prognosis

3) Ongoing prospective studies


Thank you for your attention!