PLACE

PLATFORM OF LABORATORIES FOR ADVANCES IN CARDIAC EXPERIENCE

ROMA
Centro Congressi
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9ª Edizione

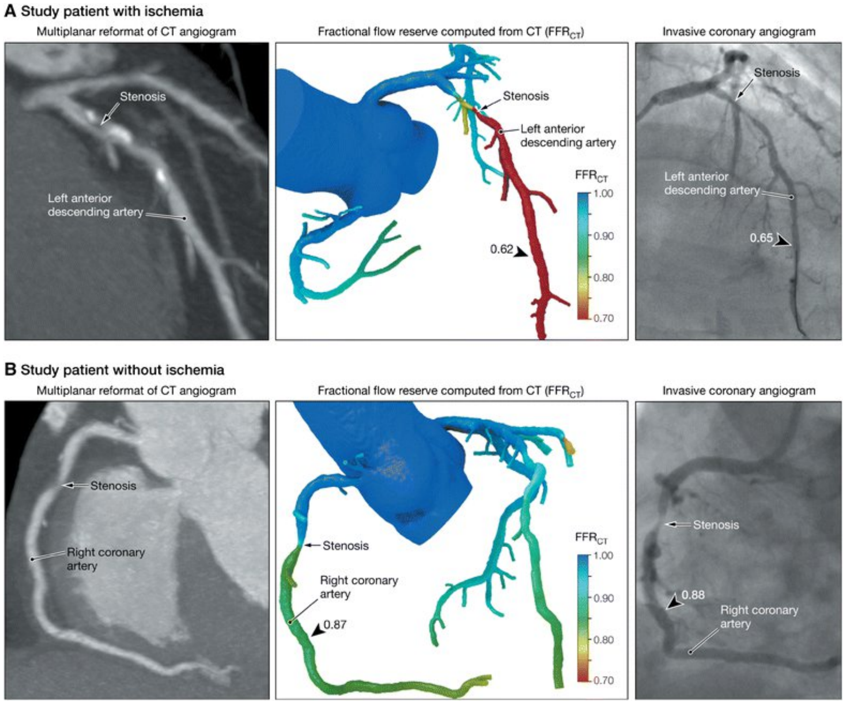
30 Settembre
1 Ottobre
2022

IMAGING E STRATIFICAZIONE DEL RISCHIO NELLA CARDIOPATIA ISCHEMICA

IMAGING IBRIDO ANATOMO-FUNZIONALE: PERCHÉ È LA DIREZIONE GIUSTA

Nudi Francesco

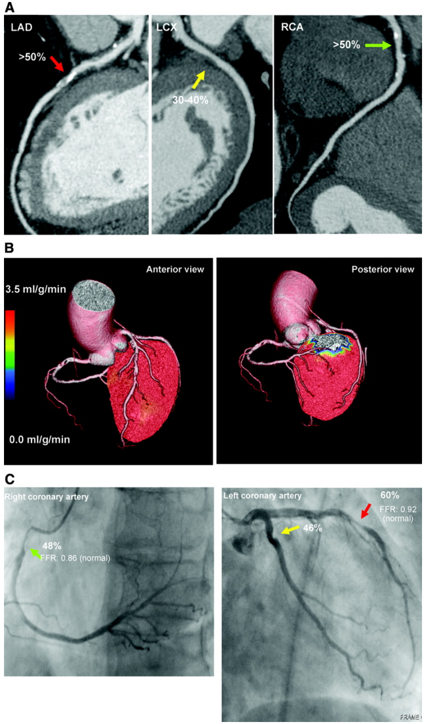
Diagnostic accuracy of fractional flow reserve from anatomic CT angiography



Non-invasive fractional flow reserve derived from conventional CCTA. Although both patients have obstructive coronary artery disease by computed tomographic angiography (CT), FFRCT identified myocardial ischemia in one patient (A), whereas FFRCT revealed no ischemia in the other patient (B). Multiplanar reformat of a CT angiogram demonstrating obstructive stenosis of the proximal portion of the left anterior descending artery (LAD) and an FFRCT value of 0.62, indicating vessel ischemia. Invasive coronary angiogram demonstrates obstructive stenosis of the proximal portion of the LAD and measured FFR values of 0.65, indicating vessel ischemia. (B) CT angiogram demonstrating obstructive stenosis of the mid portion of the right coronary artery (RCA) and an FFRCT value of 0.87, indicating no vessel ischemia. Invasive coronary angiogram demonstrates obstructive stenosis of the mid portion of the RCA and a measured FFR value of 0.88, indicating no vessel ischemia

Min JK et al., J Am Med Assoc 2012

Cardiac Positron Emission Tomography/Computed Tomography Imaging Accurately Detects Anatomically and Functionally Significant Coronary Artery Disease



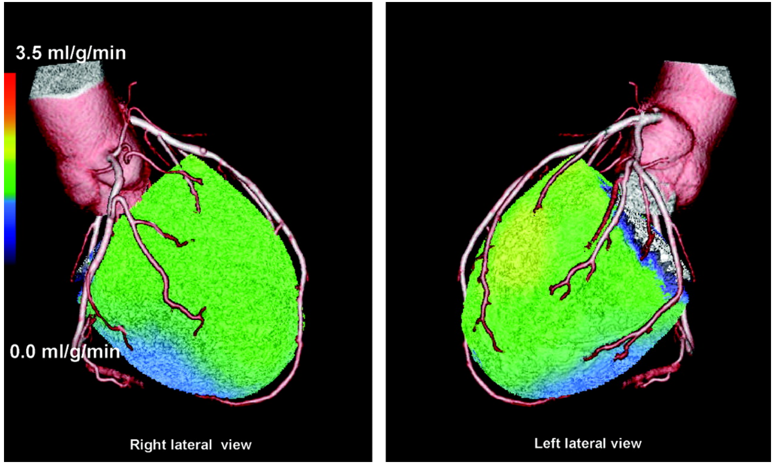
A 69-year-old man with attacks of atypical anginal pain. A, CT showed significant LAD and RCA stenoses with only mild stenosis in the LCx.

B, Hybrid images with normal stress PET perfusion (absolute scale, 0 to 3.5 mL g^{-1} min^{-1}). Normal perfusion is >2.5 mL g^{-1} min^{-1} (yellow or red). C, ICA with quantitative analysis and FFR.

Despite anatomically significant narrowing of the LAD and borderline changes in the RCA, FFR was normal in both vessels, indicating functionally nonsignificant disease.

Kajander S, et al. (Circulation. 2010;122:603-613)

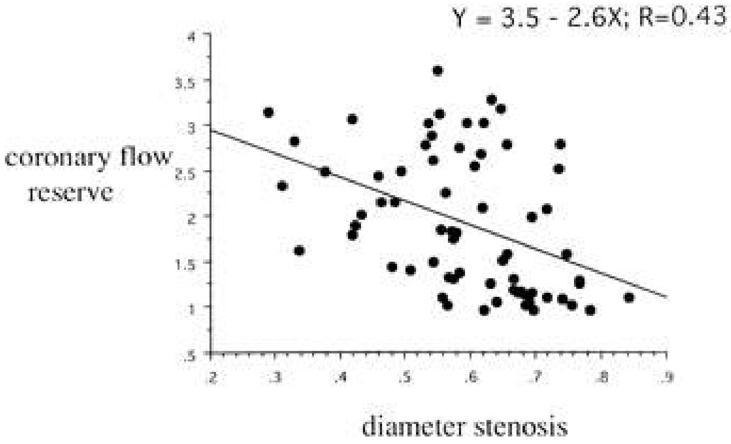
Cardiac Positron Emission Tomography/Computed Tomography Imaging Accurately Detects Anatomically and Functionally Significant Coronary Artery Disease



A 63-year-old man with positive family history. Good performance, atypical chest pain, and 2-mm ST depression in the ECG at the exercise test. In hybrid images, stress myocardial perfusion was reduced in most regions (green and blue). However, both CT and ICA showed normal coronary arteries, indicating possible microvascular disease.

Kajander S, et al. (Circulation. 2010;122:603-613)

Intracoronary Doppler assessment of moderate coronary artery disease

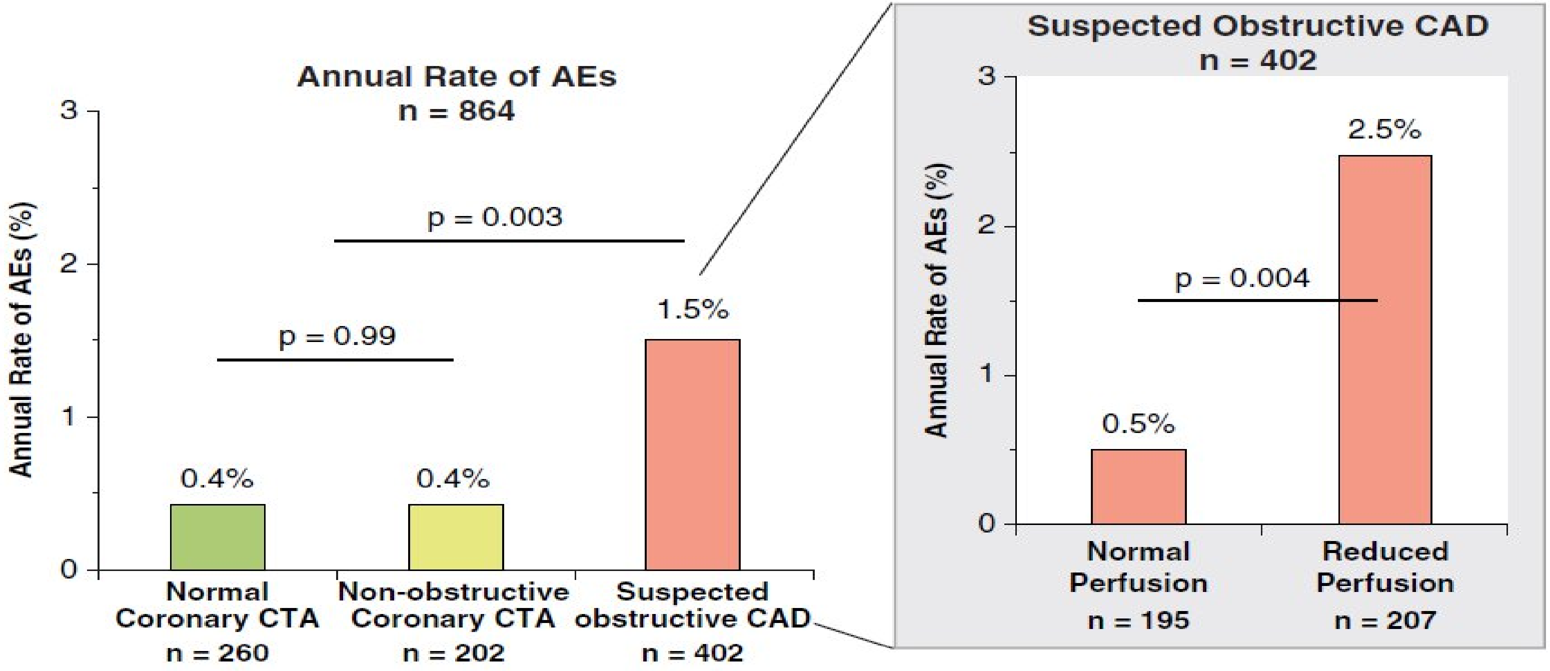


	Pos Tl-201	Neg Tl-201
CFVR < 1.7	87%	13%
CFVR > 1.7	11%	89%

r = 88%

Heller et al, Circulation 1997

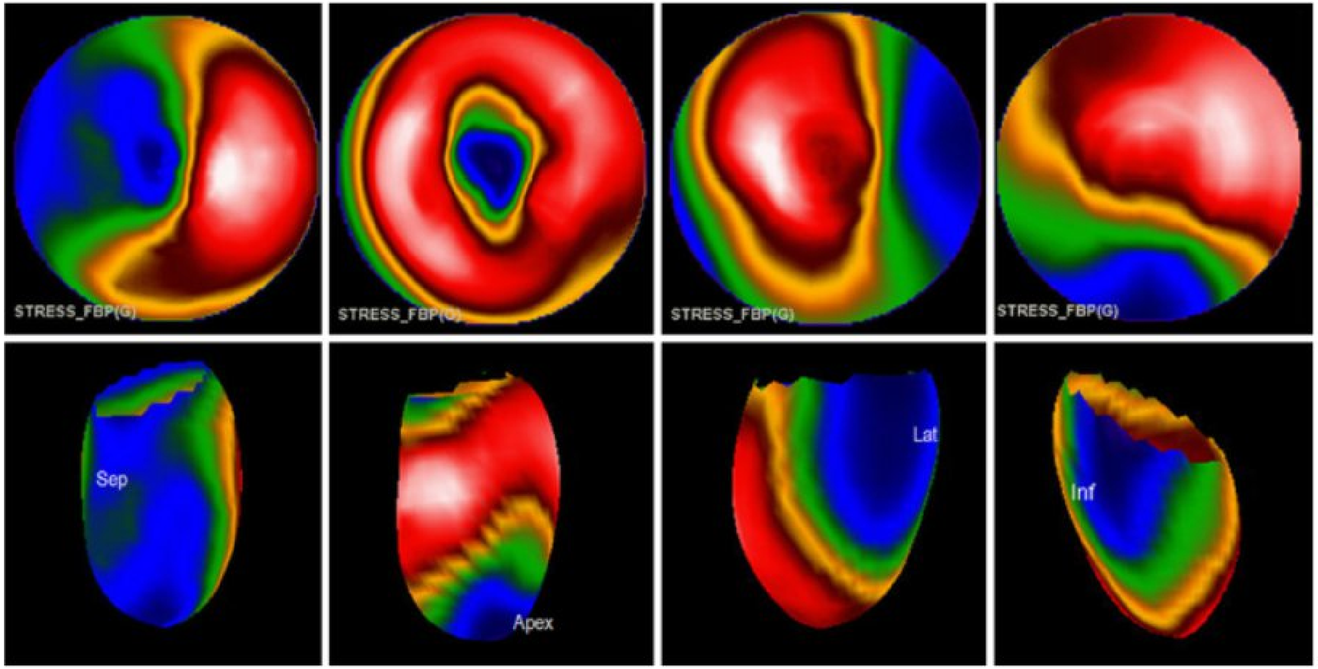
CT followed by selective PET



Maanitty et al, J Am Coll Cardiol Img 2017

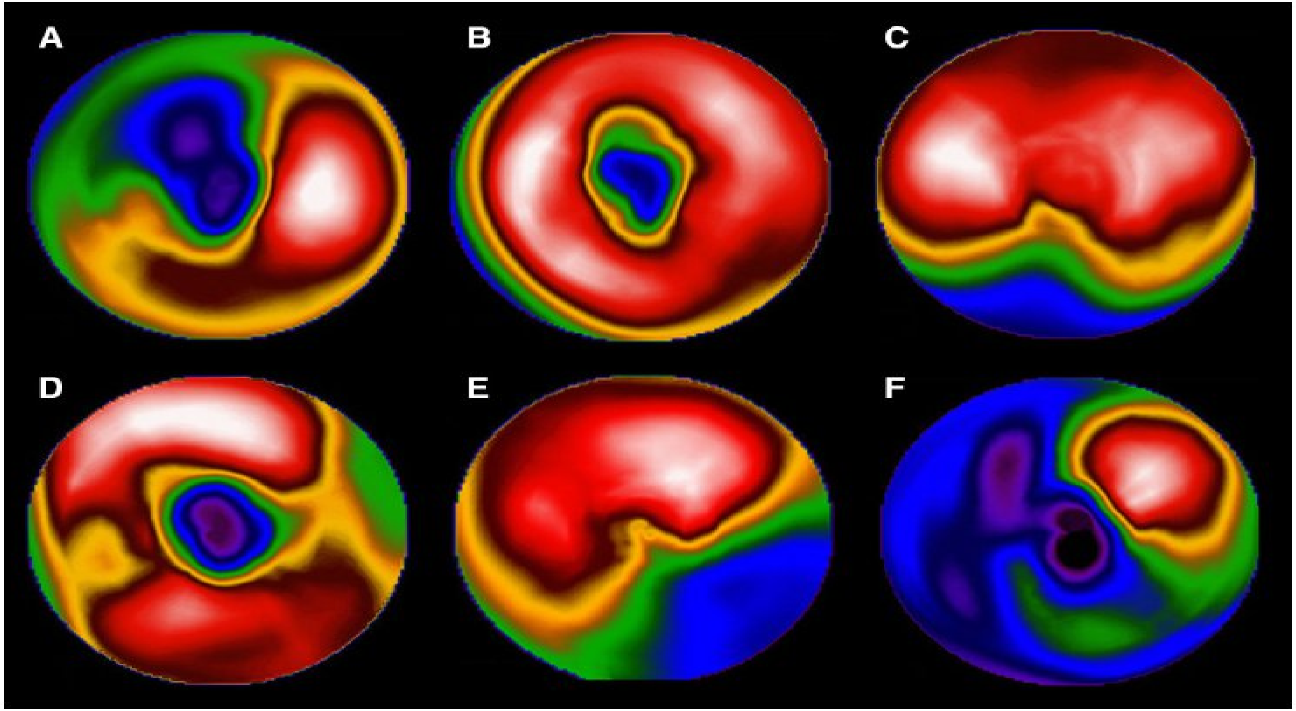
SPECT imaging: a novel and clinically-relevant segmentation approach

Prox LAD disease | Mid LAD disease | LCX disease | RCA disease



Nudi F, et al (J Nucl Cardiol 2014)

Vessel-related ischemia



Nudi et al, (J Nucl Cardiol 2016)

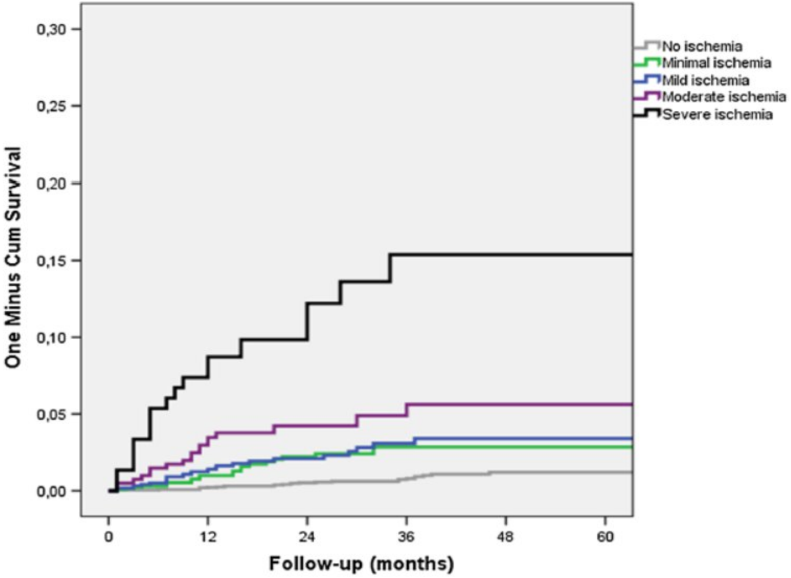
Vessel-related ischemia (VRI): 1 vs 2 vs 3

MIS 1 No LAD	MIS 1 LAD	MIS 1 Both	MIS 2 No LAD	MIS 2 LAD	MIS 2 Both	MIS 3 No LAD	MIS 3 LAD	MIS 3 Both	MIS 4 No LAD	MIS 4 LAD	MIS 4 Both

13	14	15	16	17	18	19	20	21	22-28
12	13	14	15	16	8	9	10	11	12
11	12	4	5	6	7	8	9	10	11
19	20	21	4	5	6	7	8	9	10
9	10	11	12	13	14	15	16	17	18
8	9	10	11	12	4	5	6	7	8
5	6	7	8	9	3	4	5	6	7
7	8	9	10	11	12	13	14	3	4
3	4	5	6	7	8	3	4	5	6
4	5	6	7	2	3	4	5	6	2
0	1	2	3	1	2	3	4	2	3

Nudi F, et al (J Nucl Cardiol 2015)

Risk of death according to maximal ischemia score (MIS)



Patients at risk according to maximal ischemia score:

No	4161	4147	2663	1724	778	395
Minimal	1399	1380	628	457	137	85
Mild	1566	1507	757	506	197	109
Moderate	1020	915	558	381	184	78
Severe	568	510	348	256	153	66

Nudi F, et al (J Nucl Cardiol 2014)

ESC
European Society of Cardiology

European Heart Journal - Cardiovascular Imaging (2022) **23**, e6–e33
https://doi.org/10.1093/ehjci/jeab244

EACVI DOCUMENT

Non-invasive imaging in coronary syndromes: recommendations of the European Association of Cardiovascular Imaging and the American Society of Echocardiography, in collaboration with the American Society of Nuclear Cardiology, Society of Cardiovascular Computed Tomography, and Society for Cardiovascular Magnetic Resonance

Thor Edvardsen [1,*] (chair), Federico M. Asch [2] (co-chair), Brian Davidson [3,4], Victoria Delgado [5], Anthony DeMaria [6], Vasken Dilsizian [7], Oliver Gaemperli [8], Mario J. Garcia [9], Otto Kamp [10], Daniel C. Lee [11], Danilo Neglia [12], Aleksandar N. Neskovic [13], Patricia A. Pellikka [14], Sven Plein [15], Udo Sechtem [16], Elaine Shea [17], Rosa Sicari [18], Todd C. Villines [19], Jonathan R. Lindner [20], and Bogdan A. Popescu [21]

[1]Department of Cardiology, Oslo University Hospital, Rikshospitalet, University of Oslo, Sognsvannsveien 20, 0372 Oslo, Norway; [2]MedStar Health Research Institute, Georgetown University, Washington, DC, USA; [3]Knight Cardiovascular Institute Oregon Health & Science University 3181 SW Sam Jackson Park Rd.- UNH-62 Portland, OR 97239, USA; [4]VA Portland Health Care System 3710 SW US Veterans Hospital Rd.-P3CARD Portland, OR 97239, USA; [5]Department of Cardiology, Leiden University Medical Centre, 2300RC Leiden, The Netherlands; [6]University of California, San Diego, CA, USA; [7]Department of Diagnostic Radiology and Nuclear Medicine, University of Maryland Medical Center 22 South Greene Street, Rm N2W78 Baltimore, MD 21201-1595, USA; [8]HeartClinic Hirslanden, Zurich, Switzerland; [9]Division of Cardiology, Montefiore-Einstein Center for Heart and Vascular Care, 111 East 210th Street, Bronx, NY 10467, USA; [10]Department of Cardiology, Amsterdam University Medical Center De Boelelaan 1117 1081HV Amsterdam, The Netherlands; [11]Division of Cardiology, Department of Medicine, Northwestern University Feinberg School of Medicine, 303 East Chicago Avenue, Tarry 14-725 Chicago, IL 60611, USA; [12]Department of Cardiology, Istituto di Scienze della Vita Scuola Superiore Sant'Anna - Pisa Via G. Moruzzi 1, Pisa, Italy; [13]Faculty of Medicine, Department of Cardiology, Clinical Hospital Center Zemun, University of Belgrade, Vukova 9, 11080 Belgrade, Serbia; [14]Division of Cardiovascular Ultrasound, Department of Cardiovascular Medicine, Mayo Clinic, 200 First Street SW, Rochester, MN 55905, USA; [15]Department of Biomedical Imaging Science, Leeds Institute of Cardiovascular and Metabolic Medicine, University of Leeds, Leeds Teaching Hospitals NHS Trust, Leeds LS2 9JT, UK; [16]Cardiologicum Stuttgart and Department of Cardiology, Robert Bosch Krankenhaus, Auerbachstraße 110, 70376 Stuttgart, Germany; [17]Alta Bates Summit Medical Center, Berkeley and Oakland, 2450 Ashby Ave, Berkeley, CA 94705, USA; [18]CNR, Institute of Clinical Physiology, Via G. Moruzzi 1, 56124 Pisa, Italy; [19]Division of Cardiovascular Medicine, University of Virginia Health System, University of Virginia Health Center 1215 Lee Street Charlottesville, VA 22908, USA; [20]Knight Cardiovascular Institute, Oregon Health & Science University, 3303 S Bond Ave, Portland, OR 97239, USA; and [21]Department of Cardiology, University of Medicine and Pharmacy "Carol Davila"—Euroecolab, Emergency Institute for Cardiovascular Diseases "Prof. Dr. C. C. Iliescu", Sos. Fundeni 258, sector 2, 022328, Bucharest, Romania

Received 27 October 2021; editorial decision 27 October 2021; accepted 8 November 2021; online publish-ahead-of-print 10 December 2021

Non-invasive imaging in coronary syndromes

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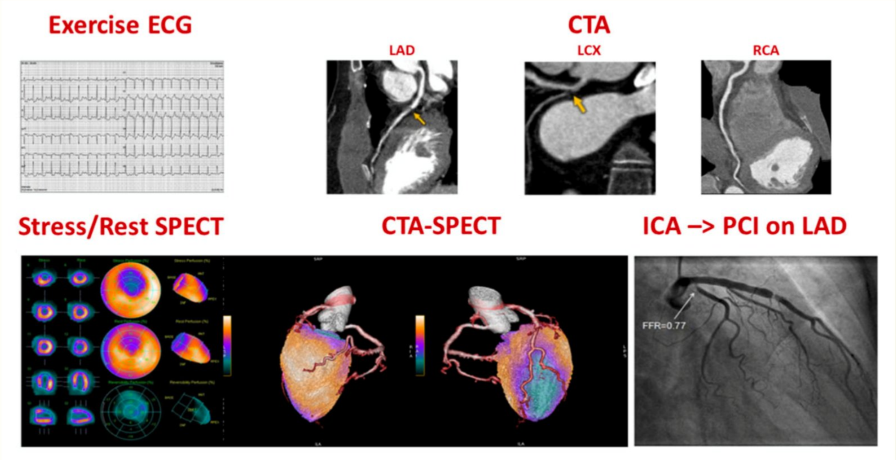

Figure 2 Chronic coronary syndrome. A 49 years old lady with family history of CAD, hypercholesterolaemia, and recent onset of effort angina with non-diagnostic ST-segment depression (0.1 mV in the anterior leads) at maximal exercise ECG. Her PTP of obstructive CAD is 10% but the clinical likelihood is higher. She performed CTA as the initial test which allowed the diagnosis of obstructive CAD (LAD middle third and proximal LCX) without high-risk features. Stress SPECT was sequentially performed. CTA-SPECT images demonstrated a severe reversible perfusion defect (>10% LV myocardium) in the LAD territory with preserved perfusion in the LCX territory. These high-risk findings prompted invasive coronary angiography and revascularization (PCI and stenting) of LAD was decided.

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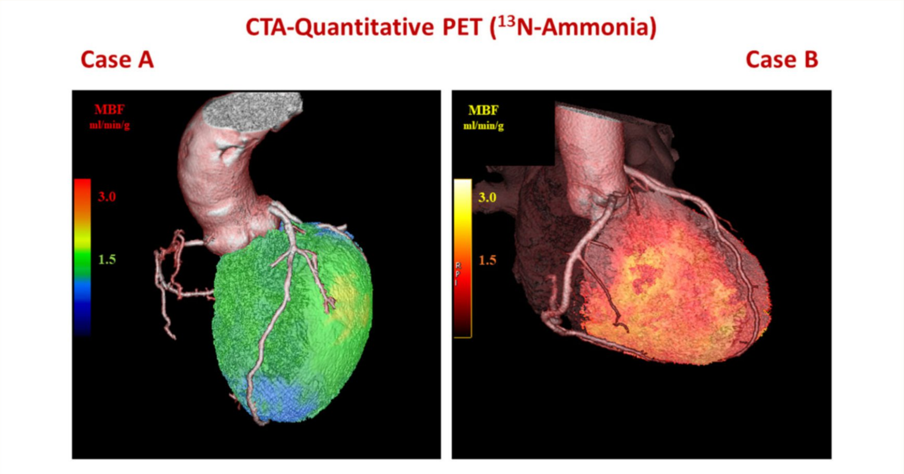

Figure 3 CTA-PET imaging. CTA-PET imaging in two patients with recent onset dyspnoea. Case A is a 67 years old man with multiple risk factors, LBBB, systolic LV dysfunction (LVEF 30%), and diffuse non-obstructive CAD at CTA. Case B is a 60 years old man with glucose intolerance, mild hypertension, systolic LV dysfunction (LVEF 33%), and normal coronary arteries at CTA. In both cases, quantitative hyperaemic (after i.v. dipyridamole) myocardial blood flow values with N-13 ammonia PET are globally reduced (normal values > 2 mL/min/g, please note different colour codes have been used in these cases) (see also Ref.[21] Liga *et al.* and Ref.[24] Neglia *et al.*).

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Conclusions and future directions

While multiple technologies and approaches to diagnose CAD in the acute and chronic stages have been developed, they address different aspects and stages of the disease. The imaging modality applied in any clinical situation should depend upon the information that is being sought. All modalities can provide information regarding LV structure and function, although echocardiography and CMR clearly have advantages. Similarly, with the general exception of CTA, all techniques can detect ischaemia and viability; although echocardiography and nuclear imaging have the largest imprint in clinical practice, CMR is increasingly being utilized. CTA is the non-invasive procedure of choice to visualize coronary anatomy. As none of them is perfect or can provide all the needed information, there is a need for clinicians to have a deep understanding of the disease within the coronary arteries and beyond. Such critical view of the disease and of our patients, together with the comprehensive knowledge of each diagnostic tool, will allow for development of the appropriate diagnostic strategies for each patient and situation, which is ultimately the goal of this document.

With the advent of newer technologies such as hybrid systems that combine nuclear imaging with CT, opportunities for obtaining complementary anatomic and functional information in a single imaging session may prove to have higher value than do current approaches. Furthermore, developments in high-definition imaging such as CT or CMR may allow for more detailed plaque evaluation and provide an opportunity to evaluate coronary plaques with a different goal, by assessing not only for stenosis and ischaemia, but to also evaluate plaque morphology and activity to improve the identification of patients at risk of acute coronary events.

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Hybrid imaging with CT and MPCI

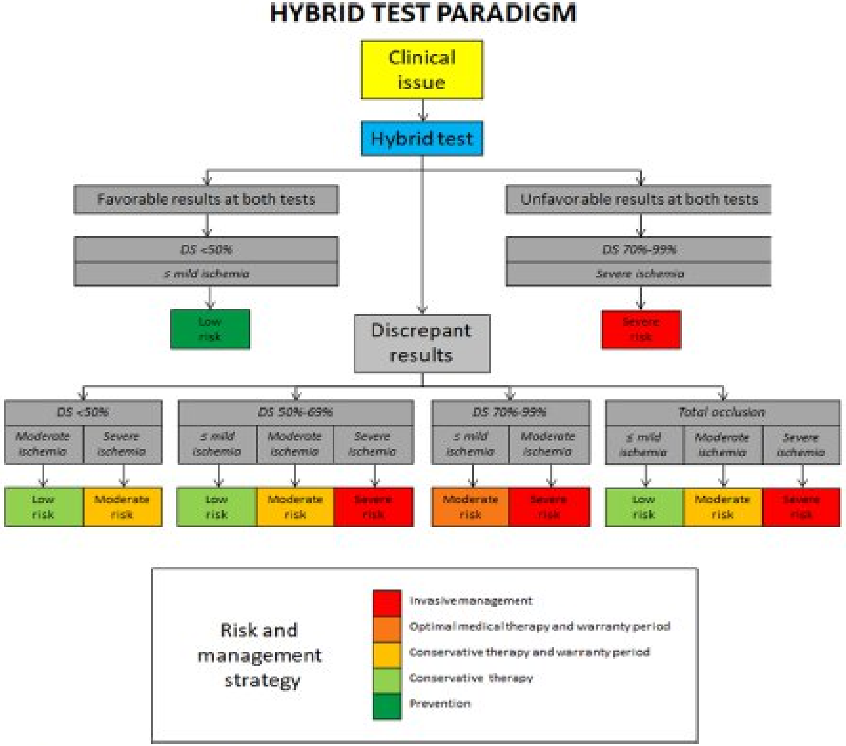
TABLE 4 Meta-Analysis for the Diagnostic Performance of Various Hybrid Cardiac Imaging Modalities

	N	Sensitivity (95% CI)	Specificity (95% CI)	Positive Likelihood Ratio (95% CI)	Negative Likelihood Ratio (95% CI)	Diagnostic Odds Ratio (95% CI)
Per-patient analysis						
SPECT/coronary CTA	5	0.92 (0.88-0.95)	0.90 (0.85-0.93)	10.38 (3.60-29.94)	0.08 (0.03-0.27)	158.16 (21.11-1185.00)
PET/coronary CTA	4	0.87 (0.80-0.92)	0.96 (0.92-0.99)	22.12 (5.20-94.00)	0.12 (0.05-0.29)	213.68 (25.94-1760.10)
CMR/coronary CTA	3	0.91 (0.83-0.96)	0.94 (0.88-0.98)	12.86 (5.90-28.02)	0.13 (0.07-0.26)	120.36 (35.42-408.98)
Per-vessel analysis						
SPECT/coronary CTA	3	0.91 (0.86-0.95)	0.95 (0.93-0.96)	18.51 (8.01-42.76)	0.11 (0.05-0.24)	174.33 (52.59-577.89)
PET/coronary CTA	3	0.81 (0.75-0.86)	0.97 (0.95-0.98)	28.42 (7.68-105.17)	0.15 (0.04-0.51)	202.03 (19.51-2091.8)
CMR/coronary CTA	2	0.80 (0.73-0.87)	0.87 (0.79-0.92)	6.37 (2.69-15.07)	0.13 (0.01-2.07)	53.95 (13.48-215.83)

CMR = cardiac magnetic resonance; PET = positron emission tomography; SPECT = single-photon emission computed tomography; other abbreviations as in Table 3.

Rizvi et al, JACC Imaging 2017

Hybrid cardiac imaging: always beneficial



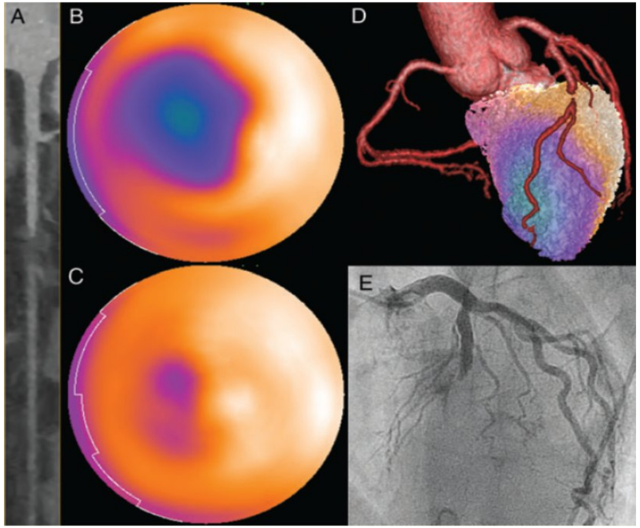
Nudi et al, J Nucl Cardiol 2019

Promise of hybrid SPECT/CT

Revolution CT:
CACS=0.7 mSv
CCTA=0.5 mSv

Discovery 530NMc:
SPECT=0.9 mSv

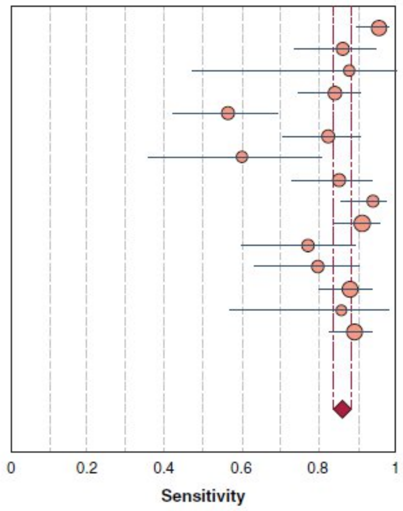
TOTAL=2.1 mSv



Benz et al, Eur Heart J 2015

CZT SPECT to diagnose CAD

FIGURE 2 Forest Plot of Univariate Analysis for Sensitivity



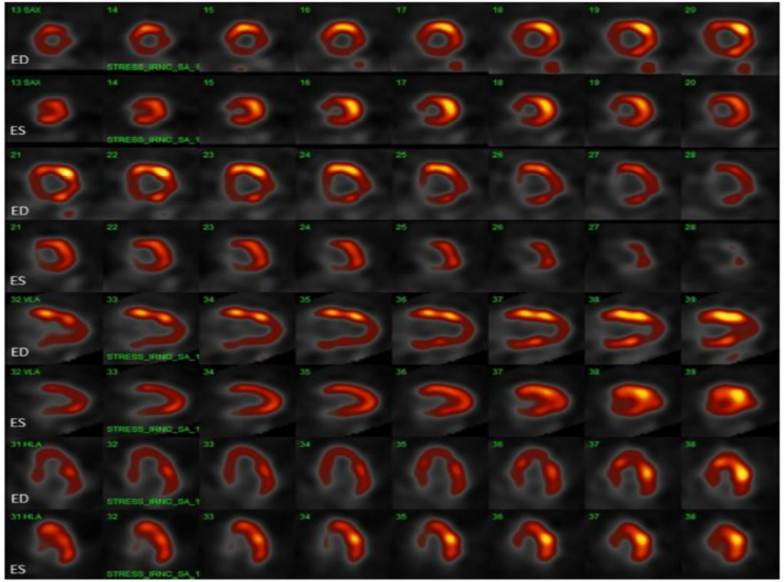
Study	Sensitivity	(95% CI)
Duvall (2011)	0.95	(0.90-0.98)
Fiechter (2011)	0.86	(0.74-0.94)
Ben-Haim (2014)	0.88	(0.47-1.00)
Chowdhury (2014)	0.84	(0.75-0.91)
Duvall (2014)	0.56	(0.42-0.70)
Goto (2014)	0.82	(0.70-0.91)
Mouden (2014)	0.60	(0.36-0.81)
Nishiyama (2014)	0.85	(0.73-0.93)
Barone-Rochette (2015)	0.94	(0.86-0.98)
Gimelli (2015)	0.91	(0.84-0.96)
Liu (2015)	0.77	(0.60-0.90)
Nakazato (2015)	0.79	(0.64-0.91)
Perrin (2015)	0.88	(0.80-0.93)
Shiraishi (2015)	0.86	(0.57-0.98)
Sharir (2016)	0.89	(0.83-0.94)

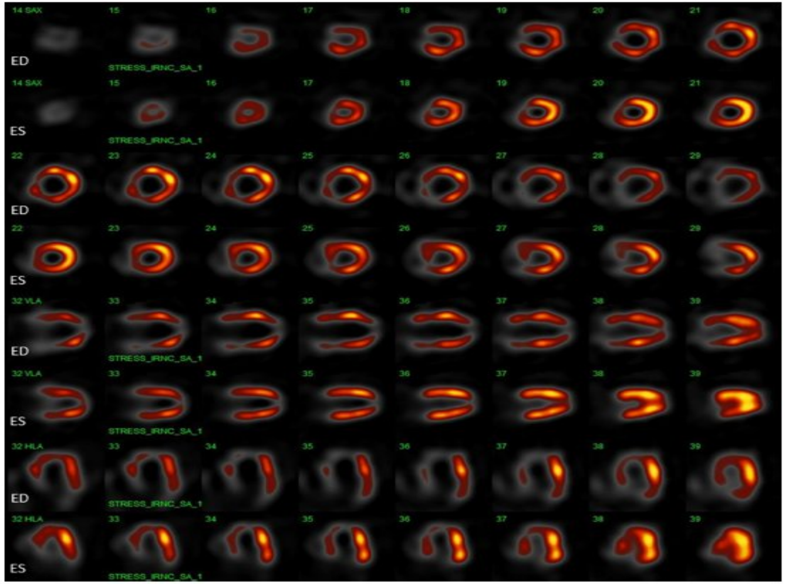
Pooled Sensitivity = 0.86 (0.83 to 0.88)
Chi-square = 61.19; df = 14 (p = 0.0000)
Inconsistency (I-square) = 77.1%

Heterogeneity was appraised using the chi-square test, with corresponding degrees of freedom (df) and p value. CI = confidence interval.

Nudi et al, J Am Coll Cardiol Cardiovasc Imag 2017

Benefits of CZT SPECT for improved diagnosis





Nudi et al, J Nucl Cardiol 2017

Myocardial Blood Flow (ml/min/g) with CZT SPECT

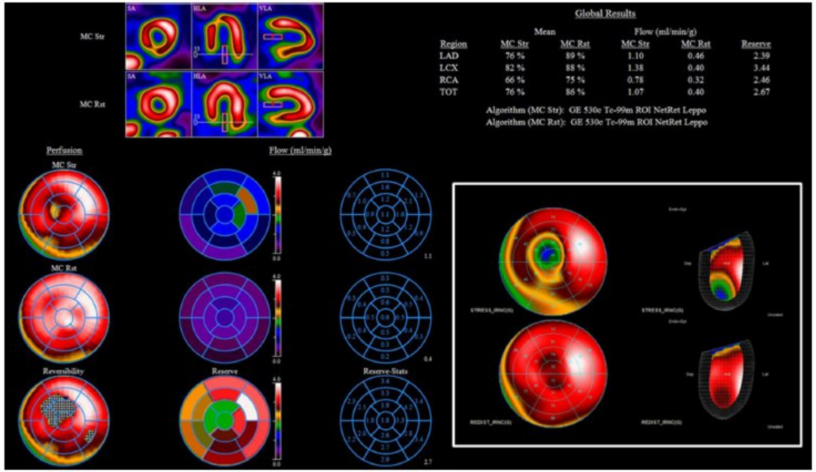


Figure 2. Myocardial blood flow and myocardial perfusion reserve (MPR), plus myocardial perfusion imaging (MPI) (right bottom inlet) in a 60-year-old gentleman with effort angina, family history of coronary artery disease (CAD), active smoking, dyslipidemia and hypertension. MPI showed ischemia in a large apical (maximal ischemia score = 3) region and the inferior (maximal ischemia score = 1) region, whereas per-vessel and global MPR were apparently normal. Notably, MPR was conversely abnormal in the apical segments. This patient later underwent invasive coronary angiography which highlighted multivessel angiographically significant CAD, and was then treated with coronary artery bypass grafting.

Nudi et al, J Nucl Cardiol 2019

Myocardial Blood Flow (ml/min/g) with CZT SPECT

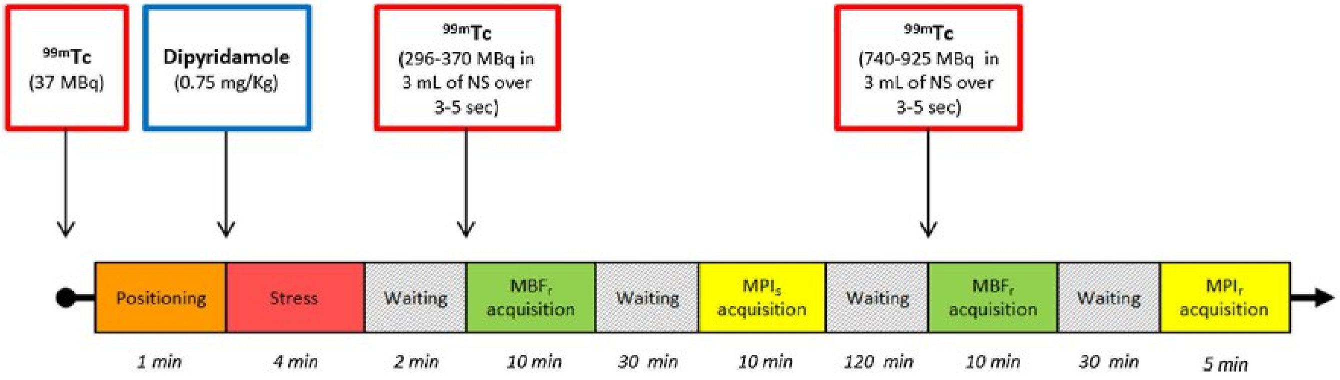


Figure 1. Study protocol. *MBF*, myocardial blood flow; *min*, minutes; *MPI*, myocardial perfusion imaging; *NS*, normal saline; *Tc*, technetium.

Nudi et al, J Nucl Cardiol 2019

Treadmill Exercise Produces Larger Perfusion Defects Than Dipyridamole Stress N-13 Ammonia PET

	Exercise Stress	Dipyridamole Stress	p Value	Correlation	Significance of Correlation
Summed stress score	9.1 ± 5.7	6.9 ± 5.9	<0.01	0.80	<0.001
Summed rest score	3.4 ± 3.3	3.2 ± 2.8	NS	0.79	<0.001
Summed difference score	5.8 ± 4.7	3.7 ± 4.6	<0.02	0.61	0.001
LV defect size (stress) (%)	19.3 ± 11.5	13.8 ± 13.6	<0.02	0.62	0.001
LV defect size (rest) (%)	8.1 ± 9.4	6.4 ± 6.5	NS	0.57	0.003

Chow al, J Am Coll Cardiol 2006

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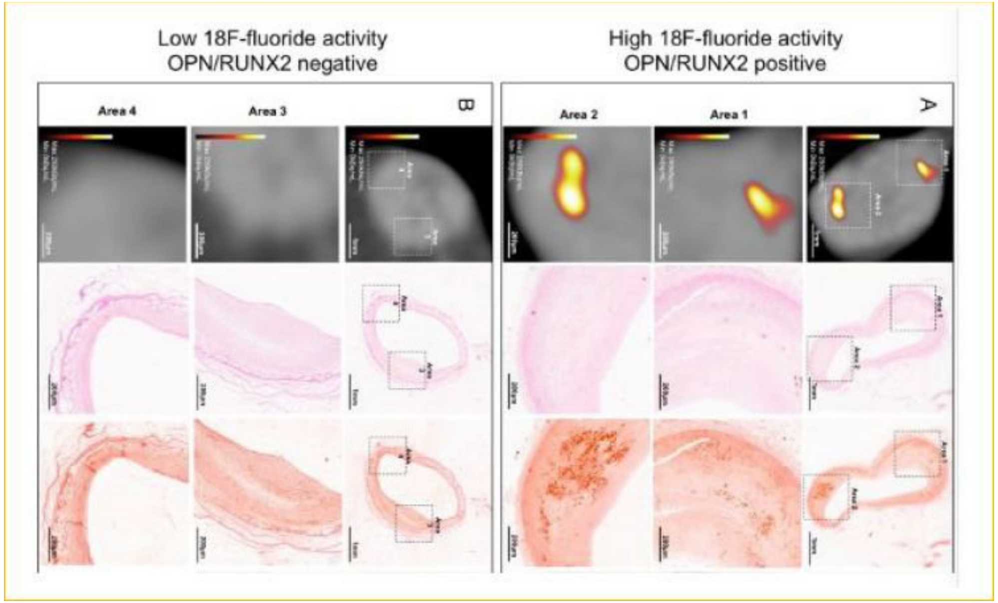
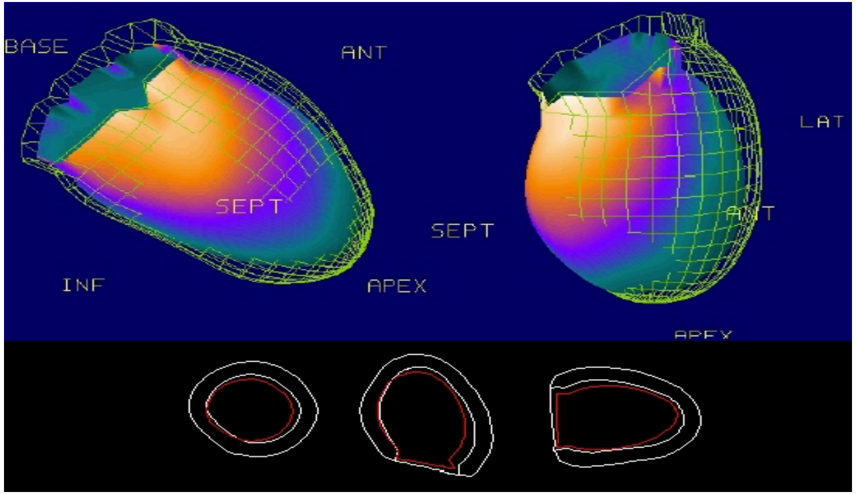
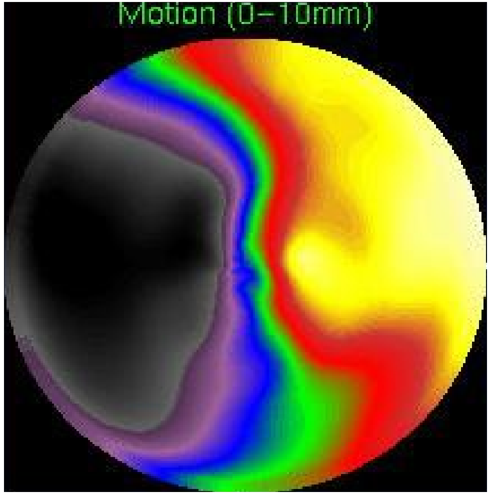


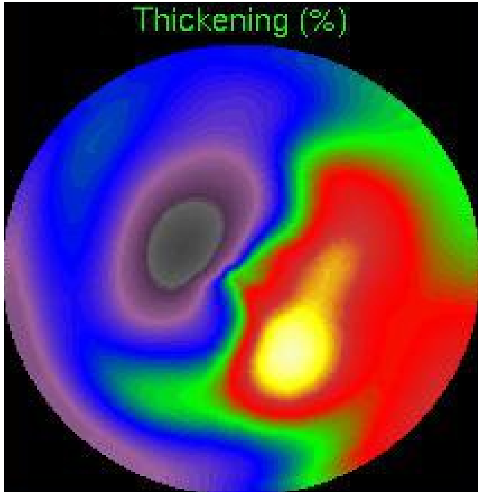
Confronto tra imaging PET con 18F-fluoruro di sodio (lesioni “calde”), reperti istologici di placca aterosclerotica.

Moss et al. Sci Rep 2020; 10; 21072

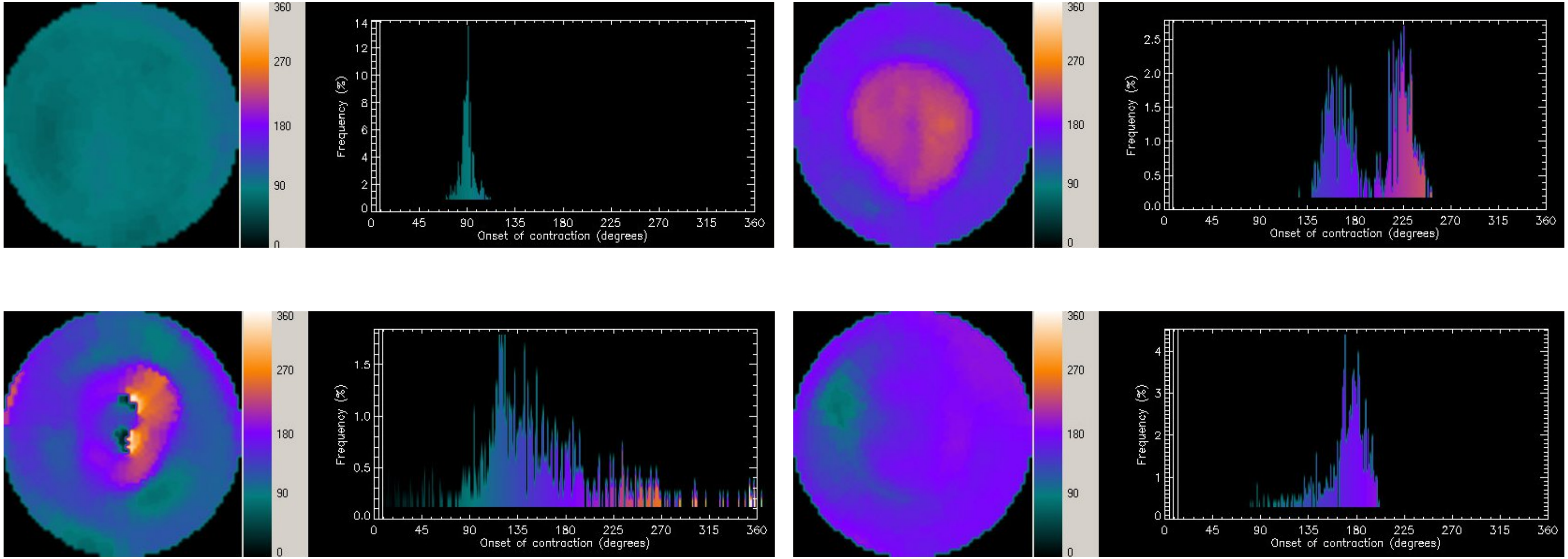
SPECT Imaging





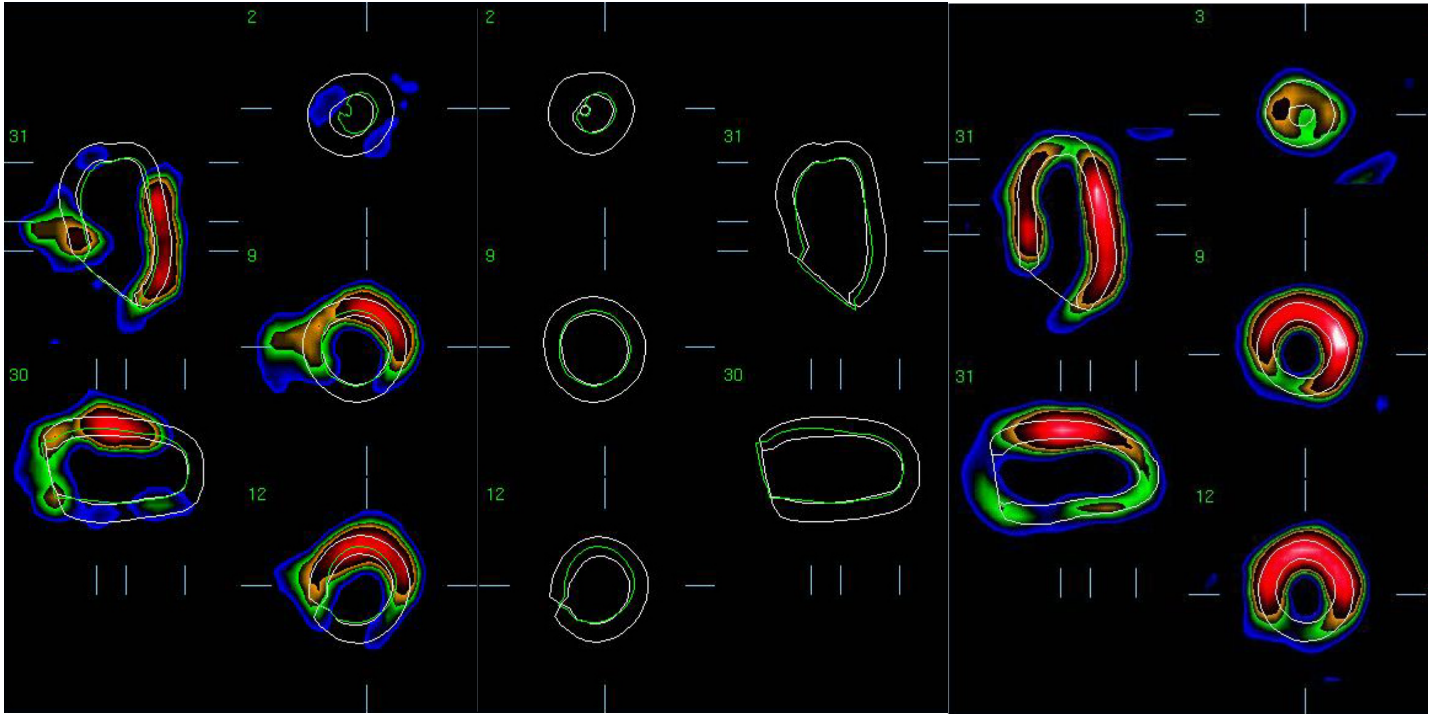


Phase Analysis of Gated Myocardial Perfusion SPECT for the Assessment of Left Ventricular Dyssynchrony

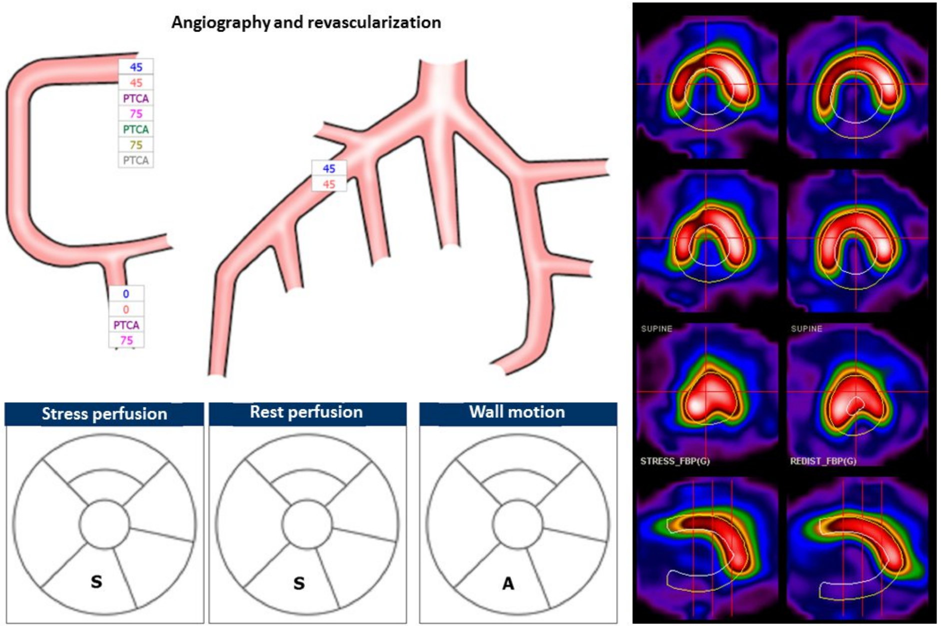


Metabolism-Perfusion Mismatch

Perfusion | Contractility | Viability



Assessment of the Fate of Myocardial Necrosis by Serial Myocardial Perfusion Imaging



Nudi et al, J Nucl Cardiol 2017

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Guidelines ESC 2019