CARDIOVASCULAR AND METABOLIC SCIENCE www.ancam.org.mx

Vol. 32 Suppl. 3
July-September 2021

doi: 10.35366/100808

Coronary atherosclerotic disease evaluation by nuclear cardiology procedures: Gate-SPECT and PET myocardial perfusion imaging

Evaluación de la enfermedad aterosclerótica coronaria mediante procedimientos de cardiología nuclear: Gate-SPECT y PET de perfusión miocárdica

Adriana Puente-Barragán, MD*

* Centro Médico Nacional «20 de Noviembre», ISSSTE, Mexico City.

Received: 14/06/2021
Accepted: 23/06/2021

INTRODUCTION

Atherosclerotic disease is the main cause of coronary obstruction, and its fearsome consequences: myocardial ischemia and infarction (MI). Significant atherosclerotic obstructions of the coronary lumen frequently produce a reduction of coronary blood flow, one of the main pathophysiologic determinants of ischemia.[1,2] The most available techniques to evaluating functional ischemia by nuclear cardiology procedures includes myocardial perfusion imaging (MPI) with single-photon emission computed tomography (SPECT), and positron emission tomography (PET). Both are effective and accurate non-invasive methods, useful not only as a diagnostic tool, but also to establish risk stratification, allowing the appropriate therapeutic decisions, regarding the need of revascularization in patients with coronary artery disease (CAD). According to the 2019 European Society of Cardiology (ESC) Guidelines for the diagnosis and management of chronic coronary syndromes,[3] it is advisable to perform a noninvasive cardiovascular imaging diagnosis functional test, with ischemic induction, in symptomatic patients with an intermediate likelihood of disease (> 15-85%), in whom obstructive CAD cannot be excluded by clinical assessment alone, and when computed tomography angiography (CTA) has shown coronary lesions of uncertain functional significance or when this latter test is not diagnostic according to the available expert specialists.

GATED-SINGLE-PHOTON EMISSION COMPUTED TOMOGRAPHY (GATED-SPECT)

Diagnosis of CAD. Gated-SPECT (Tc99m Sestamibi or tetrofosmin and Thallium-201 radiotracers), is useful in the assessment of physiological significance of anatomical coronary stenosis. In the presence of a significant coronary stenosis (≥ 50%), the sensitivity and specificity of rest/stress (stress provoked with physical exercise, drugs or both, combined) analyzed by SPECT MPI (radiation exposure 8-10 mSv with Tc and 10-12 mSv Tl-201) are 87-89% and 73-75%, with a high normalcy rate of 91%, which signals it as a good diagnostic test. Recently, novel technologies with new cardiac-dedicated ultrafast SPECT gamma cameras for MPI have been developed. The special technology with Cadmium-Zinc-Telluride (CZT) detectors have greatly improved MPI diagnosis and prognosis, enhancing imaging resolution, and decreasing time of imaging acquisition, and/or radiation exposure (5-6 mSv). Sensitivity, specificity, and diagnostic accuracy of MPI for detection of significant and functional CAD are 92.8, 69.2, and 81.4%.[4-6]

Gated-SPECT prognostic value. Simultaneous acquisition of data for the evaluation of left ventricular function (LVF),

How to cite: Puente-Barragán A. Coronary atherosclerotic disease evaluation by nuclear cardiology procedures: Gate-SPECT and PET myocardial perfusion imaging. Cardiovasc Metab Sci. 2021; 32 (s3): s258-s262. https://dx.doi.org/10.35366/100808

allows estimation of left ventricular volumes (left ventricular end systolic volume: LVESV, left ventricular end diastolic volume: LVEDV), left ventricular ejection fraction (LVEF), the assessment of the left ventricular wall movement, and wall thickness. In MPI, the size, severity, and reversibility of the defect implies the extent of risk, or the «total ischemic burden».[7] Evaluation of MPI is done following the recommendation of the American Society of Nuclear Cardiology (ASNC) SPECT Imaging Guidelines,[8] using a semi-quantitative evaluation of 17 anatomical segments[9] *(Figure 1)*. ASNC SPECT Imaging Guidelines,[8] recommend the classification of the perfusion defect severity as mild, moderate, or severe, and the extension as small, medium, or large. Also, perfusion can be classified according to the behavior of the images in rest and effort as following: 1) «fixed or nonreversible defects», refers to defects that do not change between stress and rest images 2) «reversible defects», on the contrary, are more severe and/or extensive perfusion defects on stress imaging compared to rest images. ASNC SPECT Imaging Guidelines,[8] also suggests classifying the severity of perfusion defect with a semi-quantitative evaluation, using a 0-4 score according to radiotracer uptake as normal (100% uptake), mild (10 to < 25% reduction in counts), moderate (25 to < 50% reduction), severe (≥ 50% reduction) or absent uptake. In the same way and according to the involvement of the LV mass, perfusion defects extension can be classified as a small, medium, or large defects, if respectively involves < 10, 10 to 20%, and ≥ 20% of the LV mass. Quantitative scores can be obtained, comparing the score between rest and stress in the polar maps, and can be classified in summed stress score (SSS) that results of the sum of the stress scores in all the 21 segments, summed rest score (SRS) the sum of the resting scores, and the summed difference score (SDS), which corresponds to the result of the difference obtained from the SSS and SRS (SDS = SSS-SRS). This SDS equals or corresponds to the measure of reversibility (inducible ischemia) and have shown to have a high prognostic value. Another parameter is transient cavity dilation (TID), that describes a modification if the of left ventricle (LV) cavity size, that increases on post-stress images, and it is considered abnormal with a value above 1.2. This abnormal value traduces sub-endo-cardial hypo-perfusion and it is associated with greater ischemic burden and severe and/or multivessel CAD. Lung uptake of thallium-201 in post-stress images, indicates the use of lung-heart ratio (LHR) as a prognostic indicator (> 0.55).[8] Bajaj et al. have stated that a higher pulmonary capillary wedge pressure (due to elevated LV end diastolic pressure) can lead to a slower pulmonary transit of the radioisotope and increases its extraction by pulmonary tissues. The increase of LHR represents an important marker of underlying diastolic dysfunction

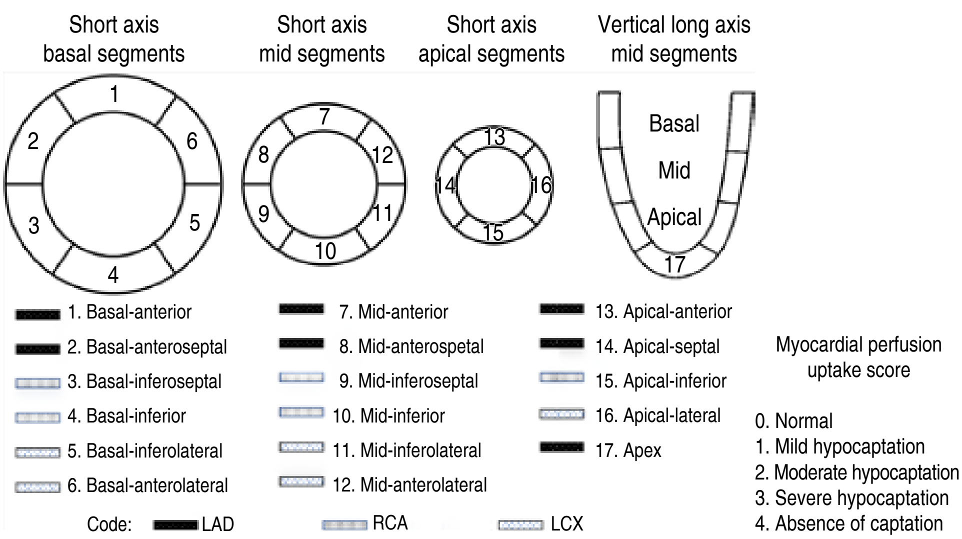

Figure 1:

Evaluation of MPI by a semiquantitative evaluation of 17 anatomical segments. MPI = myocardial perfusion imaging.
Modified from: Hansen CL et al.[9]

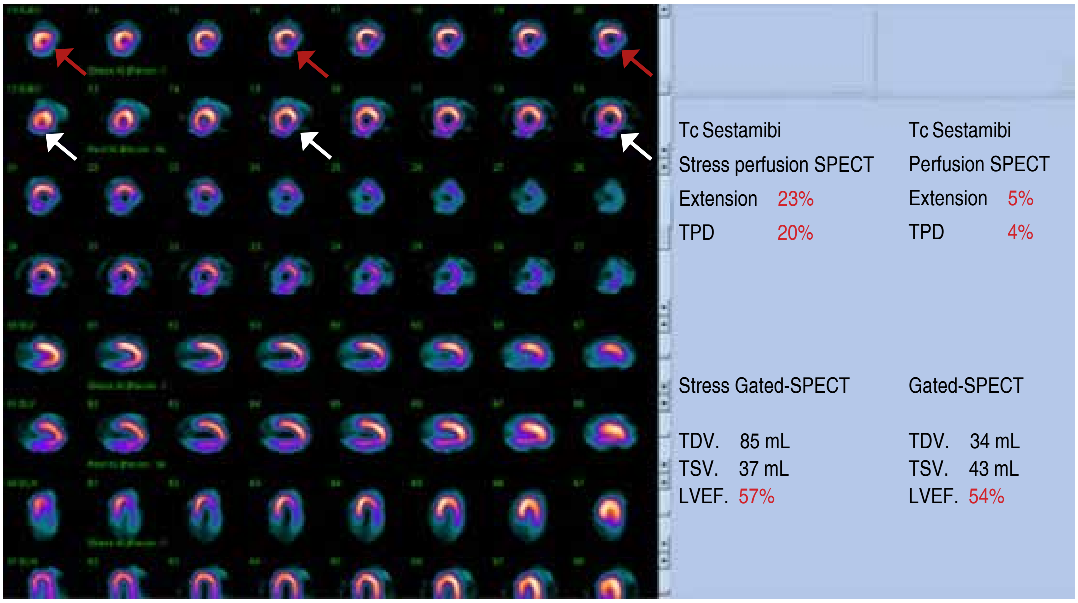

Figure 2: High risk Tc Sestamibi rest/stress Gated-SPECT. Rest image shows an extensive and moderate perfusion defect (white arrows) in the entire inferolateral wall, stress image shows moderate to severe reversibility (red arrows), equivalent to a non-transmural inferolateral infarction with moderate to severe ischemia.

SSS = summed stress score, SRS = summed rest score, SDS = summed differential score, TPD = total perfusion defect, TDV = total diastolic volume, TSV = total systolic volume, LVEF = left ventricular ejection fraction. Contribution from Nuclear Medicine Department, National Medical Center «20 de Noviembre», ISSSTE, Mexico City.

and severe CAD.[10] Quantitative perfusion and LVF evaluation, results in some independent prognostic variables associated with a high risk of mayor adverse cardiovascular events (MACE) rate. A normal Gated-SPECT MPI has an annual MACE (non-fatal myocardial infarction or cardiac death) < 1%; in the other side, a high risk MPI is accompanied by a high MACE rate (≥ 5%). The burden of ischemia guides revascularization treatment decisions. Those patients with an evidence of greater extension of ischemia (> 10-12.5%), benefit from an early revascularization, compared with those with mild degrees of ischemia who benefit better from medical therapy[10] *(Figure 2)*.

POSITRON EMISSION TOMOGRAPHY (PET)

Diagnostic and prognostic value of Stress MPI with Gated-PET. PET allows quantification of *in vivo* physiological processes of the heart. The principal characteristic of PET is its higher spatial resolution and the ability to correct scatter and soft-tissue attenuation. Also, non-invasive PET imaging technique as it has better image quality and higher interpretive accuracy, has greater sensitivity and specificity for detection of obstructive CAD than SPECT. The sensitivity of PET is around of 94-98% with a specificity of 80-89%, and an overall diagnosis accuracy of 92-100% to CAD detection.[4,5] Rest/stress PET with vasodilator (adenosine), exposes patients to significantly lower radiation dose (2.5-3 mSv) due to the nature of the radiotracers used, characterized by high energy and a very short half-life. The most common tracers used for evaluation of ischemia are Rubidium-82 (82Rb; T½ 75 sec) and Nitrogen-13-Ammonia (13 NH3; T½ 10 min). Simultaneous evaluation of coronary anatomy can be done adding computed tomography (CT) through hybrid equipment (Hybrid PET/CT), which improves the positive predictive value (PPV) and negative predictive value (NPV) of PET/CT (90 and 96% respectively) at the cost of higher exposure radiation dose (12-14 mSv).[11] ECG-gated PET (simultaneously evaluating LVF) can be done in real time at rest and during peak stress (in a different way to post-stress imaging with gated-SPECT).The evaluation of risk stratification and functional reserve are similar. Normally, LVEF increases from baseline (rest) to peak stress. This increment is named LVEF reserve or contractile reserve. When CAD is present, inversely changes in LVEF exist (decrease from rest to stress), and it is related to the magnitude of stress perfusion abnormalities (ischemic myocardium at risk), severity, and extension of CAD. Decreases of LVEF during peak stress comparing with rest, (≤ 5%), even in the absence of apparent perfusion abnormalities, reveals the existence of three-vessel disease or left main CAD. In patients with non-significant CAD obstructions or with 1-vessel disease, LVEF shows a normal contractile reserve with an increase of LVEF ≥ 5%. The NPV of an increase in the difference of LVEF from rest to peak stress with values ≥ 5%, to exclude the presence 3-vessel disease or left main CAD, is 97%. Gated-PET adds prognostic value related to a major extent and severity of perfusion defects in stress imaging (ischemia), that are associated with increasing frequency (≥ 7%) of MACE. In another way, with normal stress imaging, MACE incidence is only about 0.4%. Therefore, mortality is inversely related to LVEF. PET myocardial perfusion imaging added incremental value to LVEF (at any LVEF level, the presence of a higher summed stress score means greater risk) and in an oppositive way, LVEF added incremental value to myocardial perfusion imaging (at any summed stress score, a lower LVEF represent greater risk). PET/CT complements the anatomic information (CAD stenoses) by providing the physiologic (ischemic burden) implications[11-13] *(Figure 3)*.

Quantification of PET myocardial blood flow. PET allows the non-invasive, absolute, and dynamic global and regional quantification of myocardial blood flow (MBF) at rest (MBFR) and peak stress (MBFS), From these data,

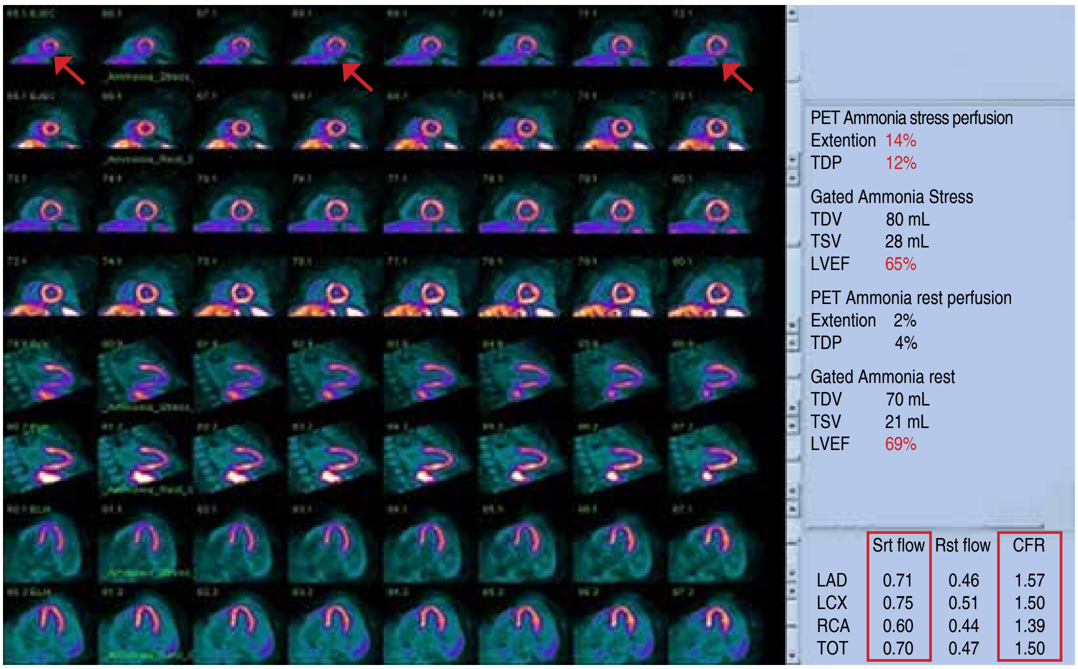

Figure 3: High risk Ammonia rest/stress Gated-PET. Rest mage with normal perfusion; stress image shows extensive moderate reversibility (red arrows) at inferolateral and inferoseptal localization in apical, mild and basal segments, equivalent to moderate ischemia. Gated images demonstrate a fall in stress LVEF > 5% (6%). MBF quantification are decreased in all coronary territories and total CFR is < 2.0 mL/g/min.
SSS = summed stress score, SRS = summed rest score, SDS = summed differential score, TDV = total diastolic volume, TSV = total systolic volume, LVEF = left ventricular ejection fraction, MBF = myocardial blood flow, CFR = coronary flow reserve. Contribution from PET-CT Unit, Medicine/Faculty, National Autonomous University of Mexico, Mexico City.

myocardial flow reserve (MFR) can be assessed (MFR = MBFS/MBFR), expressed in mL/min/g of myocardium. Blood flow quantification reflects the heart's ability to regulate coronary blood flow to the different areas of the myocardium, to reach metabolic demands, modifying the vascular tone in epicardial and small vessels. When severe multivessel CAD exist, the inability to increase flow during stress in all anatomic territories, results in a diffuse (balanced) or apparent normal myocardial perfusion, that could be accompanied with a reduction of global MBF during stress and a diminishing of MFR. A severe reduction of stress MBF (< 1.5 mL/g/min) and MFR (< 1.5) is associated with a higher risk of MACE, while a normal or preserved MFR with a value of ≥ 2.0, is associated with an excellent prognosis and better outcomes. MBF and MFR might be reduced in ischemic patients (epicardial disease), and in other special populations with endothelial dysfunction and microvascular disease, for example, women, patients with hypertrophic cardiomyopathy, diabetes, chronic kidney disease, and obesity. In the follow-up of heart transplant, these variables can signal the existence of cardiac allograft vasculopathy, characterized by intimal hyperplasia rather than CAD. In all this conditions PET MBF provides an additional incremental diagnostic and prognostic value[14,15] *(Figure 3)*.

CONCLUSIONS

Nuclear MPI with SPECT and PET, are effective and accurate non-invasive tools useful in both diagnosis and risk stratification, guiding therapeutic decisions in patients with proved or suspected atherosclerotic CAD. PET is nowadays considered the gold standard technique for non-invasive assessment of MBF. MBF quantification, allows a better assessment of MPI to detect significant epicardial CAD and it is very useful in the evaluation of coronary microvascular endothelial dysfunction, in both ischemic and non-ischemic cardiomyopathies.

REFERENCES

1. Libby P. Mechanisms of acute coronary syndromes and their Implications for therapy. N Engl J Med. 2013; 368: 2004-2013.
2. Marzilli M. Coronary atherosclerosis and myocardial ischemia. Rev Fed Arg Cardiol. 2020; 49: 43-44.
3. Saraste A, Knuuti J. ESC 2019 guidelines for the diagnosis and management of chronic coronary syndromes. Recommendations for cardiovascular imaging. Herz. 2020; 45: 409-420.
4. Al Moudi M, Sun Z, Lenzo N. Diagnostic value of SPECT, PET and PET/CT in the diagnosis of coronary artery disease: A systematic review. Biomed Imaging Interv J. 2011; 7 (2): e9.
5. Al Badarin F, Malhotra S. Diagnosis and prognosis of coronary artery disease with SPECT and PET. Curr Cardiol Rep. 2019; 21: 57-68.
6. Hage FG, AlJaroudi WA. Review of cardiovascular imaging in the Journal of Nuclear Cardiology 2019: single-photon emission computed tomography. J Nucl Cardiol. 2020; 27: 1171-1179.
7. Sabharwal N, Lahiri A. Role of myocardial perfusion imaging for risk stratification in suspected or known coronary artery disease. Heart. 2003; 89: 1291-1297.
8. Dorbala S, Ananthasubramaniam K, Armstrong I, Panithaya C, DePuey G, Einstein A et al. Single iphoton emission computed tomography (SPECT) myocardial perfusion imaging guidelines: Instrumentation, acquisition, processing, and interpretation. J Nucl Cardiol. 2018; 25: 1784-1846.
9. Hansen CL, Goldstein RA, Akinboboye OO, Berman DS, Botvinick EH, Churchwell KB et al. Myocardial perfusion and function: single photon emission computed tomography. J Nucl Cardiol. 2007; 14: e39-60.
10. Bajaj N, Singh S, Farag A, EL-Hajj S, Heo J, Iskandrian E et al. The prognostic value of non-perfusion variables obtained during vasodilator stress myocardial perfusion imaging. J Nucl Cardiol. 2016; 23: 390-413.
11. Di Carli MF, Dorbala S, Meserve J, El Fakhri G, Sitek A, Moore SC. Clinical myocardial perfusion PET/CT. J Nucl Med. 2007; 48: 783-793.
12. Dilsizian V, Bacharach S, Beanlands R, Bergmann S, Delbeke D, Dorbala S et al. ASNC imaging guidelines/ SNMMI procedure standard for positron emission tomography. (PET) nuclear cardiology procedures. J Nucl Cardiol. 2016; 23: 1187-1226.
13. Dorbala S, Di Carl M, Beanlands R, Merhige M, Williams B, Veledar E et al. Prognostic value of stress myocardial perfusion positron emission tomography. Results from a multicenter observational registry. J Am Coll Cardiol. 2013; 61: 176-184.
14. Pelletier-Galarneau M, Martineau P and El Fakhri F. Quantification of PET myocardial blood flow. Curr Cardiol Rep. 2019; 21: 11-22.
15. Ziadi M, deKemp R, Williams K, Guo A, ENG M, Chow B et al. Impaired myocardial flow reserve on rubidium-82 positron emission tomography Imaging predicts adverse outcomes in patients assessed for myocardial ischemia. J Am Coll Cardiol. 201; 58: 740-748.

Correspondence:
Adriana Puente-Barragán, MD
E-mail: adripuente@yahoo.com