Eur J Nucl Med Mol Imaging (2010) 37:349–356
DOI 10.1007/s00259-009-1308-5

ORIGINAL ARTICLE

Assessment of poststress left ventricular ejection fraction by gated SPECT: comparison with equilibrium radionuclide angiocardiography

Wanda Acampa · Maria Grazia Caprio · Emanuele Nicolai · Raffaele Liuzzi · Serena De Luca · Enza Capasso · Luca Luongo · Mario Petretta · Alberto Cuocolo

Received: 3 September 2009 / Accepted: 15 October 2009 / Published online: 1 December 2009

Abstract
Purpose We compared left ventricular (LV) ejection fraction obtained by gated SPECT with that obtained by equilibrium radionuclide angiocardiography in a large cohort of patients.
Methods Within 1 week, 514 subjects with suspected or known coronary artery disease underwent same-day stress–rest ^{99m}Tc-sestamibi gated SPECT and radionuclide angiocardiography. For both studies, data were acquired 30 min after completion of exercise and after 3 h rest.
Results In the overall study population, a good correlation between ejection fraction measured by gated SPECT and by radionuclide angiocardiography was observed at rest (r=0.82, p<0.0001) and after stress (r=0.83, p<0.0001). In Bland-Altman analysis, the mean differences in ejection fraction (radionuclide angiocardiography minus gated SPECT) were −0.6% at rest and 1.7% after stress. In subjects with normal perfusion (n=362), a good correlation between ejection fraction measured by gated SPECT and by radionuclide angiocardiography was observed at rest (r=0.72, p<0.0001) and after stress (r=0.70, p<0.0001) and the mean differences in ejection fraction were −0.9% at rest and 1.4% after stress. Also in patients with abnormal perfusion (n=152), a good correlation between the two techniques was observed both at rest (r=0.89, p<0.0001) and after stress (r=0.90, p<0.0001) and the mean differences in ejection fraction were 0.1% at rest and 2.5% after stress.
Conclusion In a large study population, a good agreement was observed in the evaluation of LV ejection fraction between gated SPECT and radionuclide angiocardiography. However, in patients with perfusion abnormalities, a slight underestimation in poststress LV ejection fraction was observed using gated SPECT as compared to equilibrium radionuclide angiocardiography.

Keywords Left ventricular function · Myocardial perfusion imaging · Gated SPECT · Radionuclide angiocardiography

W. Acampa · M. G. Caprio · R. Liuzzi · S. De Luca · E. Capasso · L. Luongo · A. Cuocolo (✉)
Department of Biomorphological and Functional Sciences,
Institute of Biostructures and Bioimages,
National Council of Research, University Federico II,
Naples, Italy
e-mail: cuocolo@unina.it

M. G. Caprio · E. Nicolai
SDN Foundation,
Institute of Diagnostic and Nuclear Development,
Naples, Italy

M. Petretta
Department of Clinical Medicine,
Cardiovascular and Immunological Sciences,
University Federico II,
Naples, Italy

Introduction

The assessment of left ventricular (LV) function is important in the management of patients with coronary artery disease. Cardiac imaging with gated single-photon emission CT (SPECT) allows the evaluation of myocardial perfusion [1–3] and subsequent analysis of global LV function from ejection fraction calculation [4, 5]. This integrated approach, combining assessment of perfusion and function, has already proven to be useful in tissue characterization [6] and prognostic stratification [7, 8]. LV ejection fraction provided by gated SPECT under resting conditions has been well validated in comparison with other techniques, such as radionuclide angiocardiography [9–11], echocardiography [10, 12], and cardiac magnetic resonance imaging [13, 14]. However, no study has been performed to compare in the same patients poststress LV ejection fraction measured by gated SPECT with data obtained by a reference technique, such as equilibrium radionuclide angiocardiography. The lack of a direct comparison is partially explained by methodological issues. In particular, stress LV ejection fraction by equilibrium radionuclide angiocardiography is usually obtained during exercise, while by gated SPECT it is in generally obtained 15 minutes to 1 hour after the stress test. Thus, this study was designed to directly compare LV ejection fraction values obtained at rest and 30 minutes after stress by gated SPECT and by equilibrium radionuclide angiocardiography in a large study population with suspected or known coronary artery disease. In addition, the impact of myocardial perfusion status on the agreement between the two techniques was evaluated.

Materials and methods

Study population

Between March 2007 and October 2008, 514 subjects with suspected or documented coronary artery disease were referred to our laboratory for the evaluation of myocardial perfusion and LV function. All subjects, following a randomized sequence, underwent within 1 week same-day stress–rest gated SPECT imaging with ^{99m}Tc-sestamibi and same-day stress–rest equilibrium radionuclide angiocardiography. No clinical or therapy changes occurred between the two studies. Patients with abnormal sinus rhythm and/or bundle branch block were excluded. The ethics committee of our institution approved the protocol and all subjects provided informed consent.

Gated SPECT imaging

All subjects underwent same-day stress–rest ^{99m}Tc-sestamibi gated SPECT according to the recommendations of the European Association of Nuclear Medicine and European Society of Cardiology [15]. A symptom-limited treadmill standardized protocol was performed with monitoring of heart rate and rhythm, blood pressure and electrocardiography (ECG). Test endpoints were age-predicted maximal heart rate, physical exhaustion, horizontal or downsloping ST segment depression of >2 mm, ST segment elevation of >1 mm, moderate to severe angina, systolic blood pressure decrease of >20 mmHg, blood pressure of >230/120 mmHg, dizziness, or clinically important cardiac arrhythmia. At peak exercise, a bolus of 370 MBq of ^{99m}Tc-sestamibi was intravenously injected. Patients continued the exercise for an additional 90–120 s after tracer injection. Two to three hours after the conclusion of the stress test, 1,110 MBq of ^{99m}Tc-sestamibi was injected at rest. Gated SPECT imaging (16 frames per cardiac cycle) was performed 30 and 60 min after tracer injection for the poststress and rest study, respectively, using a dual head rotating gamma camera (CardioMD, Philips Medical System, Best, The Netherlands) equipped with a low-energy high-resolution collimator and connected to a dedicated computer system, obtaining 64 projections (35 and 25 s per projection for the stress and the rest study, respectively) over an orbit of 180° [15]. No attenuation or scatter correction was used. After filtered back-projection, short-axis, vertical, and horizontal long-axis tomograms were generated. Relative perfusion distribution was quantitatively analysed using standardized segmentation of 17 myocardial segments [16]. A commercially available software program (Cedars-Sinai Medical Center, Los Angeles, CA) was used to automatically calculate LV ejection fraction and the variables incorporating both the extent and severity of perfusion defects (summed stress score, summed rest score and summed difference score) [17, 18]. Stress SPECT was considered abnormal in the presence of a summed stress score of ≥3. Patients with abnormal SPECT were considered to have myocardial ischaemia when the summed difference score was ≥2 [8].

Equilibrium radionuclide angiocardiography

Same-day stress–rest planar equilibrium radionuclide angiocardiography was performed in all subjects according to the recommendations of the European Association of Nuclear Medicine and European Society of Cardiology [19]. Red blood cells were labelled in vivo with 740 MBq ^{99m}Tc. Equilibrium radionuclide angiocardiography (16 frames per cardiac cycle) data were acquired 30 minutes after completion of symptom-limited physical exercise and after 2 to 3 hours rest using a dual head rotating gamma camera (CardioMD, Philips Medical System, Best, The Netherlands) equipped with a high-resolution parallel-hole collimator. Criteria for interrupting and interpreting the exercise stress test were the same as those used for the stress SPECT studies. Radionuclide angiocardiography was analysed using a semiautomatic standard commercially available software system [19]. Indices of LV function were derived by computer analysis of the background-corrected time–activity curve. Ejection fraction was computed on the basis of relative end-diastolic and end-systolic counts.

Statistical analysis

Continuous data are expressed as means±SD and categorical data as percentages. Differences were evaluated using a

t test. Linear regression analysis was used to assess the relationship between LV ejection fraction values measured by gated SPECT and radionuclide angiocardiography. A p value <0.05 was considered statistically significant. Bland-Altman analysis was used to evaluate the agreement between the two techniques [20].

Results

The study group comprised 514 subjects (349 men; mean age 61±9 years), 284 with suspected and 230 with known coronary artery disease (prior myocardial infarction in 153 patients). In all subjects, LV ejection fraction was successfully calculated at rest and after stress both by gated SPECT and by radionuclide angiocardiography. The haemodynamic parameters recorded at rest and during exercise are shown in Table 1. Heart rate, systolic and diastolic blood pressure at rest and at peak exercise, double product at peak exercise (systolic blood pressure multiplied by heart rate) and peak workload did not differ between gated SPECT and radionuclide angiocardiography. Gated SPECT showed normal myocardial perfusion in 362 subjects (220 men; mean age 61±10 years) and abnormal myocardial perfusion in 152 subjects (129 men; mean age 63±9 years). Of the latter, 47 (31%) had stress-induced ischaemia only, 44 (29%) necrosis only, and 61 (40%) necrosis with residual ischaemia.

LV ejection fraction agreement in overall study population

In the overall study population, rest and poststress LV ejection fraction values were 55±10% and 56±10% by gated SPECT and 54±9% and 58±10% by radionuclide angiocardiography, respectively. A good correlation between LV ejection fraction measured by gated SPECT and radionuclide angiocardiography was observed at rest (r=0.82, p<0.0001) and after stress (r=0.83, p<0.0001; Fig. 1). In the Bland-Altman analysis, the mean differences in LV ejection fraction (radionuclide angiocardiography minus gated SPECT) at rest and after stress were −0.6% and 1.7%, respectively. The lower and upper limits of agreement between the two techniques were −12.0% to 10.8% at rest and −10.2% to 13.7% after stress, respectively (Fig. 1).

LV ejection fraction agreement in patients with normal perfusion

In the 362 subjects with normal perfusion, rest and poststress LV ejection fraction values were 58±9% and 60±9% by gated SPECT and 57±8% and 61±9% by radionuclide angiocardiography, respectively. A good correlation between LV ejection fraction measured by gated SPECT and radionuclide angiocardiography was observed at rest (r=0.72, p<0.0001) and after stress (r=0.70, p<0.0001; Fig. 2). In the Bland-Altman analysis, the mean differences in LV ejection fraction at rest and after stress were −0.9% and 1.4%, respectively. The lower and upper limits of agreement between the two techniques were −13.1% to 11.4% at rest and −11.4% to 14.2% after stress, respectively (Fig. 2). In a separate analysis, the mean differences in LV ejection fraction at rest and after stress were 0.1% and 2.0% in men and −2.5% and 0.4% in women, respectively.

LV ejection fraction agreement in patients with abnormal perfusion

In the 152 patients with abnormal perfusion, rest and poststress LV ejection fraction values were 48±10% and 48±11% by gated SPECT and 48±9% and 51±10% by radionuclide angiocardiography, respectively. In these patients, a good correlation between the two techniques was observed at rest (r=0.89, p<0.0001) and after stress (r=0.90, p<0.0001; Fig. 3). The mean differences in LV ejection fraction at rest and after stress were 0.1% and 2.5%, respectively. The lower and upper limits of agreement were −8.6% to 8.8% at rest and −7.1% to 12.1% after stress, respectively (Fig. 3). The mean differences in LV ejection fraction at rest and after stress were 0.5% and 2.9% in men and −2.2% and 0.7% in women, respectively.

Table 1 Haemodynamic parameters recorded at rest and during exercise for the two imaging studies

	Gated SPECT		Radionuclide angiocardiography	
	Rest	Peak exercise	Rest	Peak exercise
Heart rate (beats/min)	70±13	122±11*	68±11	118±18*
Blood pressure (mmHg)				
Systolic	126±14	175±22*	125±12	172±22*
Diastolic	79±6	92±9*	79±5	92±9*
Peak double product (×10^3)	–	22±7	–	21±9
Peak workload (W)	–	96±34	–	95±33

*p<0.001 vs. rest

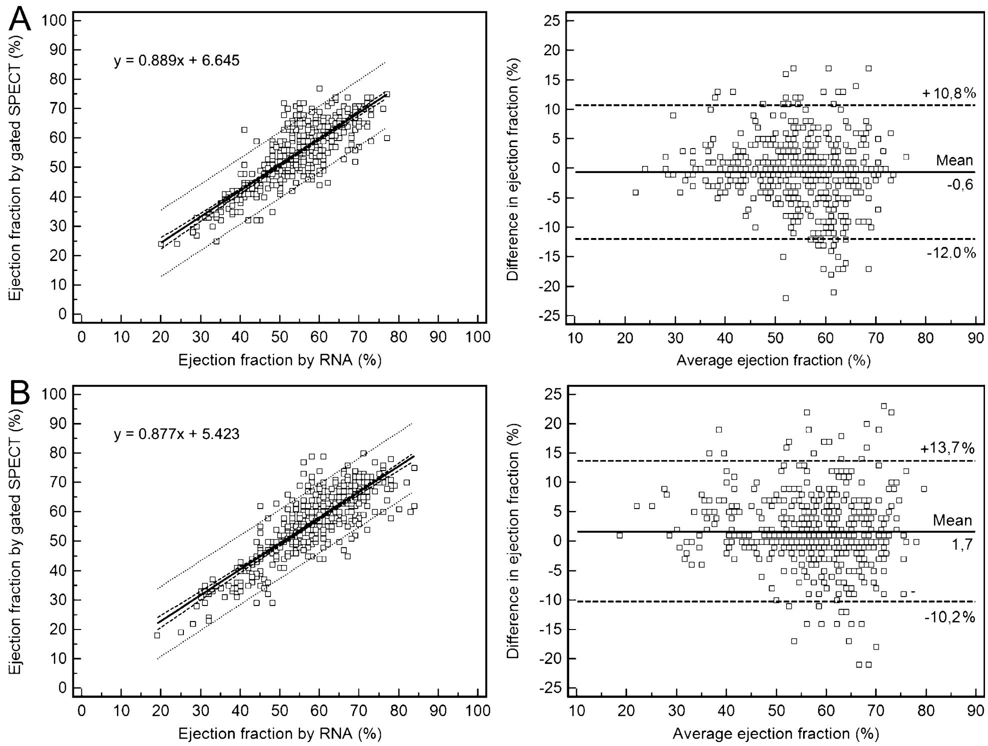

Fig. 1 Linear regression analysis and Bland-Altman plots for LV ejection fraction measurements by gated SPECT and by equilibrium radionuclide angiocardiography (*RNA*) at rest (**a**) and after stress (**b**) in the 514 subjects overall

Regression analysis and Bland-Altman analysis results, considering separately patients with stress-induced ischaemia, with necrosis, and with necrosis and residual ischaemia are presented in Table 2. In all these subgroups, a good correlation between LV ejection fraction measured by gated SPECT and radionuclide angiocardiography was observed, both at rest and after stress. In the Bland-Altman analysis, in each subgroup good agreement was found at rest, while gated SPECT slightly underestimated poststress LV ejection fraction as compared to radionuclide angiocardiography (Table 2).

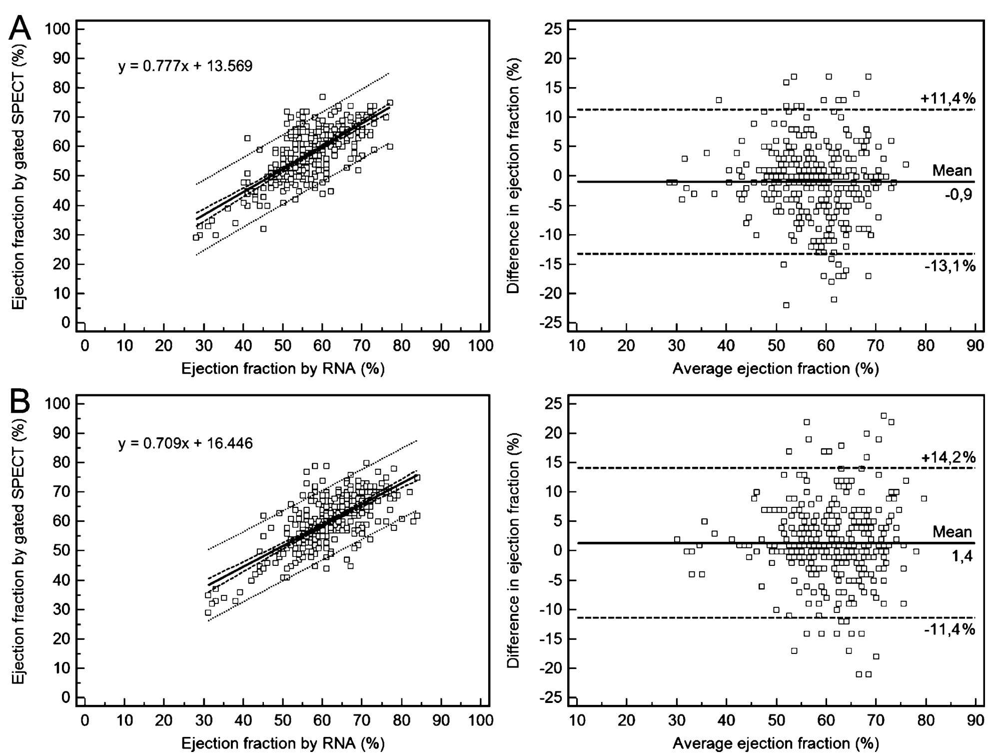

Fig. 2 Linear regression analysis and Bland-Altman plots for LV ejection fraction measurements by gated SPECT and by equilibrium radionuclide angiocardiography (*RNA*) at rest (**a**) and after stress (**b**) in the 362 subjects with normal myocardial perfusion

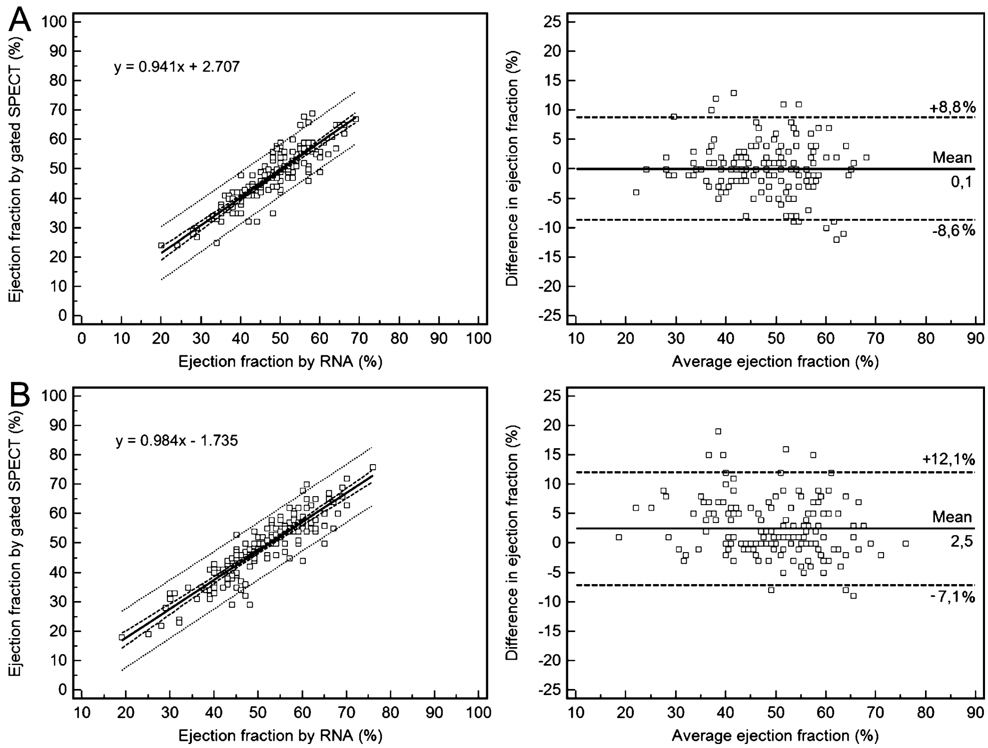

Fig. 3 Linear regression analysis and Bland-Altman plots for left ventricular ejection fraction measurements by gated SPECT and by equilibrium radionuclide angiocardiography (*RNA*) at rest (**a**) and after stress (**b**) in the 162 subjects with myocardial perfusion abnormalities

Discussion

Gated SPECT is a useful non-invasive method for the simultaneous evaluation of myocardial perfusion and LV function. Automatic quantitative programs by gated SPECT provide accurate and operator-independent information regarding LV systolic function [4, 14]. Gated SPECT measurement of LV ejection fraction at rest has been validated in several studies [9–14]. However, no study has been performed to compare gated SPECT poststress data with those obtained by other imaging modalities in the same patients.

Equilibrium radionuclide angiocardiography is an established "gold-standard" modality for the evaluation of LV function at rest and during exercise [21–23]. The lack of comparative studies between poststress gated SPECT and radionuclide angiocardiography is partially related to the different protocols recommended for the two methods [15, 19]. To our knowledge, this is the first study that directly compared LV ejection fraction by gated SPECT with equilibrium radionuclide angiocardiography. It is particularly noteworthy that, for the purposes of the present investigation, the same acquisition protocol (i.e. 16 frames per cardiac cycle) and the same delay time for poststress imaging (i.e. 30 minutes) were adopted for both techniques. Moreover, the study was large, comprising subjects with as well as without myocardial perfusion abnormalities.

Table 2 Results of linear regression and Bland-Altman analyses considering separately patients with ischaemia, necrosis and ischaemia, and necrosis

	Ischaemia (*n*=47)		Necrosis and ischaemia (*n*=61)		Necrosis (*n*=44)	
	Rest	Poststress	Rest	Poststress	Rest	Poststress
Correlation (*r*)	0.82	0.86	0.90	0.90	0.91	0.89
Slope	0.87	0.97	0.94	0.86	1.0	1.0
Intercept (%)	5.8	−0.2	0.01	−3.3	3.1	3.1
p value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Mean difference	0.8	1.8	0.0	2.5	−0.5	3.4
Limits of agreement (%)	−9.0 to 10.6	−7.8 to 11.4	-9.4 to 9-3	−8.0 to 12.9	−6.8 to 5.8	−5.0 to 11.7

Overall study population

The major finding of the present study was the good agreement between poststress LV ejection fraction by gated SPECT and radionuclide angiocardiography. In fact, there was a high correlation in the data between the two techniques and, in the Bland-Altman analysis, the mean differences in poststress LV ejection fraction was small, with reasonable limits of agreement, and without a significant degree of directional measurement bias. These results are similar to those obtained at rest in the present study as well as in previous investigations [9–14]. Interestingly, published data show a systematic underestimation by gated SPECT when eight-frame gating acquisition was used [24–26]. In contrast, Kikkawa et al. [27] compared gated SPECT results with those of radionuclide angiocardiography in the assessment of LV ejection fraction, ensuring uniform data analysis conditions with the use of a fully automated program with the same temporal resolution (32 frames per R-R interval). Their findings showed a good correlation in the data between the two techniques, and the mean difference shown in the Bland-Altman analysis, similar to our data, was considered not significant. Kikkawa et al. [27] also emphasized that despite the substantial technical differences between gated SPECT and radionuclide angiocardiography (e.g. myocardial vs. blood pool imaging, tomographic vs. planar imaging, and actual volume calculation vs. count changes) the shapes of the volume curve and the time–activity curve corresponded well, and thus any differences in these aspects can be considered trivial.

Impact of myocardial perfusion abnormalities

Patients with documented coronary artery disease and perfusion defects is a group increasingly targeted by medical therapeutic approaches [28, 29] and, therefore, it is desirable to accurately and reliably monitor these patients for the effect of therapy on cardiac function. Focusing on this cohort is a rigorous test of the gated SPECT technique, because it reflects the accuracy of an algorithm based on endocardial detection in patients whose perfusion defects prevent visualization of variable areas of the myocardium. In the 152 patients with abnormal perfusion included in the present study, a good correlation between gated SPECT and radionuclide angiocardiography was observed at rest and after stress. Accordingly, the mean difference in LV ejection fraction was 0.1% at rest and 2.5% after stress, indicating a slight underestimation for gated SPECT. Also considering separately patients with inducible ischaemia, with necrosis, and with necrosis and residual ischaemia, in all the three subgroups a good correlation was observed both at rest and after stress, and in the Bland-Altman analysis, a good agreement was found at rest. Again, gated SPECT slightly underestimated poststress LV ejection fraction values as compared to radionuclide angiocardiography.

Manrique et al. [30], in 50 patients with large perfusion defects and LV dysfunction, found that gated SPECT significantly underestimated LV ejection fraction at rest as compared to equilibrium radionuclide angiocardiography. These results could be explained by several factors. First, the gated SPECT cycle comprised eight time segments, while the equilibrium radionuclide angiocardiography cycle comprised 16 time segments; thus, end systole could be better resolved by the radionuclide angiocardiography cycle than by the gated SPECT cycle. The overall 5% underestimation reported by these authors for gated SPECT is consistent with the use of eight-frame gating [30]. This temporal under-sampling may induce a truncation of end systole, leading to a reduction in the measured LV ejection fraction. Germano et al. [4] confirmed this phenomenon, demonstrating a 4% average reduction in ejection fraction by using eight-frame as compared to 16-frame gating. On the other hand, Williams and Taillon [31] noted a greater underestimation for high values of LV ejection fraction. Another possible explanation is that, in regions with myocardial scarring, the thinner the myocardium is, the more it is subject to the partial volume effect phenomenon. A poor agreement between gated SPECT and cardiac magnetic resonance imaging in assessing wall thickening has been found in segments with severely reduced perfusion [32]. This phenomenon may lead to overestimation of end-systolic volumes and, therefore, to underestimation of ejection fraction. Finally, the extent and severity of perfusion defect, as well as the presence of dyskinesia, could potentially interfere with ejection fraction measurements.

Our findings show that the underestimation of poststress ejection fraction is higher in patients with myocardial perfusion abnormalities as compared to those without. It was demonstrated that the defect severity associated with myocardial necrosis may represent a potential limitation of the detection algorithm in finding the correct endocardial edge when myocardial counts are severely reduced [33]. It should be also considered that patients with stress-induced perfusion defects might also have reversible ischaemic LV dysfunction that may persist up to several hours after stress testing. Therefore, LV function may not have returned to baseline by the time of poststress acquisition. To avoid the possible influence of different time intervals between acquisitions, in the present investigation, the same delay time for poststress imaging was used for both gated SPECT and radionuclide angiocardiography. However, it should be considered that the underestimation of poststress ejection fraction in patients with myocardial perfusion abnormalities might affect the detection of myocardial stunning.

Conclusion

In a large cohort of subjects with suspected or known coronary artery disease, a good agreement between gated SPECT and equilibrium radionuclide angiocardiography in the evaluation of LV ejection fraction was found both at rest and poststress, using the same acquisition protocol and the same delay time for poststress imaging. However, in patients with myocardial perfusion abnormalities gated SPECT slightly underestimates poststress LV ejection fraction as compared to equilibrium radionuclide angiocardiography.

References

1. Smanio PE, Watson DD, Segalla DL, Vinson EL, Smith WH, Beller GA. Value of gating of technetium-99 m sestamibi single-photon emission computer tomographic imaging. J Am Coll Cardiol 1997;30:1687–92.
2. Germano G, Kavanagh PB, Waechter P, Areeda J, Van Kriekinge S, Sharir T, et al. A new algorithm for the quantitation of myocardial perfusion SPECT. I: technical principles and reproducibility. J Nucl Med 2000;41:712–19.
3. Sharir T, Germano G, Waechter PB, Kavanagh PB, Areeda JS, Gerlach J, et al. A new algorithm for the quantitation of myocardial perfusion SPECT. II: validation and diagnostic yield. J Nucl Med 2000;41:720–7.
4. Germano G, Kiat H, Kavanagh PB, Moriel M, Mazzanti M, Su HT, et al. Automatic quantification of ejection fraction from gated sestamibi SPECT. J Nucl Med 1995;36:2138–47.
5. Faber TL, Cooke CD, Folks RD, Vansant JP, Nichols KJ, DePuey EG, et al. Left ventricular function and perfusion from gated SPECT perfusion images: an integrated method. J Nucl Med 1999;40:650–9.
6. DePuey EG, Rozanski A. Using gated technetium-99m-sestamibi SPECT to characterize fixed myocardial defects as infarct or artifact. J Nucl Med 1995;36:952–5.
7. Sharir T, Germano G, Kavanagh PB, Lai S, Cohen I, Lewin HC, et al. Incremental prognostic value of post-stress left ventricular ejection fraction and volume by gated myocardial perfusion single photon emission computed tomography. Circulation 1999;100:1035– 42.
8. Sharir T, Germano G, Kang X, Lewin HC, Miranda R, Cohen I, et al. Prediction of myocardial infarction versus cardiac death by gated myocardial perfusion SPECT: risk stratification by the amount of stress-induced ischemia and the poststress ejection fraction. J Nucl Med 2001;42:831–7.
9. Kumita S, Cho K, Nakajo H, Toba M, Uwamori M, Mizumura S, et al. Assessment of left ventricular diastolic function with electrocardiography-gated myocardial perfusion SPECT: comparison with multigated equilibrium radionuclide angiography. J Nucl Cardiol 2001;8:568–74.
10. Chua T, Yin LC, Thiang TH, Choo TB, Ping DZ, Leng LY. Accuracy of the automated assessment of left ventricular function with gated perfusion SPECT in the presence of perfusion defects and left ventricular dysfunction: correlation with equilibrium radionuclide ventriculography and echocardiography. J Nucl Cardiol 2000;7:301–11.
11. Massardo T, Jaimovich R, Lavados H, Gutiérrez D, Rodríguez JC, Saavedra JM, et al. Comparison of radionuclide ventriculography using SPECT and planar techniques in different cardiac conditions. Eur J Nucl Med Mol Imaging 2007;34:1735–46.
12. Choragudi NL, Prakash AM, Sun Y, Prasad P, Chiaramida SA, Lucariello RJ. Comparison of echocardiography with technetium 99m-gated single photon emission computed tomography as diagnostic tools for left ventricular ejection fraction. Echocardiography 2001;18:627–32.
13. Bavelaar-Croon CD, Kayser HW, van der Wall EE, de Roos A, Dibbets-Schneider P, Pauwels EK, et al. Left ventricular function: correlation of quantitative gated SPECT and MR imaging over a wide range of values. Radiology 2000;217:572–5.
14. Schaefer WM, Lipke CSA, Standke D, Kühl HP, Nowak B, Kaiser HJ, et al. Quantification of left ventricular volumes and ejection fraction from gated 99mTc-MIBI SPECT: MRI validation and comparison of the Emory Cardiac Tool Box with QGS and 4D-MSPECT. J Nucl Med 2005;46:1256–63.
15. Hesse B, Tägil K, Cuocolo A, Anagnostopoulos C, Bardiés M, Bax J, et al. EANM/ESC procedural guidelines for myocardial perfusion imaging in nuclear cardiology. Eur J Nucl Med Mol Imaging 2005;32:855–97.
16. Cerqueira MD, Weissman NJ, Dilsizian V, Jacobs AK, Kaul S, Laskey WK, et al. Standardized myocardial segmentation and nomenclature for tomographic imaging of the heart: a statement for healthcare professionals from the Cardiac Imaging Committee of the Council on Clinical Cardiology of the American Heart Association. Circulation 2002;105:539–42.
17. Berman DS, Hachamovitch R, Kiat H, Cohen I, Cabico JA, Wang FP, et al. Incremental value of prognostic testing in patients with known or suspected ischemic heart disease: a basis for optimal utilization of exercise technetium-99m sestamibi myocardial perfusion single-photon emission computed tomography. J Am Coll Cardiol 1995;26:639–47.
18. Berman DS, Abidov A, Kang X, Hayes SW, Friedman JD, Sciammarella MG, et al. Prognostic validation of a 17-segment score derived from a 20-segment score for myocardial perfusion SPECT interpretation. J Nucl Cardiol 2004;11:414–23.
19. Hesse B, Lindhardt TB, Acampa W, Anagnostopoulos C, Ballinger J, Bax JJ, et al. EANM/ESC guidelines for radionuclide imaging of cardiac function. Eur J Nucl Med Mol Imaging 2008;35:851–85.
20. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986;1:307–10.
21. Jones RH, McEwan P, Newman GE, Port S, Rerych SK, Scholz PM, et al. Accuracy of diagnosis of coronary artery disease by radionuclide measurement of left ventricular function during rest and exercise. Circulation 1981;64:586–601.
22. Cuocolo A, Sax FL, Brush JE, Maron BJ, Bacharach SL, Bonow RO. Left ventricular hypertrophy and impaired diastolic filling in essential hypertension. Diastolic mechanisms for systolic dysfunction during exercise. Circulation 1990;81:978–86.
23. Spinelli L, Nicolai E, Acampa W, Imbriaco M, Pisani A, Rao MA, et al. Cardiac performance during exercise in patients with Fabry's disease. Eur J Clin Invest 2008;38:910–7.
24. Peace RA, Adams PC, Lloyd JJ. Effect of sex, age, and weight on ejection fraction and end-systolic volume reference limits in gated myocardial perfusion SPECT. J Nucl Cardiol 2008;15:86–93.
25. Vallejo E, Dione DP, Sinusas AJ, Wackers FJ. Assessment of left ventricular ejection fraction with quantitative gated SPECT: accuracy and correlation with first-pass radionuclide angiography. J Nucl Cardiol 2000;7:461–70.
26. Kondo C, Fukushima K, Kusakabe K. Measurement of left ventricular volumes and ejection fraction by quantitative gated SPET, contrast ventriculography and magnetic resonance imaging: a meta-analysis. Eur J Nucl Med Mol Imaging 2003;30:851–88.
27. Kikkawa M, Nakamura T, Sakamoto K, Sugihara H, Azuma A, Sawada T, et al. Assessment of left ventricular diastolic function

from quantitative electrocardiographic-gated 99mTc-tetrofosmin myocardial SPET. Eur J Nucl Med 2001;28:593–601.
28. Lüscher TF, Pieper M, Tendera M, Vrolix M, Rutsch W, van den Branden F, et al. A randomized placebo-controlled study on the effect of nifedipine on coronary endothelial function and plaque formation in patients with coronary artery disease: the ENCORE II study. Eur Heart J 2009;30:1590–7.
29. Califf RM, Lokhnygina Y, Velazquez EJ, McMurray JJ, Leimberger JD, Lewis EF, et al. Usefulness of beta blockers in high-risk patients after myocardial infarction in conjunction with captopril and/or valsartan (from the VALsartan In Acute Myocardial Infarction [VALIANT] trial). Am J Cardiol 2009;104:151–7.
30. Manrique A, Paraggi M, Véra P, Vilain D, Lebtahi R, Cribier A, et al. 201T1 and 99mTc-MIBI gated SPECT in patients with large perfusion defects and left ventricular dysfunction: comparison with equilibrium radionuclide angiography. J Nucl Med 1999;40:805–9.
31. Williams KA, Taillon LA. Left ventricular function in patients with coronary artery disease assessed by gated tomographic myocardial perfusion images: comparison with assessment by contrast ventriculography and first-pass radionuclide angiography. J Am Coll Cardiol 1996;27:173–81.
32. Gunning MG, Anagnostopoulos C, Forbat DG, SM EPJ, Underwood SR. Gated technetium-99m-tetrofosmin SPECT and cine MRI to assess left ventricular contraction. J Nucl Med 1997;38:438–42.
33. Johnson LL, Verdesca SA, Aude WY, Xavier RC, Nott LT, Campanella MW, et al. Postischemic stunning can affect left ventricular ejection fraction and regional wall motion on post-stress gated sestamibi tomograms. J Am Coll Cardiol 1997;30:1641–8.