

Ventricular Function Following Coronary Artery Bypass Grafting: Comparison between Gated SPECT and Cardiac Magnetic Resonance Imaging

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Summary

Background: The assessment of left ventricular function may be impaired by the abnormal interventricular septal motion frequently found after coronary artery bypass grafting (CABG). Studies on the validation of gated SPECT as a tool for the assessment of left ventricular function in this patient group are scarce.

Objective: We investigated the agreement and correlation between left ventricular ejection fraction (LVEF), end-diastolic volume (EDV), and end-systolic volume (ESV) as obtained using electrocardiogram-gated myocardial perfusion scintigraphy (gated SPECT) and cardiac magnetic resonance imaging in 20 patients undergoing coronary artery bypass grafting.

Methods: Correlation was measured using Spearman's correlation coefficient (ρ). Agreement was assessed using Bland-Altman analysis.

Results: A good correlation was found between gated SPECT and cardiac magnetic resonance imaging in patients after CABG with regard to left ventricular ejection fraction ($\rho = 0.85$; $p = 0.0001$), moderate correlation for end-diastolic volume ($\rho = 0.51$; $p = 0.02$), and non-significant correlation for end-systolic volume ($\rho = 0.13$; $p = 0.5$). Agreement ranges for LVEF, ESV and EDV were: -20% to 12%; -38 to 54 ml and; -96 to 100 ml, respectively.

Conclusion: A reliable correlation was found for left ventricular ejection fraction as obtained by gated SPECT and magnetic resonance imaging in patients undergoing CABG. For ventricular volumes, however, the correlation is not adequate. (Arq Bras Cardiol 2009;92(5):327-333)

Key words: Radionuclide imaging; magnetic resonance imaging; myocardial revascularization; ventricular function, left; myocardial reperfusion.

Introduction

Myocardial perfusion scintigraphy with electrocardiogram-gated tomographic images (gated SPECT) has been used for the simultaneous assessment of myocardial perfusion and the global and segmental left ventricular function. This technique is well validated and has been part of the cardiologic diagnostic armamentarium for more than a decade¹⁻³. Cardiac magnetic resonance imaging (CMRI) is considered the gold-standard technique for the assessment of ventricular function thanks to its excellent spatial and temporal resolution⁴. A meta-analysis concluded that measurements of ventricular volumes and left ventricular ejection fraction obtained using gated SPECT have a very good correlation with those obtained

using CMRI⁵. No definitive evidence exists on whether the comparative accuracy between gated SPECT and CMRI is different across the various patient subgroups. Although the development of abnormal interventricular septal motion is recognized in the postoperative period of cardiac surgeries⁶, the impact of this contractile abnormality on the accuracy of gated SPECT has not been fully assessed^{7,8}. It is important that this technique be assessed in this situation, because abnormal interventricular septal motion following cardiac surgery is known to make the assessment of left ventricular function difficult when using conventional techniques such as echocardiography, equilibrium radionuclide ventriculography and contrast-enhanced ventriculography⁹. Assessment of the left ventricular function following coronary artery bypass grafting is essential for the quantification of contractile recovery (viable myocardium) in individuals with left ventricular dysfunction, as well as for the detection of functional loss during the procedure (perioperative infarction).

The objective of this study was to evaluate the accuracy of global left ventricular function parameters, namely ventricular

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volumes and ejection fraction, using gated SPECT, and to compare these results with those obtained with CMRI in patients with abnormal septal motion following coronary artery bypass grafting.

Methods

Twenty patients who had undergone coronary artery bypass grafting in the previous 12 months and who presented abnormal interventricular septal motion on echocardiography were included in this study. Patients were excluded if one of the following factors was present:

- 1) atrial fibrillation,
- 2) third-degree left bundle branch block,
- 3) non-sinus rhythm,
- 4) artificial cardiac pacemaker,
- 5) six or more extrasystoles per minute, and
- 6) pregnancy or breastfeeding.

The study protocol was approved by the Hospital Ethics Committee. All individuals were informed of the study and gave their informed consent. The patients were selected from the Department of Cardiac Surgery of Clementino Fraga Filho University Hospital. A minimum period of three months (mean of eight months) after revascularization had elapsed for all patients.

The individuals prospectively underwent resting gated SPECT myocardial perfusion scintigraphy and cardiac magnetic resonance imaging within a 2-week interval of each other at most.

Technetium-99m-sestamibi (Tc 99m sestamibi) myocardial perfusion scintigraphy was performed as follows: after intravenous administration of 740 MBq of radiotracer at rest, tomographic images were obtained at 180° (extending from 45° right anterior oblique to 45° left posterior oblique) in 32 stops gated with the patient's electrocardiogram, and the RR interval was divided into 8 frames, in a total of 256 frames per study. The beat length acceptance window was set at 50%, with a 140-keV photopeak and 15% energy window. A low-energy, high-resolution collimator was used, with 64x64 matrices, and 35 seconds per stop. The eight ECG-gated projections were filtered using a 2-D Butterworth filter (order 2.5; frequency of 0.3 cycles per pixel) and automatically reconstructed in transaxial images using filtered backprojection with a ramp filter. Neither attenuation nor scatter correction was performed. Gated SPECT images were automatically reconstructed by the Germano et al³.

Cardiac magnetic resonance imaging was performed in a 1.5-Tesla scanner (Horizon, General Electric Medical Systems, Milwaukee, Wisconsin), with a 23-mT/m gradient, body and torso phased-array coils⁸. The Fastcard software was used during breath hold (spoiled gradient-echo, gradient-echo) in the LV horizontal (four chambers) and vertical (two chambers) long axes, as well as in the LV short axis. Nine images of the cardiac phases were obtained within the RR interval in each view plane. Ventricular volumes were calculated using the Simpson's rule with manual tracing of the endocardial border in each short-axis image⁹. Left ventricular ejection fraction

(LVEF) was calculated from the values of end-diastolic volume (EDV) and end-systolic volume (ESV)⁹.

Statistical analysis

Measurements were always taken twice by the same observer, and the mean value was used for the analysis. The reproducibility of the techniques was considered satisfactory. Regression analysis was used to determine the correlation between LVEF, EDV and ESV as measured by ECG-gated SPECT and by CMRI. Spearman's correlation coefficient (ρ) was derived in order to evaluate the correlation between the two techniques. A Bland-Altman plot was used to demonstrate systematic trends in the differences between the two techniques. With this plot, the mean value of the measurements obtained with the two techniques is depicted in the ordinate axis, and the differences between the two measurements are shown in the abscissa axis. The differences between the groups were assessed using the chi square test or Fisher's exact test, when appropriate. Values were expressed as means plus or minus one standard deviation. P values equal to or lower than 0.05 were considered significant.

Results

All the 20 patients underwent ECG-gated SPECT and CMRI uneventfully. One of the patients was excluded from the analysis due to failure in the capture of the electrocardiographic signal during the scintigraphic study; therefore the comparative analyses included the remaining 19 patients.

Left ventricular ejection fraction

Values of ejection fraction estimates are shown in Table 1. No significant difference was found between the groups regarding the mean left ventricular ejection fraction as determined by ECG-gated SPECT ($54\% \pm 8\%$) in comparison to the mean value estimated by CMRI ($58\% \pm 12\%$, $p = \text{NS}$). A good correlation was observed between LVEF measurements as obtained with ECG-gated SPECT and those obtained with CMRI ($\rho = 0.78$, $p = 0.0001$). Results of linear regression analysis in the patient sample are shown in Figure 1. Results of the Bland-Altman analysis are shown in Figure 2, where it can be observed that the left ventricular ejection fraction tends to be slightly underestimated by ECG-gated SPECT in comparison to CMRI.

End-diastolic volume

End-diastolic volume values are shown in Table 1. No significant difference was found between the groups regarding mean EDV as determined by ECG-gated SPECT (105 ± 38 ml) in comparison to the mean value estimated by CMRI (107 ± 39 ml, $p = \text{NS}$). No correlation was observed between EDV measurements as obtained with ECG-gated SPECT and those obtained with CMRI ($\rho = 0.013$, $p = 0.5$). Results of the linear regression analysis in the patient sample are shown in Figure 3. Results of the Bland-Altman analysis are shown in Figure 4, where it can be observed that left ventricular EDV tends to be slightly overestimated by ECG-gated SPECT in comparison

to CMRI; however, the 49-ml standard deviation indicates a greater variability of this measurement.

End-systolic volume

End-systolic volume values are shown in Table 1. No significant difference was found between the groups regarding mean ESV as determined by ECG-gated SPECT (50 ± 25 ml) in comparison to the mean value estimated by CMRI (42 ± 24 ml, $p = \text{NS}$). A good correlation was observed between ESV measurements as obtained with ECG-gated SPECT and those obtained with CMRI ($\rho = 0.51$, $p = 0.02$). Results of the linear regression analysis in the patient sample are shown in Figure 5. Results of the Bland-Altman analysis are shown in Figure 6, where it can be observed that ECG-gated SPECT has a better agreement with CMRI for ESV than for EDV (Figure 4).

Discussion

The present study evaluated the correlation and agreement between the measurements of left ventricular systolic function (ventricular volumes and ejection fraction) as obtained using the gated-SPECT technique in comparison to magnetic resonance imaging in patients undergoing coronary artery bypass grafting. Overall, a satisfactory correlation was found between the two techniques. However, the assessment of left ventricular end-diastolic volume showed a correlation poorer than clinically desirable. Likewise, the Bland-Altman agreement plots demonstrated broad agreement ranges between the methods, which may have practical clinical implications.

Several studies¹⁰⁻¹² demonstrated that left ventricular systolic function is an important prognostic factor, especially left ventricular ejection fraction in ischemic heart diseases in the

Table 1 - Values of ejection fraction (LVEF), end-diastolic volumes (EDV), end-systolic volumes (ESV), with means and standard deviation of the sample. EF-CMRI = ejection fraction on cardiac magnetic resonance imaging

Patients	LVEF Gated SPECT	EF CMRI	ESV – Gated SPECT	ESV CMRI	EDV – Gated SPECT	EDV CMRI
	(%)	(%)	(ml)	(ml)	(ml)	(ml)
1	68	67	16	35	51	107
2	69	59	18	42	59	105
3	45	55	55	80	100	181
4	46	47	82	47	151	90
5	38	41	102	129	164	221
6	64	67	26	39	73	122
7	52	47	64	58	133	110
8	61	70	23	31	61	107
9	55	61	32	39	71	101
10	48	55	42	38	99	87
11	53	61	66	35	134	91
12	-	46	-	93	-	172
13	54	56	44	33	96	76
14	52	67	61	33	128	100
15	48	42	79	40	152	70
16	46	38	100	45	186	87
17	48	52	46	29	90	62
18	64	84	26	12	73	80
19	64	73	30	24	82	88
20	58	75	43	20	102	82
Mean	54	58	50	42	105	107
Standard deviation	8	12	25	24	38	39
P value of the comparison Gated x CMRI	0.1		0.2		0.4	

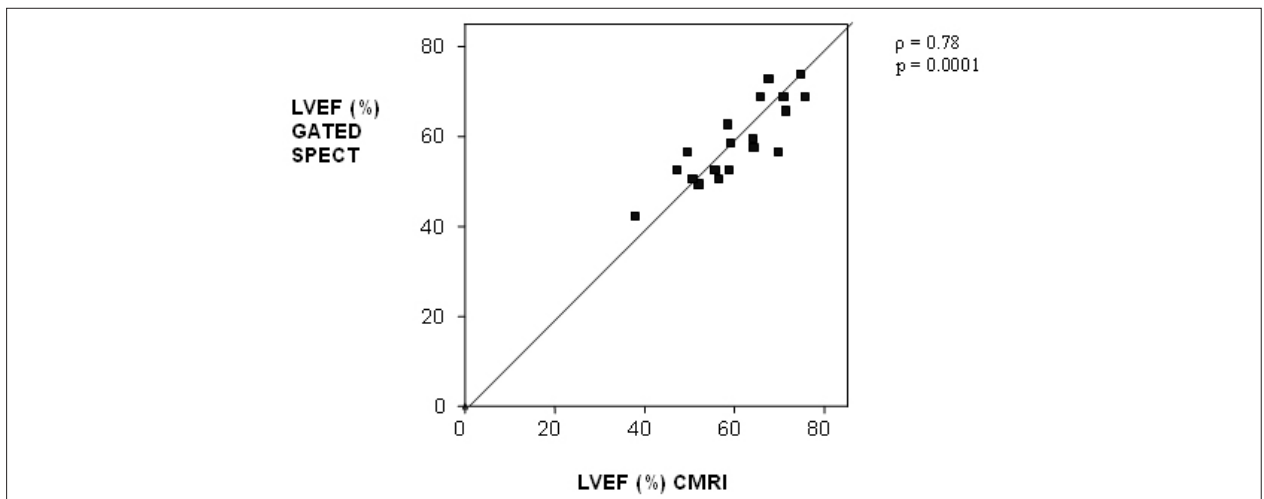


Figure 1 - Scatter plot and Spearman's correlation coefficient showing the correlation between LVEF as obtained by gated SPECT and by CMRI.

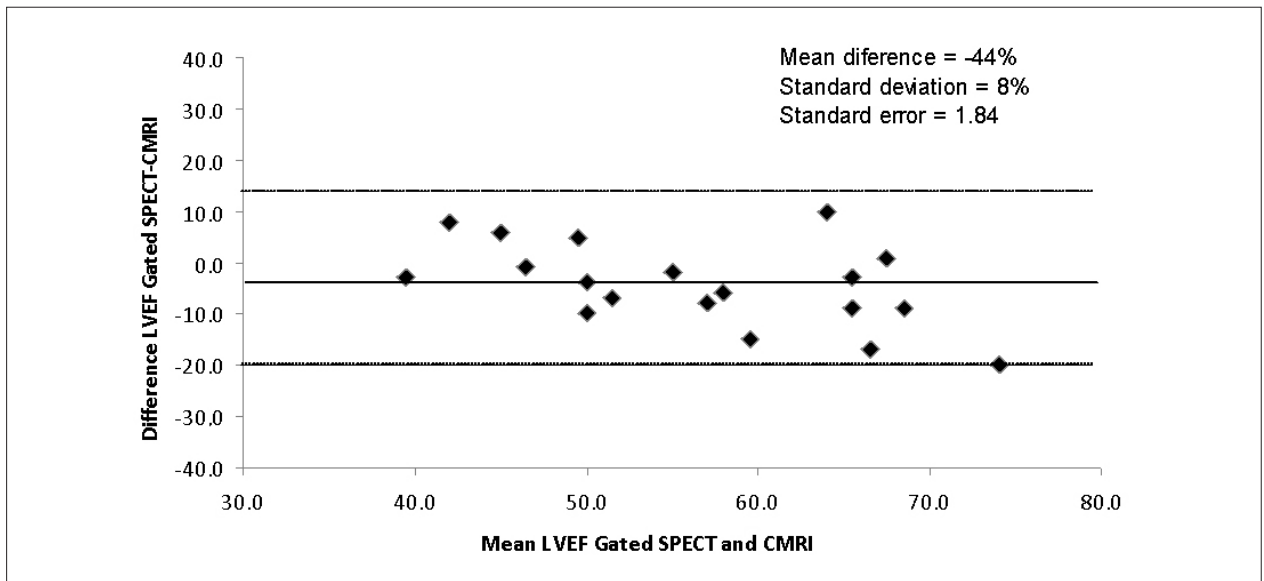


Figure 2 - Agreement plot between ejection fraction as obtained by gated SPECT and by magnetic resonance imaging; CMRI - cardiac magnetic resonance imaging.

long term. After myocardial infarction, increased ventricular volumes are associated with higher mortality, higher rate of adverse cardiovascular events and worse prognosis¹⁰. The accurate analysis of ventricular volumes and ejection fraction adds incremental value in the risk stratification of patients and helps guide therapy. Gated SPECT is a powerful clinical tool that permits the assessment of ventricular function and perfusion in a single acquisition, without any additional radiation exposure other than that needed for the performance of perfusion scintigraphy, with minimal costs and without patient discomfort³. Data from several studies showed that ventricular function parameters obtained by gated SPECT are independent prognostic variables¹⁰⁻¹². When the patient needs scintigraphic assessment of myocardial perfusion, all additional information pertaining to the ventricular function is obtained without an increased radiation dose, which is considered an

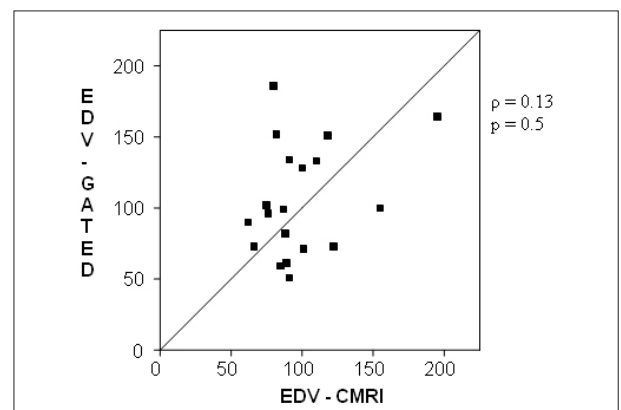


Figure 3 - Scatter plot and Spearman's correlation coefficient showing the correlation between EDV as obtained by gated SPECT and by CMRI.

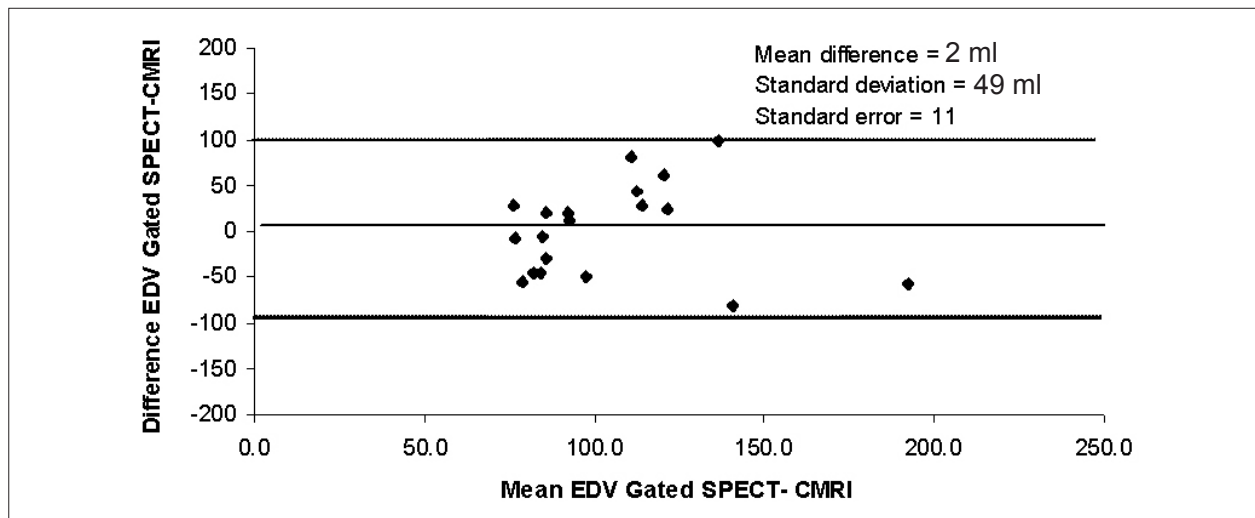


Figure 4 -Agreement plot between EDV as obtained by gated SPECT and by magnetic resonance imaging; CMRI - cardiac magnetic resonance imaging.

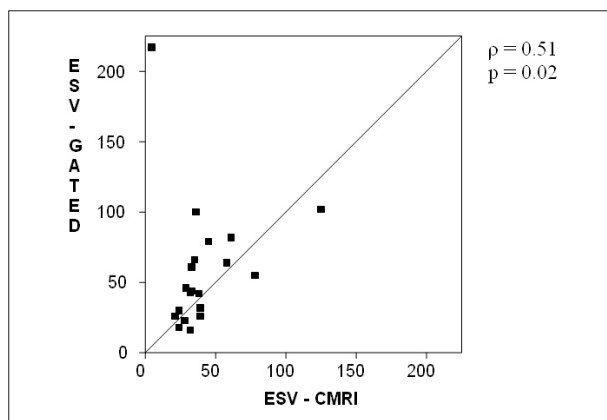


Figure 5 - Scatter plot and Spearman's correlation coefficient showing the correlation between ESV as obtained by gated SPECT and by CMRI.

increment in the benefit ratio of the test.

Gated SPECT was validated in experiments with phantoms and animals testing, as well as in patient series¹³. Cardiac magnetic resonance imaging has proved to be a very accurate technique in the determination of ventricular volumes and ejection fraction, and is considered the gold-standard for the assessment of ventricular function^{4,6}. Values obtained by gated SPECT have satisfactorily correlated with those obtained by magnetic resonance imaging; however, there are limitations that should be known¹³. Quantitative gated SPECT (QGS) is the most widely used program in the clinical practice and uses a border detection scheme to evaluate ventricular volumes and LVEF. These parameters have been demonstrated to be influenced by gender, with lower ventricular volumes and higher LVEF in women¹⁴. Quantitative programs using information on the counting density for the determination of

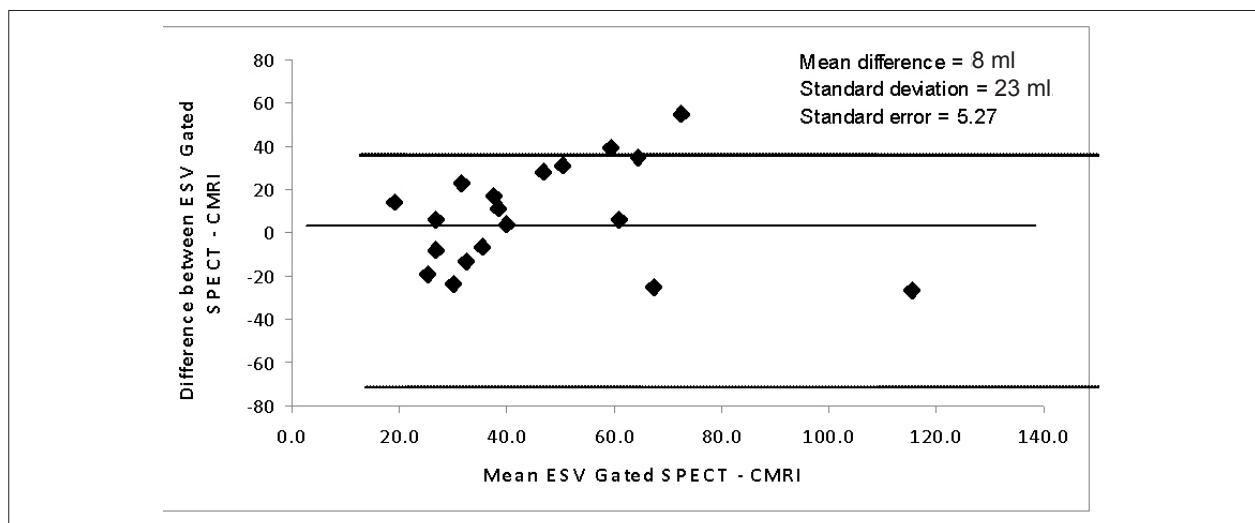


Figure 6 -Agreement plot between ESV as obtained by gated SPECT and by magnetic resonance imaging; CMRI - cardiac magnetic resonance imaging.

systolic function are less influenced by the magnitude of the left volume and by the image resolution than do algorithms based on border detection, and they generate ventricular volumes systematically greater than those calculated by the QGS program¹⁵.

In a meta-analysis on studies comparing gated SPECT with other methods for the assessment of ventricular function, excellent agreement and correlation were demonstrated between magnetic resonance imaging and gated SPECT regarding the evaluation of systolic function indexes⁵. However, in the same meta-analysis, the authors concluded that further research was necessary in some subgroups of patients who were not adequately represented in the studies available up to the moment of the analysis⁵. One of the subgroups that can be mentioned is that of patients with abnormal septal motion.

Abnormal interventricular septal motion following cardiac surgeries is related to the excessive anteromedial systolic translation of the heart inside the thorax due to the loss of ligament fixation and of pericardial integrity⁶. This abnormal motion makes the assessment of the ventricular function difficult after cardiac surgery through the use of conventional imaging techniques¹³. There is a characteristic contraction pattern seen in patients after cardiac surgery. In a study with gated SPECT that included specifically patients in the postoperative period, septal hypokinesia with preserved thickening associated with an apparently increased endocardial motion of the left ventricular lateral wall was observed, in addition to an anterior epicardial swing, different from the contraction pattern seen in normal individuals¹⁶. Tadamura et al⁷ were the first to validate gated SPECT for the evaluation of ventricular volumes and ejection fraction in 16 patients following coronary artery bypass grafting⁷. The authors concluded that gated SPECT provides satisfactory functional information, including absolute ventricular volumes in patients following cardiac surgery. However, the different temporal resolution between the techniques led to a slightly underestimated ejection fraction with gated SPECT⁷. The authors suggest that further studies on this issue should be conducted in order to adequately evaluate whether gated SPECT may be accurately applied to this population, especially to patients with perfusion defects and aneurysms⁷.

The major difference between the present study and that mentioned in the previous paragraph is that 14 of our 20 patients presented with significant perfusion defects in comparison to only five in Tadamura et al's study⁷. When

an algorithm requiring the detection of endocardial borders is used for the assessment of ventricular volumes and LVEF, it is expected that the presence of perfusion defects secondary to the infarcted areas will reduce the accuracy of the technique. This difference in the study populations may explain the disparities found between the present study and the previous one. Several studies have found similar disparities between the data obtained with gated SPECT in segments with severe reduction of radiotracer concentration and those obtained with magnetic resonance imaging¹⁷⁻¹⁹. The presence of previous infarction leads to a reduction in photon counting, particularly in the end-diastole, which underestimates motion and the regional and global functions¹².

Conclusion

Our data are still restricted to a limited group of patients, and we believe they should be validated in other series with other algorithms of ventricular function analysis, as well as with other radiotracers²⁰⁻²² for a better understanding of the limitations of gated SPECT in patients with abnormal septal motion. A more efficient and appropriate use of the imaging methods in cardiology is desired by all professionals who use these tests, whether they are specialists or not²³; thus, we believe our findings may be useful to them.

In conclusion, left ventricular ejection fraction obtained by gated SPECT showed a reliable correlation with that obtained by magnetic resonance imaging in patients undergoing CABG. Ventricular volumes, however, did not show an adequate correlation.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

Sources of Funding

There were no external funding sources for this study.

Study Association

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