Comparison of cardiac magnetic resonance with gated SPECT for evaluation of left ventricular function and volumes in patients with severe and multiple myocardial perfusion defects

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Abstract
Objectives: Gated SPECT is an accurate technique for assessment of myocardial perfusion (MP), left ventricular ejection fraction (LVEF), end-diastolic volume (EDV) and end-systolic volume (ESV). However recent studies have concluded that there are large discrepancies in assessment of LVEF and volumes by gated SPECT in patients with multiple severe myocardial perfusion defects. We sought to investigate the correlation between LVEF and volumes calculated by gated SPECT and cardiac magnetic resonance (CMR) in patients with severe multiple perfusion defects who are referred for CMR.

Methods: Twenty-nine patients (20 male and 9 female, mean age: 63 years ± 11) with multiple severe fixed perfusion defects (mean 5 ± 3 segments) were referred to undergo CMR. The average time between CMR and SPECT was 4 weeks. LVEF, EDV, and ESV were derived automatically from gated SPECT. In the CMR studies, the endocardial and epicardial borders were delineated manually in the short axis planes to calculate the LVEF and volumes.

Results: The different parameters were compared using linear regression, and correlation coefficients were calculated. Substantial correlation was found between CMR and gated SPECT for EDV: \( r = 0.7, p < 0.001 \). Moderate correlation between CMR and gated SPECT for LVEF: \( r = 0.5, p < 0.007 \) and ESV \( r = 0.53, p < 0.003 \).
1. Introduction

Single photon emission computed tomography (SPECT) can evaluate accurately myocardial perfusion and function in patients with known or suspected coronary artery disease (CAD) (Germano et al., 1995; DePuey et al., 1993; Faber et al., 1999) the integrated information about perfusion and function enhanced diagnostic value of the test in management for patients with CAD. While the value of ECG-gated SPECT in assessing myocardial perfusion is well established, there are fewer data on the accuracy of ECG-gated SPECT for estimating left ventricular (LV) volumes and ejection fraction (EF) particularly in patients with severe and multiple perfusion defects caused by ischemic cardiomyopathy (Lim et al., 2006; Ioannidis et al., 2002; Chan et al., 2006).

CMR is considered to be the current noninvasive reference standard for the assessment of LV functions. The assessment of LV volumes by CMR is operator-independent and does not depend on geometric assumptions. It has high reproducibility, excellent temporal and spatial resolution, and low inter-observer and intraobserver variability (Bellenger et al., 2000; Longmore et al., 1985; Sechtem et al., 1987).

Therefore, this study was designed to compare gated SPECT with MRI for the assessment of left ventricular function and volumes in patients with multiple severe perfusion defects caused by ischemic cardiomyopathy.

2. Methods

2.1. Patients

Twenty-nine patients (20 men and 9 women; mean age 63 years ± 11, age range, 38–77 years) with known CAD were included in our study. They had been referred for gated SPECT for accepted clinical indications. They were scheduled to undergo CMR imaging for viability and LV function evaluation. The inclusion criteria: (1) impaired LV function (documented on 2-dimensional echocardiography or LV angiography). (2) The time interval between both studies was 4 weeks. (3) SPECT with multiple and severe perfusion defects. Exclusion criteria: (1) cardiac pacemakers or intracranial aneurysm clips. (2) Recent myocardial infarction or unstable patient.

2.1.1. Gated SPECT acquisition and analysis

Patients underwent rest–stress myocardial perfusion studies with either a separate-day protocol or a same-day stress–rest sequence (Hansen et al., 2006). The choice of tracer and same-day or separate-day protocol was based on logistic requirements. The rest dose in patients who underwent a separate-day rest–stress protocol was 10 to 12 mCi of either sestamibi or tetrofosmin. The stress dose in patients who underwent the rest–stress same-day protocol was 25 mCi of either sestamibi or tetrofosmin. Tc-99m sestamibi or Tc-99m tetrofosmin was injected either during peak treadmill exercise or during peak pharmacological vasodilatation with adenosine (140 μg/kg/min). SPECT imaging was started approximately 15 min after injection during exercise or at 30 min after pharmacological vasodilatation. Rest SPECT myocardial perfusion imaging was started at ~60 min after Injection. SPECT imaging was performed with Dual-head gamma cameras, equipped with high-resolution collimators. All images were acquired by using a 360-degree orbit and a step and shoot acquisition protocol (6°/stop). The time per stop was 40 s for a low Tc-99m sestamibi or Tc-99m tetrofosmin dose and 30 s for a high dose. A 20% window was set symmetrically over the 140 keV photon peak of Tc-99m. The matrix size was 64- by 64-pixels. Images were reconstructed by using standard filtered back-projection and a ramp filter. ECG-gated images were acquired with 8 frames per R–R cycle. No attenuation correction or scatter correction was applied. The Cedars-Sinai Quantitative Gated SPECT (Germano et al., 1994) program was then applied to the short axis data-sets to derive the LV EF and volumes by using the standard formula:

\[ LVEF = \frac{EDV - ESV}{EDV} \]

- End-diastolic volume
- End-systolic volume/End-diastolic volume.

Both stress and rest SPECT images were used for the assessment of myocardial perfusion. Data were displayed in polar maps (normalized to the maximum activity) and divided into 17 segments (Cerqueira et al., 2002). Segments were scored according to a 4-point scoring system: 0 = normal (activity 70%), 1 = mild to moderate defect (activity 50% to 70%), 2 = severe defect (activity 30% to 50%), and 3 = absent tracer uptake (activity, less than 30%).

2.1.2. Magnetic resonance imaging acquisition and analysis

Cine MRI was performed with a 1.5 tesla (GE Health care, Milwaukee, WI, USA). Acquisitions were electrocardiographically synchronized to the cardiac cycle (Pattynama et al., 1993). The imaging with steady state precession technique was used with flip angles of 30° and 60°, a TE of 12 ms, and a TR of 50 ms. Slice thickness was 6 to 8 mm. The framing number was the maximum allowed by the RR interval of the patient’s electrocardiogram in the range of 10 to 16 frames. The acquisition matrix was 128 × 256, with interpolation to 256 × 256 during reconstruction. Coronal positioning sections were obtained, followed by axial positioning sections at the mid-ventricular level. Vertical cardiac long-axis sections were obtained through the left ventricle parallel to the inter-ventricular septum. Horizontal cardiac long-axis sections were acquired through the center of the left ventricle as demonstrated by the vertical long-axis sections. The long axis of the left ventricle was measured from the midpoint of the mitral valve annulus to the ventricular apex. Cardiac short-axis section positions were selected so that 3 equidistant sections were obtained (basal, mid-portion, and apex). End-diastolic and end-systolic frames for volume determination were selected by stepping through the cine loop display of MRI images. These short-axis slices were used for the left ventricular volume analysis.

Conclusion: Our data showed that the gated SPECT correlates substantially with MRI for measurement of EDV and moderately for ESV and LVEF in patients with multiple and severe perfusion defects. Thus, when accurate measurement is required, cardiac MRI is recommended.

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2.2. Statistical analysis

Left ventricular EDV, ESV, and EF by gated SPECT and MRI were compared using the Student \( t \) test. All continuous variables were represented as mean and standard deviation(SD). The correlation of EDV, ESV, and EF measurements between gated SPECT and MRI was assessed by linear regression analysis (Pearson \( r \)) and Bland–Altman plots. A \( p \) value of less than 0.05 was considered statistically significant (Altman, 1991).

3. Results

3.1. Demographic data

Twenty-nine patients were selected for the study protocol, 20 male and 9 female (mean age 63 ± 11), and these patients are known to have CAD by gated SPECT or prior coronary angiography. All selected patients have two or more moderate and/or severe perfusion defects (mean 5 ± 3).

LV volumes and Ejection fraction measured by MRI and gated SPECT: The quantitative measurements of LV volumes and LVEF are presented in Table 1. The LV end-diastolic volume measured by MRI ranged from 62 to 250 ml (mean 145 ± 46). The corresponding values for gated SPECT were slightly lower: LV end-diastolic volume ranged from 29 to 215 ml (mean 126 ± 43). Linear regression revealed a significant statistical correlation (\( r \) 0.7 and \( P \) value < 0.001) between LV end-diastolic volume measured by MRI and gated SPECT (Fig. 1). The Bland–Altman plot showed a mean difference of 16 ± 70 ml with no special trend (Fig. 2).

The LV systolic volume measured by MRI ranged from 19 to 157 ml (mean 88 ± 42). The corresponding values for gated SPECT were: LV systolic volume ranged from 13 to 131 ml (mean 73 ± 37). Linear regression revealed a significant statistical correlation (\( r \) 0.53 and \( P \) value < 0.003) between LV systolic volumes measured by MRI and gated SPECT (Fig. 3). The Bland–Altman plot showed a mean difference of 14 ± 76 ml with no special trend (Fig. 4).

The LVEF measured by MRI ranged from 18% to 78% (mean 41 ± 15). The corresponding values for gated SPECT were similar: LVEF ranged from 11 to 89% (mean 41 ± 17). Linear regression revealed a significant statistical correlation (\( r \) 0.5 and \( P \) value < 0.007) between LVEF measured by MRI and gated SPECT (Fig. 5). The Bland–Altman plot showed a mean difference of –0.72 ± 32% with no special trend (Fig. 6).

4. Discussion

Our present study demonstrates substantial correlations between gated SPECT and MRI for measurement of the EDV and moderate correlation for LVEF and ESV in patients with chronic ischemic cardiomyopathy with severe and multiple perfusion defects. This is one of the few studies which addresses this common clinical problem in daily practice. Gated myocardial perfusion SPECT is a very well established technique for the assessment of myocardial perfusion, function and sometimes myocardial viability as well. However, there are some clinical varieties where the accuracy of EF and LV volumes is uncertain. In patients with multiple, severe perfusion defects, severe reduction of the photon count in the myocardial region (or absence of photon count) may lead to underestimation of regional wall motion due to inadequate

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Comparison of findings with gated SPECT and MRI.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Findings</td>
<td>Gated SPECT</td>
</tr>
<tr>
<td>LVEDV</td>
<td>Mean (ml)</td>
</tr>
<tr>
<td></td>
<td>Range (ml)</td>
</tr>
<tr>
<td>LVESV</td>
<td>Mean (ml)</td>
</tr>
<tr>
<td></td>
<td>Range (ml)</td>
</tr>
<tr>
<td>LVEF</td>
<td>Mean (%)</td>
</tr>
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<td></td>
<td>Range (%)</td>
</tr>
</tbody>
</table>

![Figure 1](image-url) Linear regression demonstrating the relation between LV end-diastolic volume assessed by MRI and gated SPECT.
Figure 2  Bland–Altman plot for LV end-diastolic volume (LVEDV).

Figure 3  Linear regression demonstrating the relation between LV end-systolic volume assessed by MRI and gated SPECT.

Figure 4  Bland–Altman plot for end-systolic volume (LVESV).
visualization and subsequently underestimation of the EF and volumes. In our experience, LV aneurysm after myocardial infarction may cause inaccurate EF calculation by poor counting determination using automatic algorithm.

One of the most important advantages of this study compared to the previous studies using 17 segments model for myocardial segmentation which has been recommended as a standard by many societies, is, this will facilitate the comparison of different tomographic techniques for the same patients, while some previous studies use a different segmentation model which is not in use, currently. In addition, the unique advantage of this study is that the patients’ populations were selected with multiple, severe perfusion abnormalities in chronic ischemic cardiomyopathy, while the previous study was of patients’ population with different etiologies including normal, acute myocardial infarction or non-ischemic cardiomyopathy. There is a possibility of great discrepancy between MR and other modalities in patients with chronic ischemic cardiomyopathy due to occurrence of LV remodeling and mechanical and geometric changes which affect the accuracy of EF calculation with echocardiography and SPECT.

In general there is a good correlation and agreement between these two modalities for measurements of EF and LV volumes (Williams and Taillon, 1996; Vallejo et al., 2000). The EDV correlates substantially but the ESV and EF correlate moderately between MRI and gated SPECT. Factors that contribute to the discrepancies between these two modalities include: low spatial and temporal resolution of gated SPECT compared with MRI, different algorithm used by MRI, for example cardiac MRI consider papillary muscle as a part of LV cavity but this is not well-visualized by gated SPECT and in patients with severe perfusion defects severe reduction of photon counts in a myocardial region (or absence of photon counts) may lead to an underestimation of regional wall motion, due to inadequate visualization. Nevertheless, gated SPECT offered several advantages besides being a very good
test for myocardial perfusion, these advantages include simple and quick automated technique, no additional radiation or cost, no special patient preparation or extra time for manually calculating LV volumes and EF (Bavelaar-Croon et al., 2000).

Gated SPECT may not be very reliable if accurate calculation of EF is required in such patients with severe ischemic and non-ischemic cardiomyopathy, patients with known LV aneurysm and monitoring patients on chemotherapy (Germano et al., 1995; Parker et al., 1985). We strongly recommend MRI for EF measurement in these circumstances, the several advantages of MRI include: the gold standard for EF calculation, very accurate and reproducible, no geometric assumption, assessment of myocardial viability, detecting LV thrombus, detecting LV aneurysm and false aneurysm among other many benefits (Lorenz et al., 2000; Wagner and Mahrholdt, 2003).

5. Conclusion

Our data showed that the gated SPECT correlates moderately with MRI for measurement of EF and ESV and substantially with EDV in ischemic cardiomyopathy patients with multiple and severe perfusion defects. Most of these patients do not require cardiac MRI for measurement of LV volumes and function. However, when an accurate measurement is required, Cardiac MRI is recommended.

References