Evaluation of left ventricular diastolic function with a dedicated cadmium-zinc-telluride cardiac camera: comparison with Doppler echocardiography

Alessia Gimelli1†*, Riccardo Liga2†, Emilio Maria Pasanisi1, Assuero Giorgetti1, Gavino Marras1, Brunella Favilli1, and Paolo Marzullo1,2,3

1Fondazione Toscana G. Monasterio, Via Moruzzi, 1, 56124 Pisa, Italy; 2University Hospital of Pisa, Pisa, Italy; and 3CNR, Institute of Clinical Physiology, Pisa, Italy

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Aims
To evaluate the relationships between measures of left ventricular (LV) filling dynamics at cadmium–zinc–telluride (CZT) imaging and indexes of LV diastolic function at transthoracic echocardiography.

Methods and results
Two hundred and forty-seven patients underwent myocardial perfusion imaging at rest and after stress with a low-dose CZT protocol and a baseline transthoracic echocardiography study. All patients were submitted to invasive or computed coronary angiography. The peak filling rate (PFR) and the time to PFR (TPFR) were derived from gated CZT images as measures of LV filling dynamics. LV diastolic function was also evaluated at echocardiography and the presence of significantly increased LV filling pressures determined. Increased LV filling pressures at transthoracic echocardiography were evident in 103 (42%) patients. Interestingly, independently from the presence of coronary artery disease, there was a strict correlation between the presence and severity of LV diastolic dysfunction at echocardiography and CZT-derived measures of filling dynamics, i.e. PFR ($P = 0.001$) and TPFR ($P = 0.001$). At receiving operating characteristic analysis, a composite index of reduced PFR ($\leq 2.11$ end-diastolic volume s$^{-1}$) and increased TPFR (>234 ms) showed a sensitivity of 84% and a specificity of 67% in unmasking the presence of elevated LV filling pressures at echocardiography.

Conclusions
CZT-derived measures of LV filling dynamics correlate with echocardiographic parameters of diastolic function and may identify the presence of increased LV filling pressures.

Keywords
CZT • Diastolic function • Peak filling rate • Filling pressures • Doppler echocardiography

Introduction
Cardiac imaging with single-photon emission computed tomography (SPECT) has become one of the most diffuse techniques for the evaluation of myocardial perfusion, allowing to obtain reproducible measures of myocardial blood flow distribution.1

In addition to perfusion data, electrocardiogram (ECG)-gated cardiac SPECT offers the chance to obtain functional parameters that may help to investigate left ventricular (LV) systolic and diastolic functions.2–4 Specifically, different measures of LV diastolic function, such as the ‘peak filling rate’ (PFR) and the ‘time to PFR’ (TPFR), may be automatically obtained from the analysis of SPECT-derived filling curves with a commercially available software.5,5 However, while the accuracy of those parameters in the estimation of LV filling pressures has been validated against non-invasive and invasive gold standards,3–5 their wide implementation is still lacking.

In clinical practice, the evaluation of diastolic function is mainly performed by means of transthoracic echocardiography, and different parameters, mostly obtained through Doppler techniques, have been developed for the non-invasive estimation of LV filling pressures.6 To this respect, even if the correlation between SPECT-derived filling parameters and some measures of LV diastolic function

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1 A.G. and R.L. contributed equally to this study.

* Corresponding author. Tel: +39 503152153. E-mail: gimelli@ftgm.it

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has been suggested, the relationships between more robust echocardiographic indicators of diastolic function and measures of LV filling dynamics at cardiac SPECT should be determined.

Dedicated multi-pinhole cardiac cameras with cadmium–zinc–telluride (CZT) detectors, characterized by a higher photon sensitivity and spatial resolution, can be used to evaluate not only myocardial perfusion, but also cardiac function with a low-dose protocol. Interestingly, while cardiac CZT has been recently validated against magnetic resonance imaging in the evaluation of LV volumes and systolic function, the correlations between CZT-derived LV filling parameters and robust echocardiographic measures for the estimation of LV diastolic function should be investigated.

We sought to assess the relationships between LV diastolic parameters evaluated at cardiac CZT and at transthoracic echocardiography in a large population of patients with or without LV systolic dysfunction.

Methods

Patient population

Between 2011 and 2013, 247 consecutive subjects with an intermediate probability of coronary artery disease (CAD) underwent a scintigraphic evaluation of myocardial perfusion at rest and after stress with a CZT camera followed by invasive or computed tomography coronary angiography, as indicated by the referring physicians. In every patient, the time interval between coronary angiography and CZT study was <3 months. A coronary stenosis >50% was considered significant. As part of the study protocol, in the same week of the CZT evaluation, each patient was also submitted to a complete evaluation of cardiac structure and function with transthoracic echocardiography. Exclusion criteria were haemodynamic instability, severely symptomatic heart failure [New York Heart Association (NYHA) Class IV], myocardial or pericardial inflammatory disease, atrial fibrillation, and more than moderate valvular disease. The presence of major cardiovascular risk factors was ascertained in every patient. The study was approved by the Local Ethical Committee and conformed to the Declaration of Helsinki on human research. Written informed consent was obtained from every patient after explanation of the protocol, its aims and potential risks.

Patients’ preparation and stress protocols

Patients were instructed to discontinue beta-blockers, calcium antagonists, and nitrates for 24 h before testing. One hundred and seventy-eight (72%) patients underwent exercise, whereas 69 (28%) patients underwent dipyridamole stress testing. A bicycle exercise stress test (stepwise increments of 25 W every 2 min) or dipyridamole (0.56 mg/kg IV over 4 min) was chosen on the basis of the patients’ ability to exercise and to reach ≥85% of the maximal age-predicted heart rate. Of the 178 patients undergoing exercise stress testing, 145 reached 85% of the agepredicted maximum heart rate, while the remaining 33 reached a peak rate pressure product higher than 26,000. Adverse events were defined according to the international guidelines.

Acquisition protocol

Each patient underwent stress—rest CZT imaging according to a single-day protocol (185–222 MBq of 99mTc-tetrofosmin during stress and 370–444 MBq at rest). All patients with known prior myocardial infarction were injected at rest after sublingual administration of nitrates. In all patients, stress and rest CZT imaging were acquired as previously described. Patients were imaged in the supine position with arms placed over their head without any detector or collimator motion. All images were acquired with a 32 × 32 matrix and a 20% energy window centred at the 140 keV photopeak of 99mTc. List mode files were acquired and stored. Images were reconstructed on a standard workstation (Xeleris II; GE Healthcare, Haifa, Israel) using a dedicated iterative algorithm. A Butterworth post-processing filter (frequency 0.37, order 7) was applied to the reconstructed slices. The tomographic studies were also re-projected into 60 planar projections to emulate a standard SPECT layout. No scatter or attenuation correction was used.

Semi-quantitative analysis of perfusion images

Stress and rest perfusion images were semi-quantitatively scored according to the 17-segment LV model and a five-point scale (0 normal, 1 equivocal, 2 moderate, 3 severe reduction in radioisotope uptake, and 4 absence of detectable tracer uptake). Accordingly, the summed stress score (SSS) and summed rest score (SRS) were calculated. Two experienced nuclear cardiologists performed the semi-quantitative analysis independently and consensus was reached on all analyses.

Analysis of gated images

LV function analysis was performed from 16-frames reformatted images using the commercially available software (Corridor4DM; Invia, Ann Arbor, MI, USA). In patients with inadequate border detection, manual editing was performed. This software automatically fits the LV volume curve with a fourth-order harmonic function in order to derive the PFR (end-diastolic volume (EDV) s⁻¹) and the TPFR (ms), as indicators of LV diastolic function, and the peak ejection rate (PER, EDV s⁻²), as a measure of LV contractility. All functional measurements were obtained from rest gated 99mTc-tetrofosmin images.

To account for the influence of heart rate to the diastolic functional parameters, both the PFR and TPFR were also corrected for the R–R interval on ECG.

Transthoracic echocardiography

Each patient was submitted to a complete transthoracic echocardiographic evaluation (IE33, Philips, Andover, MA, USA or Vivid System 7, GE Healthcare, Milwaukee, WI, USA) performed by an experienced cardiologist unaware of the results of the CZT study.

For the evaluation of LV diastolic function, each patient underwent a pulsed-wave Doppler evaluation of mitral inflow coupled with the assessment of septal and lateral mitral annular velocities at tissue Doppler imaging. Accordingly, the early (E) and late (A) diastolic velocities, the mitral deceleration time (DT), the mean early diastolic annular velocity (E', derived from averaging septal and lateral velocities), and the average E/E' ratio were computed in each patient. LV ejection fraction was considered normal if >50%, whereas left atrial (LA) volume was considered normal if <34 mL/m². In the entire population, the severity of LV diastolic dysfunction was graded in agreement with the current recommendations. Diastolic function was considered normal according to the presence of preserved mitral annular velocities (septal E' ≥ 8 and lateral E' ≥ 10). In the remaining patients, diastolic dysfunction was graded as follows: Grade I — dysfunction impaired relaxation (E/A < 0.8, DT > 200 ms, and average E/E' ≤ 8), Grade II dysfunction or pseudonormal pattern (E/A 0.8–1.5, DT 160–200 ms, and average E/E' 9–12), and Grade III dysfunction or restrictive pattern (E/A > 2, DT < 160 ms, and average E/E' > 13). When appropriate, i.e. in the case of borderline or inconclusive E/A or E/E' values, other surrogate indicators of LV diastolic function, such as pulmonary...
venous inflow and mitral-to-apical flow propagation velocity, were evaluated. In agreement with the same recommendations, LV filling pressures were assessed in each patients and those with signs of significantly elevated filling pressures individuated. In patients with preserved LV systolic function, the presence of an average E/E' \leq 8 and \geq 13 identified those with normal and elevated filling pressures, respectively. In the case of an E/E' 9–14, surrogate measures of diastolic dysfunction, i.e. abnormal pulmonary venous flow or LA dilatation, were used to define the presence of elevated filling pressures. In patients with depressed LV systolic function, filling pressures were considered elevated in the presence of a restrictive mitral pattern and normal in those with impaired relaxation, provided that the E velocity was \leq 50 cm/s. In remaining patients, LV filling pressures were deemed elevated in case of the presence of at least two surrogate measures of diastolic dysfunction, i.e. elevated E/E' ratio, abnormal pulmonary venous flow, elevated pulmonary artery systolic pressure, and impaired mitral-to-apical flow propagation velocity.

### Statistical analysis

Continuous variables were expressed as mean ± 1 SD and categorical variables as percentages. Groups were compared for categorical data using Fisher’s exact test and for continuous variables using the analysis of variance followed by Fisher’s protected least significant difference for multiple comparisons. All tests were two-sided; a P-value of <0.05 was considered to be significant. The inter-observer variability in semi-quantitative CZT perfusion analysis was measured using per cent agreement and k-value. The accuracy of CZT-derived parameters of LV diastolic function in detecting the presence of significantly increased LV filling pressures at transthoracic echocardiography was assessed at receiving operating characteristic (ROC) analysis. Accordingly, for each parameter, the area under the curve (AUC) and the relative 95% confidence intervals (CIs) were determined. Statistical analyses were performed using the JMP statistical software (SAS Institute, Inc., version 4.0.0) and the Stata software (Stata Statistical Software: release 10, StataCorp., College Station, TX, USA).

### Results

#### Characterization of the study population

The characteristics of the overall population and of the patients with (Group 1) and without (Group 2) signs of significantly elevated LV filling pressures at transthoracic echocardiography are summarized in Table 1. When compared with patients with normal LV filling pressures, Group 1 patients showed a more frequent history of previous myocardial infarction (P = 0.003).

Interestingly, none of the major cardiovascular risk factors significantly associated with the presence of increased LV filling pressures at echocardiography. Similarly, while 103 of 247 (42%) of the patients showed the presence of significant CAD in one (14%), two (15%), or three (13%) vessels, a worsening coronary anatomy did not associate with a more compromised diastolic function at rest.

#### Evaluation of LV diastolic function at transthoracic echocardiography

As presented in Table 2, Group 1 patients more frequently showed a pseudonormal or restrictive LV filling pattern than those with normal filling pressures (P < 0.001). As expected, the presence and severity of a more compromised diastolic function was significantly associated with a lower LV ejection fraction and a higher LA volume at echocardiography (Table 2 and Figure 1A). Finally, among the different echocardiographic measures of LV diastolic function, a higher E/E' ratio resulted the strongest predictor of both a more impaired LV systolic function and a more elevated LA volume (Figure 1B).

#### Evaluation of LV diastolic function at CZT

The inter-observer agreement rate of semi-quantitative perfusion analysis at CZT was 93% (k 0.83, 95% CI 0.72–0.94). As reported in Table 3, Group 1 patients were characterized by a significantly more altered regional myocardial perfusion, both at rest (P < 0.001)

![Table 1 Characteristics of patients](https://academic.oup.com/ehjcimaging/article-abstract/15/9/972/2366861/159962336861)
During stress ($P = 0.004$), than those of Group 2. These data were confirmed by a significant association between an increasing severity of LV diastolic dysfunction at transthoracic echocardiography and more impaired measures of regional myocardial perfusion at CZT (Figure 2).

Furthermore, Group 1 patients presented significantly more impaired CZT-derived measures of both diastolic (PFR and TPFR, $P < 0.001$ for both) and systolic functions (ejection fraction and PER, $P < 0.001$ for both) at rest than those of Group 2. To this respect, a significant correlation between both PFR ($R = 0.52, P < 0.001$) and

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Echocardiographic data</th>
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</thead>
<tbody>
<tr>
<td>Parameter</td>
<td>Overall population ($n = 247$)</td>
</tr>
<tr>
<td>Mitral inflow data</td>
<td></td>
</tr>
<tr>
<td>$E$ wave velocity, cm/s</td>
<td>$81 \pm 25$</td>
</tr>
<tr>
<td>$A$ wave velocity, cm/s</td>
<td>$81 \pm 26$</td>
</tr>
<tr>
<td>$E/A$ ratio</td>
<td>$1.04 \pm 0.57$</td>
</tr>
<tr>
<td>Mitral DT, ms</td>
<td>$213 \pm 61$</td>
</tr>
<tr>
<td>Tissue Doppler data</td>
<td></td>
</tr>
<tr>
<td>Septal $E'$ velocity, cm/s</td>
<td>$6.7 \pm 2.2$</td>
</tr>
<tr>
<td>Lateral $E'$ velocity, cm/s</td>
<td>$8.7 \pm 2.6$</td>
</tr>
<tr>
<td>Average $E/E'$ ratio</td>
<td>$11.4 \pm 5.0$</td>
</tr>
<tr>
<td>LA volume and LV systolic function</td>
<td></td>
</tr>
<tr>
<td>LA volume index, mL/m$^2$</td>
<td>$31 \pm 13$</td>
</tr>
<tr>
<td>LV ejection fraction, %</td>
<td>$50 \pm 14$</td>
</tr>
<tr>
<td>Severity of LV diastolic dysfunction</td>
<td></td>
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<tr>
<td>Normal diastolic function, $n$ (%)</td>
<td>$64 \ (26)$</td>
</tr>
<tr>
<td>Grade I dysfunction, $n$ (%)</td>
<td>$91 \ (37)$</td>
</tr>
<tr>
<td>Grade II dysfunction, $n$ (%)</td>
<td>$60 \ (24)$</td>
</tr>
<tr>
<td>Grade III dysfunction, $n$ (%)</td>
<td>$32 \ (13)$</td>
</tr>
</tbody>
</table>

**Figure 1:** (A) Upper panels: relationship between the presence and severity of LV diastolic dysfunction at echocardiography, ejection fraction (left), and LA volume index (right). (B) Lower panels: correlation of average $E/E'$ ratio with LV ejection fraction (left) and LA volume index (right).
TPFR (R = 0.40, P < 0.001) at rest and patients' individual LV ejection fraction was evident. Moreover, as shown in Figure 3, worsening LV diastolic function at transthoracic echocardiography was associated with gradually more altered CZT-derived filling parameters. Interestingly, among the different echocardiographic parameters of LV diastolic function, the mean E/E’ ratio was closely related to CZT-derived measures of LV diastolic function (Figure 4), independently from the presence of LV systolic dysfunction (P < 0.001 and P = 0.004 for PFR and TPFR, respectively, in the presence of depressed ejection fraction, and P < 0.001 and P < 0.001 for PFR and TPFR, respectively, in the absence of depressed ejection fraction). These correlations were further confirmed after correction for patients’ individual heart rate (R = −0.39, P < 0.001 and R = 0.32, P < 0.001 for PFR/R – R and TPFR/R – R, respectively) and were confirmed in patients with (P < 0.001 for both PFR and TPFR) and without (P < 0.001 for both PFR and TPFR) CAD.

As summarized in Table 4, at ROC analyses, the AUCs of PFR and TPFR for the discrimination of the presence of elevated LV filling pressures were 0.81 and 0.78, respectively (Figure 5). The combined presence of a depressed PFR (≤2.11EDV s⁻¹) and/or prolonged TPFR (>234 ms) showed a high sensitivity in unmasking the presence of elevated LV filling pressures (Table 4). Moreover, PFR and TPFR showed a high accuracy in discriminating the different degrees of diastolic dysfunction at echocardiography (Table 5).

Discussion

In patients submitted to a CZT perfusion scan, an accurate evaluation of resting LV diastolic function is feasible with a fast imaging protocol and a limited radiation burden. CZT-derived filling parameters correlate with clinically used measures of LV diastolic function and predict the presence of elevated filling pressures. Therefore, a quantitation of LV diastolic function could help to improve the functional evaluation of patients submitted to a CZT perfusion scan.

The role of LV diastolic dysfunction in cardiac pathophysiology

The evaluation of LV diastolic function is a central part of any cardiac examination, since the assessment of diastolic dynamics may give important information on cardiac mechanics. In fact, independently from LV systolic function, the presence and severity of diastolic dysfunction may have profound diagnostic and prognostic impacts.\(^\text{14,15}\)
To this respect, echocardiography is considered the gold standard for the non-invasive evaluation of LV diastolic function, offering the chance to obtain reproducible and validated indexes of LV filling dynamics. Similarly, while giving capital information on myocardial perfusion and viability, gated SPECT may offer the chance to perform a thorough assessment of LV diastolic function in a semi-automated manner. Previous published studies validated SPECT-derived measures of LV diastolic function, such as the PFR and the TPFR, against both invasive and non-invasive imaging modalities. Our result indicated for the first time that LV filling parameters derived through gated CZT scintigraphy strongly correlate with echocardiographic measures of diastolic function, accurately predicting the presence of elevated LV filling pressures in a large series of patients with and without LV systolic dysfunction. The relationship between CZT-derived diastolic parameters at rest and LV filling pressures is independent on the presence and severity of significant CAD and may help to obtain a better functional characterization of patients submitted to myocardial perfusion imaging.

### Evaluation of LV diastolic function through gated SPECT

Myocardial perfusion imaging on gated SPECT has repeatedly been shown to allow a complete, semi-quantitative, evaluation of regional blood flow distribution, guiding clinical decision-making and predicting adverse prognosis. Moreover, gated SPECT allows an

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**Figure 3:** Relationships between the presence and severity of LV diastolic dysfunction at echocardiography and CZT-derived measures of LV filling dynamics.

**Figure 4:** Correlation between average $E/E'$ ratio and CZT-derived measures of LV diastolic function.

### Table 4  Accuracy of CZT-derived parameters for the identification of elevated LV filling pressures

<table>
<thead>
<tr>
<th>Parameter</th>
<th>AUC (95% CI)</th>
<th>P-value</th>
<th>Sensitivity % (95% CI)</th>
<th>Specificity % (95% CI)</th>
<th>Positive predictive value, %</th>
<th>Negative predictive value, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFR $&lt; 2.11 EDV s^{-1}$</td>
<td>0.81 (0.76–0.86)</td>
<td>$&lt;0.001$</td>
<td>71 (61–79)</td>
<td>78 (70–84)</td>
<td>70</td>
<td>79</td>
</tr>
<tr>
<td>TPFR $&gt; 234$ ms</td>
<td>0.78 (0.73–0.83)</td>
<td>$&lt;0.001$</td>
<td>65 (55–74)</td>
<td>74 (66–81)</td>
<td>64</td>
<td>75</td>
</tr>
<tr>
<td>PFR $&lt; 2.11 EDV s^{-1}$ or TPFR $&gt; 234$ ms</td>
<td>0.76 (0.70–0.81)</td>
<td>$&lt;0.001$</td>
<td>84 (76–91)</td>
<td>67 (58–75)</td>
<td>64</td>
<td>86</td>
</tr>
</tbody>
</table>
evaluation of both LV global and regional functional parameters, adding relevant diagnostic information in the functional evaluation and risk stratification of different categories of patients.8–10,12 Finally, gated SPECT allows the assessment of LV diastolic function through the non-invasive estimation of ventricular filling dynamics.3–5 Previous studies demonstrated that the alteration of SPECT-derived diastolic parameters increased the accuracy in the identification of patients with ischaemic heart disease and significant CAD.17

In our study, CZT-derived LV filling measures significantly correlated with widely validated echocardiographic parameters of diastolic function. This relationship was independent on global LV systolic function and was unaffected by patients’ heart rate, as a measure of LV filling time. Interestingly, a composite index of reduced PFR and increased TPFR yielded an elevated sensitivity in identifying patients with increased LV filling pressures, helping to individuate patients at higher cardiovascular risk.

Advantages of CZT technology in the assessment of myocardial perfusion and function

The introduction of solid-state cardiac cameras equipped with CZT detectors has been a relevant innovation in the field of nuclear cardiology.8,12 Owing to their characteristics, these dedicated cameras allow a consistent reduction of both imaging time and injected dose, while maintaining an excellent image quality.9,13

Moreover, because of their higher spatial resolution, CZT cameras give the chance to obtain an accurate evaluation of both LV regional wall motion and global systolic function, allowing to perform a combined evaluation of myocardial perfusion and contractile state.10,18

While the elevated accuracy of CZT-derived perfusion and systolic function parameters has been already demonstrated,10 the validation of CZT-derived measures of LV diastolic function is lacking. Our study shows for the first time that, in patients with or without LV systolic dysfunction, quantitative indexes of LV filling dynamics derived through gated CZT, i.e. the PFR and the TPFR, significantly correlate with widely validated echocardiographic parameters of diastolic function, accurately identifying patient with increased LV filling pressures.

Finally, our results suggest that, in patients with or without significant CAD, the presence of an increasingly more impaired myocardial perfusion predicts a significantly more altered LV diastolic function. Present and previous results suggest that, in patients submitted to myocardial perfusion imaging on a CZT camera, a combined evaluation of myocardial perfusion together with an accurate assessment of systolic and diastolic functions is feasible despite a contained acquisition time and a limited radiation burden.

![Figure 5](https://academic.oup.com/ehjcimaging/article-abstract/15/9/972/2366861) ROC curves showing the accuracy of CZT-derived indicators of LV diastolic function in unmasking the presence of increased ventricular filling pressures at echocardiography.

| Table 5 | Accuracy of CZT-derived parameters in discriminating the degree of diastolic dysfunction |
|-----------------|----------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Parameter       | Peak filling rate (EDV s⁻¹)      | Time to PFR (ms) |
|                 | Cut-off | Sensitivity % (95% CI) | Specificity % (95% CI) | Cut-off | Sensitivity % (95% CI) | Specificity % (95% CI) |
| Normal diastolic function | ≥2.55 78 (66–88) 95 (90–97) | ≤170 72 (59–82) 86 (80–91) |
| Grade I dysfunction | ≤2.55 94 (90–97) 78 (66–87) | >170 86 (80–90) 72 (59–82) |
| Grade II dysfunction | ≤2.15 79 (70–87) 70 (62–77) | ≥235 67 (57–77) 73 (65–80) |
| Grade III dysfunction | ≤1.9 94 (79–99) 87 (82–92) | >303 100 (89–100) 96 (92–98) |
Limitations

The consecutive nature of the enrolment prevented the selection of a homogeneous population of patients. Moreover, in our study, only resting LV diastolic function was assessed at CZT. As a matter of fact, the evaluation of LV filling dynamics during stress may shade lights on the presence of subclinical diastolic dysfunction, possibly helping in the precocious identification of significant CAD. However, since echocardiography has emerged as the modern gold standard technique for the assessment of LV diastolic function, an invasive evaluation of LV filling dynamics was performed. However, to the best of our knowledge, no medication was stopped before echocardiography. For those reasons, the actual correlations among the variables explored might have been slightly weakened. Furthermore, while in previous reports SPECT-derived measures of LV diastolic function were validated against invasive LV filling parameters, giving different cut-off values of both abnormal PFR and TPFR, in the present study only a non-invasive evaluation of LV filling dynamics was performed. However, since echocardiography has emerged as the modern gold standard technique for the assessment of LV diastolic function, an invasive evaluation of LV filling should be considered unnecessary. Finally, in the present study, no attenuation correction of CZT images was performed. However, to the best of our knowledge, attenuation correction of scintigraphic images was never performed in the previous studies on LV diastolic function.

Conclusions

In patients with or without CAD, CZT-derived measures of LV filling dynamics significantly correlate with echocardiographic parameters of diastolic function and may identify the presence of increased LV filling pressures. Present data show the feasibility of an integrated evaluation of myocardial perfusion and function with a rapid, low-dose, CZT imaging protocol.

Conflict of interest: The Authors declare no relationship with industry.

References