Myocardial perfusion imaging parameters: IQ-SPECT and conventional SPET system comparison

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Abstract

Technological advancement in hardware and software development in myocardial perfusion imaging (MPI) leads to the shortening of acquisition time and reduction of the radiation burden to patients. *We compared* semiquantitative perfusion results and functional parameters of the left ventricle between new dedicated cardiac system with astigmatic collimators called IQ-SPECT (Siemens Medical Solutions, USA) and conventional single photon emission tomography (SPET) system equipped with standard low energy high resolution collimators. *A group of randomly selected 81 patients* underwent consecutively the MPI procedure on IQ-SPECT and on conventional SPET systen, both without attenuation correction. The summed scores and the values of the functional parameters of the left ventricle: ejection fraction (EF), end-systolic and end-diastolic volumes (ESV, EDV) received from the automatic analysis software were compared and statistically analyzed. *Our results showed* that summed scores values were significantly higher for the IQ-SPECT system in comparison to the conventional one. Calculated EF were significantly lower for IQ-SPECT, whereas evaluated left ventricular volumes (LVV) were significantly higher for this system. *In conclusion*, we recorded significant differences in automatically calculated semiquantitative perfusion and functional parameters when compared uncorrected studies obtained by the IQ-SPECT with the conventional SPET system.

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Introduction

Myocardial perfusion imaging (MPI) by single photon emission tomography (SPET) combined with electrocardiography-gated acquisition of data (gSPET) is suitable for the diagnosis and prognosis of coronary artery disease (CAD). It gives information about perfusion, myocardial viability and function of the left ventricle (LV) [1-4]. Quantitative parameters calculated in specialized software applications help to stratify the probability of developing angina or myocardial infraction even in asymptomatic patients [5].

Technological progress in computers hardware and software tends to shorten the acquisition time and allows reduction of the dose of the administrated radiopharmaceutical (rph) and of radiation burden to patients [6, 7]. We upgraded the new system for MPI, which is called IQ-SPECT. This system uses dedicated multifocal collimators, "SMART ZOOM" and specialized software for reconstruction. With the above equipment we noticed some differences in the reconstructed images and in the semiquantitative results describing perfusion and function of LV, in comparison to the conventional gSPET imaging system using low energy high resolution (LEHR) collimators.

The aim of our study was to compare automatically produced semiquantitative parameters of perfusion and function of the LV between the IQ-SPECT and the conventional gSPET system.

Patients and methods

We studied a group of randomly selected 81 patients, 47 male, 34 female, with mean age of 62.2±8.4 years, who were examined according to a 2 days stress-rest protocol. The stress test was done by a bicycle ergometer or by dipyridamole (persantin) administered intravenously (i.v.). The rph was injected i.v. during the bicycle ergometry at the time when 85% of the age-predicted maximal heart rate was achieved or at the clinical appearance of angina, dyspnea, dizziness, frequent ventricular extrasystoles, significant ST segment depression on the electrocardiogram (ECG) or when a blood pressure decrease of 10Torr below the previous stage value was apparent. If the subject did not meet the criteria mentioned above for the rph administration, the 4min infusion with persantin in a dose of 0.56mg/kg of body weight was applied, followed by low-level ergometric exercise. Patients with complete left bundle branch block were stressed only by dipyridamole infusion to avoid tachycardia and to reduce the possibility of septal artifacts [8].

The rph used was technetium-^{99m}-tetrofosmin (^{99m}Tc-TF) or ^{99}mTc-sestamibi (^{99}mTc-MIBI) in a dose of 400MBq.

Patients were first examined by the IQ-SPECT system and immediately after by the conventional gSPET system. For the exercise stress test the acquisition started approximately 15min after rph administration. For the dipyridamole stress test the acquisition started within 45min. If the stress study was completely normal in terms of perfusion and LV function, the rest study was waived (total of 24 cases, 29.6%).

The IQ-SPECT system consisted of three main components [7].
1. Dedicated multifocal collimators, which magnify the heart region in the central part of the field of view by means of converging collimation while keeping the rest of patient's torso in the field of view and not truncated. This is achieved by morphing the collimator holes to a near parallel geometry at the periphery of the collimator. This tends to quadruple the sensitivity for the cardiac region without truncation artifacts at the periphery.
2. Cardiocentric acquisition, which keeps the heart region focused at the center of the collimator, which is the most sensitive area. The detectors are in a configuration of 76 degrees, with scan arc of 104 degrees and radius of rotation 28cm.
3. Advanced reconstruction algorithm optimized for the special geometry of the SMART ZOOM collimators and for the cardiocentric orbit of the detectors with implementation of distance dependent 3D resolution recovery and the possibility of energy window based scatter correction and attenuation correction with computed tomography (CTAC).

The system was installed on a dual head Symbia S tomographic camera (Siemens Medical Solutions, USA). The acquisition parameters were: matrix 128x128, 17 views per detector obtained at 20s per view. Studies were gated at 8 frames per cardiac cycle and neither attenuation nor scatter correction were applied. The series were reconstructed by Flash-3D (3-dimensional ordered subset expectation maximization) algorithm, 30 iterations with 1 subset. Gauss filter with FWHM 14mm was applied.

The conventional system consisted of the e-Cam DUAL two-headed scintillation camera (Siemens Medical Solutions, USA), equipped with standard LEHR collimators in configuration of 90 degrees (L-mode). Acquisition parameters were: matrix 64x64, zoom 1.45 and 32 views per head obtained at 20s per view. Studies were gated at 8 frames per cardiac cycle and neither attenuation nor scatter correction were applied. Filtered back projection (FBP) was used for reconstruction of the tomographic data, Butterworth filter (cut-off Nyquist frequency 0.4, order 5) was also used.

Reconstructed images from both systems were processed in Corridor4DM application software package (INVIA, Ann Arbor, Michigan, USA) charged with appropriate normal databases. Normal databases were gender-specific, for IQ-SPECT, with samples from 30 men and 20 women and for the conventional system with samples from 70 men and 60 women.

We compared the values of summed stress scores (SSS), summed rest scores (SRS), summed difference scores (SDS), EF, EDV and ESV in stress and rest conditions (EFStr, EDVStr, ESVStr, EFRst, EDVRst, ESVRst). Data were statistically evaluated with the non-parametric test for paired data (Wilcoxon signed-rank test). The level of significance was set on 5%. Variables were expressed as the mean±standard deviation (SD) and median.

Results

Values of SSS, SRS and SDS were all significantly higher for the IQ-SPECT system in comparison with the conventional one (P<0.001 for all 3, Table 1).

Results of calculated functional parameters, EFStr and EFRst were significantly lower for the IQ-SPECT (P<0.001 and P<0.001). The average EFStr for the IQ-SPECT was 57.79±13.68% vs. 66.31±14.35% for the conventional system. The average EFRst for the IQ-SPECT was 54.05±13.99% vs. 61.93±12.24% for the conventional system. Results of the semiquantitative parameters are found in Table 1.

***Table 1**. Results of semiquantitative analysis in Corridor4DM application*

Parameter		IQ-SPECT	Conventional system	Significant P
SSS	Mean±SD	6.95±7.89	4.27±6.85	✓
	Median	4	1	✓
SRS	Mean±SD	5.82±7.07	3.98±5.79	✓
	Median	3	1	✓
SDS	Mean±SD	4.46±4.37	2.37±3.60	✓
	Median	3	1	✓
EF Str	Mean±SD (%)	57.79±13.68	66.31±14.35	✓
EDV Str	Mean±SD (ml)	113.31±49.21	103.51±57.51	✓
ESV Str	Mean±SD (ml)	52.05±42.05	40.74±50.55	✓
EF Rst	Mean±SD (%)	54.05±13.99	61.93±12.24	✓
EDV Rst	Mean±SD (ml)	127.58±62.41	116.54±65.79	✓
ESV Rst	Mean±SD (ml)	64.54±58.71	50.32±59.94	✓

SSS: summed stress score; SRS: summed rest score; SDS: summed difference score; EF: ejection fraction of the left ventricle; EDV: end diastolic volume of the left ventricle; ESV: end systolic volume of the left ventricle; Str: values related to stress conditions; Rst: values related to rest conditions; P: always <0.001.

Discussion

The time consumed for the application of the conventional gSPET acquisition is a disadvantage in comparison with other available procedures as stress echocardiography or cardiac computed tomography (CT) [7]. The radiation exposure to the patient has been discussed recently [9].

The technological progress in the MPI systems increases detection sensitivity and so improves the SPET image quality and also decreases the radioactivity administered to the patient and the acquisition time [6, 7].

The iterative reconstruction itself improves quality of images and in comparison to FBP reconstruction, the image contrast is enhanced. In addition resolution recovery technique improves spatial resolution and decreased the noise in comparison to the conventional procedures [7]. The new IQ-SPECT system implemented all these software possibilities but also introduced dedicated astigmatic multi-focal collimators that can be set on the standard Anger SPET cameras. As a result, IQ-SPECT system allows reduction in acquisition time or in administer activity or in a combination of both by a factor of 4 (e.g. in order to decrease in half both the administered radioactivity and the length of the acquisition) while still keeping acceptable spatial resolution [7].

The scoring system for the assessment of perfusion defects is suitable for risk stratification of the patients [1, 3]. The 17-segments model of the left ventricle is preferred recently [10, 11]. The visual analysis by expert readers has been used in many previous studies [12] and semiquantitative analysis is recommended only as an adjunct to visual analysis [11]. However, visual analysis is dependent on reader's expertise [13]. A recent study from Arsanjani R et al (2013) confirmed that automated analysis of non-corrected and the attenuation corrected, data with contours checked by an experienced technologist are at least equivalent to visual analysis in terms of detection of coronary angiographic findings with 70% stenosis [14].

In our department the automated quantitative analysis of perfusion deficits as well as functional parameters calculated by Corridor4DM application are used as a standard protocol. After adopting the new IQ-SPECT system we found differences in the appearance of reconstructed images (example Fig. 1 a-d). Furthermore, we found significant differences in all monitored parameters while comparing both systems.

Our results are in discrepancy with those from a recent study by other researchers [12] who found only minimal disagreement. However there are some differences in their adopted protocol, used in the conventional system, the OSEM algorithm for reconstruction of tomographic data and differences in the fact that their studies were recorded with CT attenuation correction. They assessed perfusion defects visually while we used FBP as reconstruction algorithm, no attenuation correction and all parameters were assessed automatically.

We know that soft tissue attenuation artifacts are the most common artifacts in MPI [15]. The CT-based attenuation correction (CTAC) should improve risk stratification [16]. The prognostically relevant SSS cut-off is then shifted towards lower values [17]. On the other hand CTAC can be the source of artifacts from misregistration [18]. Another way to reduce

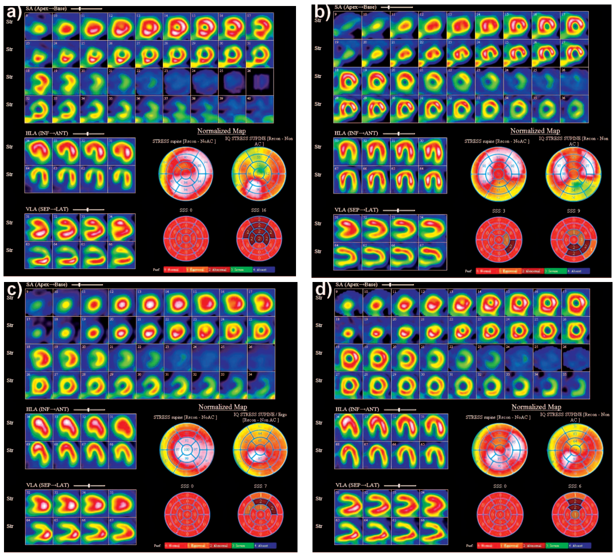

Figure 1. Examples of evident differences in studies from conventional SPET (upper rows and left polar maps) and IQ-SPECT (lower rows and right polar maps). a) In a 73 years old female, b) In a 68 years old male. c) In a 66 years old female. d) In a 63 years old female.

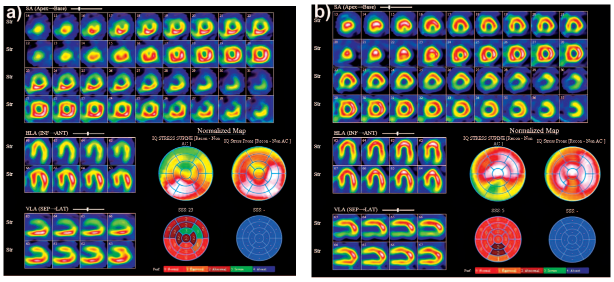

Figure 2. Example of the impact of the prone position acquisition. a) IQ-SPECT slices and polar maps in supine and prone position in a 67 years old female patient. An anterior wall defect is mostly refined in prone position, b) IQ-SPECT slices and polar maps in a 62 years old male patient. An inferior wall defect normalization is seen in the prone position.

the attenuation artifact is the prone position acquisition [8, 19, 20]. In our recent study we did not evaluate the impact of adding the prone position acquisition for IQ-SPECT system, but from our experience there exists the potential to improve the specificity of the examination (Fig. 2 a-b).

Differences in acquisition and reconstruction parameters caused different reconstruction voxel size-6.6mm for conventional system vs. 4.8mm for IQ-SPECT. Other authors [21] analyzed relative myocardial uptake in a 20 segments model of images obtained from triple-head system equipped with LEHR collimators (matrix 64x64) and reconstructed with FBP and dual-head camera with IQ-SPECT (matrix 128x128), both without attenuation correction. No significant differences in the percentage uptake of these segments were found, but the scoring based on comparison with corresponding normal databases was not used.

Variations in EF and LVV when comparing gSPET for FBP and iterative reconstruction were described in previous studies [22, 23]. We have also found significant differences. But still our results are discrepant with the previously mentioned studies [12, 21], which did not find significant variations in their results.

Other researchers [24] found significant discordance in the evaluation of the size of perfusion defect among three widely used software packages for automated analysis of MPI studies: the Quantitative Perfusion SPECT (Cedar-Sinai Medical Center, Los Angeles, USA), the Emory Cardiac Toolbox (Emory University, Atlanta, USA), and the Corridor4DM. Utilization of different software packages can limit the accuracy of inter-institutional comparisons and of multi-center studies. The impact of this disagreement should be evaluated in future in relation to IQ-SPECT. Further studies should evaluate the correlation of uncorrected IQ-SPECT data with clinical findings and the impact of prone position acquisition on data without CTAC.

Accurate identification of the extent of perfusion deficit is necessary for making clinical decisions and for randomizing the patients in clinical trials [24, 25].

In conclusion, although the new IQ-SPECT system can shorten the acquisition time and/or reduce the radiation dose delivered to the patients, we found significant differences in automatically calculated semiquantitative perfusion and functional parameters when comparing uncorrected studies obtained by IQ-SPECT and by the conventional MPI SPET system. Summed scores describing myocardial perfusion deficits tend to be higher for IQ-SPECT while EF values tend to be lower. The new protocol needs to be verified in future studies, especially its correlation with clinical data should be examined.

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