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Short communications

Does quantification of myocardial perfusion SPECT study differ while image reconstruction is carried out using iteration algorithm instead of filtered back-projection? – a preliminary report

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Abstract

BACKGROUND: The purpose of this study was to compare the performance of two reconstruction algorithms: conventional filtered back-projection (FBP) and an iterative algorithm – ITW – in quantitative analysis of myocardial perfusion SPECT studies. The defect size and defect severity were assessed on ^{99m}Tc-MIBI images reconstructed using both methods and estimation of sensitivity in the detection of perfusion deficits and myocardial viability were performed as well.

METHODS AND RESULTS: The study group comprised 43 patients (38 men and 5 women) in the age of 40-73 years (mean 59 years). Heart perfusion scintigraphy was performed following an injection of 22 to 25 mCi ^{99m}Tc-MIBI for exercise and rest myocardial perfusion study. Images were reconstructed using FBP and ITW algorithms. Defect size (DS) was quantified by a threshold program and CEqual programme. Defect severity (nadir) was calculated as the ratio of minimal/maximum counts from bull's eye polar map. Coronary arteriography was performed in all patients.

RESULTS: Defect size calculated by threshold method on resting images did not differ between reconstruction methods (p = 0.61 for cut-off 50% and p = 0.24 for cut-off 60%); defect severity was higher on images reconstructed with ITW ($CI_{0.95}$ = 2.4%÷5.2% of maximal counts).

CONCLUSIONS: Sensitivity for detection of heart perfusion defects and estimation of myocardial viability were similar on images reconstructed by both algorithms.

Key words: single-photon emission tomography, ^{99m}Tc-MIBI, reconstruction algorithms

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Introduction

Myocardial perfusion SPECT studies have gained wide acceptance as a useful non-invasive technique for the identification and evaluation of patients with known or suspected coronary artery disease (CAD) [1, 2]. This enables the localisation of perfusion defects and an estimation of their size and severity. Quantification of the extent of myocardium at risk is of outstanding value in the prognostic stratification of patients with CAD and provides an important tool for the evaluation of the efficacy of therapeutic interventions. ^{99m}Tc-MIBI is a blood flow tracer which provides an accurate measurement of the defect size and severity, good identification of coronary artery stenosis and recognition of viable, hypoperfused, hypocontractile myocardium [3, 4].

Myocardial perfusion SPECT studies have been reconstructed so far by a FBP algorithm. The FBP was pioneered in conjunction with the development of X-ray computed tomography [5]. Lately, iterative algorithms have become widely used because of their theoretical superiority in rendering tracer distribution and better noise characteristics. They yield an estimate which has the highest likelihood of giving the observed projection data, after modelling the physics of the acquisition process [6]. To shorten the reconstruction time of a standard iterative MLEM [7] algorithm, several methods were developed to accelerate convergence, including ITW [8]. The ITW algorithm employs a ramp filter to accelerate convergence of the high frequency components of the estimate.

The aim of study was to compare quantified images of myocardial perfusion reconstructed by FBP and ITW methods and to assess the influence of defect calculation on sensitivity in the detection of heart perfusion deficits and myocardial viability estimation.

Material and methods

Patients. The study group comprised 43 patients (38 men and 5 women), aged 40–73 years (mean 59 years), who underwent nuclear studies before planned cardiovascular operation. Coronary angiography was performed in all patients. Significant CAD was defined as a luminal narrowing of 50% or greater of one or more coronary arteries or its major branches. 2 patients had one-vessel disease, 12 patients two-vessel and 29 patients three-vessel disease. 36 people had experienced myocardial infarction in the past.

The study group was divided into 2 groups: 24 patients with heart weight (estimated by CEqual programme) above 115 g (group I) and 19 patients with heart weight below 115 g (group II).

Single Photon Emission CT Imaging. Heart perfusion scintigraphy was performed following the injection of 22 to 25 mCi ^{99m}Tc-MIBI for each study (exercise and rest) performed with the 2-day protocol. SPECT imaging was performed using a triple-head rotating gamma camera. 64 views in 64x64 matrix were acquired for 20 sec each view, rotation over 180-degree arc in step-and-shoot method, progressing from the 45-degree RAO to the 45-degree LPO. Low energy, high resolution collimation was used with the camera peaked at 140-keV using a 15% energy window.

The transaxial tomographic images were reconstructed using conventional FBP method and filtered afterwards with stationary Butterworth filter, recommended by the CEqual programme provider of order 5 with cut-off at 0.4 cycles/pixel (stress study) or 0.35 cycles/pixel (rest study). Iterative reconstruction was performed using the ITW method for 6 iterations recommended by IDL software provider (Version 5.0.3. — Research Systems, Boulder, USA) and filtered with 9-mm Gaussian filter. The transaxial slices were used to generate oblique sections, reoriented along the horizontal and vertical long axis and the short axis of the left ventricle. Polar plots (bull's eye maps) were generated according to Verani method [9].

Defect size, defect severity, sensitivity in the detection of heart perfusion deficits and myocardial viability. Size of the perfusion defect (defect size — DS) was expressed as a percentage of the total of left ventricle. It was calculated using the comparison to CEqual database or with the use of two threshold values. We used the threshold method at rest studies and the CEqual method at stress studies.

In the CEqual programme analysis, each heart perfusion image was compared to a gender-matched normal file for stress imaging. As hypoperfused myocardium were considered pixels of polar map with a ^{99m}Tc-MIBI uptake below gender-matched lower limit.

Two threshold values of 50% and 60% of the maximum left ventricular count were used to define the limits of the perfusion defect in the second method. Defect severity (nadir) was calculated as the ratio of minimal/maximal counts in pixels of bull's eye map. Its value was a criterion of viability of abnormal segments: segments with nadir below 60%, 50% or 30% were considered nonviable (scar).

Sensitivity in the detection of heart perfusion deficits was defined as the number of true positive tests (abnormal segments on stress images when compared to CEqual database) x 100 divided by the sum of the true-positive and false-negative tests. Coronary angiography was used as a reference.

Statistical analysis. Statistical analysis was performed using software Statistica for Windows (StatSoft, USA). All data were expressed as medians and 95% confidence intervals. Wilcoxon signed ranks test (non-parametric) was used to analyse differences in defect size and severity between groups on images reconstructed with FBP and ITW methods. McNemar test (non-parametric test of proportions) was used to compare sensitivity of detection of coronary stenosis and viability of myocardium on images reconstructed with FBP and ITW methods. Differences were considered significant when $p < 0.05$.

Results

Perfusion defect size calculated by the threshold method on resting images reconstructed by both algorithms did not differ in group I ($p = 0.78$ for cut-off 50% and $p = 0.86$ for cut-off 60%) and group II ($p = 0.68$ for cut-off 50% and $p = 0.13$ for cut-off 60%). Defect size was bigger in regions assigned to LAD territory in group II (but not group I) on images reconstructed by FBP algorithm (difference of 0.67% of ventricular mass for cut-off 50%; 0.92% for cut-off 60%). The ITW reconstruction provided a higher median value of defect size in regions of RCA supply in both groups (difference of 1.0% of ventricular mass for cut-off 50% and 0.83% for cut-off 60% in group I and, respectively, 0.58% and 0.67% in group II). Differences in defect size in particular coronary arteries' beds in both groups are presented in Table 1.

Calculation of defect size when compared to CEqual database on exercise stress images reconstructed by both algorithms showed similar differences as noted above on resting images.

Defect severity (nadir). The median values of the defect severity were lower in both groups on resting images reconstructed by ITW method (difference was 3.1% of maximal counts in group I and 5.3% in group II). Those differences were highly significant (Table 2).

Sensitivity for detection of hypoperfusion in individual coronary artery perfusion beds and estimation of myocardial viability. Sensitivity for detection of hypoperfusion in individual coronary artery perfusion beds was similar on images recon-

Table 1. Difference in defect size (%) in regions assigned to specific coronary arteries on rest images reconstructed with FBP and ITW algorithm

($n_{50\%}/n_{60\%}$)			Cut-off 50% ($CI_{0.95}$)			p	Cut-off 60% ($CI_{0.95}$)			p
MYO	group I and II	(43)	–1.00	÷	1.50	0.61	–0.50	÷	2.50	0.24
	group I	(24)	–1.50	÷	2.00	0.78	–2.00	÷	2.50	0.86
	group II	(19)	–1.50	÷	2.00	0.68	–0.50	÷	4.50	0.13
LAD	group I and II	(43)	0.00	÷	0.83	0.07	–0.67	÷	1.00	0.50
	group I	(24)	–0.83	÷	0.83	0.75	–2.00	÷	0.83	0.43
	group II	(19)	0.17	÷	1.00*	0.02	0.17	÷	1.50*	0.02
LCx	group I and II	(18/39)	–0.17	÷	0.42	0.35	–0.08	÷	0.67	0.15
	group I	(10/21)	–0.33	÷	0.75	0.25	0.00	÷	1.08	0.08
	group II	(8/18)	–0.42	÷	0.50	1.00	–0.58	÷	0.50	0.87
RCA	group I and II	(42/43)	–1.24	÷	–0.42*	0.00	–1.33	÷	0.33*	0.00
	group I	(24)	–1.67	÷	–0.42*	0.00	–1.67	÷	–0.25*	0.00
	group II	(18/19)	–1.33	÷	0.00*	0.04	–1.50	÷	0.00*	0.04

*statistically significant ($p<0.05$), $n_{50\%}$, $n_{60\%}$ — number of hearts with defect size estimated using cut-off level of 50% and 60%
MYO — myocardium, LAD — left anterior descending artery, LCx — left circumflex artery, RCA — right coronary artery

Table 2. Difference of nadir (defect severity) on rest images reconstructed with FBP and ITW algorithm (%)

(n)		nadir ITW- nadir FBP ($CI_{0.95}$)			p
Group I and II	(35)	2.4	÷	5.2*	< 0.0001
Group I	(23)	1.4	÷	4.7*	0.0004
Group II	(12)	2.3	÷	10.7*	0.0015

*statistically significant ($p < 0.05$), n — number of hearts within each group

structed by both algorithms. Estimation of myocardial viability did not differ between reconstruction methods. Results of SPECT ^{99m}Tc-MIBI perfusion study in identifying individual coronary artery stenosis and myocardial viability are presented in Tables 3 and 4.

Discussion

^{99m}Tc-MIBI SPECT heart perfusion imaging is a highly accurate technique for quantifying the extent of acute and healed myocardial infarction in humans [10]. Different ischaemic cut-off levels have been employed in the quantification of the perfusion defect. The most popular cut-off levels: 50% and 60% of the maximum left ventricular (LV) count, were used to define the limits of the perfusion defect in this study. The threshold value of 60% was originally validated in a phantom study using ^{99m}Tc-MIBI [11]. It is very close to the inferior limits (63% of the normal myocardial uptake) of the MIBI distribution in normoperfused myocardial segments. When Verani employed the polar map method he chose an arbitrary threshold of 50% of the maximum myocardial uptake [9]. Artefacts due to photon attenuation and scatter, alternations in left ventricular geometry and function, a partial volume effect, degrade the image quality and limit the accuracy of scintigraphic quantification of defect size in vivo.

Small discrepancies between defect size estimated on resting images reconstructed by both methods using the same threshold values indicate that the location of the perfusion defect does not affect the comparability of the techniques.

In the CEqual programme different standard deviations in different myocardial regions were found and used to optimise threshold limits for abnormality [4]. Normal ranges of myocardial perfu-

Table 3. Sensitivity for detection of hypoperfusion in individual coronary artery perfusion beds on images reconstructed by FBP and ITW algorithm (%)

	FBP			ITW			p
	Sensitivity	(T/n)§		Sensitivity	(T/n)§		
LAD	70	30	/43	65	28	/43	0.500
LCx	59	20	/34	50	17	/34	0.250
RCA	36	13	/36	39	14	/36	1.000
Individual vessel	56	63	/113	52	59	/113	0.219
All patients	93	40	/43	84	36	/43	0.125

§ T/n — number of true results among analysed hearts (n)
MYO — myocardium, LAD — left anterior descending artery, LCx — left circumflex artery, RCA — right coronary artery

Table 4. Number of hearts with scar on rest images reconstructed with FBP and ITW algorithm estimated using cut-off level of 30%, 50% and 60%

(n)		Cut-off level (%)	FBP	ITW	p
Group I and II	(35)	30	8	11	0.2500
		50	15	18	0.3750
		60	25	30	0.0625
Group I	(23)	30	7	10	0.2500
		50	13	13	1
		60	19	20	1
Group II	(12)	30	1	1	1
		50	2	5	0.2500
		60	6	10	0.1250

sion of normal reference patients of the database are based on the best discriminatory level, tested in patients with CAD. This approach minimises the impact of some artefacts, although normal limits of perfusion are still wide. Performed evaluation of stress studies rendered similar differences as rest studies results.

In the study presented above only quantitative analysis of myocardial perfusion was used to calculate detection of individual coronary artery stenosis. Defects in particular vascular beds were assigned to a specific coronary lesion. The sensitivity for detection of individual vessel involvement was only 52–56%. The reason for the relatively low rate was inadequate exercise level during stress study. In the majority of cases, patient's test was terminated by ischaemia in a more severely diseased vessel. Although the supplying vessel had a significant stenosis, the myocardial segment did not become ischaemic.

^{99m}Tc-MIBI is a known marker of blood flow. It is also used to assess myocardial viability: it differentiates viable from scarred, nonviable myocardium. At the cellular level, both the uptake and retention of MIBI are profoundly affected by metabolic derangements of mitochondrial and cell membranes. It is not retained by perfused but nonviable myocardium.

The criteria of tracer distribution (30%, 50% or 60% of maximal myocardial counts [12, 13] within the perfusion defects for assignment of myocardial segments as predominantly scar tissue or viable myocardium are arbitrary. In this study rest-stress ^{99m}Tc--MIBI imaging yielded comparable results for distinguishing between ischaemia and scar.

Conclusions

Sensitivity for detection of heart perfusion defects and estimation of myocardial viability were similar on images reconstructed by both algorithms.

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