Rapid data acquisition protocol in ECG-gated myocardial perfusion SPECT with Tc-99m-tetrofosmin

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Into 25 patients with heart disorders, $^{99m}$Tc-tetrofosmin 555–740 MBq was injected intravenously at rest. After 40 minutes, ECG-gated myocardial perfusion SPECT was performed with a two detector gamma camera VERTEX (ADAC), setting up two detectors to form a 90-degree angle. Sixteen frames per R-R interval were acquired during a 180° rotation from the RAO 45° to the LPO 45°. A pair of data sets with standard (SDA) and rapid data acquisition (RDA) protocols was collected. In an SDA protocol, SPECT imaging was performed for 50 sec per step in 5° angular steps (total acquisition time; 15 minutes). An RDA protocol was conducted with 12 sec per step, 6° angular steps (acquisition time, 3 minutes). LVEF (%) and LVEDV (mL) quantitated automatically with a QGS program showed excellent correlations between two protocols with correlation coefficients of 0.980 (p < 0.01) and 0.983 (p < 0.01), respectively. Subsequently visual assessment of regional wall motion based on a four-point grading system was carried out with a 3-D cine LV display. High complete agreement was gained with 158 (90.3%) out of total 175 segments, so that assessment of the global and regional LV function with the RDA protocol demonstrated high reliability and feasibility.

Key words: technetium-99m-tetrofosmin, Single-photon emission computed tomography, left ventricular ejection fraction

INTRODUCTION

Technetium-labeled myocardial perfusion tracers, such as $^{99m}$Tc-1,2-bis[2(ethoxyethyl)phosphino]ethane ($^{99m}$Tc-tetrofosmin) and $^{99m}$Tc-methoxy-isobutylisonitrile ($^{99m}$Tc-sestamibi), allow simultaneous assessment of myocardial perfusion and left ventricular function by means of ECG-gated single-photon emission computed tomography (SPECT).\textsuperscript{1-5} Myocardial perfusion data with a technetium-labeled tracer is usually acquired 30 to 40 minutes after the intravenous injection taking account of washout through the hepatobiliary system. Since this agent does not show a significant redistribution phenomenon clinically, SPECT images reflect myocardial perfusion at injection, but left ventricular function based on the ECG-gated data is always estimated at rest in spite of the actual situation at injection. For assessment of left ventricular function at exercise or in drug loading such as dobutamine, we need to contract the data collection time as soon as possible. We therefore tried rapid ECG-gated SPECT acquisition in patients with heart disease, and examined the reliability of the left ventricular functional data.

MATERIALS AND METHODS

Patient population

Twenty-five patients with heart disorders (15 men and 10 women, mean age: 54 years) were included in this study. Of these 22 had ischemic heart disease, two had cardiomyopathy and one had valvular disease. Of those with ischemic heart disease, six had a record of previous myocardial infarction.
ECG-gated myocardial SPECT data acquisition

Tc-tetrofosmin 555–740 MBq was injected intravenously at rest. After 40 to 60 minutes, ECG-gated myocardial perfusion SPECT was performed with a two detector gamma camera (VERTEX, ADAC) equipped with low-energy, general purpose collimators, with the detectors set up to form a 90-degree angle (L-shape). Sixteen frames per R-R interval were acquired during 180° rotation in a 64 x 64 matrix from the 45° right anterior oblique to the 45° left posterior oblique projection (each head performing 90° rotation). A pair of data sets obtained with the standard and rapid data acquisition protocol were collected. In a standard data acquisition (SDA) protocol, SPECT imaging was performed for 50 sec per step in 5° angular steps in the continuous acquisition mode, so that there was no rotational dead time and total acquisition time was 15 minutes. A rapid data acquisition (RDA) protocol was conducted with 12 sec per step, 6° angular steps and total acquisition time of 3 minutes.

Visual scintigraphic evaluation of image quality
The SPECT data used a Butterworth filter (order = 10, critical frequency = 0.2 cycles/pixel, slice thickness = 6.5 mm) and reconstruction was carried out by the filtered back projection method (ramp filter). Two sets of short-axis images employing the summed non-gated data from the SDA and the RDA protocols were compared separately and independently by two experienced observers. Image quality was subjectively assessed by means of a four-point system (1–4; poor, fair, good and excellent), based on visual myocardial-to-background activity ratios, left ventricular endocardial and epicardial border definition.

ECG-gated myocardial SPECT data analysis
From the respective ECG-gated SPECT data, the Pegasys™ processing computer and the function analysis software program, QGS (Cedars-Sinai Medical Center) were used, and the left ventricular ejection fraction (LVEF; %) and left ventricular end-diastolic volume (LVEDV; ml) were calculated automatically. With the QGS program, LV endocardial and epicardial surfaces were determined for all gating intervals in the cardiac cycle, and the contours were generated even in the apparent absence of myocardial perfusion.

Subsequently, to compare SDA and RDA protocol regional wall motion, a 3D-cine mode display was created with the QGS program. The mobile images of the left anterior oblique (LAO) and left lateral (LLT) views for each case were recorded on a video tape. The mobile images above including the acquisition method and order of cases were recorded at random on video tape, and visual assessment of regional wall motion was made by two experienced observers after consultation. As a semi-quantitative assessment of wall motion, the left ventricle was divided into 7 segments as in Fig. 1, and graded on a four-point scoring system as normokinetic (score 0), mild hypokinetic (score 1), severely hypokinetic (score 2) or akinetic-dyskinetic (score 3).

Statistical analysis
Comparison of proportions was made with chi-square statistics. The agreements of LVEF and LVEDV measurements derived from the SDA and the RDA protocols were assessed by linear regression. A p value < 0.05 was considered significant.

RESULTS

Non-gated myocardial SPECT image quality derived from the SDA protocol was rated as excellent, good, fair or poor in 11 (44%), 12 (48%), 2 (8%) and 0 (0%) patients, respectively. The corresponding values from the RDA protocol were 2 (8%), 15 (60%), 7 (28%) and 1 (4%), respectively (Fig. 2).

In comparing the LVEFs (%) obtained from the SDA and the RDA protocols, an excellent correlation was obtained with a correlation coefficient of 0.980 (p < 0.01) (Fig. 3). Again, an excellent correlation of LVEDVs (ml) for the two protocols is shown in Fig. 4 (r = 0.983, p < 0.01).

Next, both acquisition data were used to create a 3D-cine display and good left ventricular mobile images were obtained in 24 cases (96.0%), excluding only one case out of the 25 for both protocols associated with insufficient separation between the left ventricular inferior wall and the liver.

As for visual assessment of the regional contractility based on the 3D-cine display, a high rate of complete matching was gained in 158 of the 175 segments (90.3%) in all 25 cases. Also, even in the remaining 17 segments where complete matching was not gained, there was a score difference of only 1 (Table 1).

Case example
Figure 5 shows myocardial perfusion and LV functional images obtained from the RDA protocol in a patient with anterior myocardial infarction. In the summed non-gated myocardial image, perfusion defects are observed in the anterior and apical regions of the left ventricle. And the
LV functional images demonstrate akinesis in the anterior, apical and septal walls.

DISCUSSION

Technetium-labeled myocardial perfusion tracers, such as $^{99m}$Tc-tetrofosmin and $^{99m}$Tc-sestamibi, allow simultaneous assessment of the left ventricular function with ECG-gated SPECT imaging and provide useful information for the diagnosis of heart disorders, especially of the ischemic heart disease. SPECT images with a $^{99m}$Tc-labeled tracer reflect the myocardial perfusion at injection, either at rest or stress, but as imaging is usually started 30 to 60 minutes after the intravenous injection, the left ventricular functional data obtained by the ECG-gated method come to reflect a state of rest. In ECG-gated myocardial SPECT under dobutamine loading, an acquisition time such as in the SDA protocol permits infusion of only a low dose to protect the myocardium from long exposure to ischemia. Also, regarding exercise stress, it is not possible to carry out a submaximal-maximal load by means of the SDA protocol, so that among nuclear medical techniques, only radionuclide ventriculography has
been generally used for functional analysis in loading.\textsuperscript{8-11} This was our objective in collecting ECG-gated myocardial perfusion SPECT data within a short time.

The relationship between reconstructed image quality and the two acquisition protocols is shown in Fig. 2. The images obtained from the RDA protocol appeared to contain a higher proportion of lower quality images associated with short time acquisition, but only one case (4\%) was considered to be poor quality even in the RDA protocol. In this study, assessment of segmental myocardial perfusion in the two protocols was not performed, as only 6 patients in our study population had prior myocardial infarction. Further studies will be required to compare the detectabilities of infarcted area in the SDA and the RDA protocols.

In comparing the LVEF in both protocols, an excellent correlation was obtained ($r = 0.980, n = 25$), suggesting high reliability as a quantitative assessment of global left ventricular function, as well as LVEDV ($r = 0.983, n = 25$). As a result, the comparisons of the LVEF and LVEDV at rest and stress with the RDA protocol could be important tools in diagnosing whether a patient has ischemic heart disease or not. In the assessment of ischemic heart disease, detection of regional asynchrony making possible the identification of affected coronary artery branches becomes necessary. A high rate of complete agreement between both protocols, 90.3\% (158/175 segments), was gained in visual assessment of regional wall motion with automated 3-D display. This demonstrates the possibility of a clinical application of the RDA protocol.

It will now be necessary to carry out stress ECG-gated myocardial perfusion SPECT studies to validate the usefulness of the RDA protocol under actual loading. In particular, when a patient is being exercised, further examination may be required for the identification and correction of motion artifacts due to exercise.\textsuperscript{12}

**CONCLUSION**

The global and regional LV functions obtained with the RDA protocol closely agreed with those obtained with the

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**Fig. 4** Correlation of LVEDV (ml) between the SDA and the RDA protocols.

**Fig. 5** A 69-year-old male with anterior myocardial infarction. Short-axis myocardial perfusion image (top) and LV functional images (bottom) obtained from ECG-gated myocardial SPECT data of the RDA protocol.

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*Annals of Nuclear Medicine*
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