Detecting Viable Hibernating Myocardium in Chronic Coronary Artery Disease

— A Comparison of Resting ^{201}Tl Single Photon Emission Computed Tomography (SPECT), $^{99\text{m}}\text{Tc}$ -Methoxy-Isobutyl Isonitrile SPECT After Nitrate Administration, and ^{201}Tl SPECT After ^{201}Tl -Glucose-Insulin Infusion —

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To identify and quantify the amount of viable hibernating myocardium in patients with chronic coronary artery disease, resting ^{201}Tl single photon emission computed tomography (SPECT) was compared with $^{99\text{m}}\text{Tc}$ -methoxy-isobutyl isonitrile (MIBI) SPECT after nitrate infusion (nitrate- $^{99\text{m}}\text{Tc}$ -MIBI) and ^{201}Tl SPECT after ^{201}Tl with glucose-insulin-potassium infusion (^{201}Tl -GIK) in 25 patients. Twenty-one patients also underwent completely left ventriculography beforehand and 5±4 months afterwards. SPECT images were divided into 9 segments and scored visually from 0 (normal uptake) to 3 (absent). The defect score was calculated as the summation of the total scores (TDS) in each patient. The TDS of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI images (6.3 ± 4.3) and ^{201}Tl -GIK images (5.8 ± 4.2) were significantly lower than the 7.4 ± 4.3 of resting ^{201}Tl images ($p<0.01$). Based on the improvement of wall motion after coronary revascularization, the sensitivity of ^{201}Tl -GIK imaging (85%) was significantly higher ($p<0.05$), and that of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI imaging (79%) also tended to be higher ($p=0.08$), than that of ^{201}Tl imaging (62%) in detecting viable myocardium. The specificity of the 3 methods was almost the same. The nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GIK methods were more useful than the resting ^{201}Tl method for evaluating viable hibernating myocardium. Furthermore, the ^{201}Tl -GIK method may provide a more accurate estimate of the amount of viable myocardium than the nitrate- $^{99\text{m}}\text{Tc}$ -MIBI method. (*Jpn Circ J* 2000; 64: 937–942)

Key Words: Hibernation; Nitrate- $^{99\text{m}}\text{Tc}$ -MIBI; ^{201}Tl -GIK; ^{201}Tl -rest

In patients with chronic coronary artery disease (CAD), it is clinically important to distinguish viable myocardium from nonviable myocardium to determine whether revascularization will be beneficial.^{1,2} Although positron emission tomography (PET) is considered the gold standard for assessing myocardial viability, alternative procedures based on radionuclide imaging have been proposed. Thallium-201 (^{201}Tl) myocardial scintigraphy has been widely used to detect myocardial viability using either late redistribution³ or a reinjection imaging technique.^{4,5} Technetium-99m ($^{99\text{m}}\text{Tc}$)-methoxy-isobutyl isonitrile (MIBI) and $^{99\text{m}}\text{Tc}$ -tetrofosmin are new myocardial perfusion imaging agents that are used as alternatives to conventional ^{201}Tl imaging.^{6–10} However, several studies have suggested that $^{99\text{m}}\text{Tc}$ -MIBI cardiac imaging may underestimate the presence of myocardial viability,^{11–16} although one study showed that rest $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl cardiac imaging detect myocardial viability equally well.⁷ Furthermore, other studies suggest that $^{99\text{m}}\text{Tc}$ -MIBI cardiac imaging with nitrate administration enhances detection of viable myocardium.^{18–21} A recent study by Tartagni et al describes a new method for

cardiac imaging after infusion of ^{201}Tl , insulin and potassium in a glucose solution, which improved the detection of viable myocardium.²² Insulin is well known to augment the myocardial uptake of potassium through translocation of Na–K ATPase from the cytosol to the sarcolemma.^{23,24} Likewise, ^{201}Tl is taken up by myocardium through Na–K ATPase,^{25,26} and its uptake may be enhanced by insulin administration.

We compared resting ^{201}Tl imaging with resting $^{99\text{m}}\text{Tc}$ -MIBI imaging after nitrate administration, and resting ^{201}Tl imaging after ^{201}Tl with glucose-insulin-potassium infusion, for detecting severely hypoperfused, but viable myocardium in patients with CAD.

Methods

Patients

The study population consisted of 25 patients (23 males, 2 females; aged 56–76 years, mean age, 68 ± 6 years) with angiographically documented CAD and with left ventricular dysfunction. Nine patients had significant stenosis of all 3 major vessels, 13 patients had significant stenosis of 2 major coronary vessels and 3 patients had significant stenosis of only 1 major coronary vessel (defined as a 75% luminal reduction). The mean left ventricular ejection fraction (LVEF) by left ventriculography (LVG) was $44\%\pm 11\%$. All patients had a chronic myocardial infarction (12 anterior, 4 lateral and 18 inferior) that was documented clinically and

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Fig 1. Diagram of study protocol. ISDN, isosorbide dinitrate; GIK, 10% glucose 250 ml + insulin 5 units + KCl 10 mmol.

by electrocardiography and they had not undergone previous revascularization. Nine patients had 2 infarcted major coronary vessels. The patient numbers of 75%, 90%, 99% and 100% stenosis of infarcted vessels were 1, 2, 9 and 22, respectively (Table 1). No patients, however, had an acute myocardial infarction within 3 months of the study. Patients with diabetes or glucose intolerance were excluded from the study. The scintigraphic studies used were resting ^{201}Tl single photon emission computed tomography (SPECT) imaging, $^{99\text{m}}\text{Tc}$ -sestamibi SPECT imaging after nitrate infusion and ^{201}Tl SPECT imaging after ^{201}Tl -glucose-insulin-potassium infusion, all of which were performed after a 12-h overnight fast and in the absence of antianginal medication. After scintigraphic examinations and LVG, all patients underwent coronary revascularization; coronary artery bypass graft was performed in 15 patients and percutaneous transluminal coronary angioplasty in 10 patients. None had clinical evidence of perioperative or postangioplasty myocardial infarction. One patient had occlusion in the graft after coronary artery bypass grafting and 3 had restenosis after angioplasty. All patients gave informed consent in accordance with the guidelines of the hospital's Human Clinical Study Committee prior to participation in the study.

Resting Thallium-201 SPECT

All patients underwent ^{201}Tl imaging after a 30-min rest period. ^{201}Tl (111 MBq) was injected intravenously and the images were acquired 15 min after the injection (Fig 1).

Technetium-99m-Sestamibi SPECT

Within 1 week of the resting ^{201}Tl study, $^{99\text{m}}\text{Tc}$ -MIBI imaging was performed after an overnight fast to minimize gallbladder activity. Patients were instructed to consume milk just before imaging. After 5 mg of isosorbide dinitrate, in 20 ml isotonic saline solution, was infused over 5 min, $^{99\text{m}}\text{Tc}$ -MIBI (500 MBq) was injected 5 min later and then imaging began 30 min later (nitrate- $^{99\text{m}}\text{Tc}$ -MIBI) (Fig 1).

Glucose-Insulin Thallium-201 SPECT

SPECT imaging was also performed within 1 week of the resting ^{201}Tl study. After a 30-min infusion of ^{201}Tl (111 MBq) in 250 ml of 10% glucose plus insulin (5 U) and 10 mmol potassium chloride²² (^{201}Tl -GIK), imaging was begun 15 min later (Fig 1). Two catheters were inserted in the antecubital veins, one for infusion of the radiolabeled solution and one for blood sampling. The infusion rate was adjusted

Fig 2. Diagram of the standard segmentation scheme used for regional quantitative analysis of ^{201}Tl and $^{99\text{m}}\text{Tc}$ -MIBI uptake.

Fig 3. Diagram of the standard segmentation scheme used for regional wall motion analysis of left ventriculography. RAO, right anterior oblique projection; LAO, left anterior oblique projection.

automatically and blood samples were taken at the beginning and end of the infusion and 30 min later. Plasma glucose, potassium activity and plasma-free insulin were measured.

Myocardial SPECT Imaging

Myocardial SPECT imaging was performed using a 3-headed SPECT system with low-energy, high-resolution, parallel-hole collimators. The detector system was interfaced to a dedicated nuclear medicine computer. A total of 72 projection images were obtained over 360° in 5° increments, with 40 s per view for resting ^{201}Tl , $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GIK SPECT. The energy discriminator was centered on 72 keV for ^{201}Tl with a 30% window, and 140 keV for $^{99\text{m}}\text{Tc}$ -MIBI with a 15% window. The data were recorded in 64×64 matrices on a magnetic disk. To reconstruct transaxial tomographic images from each acquisition, Butterworth and ramp filters were used. The parameter of the Butterworth filter was order 8, and the cutoff frequency was 0.24–0.28 cycle/pixel. Short- and long-axis slices, 5-mm thick, were also generated.

SPECT data analysis was based on 1 vertical long-axis slice and 2 short-axis slices. In each patient, the corresponding vertical long- and short-axis tomograms from resting ^{201}Tl , $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GIK SPECT sets were aligned. One vertical long-axis slice and 2 short-axis views from the apical and basal ventricular levels were chosen for comparison. The vertical long-axis slice was used to evaluate the apical region, whereas each short-axis slice was divided into 4 segments (Fig 2). All SPECT images were displayed and analyzed by 3 experienced observers who were unaware of the patient's clinical history. Semiquantitative visual analysis was performed by assigning regional tracer activities on a 4-point scoring system (defect score): 0 = normal uptake, 1 = mildly reduced uptake, 2 = definitely reduced uptake and 3 = absent. Disagreements in interpretation were resolved by consensus. The defect score was calculated as the summation of the total scores (TDS) in each patient. We hypothesized that myocardial viability was maintained as a defect score of 2 or less ($\text{TDS} \leq 2$).

Table 1 Vessel Distribution, Infarcted Region and % Stenosis of Infarcted Vessel

<i>Vessel distribution</i>	
IVD	3
2VD	13
3VD	9
<i>Infarcted region</i>	
Anterior	12
Lateral	4
Inferior	18
<i>% Stenosis of infarcted vessel</i>	
75%	1
90%	2
99%	9
100%	22

Table 2 Differences in Defect Score in the 225 Myocardial Segments

	<i>Resting-Tl</i>	<i>Nitrate-MIBI</i>	<i>Tl-GIK</i>
Score 0	140	150	152
Score 1	18	18	24
Score 2	37	30	25
Score 3	30	27	24

Left Ventriculography

Contrast LVG was acquired in the 30° right anterior oblique projection (RAO) and the 45° left anterior oblique projection (LAO), with the patient supine. For regional wall motion analysis, the left ventricular wall was divided into 7 segments using American Heart Association classification, including 5 RAO and 2 LAO segments, and the wall motion of each segment was evaluated using the following 6-point grading system: -1 = dyskinesis, 0 = akinesis, 1 = severe hypokinesis, 2 = moderate hypokinesis, 3 = mild hypokinesis, and 4 = normokinesis (Fig 3). Improvement in wall motion was defined as an improvement in the wall motion score by 1 point or greater. All patients underwent LVG before and 4–6 months (5±4 months) after coronary revascularization.

Correspondence of Segments Between LVG and SPECT Images

Segment number 1–5 of LVG corresponded to the same segment number of the SPECT image. Segment number 6 of LVG corresponded to segment numbers 6 and 7 of the SPECT images. Segment number 7 of LVG also corresponded to segment numbers 8 and 9 of the SPECT images. The regional tracer activities of the septal and lateral walls in the SPECT images were estimated as the mean of the basal and apical segments, when we compared these tracer activities with the wall motion of the septal or lateral wall (Figs 2, 3).

Statistical Analysis

All data are presented as the mean±SD. A paired Student's *t*-test was used to test the difference between paired data. Chi-square analysis was used to compare the percentages of sensitivity and specificity. A *p* value of less than 0.05 was considered statistically significant.

Results

A total of 225 myocardial segments were analyzed. Normal and abnormal resting ²⁰¹Tl uptakes were found in

Fig 4. Comparison of total defect score using the different imaging techniques.

Fig 5. Sensitivity and specificity of different imaging modalities for detecting myocardial viability on the basis of improvement in wall motion. **p*<0.05 vs resting ²⁰¹Tl.

140 (62%) and 85 (38%) myocardial segments, respectively. Of the 85 segments with abnormal tracer uptake, 18 (21%) showed a mildly reduced uptake, 37 (43%) showed a severely reduced uptake and 30 (35%) segments had no uptake.

Normal and abnormal nitrate-^{99m}Tc-MIBI uptakes were found in 150 (67%) and 75 (33%) myocardial segments, respectively. Of the 75 segments with abnormal tracer uptake, 18 (24%) showed a mildly reduced uptake, 30 (40%) showed a severely reduced uptake and 27 (36%) segments had no uptake. In 29 (34%) of the 85 segments with abnormal resting ²⁰¹Tl uptake, nitrate-^{99m}Tc-MIBI uptake was better than the resting ²⁰¹Tl uptake. On the other hand, only 6 (7%) segments on the nitrate-^{99m}Tc-MIBI images showed a lower uptake than that seen on the resting ²⁰¹Tl images.

Normal and abnormal ²⁰¹Tl-GIK uptakes were found in 152 (68%) and 73 (32%) myocardial segments, respectively. Of the 73 segments with abnormal tracer uptake, 24 (33%) showed a mildly reduced uptake, 25 (34%) showed a severely reduced uptake and 24 (33%) segments had no uptake. In 33 (39%) of the 85 segments with abnormal resting ²⁰¹Tl uptake, ²⁰¹Tl-GIK uptake was better than the resting ²⁰¹Tl uptake. On the other hand, there was no segment in which the resting ²⁰¹Tl uptake was better than the ²⁰¹Tl-GIK uptake. In 17 (23%) of the 75 segments with abnormal nitrate-^{99m}Tc-MIBI uptake, ²⁰¹Tl-GIK uptake was better than the nitrate-^{99m}Tc-MIBI uptake. However, only 6 (8%) segments with ²⁰¹Tl-GIK uptake showed a lower uptake than with nitrate-^{99m}Tc-MIBI (Table 2).

The TDS of nitrate-^{99m}Tc-MIBI imaging (6.3±4.3) and ²⁰¹Tl-GIK imaging (5.8±4.2) were both significantly lower than that of resting ²⁰¹Tl imaging (7.4±4.3) (*p*<0.01) (Fig 4).

Of the total 147 myocardial segments in the 21 patients

Fig 6. Resting ^{201}Tl , nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GKI SPECT. Short-axis and vertical-long-axis slices show a defect involving the inferior area. Resting- ^{201}Tl , resting ^{201}Tl images; Nitrate-MIBI, nitrate- $^{99\text{m}}\text{Tc}$ -MIBI images; Tl -GKI, ^{201}Tl -GKI images.

with a complete LVG study, excluding the 1 patient with bypass occlusion and the 3 patients with restenosis, 92 (63%) segments showed normal or mild hypokinesis on LVG, 55 (37%) showed a definite wall motion abnormality, which included 11 segments with moderate hypokinesis, 24 with severe hypokinesis and 20 with akinesis or dyskinesis. Of the 55 segments with a definite wall motion abnormality, 39 (71%) had improved on the follow-up LVG, but 16 (29%) had not. The sensitivity and specificity of the different imaging modalities for detecting myocardial viability on the basis of improvement in wall motion are shown in Fig 5. The sensitivity of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI imaging (79%) tended to be higher than that of resting ^{201}Tl imaging (62%) ($p=0.08$). The sensitivity of ^{201}Tl -GKI imaging (85%) was significantly higher than that of resting ^{201}Tl imaging ($p<0.05$). The specificity of rest ^{201}Tl imaging and ^{201}Tl -GKI imaging was 88% and that of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI imaging was 82%.

Plasma serum glucose, insulin and potassium levels were measured at the beginning and end of GIK infusion. Insulin levels were affected significantly by the exogenous administration of insulin ($7.1\pm 6.0\text{ mU/ml}$ at baseline vs $126\pm 88\text{ mU/ml}$ after GIK infusion; $p<0.0005$). Serum glucose levels increased during GIK infusion, from $102\pm 16\text{ mg/dl}$ to $219\pm 40\text{ mg/dl}$, and then rapidly decreased over the following 30 min to $126\pm 44\text{ mg/dl}$. Potassium levels were not affected by this infusion ($4.3\pm 0.4\text{ mmol/L}$ at baseline vs $4.3\pm 0.4\text{ mmol/L}$ after GIK infusion).

Fig 6 is a representative case, a 70-year-old man with a 90% stenosis of the right coronary artery and an old inferior myocardial infarction. Perfusion defects was found on resting ^{201}Tl imaging, which improved on nitrate- $^{99\text{m}}\text{Tc}$ -MIBI imaging, and improved further on ^{201}Tl -GKI imaging. The wall motion of this area also improved after percutaneous transluminal coronary angioplasty, with improvement of the LVEF from 48% to 54%.

Discussion

Myocardial contractile dysfunction in patients with chronic CAD can be caused either by cellular necrosis or

hibernation.^{1,2} In contrast to necrotic tissue, hibernating myocardium may recover function after revascularization and so it is clinically important to differentiate viable from necrotic myocardium.

Myocardial viability is determined by PET on the basis of preserved metabolic activity, irrespective of hypoperfusion or the presence of abnormal wall motion at rest. A mismatch pattern between perfusion and ^{18}F -fluorodeoxyglucose (FDG) images indicates ischemic or hibernating myocardium^{27,28} with a high probability of recovery of left ventricular contractile function after revascularization.²⁹⁻³¹

The administration of nitrate has been reported to enhance the ability of ^{201}Tl , $^{99\text{m}}\text{Tc}$ -teboroxime or $^{99\text{m}}\text{Tc}$ -MIBI imaging to detect viable myocardium relative to the standard ^{201}Tl reinjection technique.¹⁸⁻²⁰ It has been hypothesized that nitrates dilate flow-limiting obstructions in both the coronary arteries^{32,33} and the coronary collaterals.³⁴ This latter mechanism may explain the improvement in ^{201}Tl uptake seen after nitroglycerin infusion in the hypoperfused regions that are related to totally occluded coronary arteries, but which have a well-developed collateral circulation.³⁵

However, some studies have shown that insulin augments myocardial ^{201}Tl uptake.^{22,36} Because of the similarities in ^{201}Tl and potassium kinetics,³⁷⁻³⁹ the uptake of the former may be affected by insulin administration. Insulin increases myocardial potassium turnover independent of metabolic changes⁴⁰⁻⁴³ and this phenomenon may help to detect hypoperfused but viable myocardium, because insulin administration before or during ^{201}Tl infusion promotes ^{201}Tl cellular uptake, especially in severely ischemic regions.³⁶ Insulin increases membrane conductance to cations by activation of the Na/K ATP-sensitive pump⁴⁴ with passive ^{201}Tl influx as a consequence of sodium efflux. This is the rationale behind the development of the ^{201}Tl -GKI infusion method.

In the present study we focused our analysis on abnormal perfused myocardium. Of the 85 segments showing abnormal uptake on resting ^{201}Tl images, 29 (34%) showed enhanced $^{99\text{m}}\text{Tc}$ -MIBI uptake after nitrate administration and 33 (39%) showed enhanced ^{201}Tl uptake after ^{201}Tl -GKI infusion. Consequently, regional tracer uptake on the nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GKI images was better than that on the resting ^{201}Tl images. Furthermore, the TDS of both nitrate- $^{99\text{m}}\text{Tc}$ -MIBI imaging and ^{201}Tl -GKI imaging were significantly lower than that of resting ^{201}Tl imaging. These findings confirm that both nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GKI imaging are more sensitive than conventional resting ^{201}Tl imaging in detecting viable hibernating myocardium.

The ability to detect viable myocardium was almost the same for the nitrate- $^{99\text{m}}\text{Tc}$ -MIBI method and the ^{201}Tl -GKI infusion method. However, of the 75 segments showing abnormal uptake on nitrate- $^{99\text{m}}\text{Tc}$ -MIBI images, 17 (23%) showed enhanced ^{201}Tl uptake after ^{201}Tl -GKI infusion. Compared with this result, only 6 (8%) showed a lowered ^{201}Tl -GKI uptake. Furthermore, the TDS of ^{201}Tl -GKI images tended to be lower than that of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI images. These results suggest that the ^{201}Tl -GKI infusion method may be better able to identify areas of potentially viable hibernating myocardium than the nitrate- $^{99\text{m}}\text{Tc}$ -MIBI method.

Although ^{201}Tl uptake may be considered an accurate marker of myocardial viability⁴⁵⁻⁴⁷ the functional recovery after coronary revascularization is the most important variable.^{1,2} We evaluated the clinical significance of myocardial viability based on the sensitivity and specificity of wall

motion improvement following revascularization in a subgroup of 21 patients. The results of that study showed that the ^{201}Tl -GIK method was the most sensitive, the nitrate- $^{99\text{m}}\text{Tc}$ -MIBI method was next and the resting ^{201}Tl method was the least sensitive for detecting viability. The specificity of the 3 methods was almost equivalent. Maurea et al defined a reversible defect as an improvement in the activity on nitroglycerin $^{99\text{m}}\text{Tc}$ -MIBI images compared with reduced activity on resting $^{99\text{m}}\text{Tc}$ -MIBI images.²¹ Their sensitivity and specificity of such images, on the basis of improvement in wall motion, were 88% and 89%, respectively. Bisi et al similarly reported that the sensitivity and specificity of these tests were 95% and 88%.⁴⁸ The reason for the lower sensitivity in our results may be related to the fact that we evaluated the wall motion using a 6-point grading system and the improvement in wall motion was defined as an improvement in the wall motion score by 1 point or greater. However, no reports have estimated the amount of viable myocardium using the correlation between ^{201}Tl -GIK infusion imaging and improved wall motion following revascularization, so we may have used a more rigorous index than previous investigators. Tartagni et al reported 141 (47%) and 74 (25%) severely underperfused segments in resting ^{201}Tl and ^{201}Tl -GIK infusion studies, respectively, in patients with chronic CAD ($p < 0.001$).²² Their results suggest that the ^{201}Tl -GIK infusion method is better at detecting viable myocardium than the resting ^{201}Tl method, which concurs with our results. Instead of insulin administration, Chiba et al used glucose loading to stimulate secretion of endogenous insulin and showed that this maneuver produced filling in some regions labeled as defects by conventional ^{201}Tl imaging.³⁶

Study Limitations

Some limitations in this study should be considered. First, there is a difference in energy level between $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl . In addition, the uptake of ^{201}Tl is lower than that of $^{99\text{m}}\text{Tc}$ -MIBI especially at the inferior to septal wall. However, we did not take this difference into account when analyzing the SPECT images.

Second, we obtained follow-up data after coronary revascularization from only a limited number of patients. Nonetheless, even though that data need to be confirmed in a larger series, our findings strongly suggest that nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GIK imaging enhance the detection of viable myocardium.

Third, we estimated the amount of viable myocardium using resting ^{201}Tl imaging, which has been reported to underestimate viable myocardium when compared with rest-redistribution ^{201}Tl imaging.⁴⁶ Maurea et al showed that $^{99\text{m}}\text{Tc}$ -MIBI uptake after nitroglycerin is significantly higher than that seen on rest-initial ^{201}Tl uptake scan, but is not different from rest-redistribution ^{201}Tl uptake.²¹ In the future, we plan to compare the abilities of nitrate- $^{99\text{m}}\text{Tc}$ -MIBI and ^{201}Tl -GIK imaging with rest-redistribution ^{201}Tl imaging to identify viable myocardium.

Conclusion

$^{99\text{m}}\text{Tc}$ -MIBI imaging after nitrate administration and ^{201}Tl imaging after ^{201}Tl -GIK infusion are significant improvements over resting ^{201}Tl imaging in identifying viable myocardium of patients with chronic CAD and impaired left ventricular function. ^{201}Tl imaging after ^{201}Tl -GIK infusion may better estimate the amount of viable myocardium than

$^{99\text{m}}\text{Tc}$ -MIBI imaging with nitrate administration.

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