Long-Term Outcome of a Residual Scar From Myocardial Infarction After Coronary Artery Bypass Grafting — A 100-Month Study Using Myocardial Perfusion Scintigraphy —

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The prognosis for patients with a residual scar from myocardial infarction (MI) after coronary artery bypass grafting surgery (CABG) has not been fully evaluated, so the present study retrospectively evaluated such patients with stress myocardial single photon emission computed tomography (SPECT) at 100 months after CABG. The study group consisted of 24 subjects (23 males, 1 female; mean age, 59±9 years) in whom CABG had been performed more than 100 months (mean follow-up period 135±25 months) previously. The 24 subjects were classified into 3 groups according to their summed stress score (SSS) and summed reversibility score (SRS) in the early period after CABG. Eight subjects with MI (SSS≥2 and SRS<2) were classified into the group MI, 8 subjects with ischemic myocardium (SSS≥2 and SRS≥2) was classified into the group RE, and 8 subjects with normal perfusion (SSS<2 and SRS<2) was classified into group N. None of the subjects in group MI required revascularization. Cardiac events occurred in 4 of the group RE patients and all required revascularization. As to the SPECT scoring system, the long-term SSS of group MI (6.4±3.1) was not different from that in the early periods (4.3±4.0; NS). However, the long-term SSS values of group RE (8.8±6.2) were significantly greater than those soon after CABG (3.4±1.8; p=0.03). In group N, there was also no difference in the SSS values between the early period (0.3±0.5) and the long-term period (0.0±0.0; NS). Patients with a residual scar from MI in the early period after CABG did not worsen over a period of 100 months. Moreover, there was no significant difference in the SPECT score in the segment with the residual scar in the short or long term after CABG. However, the extent of reversibility was directly associated with the presence of clinical events. Therefore scintigraphic imaging remains an important and clinically relevant risk stratification tool. Stress myocardial SPECT, early after CABG, can be used to predict the possibility of future cardiac events or the need for revascularization. (Circ J 2002; 66: 445–449)

Key Words: Coronary artery bypass grafting surgery; Myocardial infarction; Prognosis; Scar; Single photon emission computed tomography

Exercise myocardial perfusion single photon emission computed tomography (SPECT) is a powerful tool for predicting the long-term outcome of major ischemic events and using it to evaluate the extent of reversible defects might provide original information that could improve prognosis;̊ for example, SPECT has shown significant prognostic value in a variety of populations after coronary artery bypass grafting surgery (CABG)̊̊ Recent studies have detected a trend toward decreasing mortality after myocardial infarction (MI), which is likely a result of improvements in both short-term treatment of MI and secondary prevention, resulting in more favorable characteristics of patients who have had MI. However, the value of SPECT in patients with a residual scar from MI after CABG has not been fully evaluated and so we retrospec-tively evaluated such patients 100 months after their CABG.

Methods

Subjects
Participants in this investigation were from a group of adults who were followed by stress myocardial SPECT over 100 months after having CABG and who were consecutively referred for stress myocardial SPECT to the Osaka Medical College Hospital between 1985 and 2001. The study group consisted of 24 subjects (23 males, 1 female; mean age 59±9 years) in whom CABG had been performed more than 100 months (mean follow-up period 135±25 months) previously. Coronary angiography was performed to estimate coronary artery stenosis before CABG; significant stenosis was defined as ≥75% luminal stenosis. Before CABG, stenosis of a single coronary artery was observed in 1 patient and multiple stenoses of both the left anterior descending coronary artery (LAD) and the left circumflex coronary artery (LCX) were observed in 5 patients, of both the LAD and the right coronary artery (RCA) in 3 patients,
of both RCA and LCX in 1 patient and of all 3 coronary arteries in 11 patients. Stenosis including the left main trunk (LMT) was observed in 3 patients. Thirteen patients had a prior MI.

**SPECT Protocol**

One hundred and forty-two stress myocardial SPECT scans were performed (5.9 scans per subject). Twenty-one patients (128 scans) underwent an exercise-loading test using a bicycle ergometer RH-32 (Lode Instrumenten, Groningen, Holland) and 3 patients (14 scans) had a pharmacological loading test because of limited exercise capacity of the legs from arteriosclerosis obliterans. Before 1994, patients were injected with 111 MBq thallium-201 (201Tl) intravenously at near-maximal exercise, and myocardial SPECT was performed about 40 min after injection. Resting SPECT was performed approximately 1 h after injection of 740 MBq of 99mTc-tetrofosmin. For the pharmacological loading test, 1-day dipyridamole stress myocardial SPECT was performed. Dipyridamole was infused intravenously at a dosage of 0.56 mg/kg for 4 min and 3 min after infusion. 111 MBq of 201Tl or 370 MBq of 99mTc-tetrofosmin was administered intravenously, with imaging taking place 30–45 min later; the same protocol used for the exercise loading test was then used at rest. A single-head SPECT system (ZLC-7500, Siemens Medical System, Germany) equipped with a low-energy high-resolution collimator was used in both the 201Tl and the 99mTc-tetrofosmin studies. The resolution of the imaging system was 10 mm full width half maximum (FWHM). The projection data were acquired from a 180-degree circular orbit, starting with the 45-degree left posterior oblique view and ending with the short, vertical long, and horizontal long axes. Reconstructed slices were set parallel to the 45-degree left anterior oblique and positioned using the filtered back projection technique with a Butterworth filter. Reconstructed slices were set parallel to the short, vertical long, and horizontal long axes.

**Evaluation of Perfusion**

SPECT images from the post-stress and resting studies were displayed on transparent films to evaluate myocardial perfusion, and 2 expert nuclear physicians and 1 cardiologist examined the images using a 13-segment model. The heart was subdivided into its 4 major walls: anterior, septum, inferior, and lateral. Each of these 4 major segments was further subdivided into 3 subsegments: basal, mid, and distal, with the apex considered to be 1 segment.
The anterior, apical, and septal walls were assigned to the LAD, the lateral wall to the LCX and the LMT included both LAD and LCX territories. The inferior and basal septal segments were assigned to the RCA. The SPECT score (0, normal perfusion; 1, mildly decreased; 2, moderately decreased; 3, severe perfusion defect) in each segment was calculated for each subject. Differences between the readers were resolved by consensus.

**Classification and Statistical Analysis**

A summed stress score (SSS) was obtained by adding the scores of the 13 segments of the stress images, and a summed reversibility score (SRS) was obtained by adding the differences between the stress and rest scores for each of the 13 segments. The 24 subjects were then classified into 3 groups according to their SSS and SRS in the early period after CABG. Eight subjects with a MI, which was defined as SSS $\geq$ 2 and SRS $<$ 2, were classified into the group MI, 8 subjects with redistribution of the myocardium, which indicated myocardial ischemia and was defined as SSS $\geq$ 2 and SRS $\geq$ 2, were classified into group RE, and 8 subjects with normal perfusion, which was defined as SSS $<$ 2 and SRS $<$ 2, were classified into group N. The findings were expressed as means ± standard deviation, and the parameters were compared among the 3 groups by ANOVA. A p value less than 0.05 was considered statistically significant.

### Results (Table 1)

There were no significant differences in age among the 3 groups nor was there a gender difference because there was only 1 female patient in the study group. Many patients in the 3 groups had multivessel coronary artery stenosis: LMT stenosis was observed in the MI and RE groups, but not in group N. All patients in group MI had a prior myocardial infarction, as did 3 patients in group RE and 2 in group N. The number of graft vessels did not differ among the 3 groups. The average period of initial SPECT after CABG was 8.4±4.7 months (shortest: 3 months, longest: 20 months), and no significant difference was observed among the 3 groups. The follow-up period of group RE (154±18 months) was longer than those of the other 2 groups (group MI=123±20 months, group N=129±30 months; p=0.05). During the follow-up period, the number of times stress myocardial SPECT was performed did not differ among the 3 groups. None of the subjects in group MI required revascularization. Cardiac events occurred in 4 of the group.

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**Table 1**

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Fig 1. Myocardial SPECT images from short-axis slices of patient no.2 who underwent CABG in 1990. Myocardial redistribution was observed in the posterior wall and a myocardial perfusion defect was observed in the anteroseptal wall before CABG. The perfusion defect remained in the anteroseptal wall but the redistribution in the posterior wall disappeared after CABG. The myocardial perfusion defect remained until 1999.

Fig 2. Myocardial SPECT images from short-axis slices of patient no.14 who underwent CABG in 1985. Minimal myocardial redistribution was observed in the posterior wall in 1991. The region of redistribution gradually increased although the patient did not have chest symptoms. PTCA was performed in 1998 for a stenotic coronary artery.
patients who have not had an infarction. The number of prognosis after acute MI and a less beneficial effect for coronary angioplasty, has a highly favorable influence on patients with diabetes, previous CABG, as compared with group N, there was no difference in the SSS values between the early period (0.3±0.5) and the long term (0.0±0.0; NS). There was no significant difference in the SRS values between the early (2.8±1.8) and long-term periods (4.9±4.4) in the RE group.

Discussion

This study selected survivors more than 100 months after CABG for MI and classified them into 3 groups: those with a residual scar from MI, those with myocardial ischemia and those with normal myocardial perfusion. Even in these selected patients, a significant proportion had cardiac events or required revascularization for symptomatic deterioration. The results of scintigraphy were prognostically useful and were the most significant predictors of future outcome after CABG. Neither cardiac events nor a significant difference between the early and long-term SPECT score was observed in group MI. The absence of reversibility on scintigraphy had a high negative predictive value; patients with fixed defects had excellent outcomes. Cardiac events occurred in group RE, and the SPECT scores also worsened in that group. The presence of reversibility early after CABG was correctly identified in 3 of 8 patients (37.5%) who experienced cardiac events that required revascularization.

Comparison of Other Clinical Variables and Scintigraphic Findings

Clinical variables, such as older age, female gender, previous MI, Q-wave infarction and risk factors, are important for evaluating the correlation with clinical events. Hachamovitch et al reported that stress myocardial SPECT identifies relatively high-risk women more accurately than relatively high-risk men. Detre et al reported that among patients with diabetes, previous CABG, as compared with coronary angioplasty, has a highly favorable influence on prognosis after acute MI and a less beneficial effect for patients who have not had an infarction. The number of patients in the present study was small and there were few cardiac events requiring revascularization, so we could not evaluate the influence of gender and risk factors in each group. Lauer et al reported that in a group of patients who were symptom-free after CABG, the myocardial perfusion defect was strongly and independently predictive of subsequent death or non-fatal MI but in our study neither the occurrence of cardiac events nor a significant difference between the early and long-term SPECT score was observed in the MI group. This discrepancy may also be attributable to the small number of patients in the MI group.

Our long-term follow-up study shows the superiority of a more physiologic assessment of myocardial perfusion for predicting future events and the need for intervention. Thus, a strategy of early noninvasive testing of patients with coronary artery disease (CAD) after CABG may be useful for assessing the possibility of future cardiac events or the need for revascularization in post-CABG patients. Although the SRS is useful for detecting ischemic myocardium, it did not show a significant difference between the early and long-term period after CABG in group RE. An increased SRS value was observed in 1 patient (no. 16) who had myocardial ischemia and became worse with angina pectoris. The size of fixed defect gradually increased in another 3 patients (nos. 10, 13 and 14), and a significantly increased SSS value was observed without an increased SRS value. This finding may reflect MI rather than angina pectoris and suggests that a careful observation is needed when a patient records increased SSS and SRS values.

Imaging Protocol

The radiopharmaceuticals used for stress myocardial SPECT changed from $^{201}$Tl to $^{99m}$Tc-tetrofosmin in 1995, but have shown similar efficacy in identification and risk stratification of CAD. Chikamori et al reported that myocardial viability observed on $^{201}$Tl SPECT perfusion imaging predicts a significant improvement in left ventricular (LV) function after CABG in patients with severe LV dysfunction. Tamaki et al reported a high concordance for the stress perfusion scores between the 2 radiopharmaceuticals; reversible perfusion abnormalities were similar between stress-rest tetrofosmin and stress-delayed $^{201}$Tl studies. Stress tetrofosmin perfusion tomography is a valuable method for detecting CAD and assessing tissue viability, with an accuracy similar to that of stress $^{201}$Tl tomography. Dipyradomole loading SPECT thallium imaging is a safe and highly accurate imaging mode for the detection of CAD in patients with limited exercise capacity and the one-day dipyridamole/rest $^{99m}$Tc-tetrofosmin myocardial perfusion imaging protocol is appropriate. In the present study, the results of the dipyridamole loading SPECT imaging were considered highly concordant with the exercise SPECT thallium imaging.

Study Limitations

With the improved outcomes in patients with CAD after CABG, the objective of our study was to clarify the additional value of scintigraphic imaging for predicting future events. Therefore, our study enrolled highly selected subjects. Although the results may not be generalized, we have demonstrated that nuclear imaging still has prognostic value in patients with a MI, but suggest that myocardial SPECT is far from ideal for independent characterization of perfusion and viability because hibernating myocardium may be present in the area of reversible defects. Because the patients in this study were predefined survivors, more than 100 months after CABG, there were few clinical events, so we combined a clinical event with the need for revascularization to increase the number of events to achieve greater statistical reliability. In addition, we excluded patients requiring vasodilator testing occurring within 1 year of study entry to reduce the likelihood of including any revascularization that was performed as a result of additional scintigraphic information. Overall, because patients were deemed to be clinically stable from the clinical and angiographic findings, it is more likely that later revascularization procedures would have been performed based on evidence of clinical deterioration rather than on additional scintigraphic data alone. The long-term prognosis after CABG relates not only to the results of myocardial SPECT, but also to various risk factors. Multiple logistic regression analysis is needed to clarify the usefulness of
myocardial SPECT in comparison with the other risk factors. Hachamovitch et al have already reported that myocardial perfusion SPECT yields incremental prognostic information about future cardiac events and thus the patient may benefit from a noninvasive strategy and may not require invasive management.

Conclusions

Patients with a residual scar from MI in the early period after CABG did not become worse over a period of 100 months. Moreover, there was no significant difference in the SPECT score for the segments with the scar in the short or long term after CABG. However, the extent of reversibility was directly associated with the presence of clinical events and so scintigraphy remains an important and clinically relevant risk stratification tool. Stress myocardial SPECT carried out soon after CABG can be used to predict future cardiac events or the need for revascularization.

References