Original Article

MEMOIRS HEALTH SCI. MED. KANAZAWA UNIV. Vol. 21
7~13 1997

Evaluation of Tracer Uptake in the Infarcted Area on Myocardial SPECT Images : Comparison Between Tl-201 and Tc-99m Using a Phantom

Masahisa Onoguchi Hirotaka Maruno* Teruhiko Takayama Hajime Murata**

ABSTRACT

In order to study whether SPECT images reflect tracer uptake in the infarcted area exactly, we compared relative count of Tl-201 or Tc-99m on the SPECT images with true radioactivity in a myocardial phantom. To simulate an infarcted area, the ratio of tracer concentration in the anterior wall and the inferior wall to normal myocardium (D/N ratio) was changed to 20%, 40% and 60%. In addition, to study the effect of radioactivity in the lung, the ratio of tracer concentration in the lung to normal myocardium (L/M ratio) was changed to 10% and 30%. Using the transaxial image, relative count on the SPECT image was calculated by the maximum count on the circumferential profile curve to compare the count distribution for SPECT transaxial images. In various D/N ratio and L/M ratio, relative count in defect area of Tl-201 was generally higher than that of Tc-99m. When there is an infarcted area in the anterior wall, relative count in defect area of Tl-201 and relative count in defect area of Tc-99m on the SPECT images were lower than true radioactivity. On the contrary, when there is an infarcted area in the inferior wall, relative count on the SPECT images for 20% and 40% of D/N ratio was higher than true radioactivity, whereas relative count for 60% of D/N ratio was lower than true radioactivity. Therefore, when there is an infarcted area in the anterior wall, SPECT images shows decreased perfusion more clearly. On the other hand, when there is an infarcted area in the inferior wall, SPECT images obscures decreased perfusion. In conclusion, we should be careful for the visual interpretation of SPECT images, especially when the lesion is in the inferior wall.

KEY WORDS

Myocardial phantom, SPECT, Tl-201, Tc-99m, %uptake

INTRODUCTION

Myocardial perfusion imaging with thallium-201 (Tl-201) has been used for decades for the diagnosis of coronary artery disease. However, this agent has some disadvantages including low-energy photons of 71 KeV, and long half-life of 73 hours, causing to decrease the overall image resolution. In order to overcome the disadvantages of Tl-201, Tc-99m heart imaging agent has been recently developed as an alternative to Tl-201[1)–6)]. This agent has several advantages over Tl-201 because of its ideal 140 KeV photopeak, high injectable dose due to a six-hour half life, and allows first-pass studies and cardiac gating. In our clinical experience, we often noticed that there were

Department of Radiological Technology, School of Health Sciences, Faculty of Medicine, Kanazawa University
* Division of Nuclear Medicine, Toranomon Hospital, Tokyo
** National Institute of Radiological Sciences, Chiba

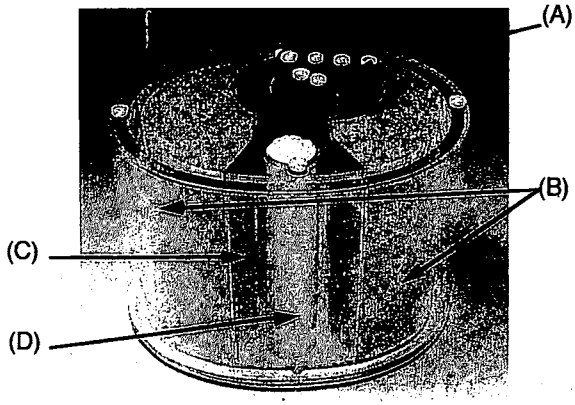

Fig. 1-1 Body phantom including myocardial phantom.
(A), myocardium ; (B), lung ; (C), mediastinum ; and (D), spine

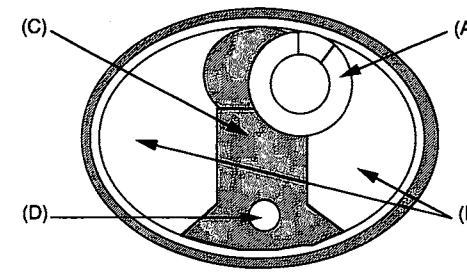

Fig. 1-2 The schema of body phantom including myocardial phantom.
The other abbreviations are shown in Fig. 1-1.

some cases with discrepancy on myocardial uptake between Tl-201 and Tc-99m. It might be caused by the difference for the uptake between Tl-201 and Tc-99m. Or it might be induced by the difference for photopeak of both tracers. Therefore, we tried to solve this problem by performing the experiment with myocardial phantom.

The purpose of this study is to compare the relative count of Tl-201 or Tc-99m in an infarcted area on the SPECT images with true radioactivity in the phantom and investigate whether SPECT images would represent accurate tracer uptake in the infarcted area.

MATERIALS AND METHODS

Phantom Study

A 10 cm-diameter polyacryle cylinder was used as a myocardial phantom with a defect. The cylinder was inserted into the body phantom containing the lung, mediastinum and spine (Fig. 1-1, 1-2). The space corresponding to the normal myocardium of left ventricle was filled with 144 KBq/ml of Tl-201 or Tc-99m, whereas the mediastinum and the right ventricle were filled with water. The lung was filled with sawdust, on which Tl-201 or Tc-99m was sprayed. In order to simulate the infarcted area, tracer concentration of defect in the anterior wall and the inferior wall were changed to 20%, 40% and 60% of that in the normal myocardium (100%). The defect to normal myocardium activity ratio of tracer concentration was expressed as "D/N ratio". Similarly, tracer concentration in the lung was changed to 10% and 30% of that in the normal myocardium (100%). The lung to normal myocardium activity ratio was defined as "L/M ratio".

SPECT imaging protocol

A gamma camera of 4000XC/T-STAR system (General Electric Corp. USA) with a low-energy, all-purpose, parallel-hole collimator was used.

SPECT Tl-201 and SPECT Tc-99m acquisition parameters were identical. View data were acquired using a zoom factor of 1.33 into 64× 64 digital matrix (i.e., sampling size equaled 4.7 mm/pixel). Each dataset, consisting of 32 views, was acquired using a circular 180-degree anterior arc scan with a 45-degree left posterior oblique starting angle; time per view was 15 sec for a acquisition count per pixel of nearly 200K counts. All data were prefiltered with a Hanning filter (cutoff 0.8 cycles/pixel). Images were reconstructed by a filtered backprojection algorithm and ramp filter (cutoff 0 cycles/pixel). No attenuation nor scatter correction was performed. For Tl-201 image acquisition a peak energy setting at 71 KeV x-ray with a 20% window and for Tc-99m image acquisition a peak energy setting at 140 KeV with a 20% window were used, respectively.

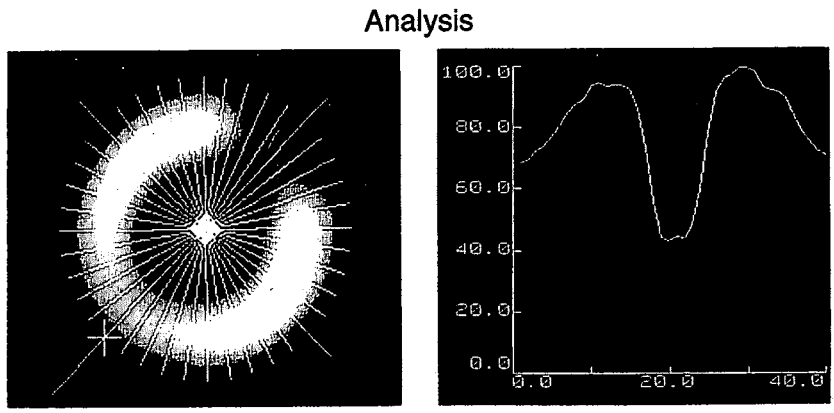

Fig. 2 Forty segments of a transaxial SPECT image (left), and circumferential profile curve (right).

For planar imaging, data obtained by SPECT imaging was used.

Data analysis

As shown in Fig. 2, %uptake was evaluated by circumferential profile curves generated from a transaxial SPECT image, and this transaxial SPECT image at the middle portion was divided into 40 segments by drawing 40 radio through the center at 9 degree intervals. Peak count per pixel along the radius was calculated, and circumferential profile curves obtained from 40 segments was described. Further, circumferential profile curves were normalized to the highest count which was represented to 100%. The count in defect area was calculated by the mean value of 5 segments, and that in normal area was calculated from the mean value of 35 segments.

RESULTS

Planar imaging

Table 1 shows the radioactivity per volume and the L/M ratios obtained from anterior planar image. For 10% of L/M ratio in the phantom, planar images showed 53.8% and 44.3% for Tl-201 and Tc-99m, respectively. Compared with 10% of true radioactivity, these values were markedly higher. For 30% of the L/M ratio in the phantom, planar images showed 114.6% and 115.5% for Tl-201 and Tc-99m, respectively.

Table 1 Measured L/M ratios obtained from the normal myocardium on the anterior planar image.

L/M ratio (Normal portion)

Radioactivity	Anterior planar image count ratio	
	Tl-201	Tc-99m
10%	53.8 %	44.3 %
30%	114.6%	115.5%

SPECT imaging

Figure 3 and Figure 4 show comparison between D/N ratio on the SPECT images and true radioactivity when there is an infarcted area in the anterior wall and in the inferior wall, respectively. At every D/N ratios, relative count for Tl-201 or Tc-99m in the anterior wall was lower than true radioactivity. There was no significant difference of value between Tl-201 and Tc-99m, whereas value of Tl-201 was slightly higher than that of Tc-99m. When there is an infarcted area in the anterior wall, relative count on the SPECT images was lower than true radioactivity in the phantom. On the other hand, when there is an infarcted area in the inferior wall, relative count on the SPECT images for 20% and 40% of D/N ratio was higher than true radioactivity in the phantom. Without regard to the values of D/N ratio and L/M ratio, value of Tl-201 was generally higher than that

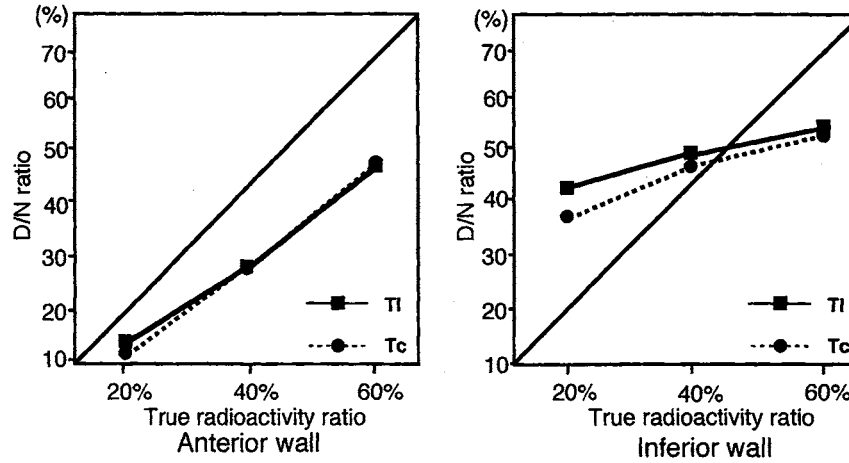

Fig. 3 Measured D/N ratios for 10% of L/M ratio. Anterior wall (left) and inferior wall (right).

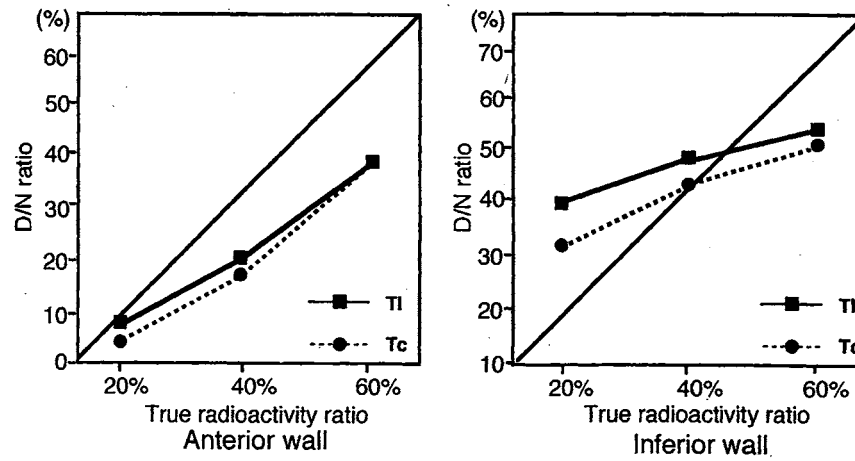

Fig. 4 Measured D/N ratios for 30% of L/M ratio.
The other abbreviations are shown in Fig. 3.

of Tc-99m. When there is an infarcted area in the anterior wall, relative count on the SPECT images was lower than true radioactivity in the phantom. On the contrary, when there is an infarcted area in the inferior wall, relative count on the SPECT images for 20% and 40% of D/N ratio was higher than true radioactivity in the phantom, whereas value for 60% of D/N ratio was lower than true radioactivity. Figure 5 illustrates transaxial images for 20% of D/N ratio and 10% and 30% of L/M ratio.

DISCUSSION

Myocardial imaging with Tl-201 has been widely used for the noninvasive evaluation of coronary artery disease. However, it has significant disadvantages including soft tissue attenuation, scatter caused by low photon energy emission, and a relatively long half-life (73 hr) limiting the administration dose. On the other hand, Tc-99m agents have several properties including minimal lung uptake, transient liver uptake and no or minimal myocardial redistribution[1)-2)]. Several authors investigated the validity of both tracers for the evaluation of myocardial perfusion. Maurea, et al[7)]. compared between rest-injected Tl-201 redistribution and resting Tc-99m-MIBI myocardial uptake in the patients with coronary artery disease and concluded that Tl-201 uptake was significantly higher than Tc-99m-MIBI uptake in myocardial segments with total coronary occlusion, while no significant difference was observed in 50%-99% of stenosis. Also

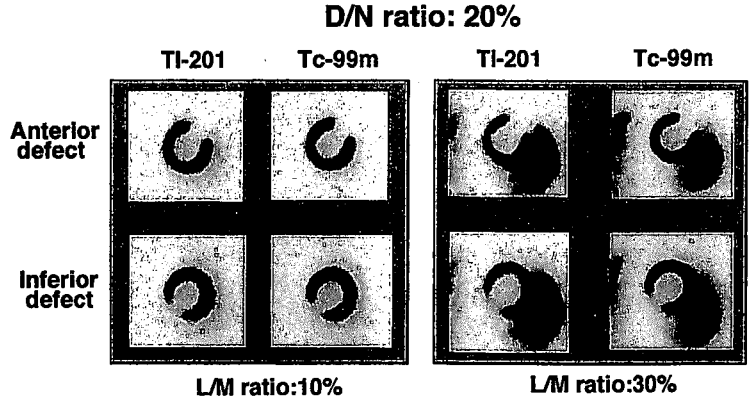

Fig. 5 Transaxial images for 20% of D/N ratio and 10% and 30% of L/M ratio.

in our study, relative count for Tl-201 was generally higher than that for Tc-99m, in various D/N ratio and L/M ratio. Rigo, et al[8]. documented that Tl-201 and Tc-99m-tetrofosmin show almost same sensitivity for detecting myocardial infarction. Kasalick, et al[11]. compared between Tl-201 and Tc-99m-MIBI, and reported that the sensitivity of the detection of ischemic area in reference to the coronary angiography was nearly identical in Tl-201 (75%) and Tc-99m-MIBI (81.2%), thus Tc-99m-MIBI is equivalent to Tl-201 as used for myocardial scintigraphy in patients with ischemia heart disease. Tartagni, et al[9]. studied a sensitivity and specificity for detecting coronary lesions using Tl-201 and Tc-99m-MIBI. They reported that sensitivity was 88% with Tl-201 and 78% with MIBI for the anterior descending artery (LAD), 86% and 64% respectively for the right coronary artery (RCA), and specificity was 88% with Tl-201 and 78% with MIBI, 60% with both procedures for RCA. As Benoit, et al[10]. described, the severity of perfusion defect should be evaluated in consideration of background for precise quantitative analysis of the distribution of myocardial tracers. Also in our study the effect of radioactivity in the lung could not be ignored. So, tracer concentration in the lung was changed to 10% and 30% of that in the normal myocardium (100%). The "L/M ratio" was used to express the ratio of tracer concentration. Nordrehaug, et al[19]. studied the lung/myocardial uptake ratio for Tl-201 about normal case, and reported the lung/myocardial uptake ratio was 44% for Tl-201. For 10% of the L/M ratio, the values for phantom was almost same for the normal case. Martinez, et al[20]. reported the lung/myocardial uptake ratio for Tl-201 about patients with congestive heart failure, and described the lung/myocardial uptake ratio was 83% for Tl-201 . The value of the L/M ratio 30% were nearly equal to that of patients with the accumulation of lung was accelerated.

For analysis method, it was reported that circumferential profile analysis[12–15] and the other quntitative analysis[16)–18)] for the evaluation of myocardial viability in patients with previous myocardial infarction were used. Gang, et al[14]. compared between Tc-99m-MIBI and [18F]FDG for the evaluation of viable myocardium, and reported that [18F]FDG uptake was present in 95% of the segments that had >40% of the peak tracer uptake at the rest SPECT/Tc-99m-MIBI study. Matsunari et al[15] documented that the optimal threshold cutoffs for myocardial viability were considered to be 50% of peak activity for Tc-99m tetrofosmin and 55% of peak activity for Tl-201. Then, in order to simulate the infarcted area, tracer concentration in the anterior wall and the inferior wall were changed to 20%, 40% and 60% of that in the normal myocardium (100%), and the ratio of tracer concentration was expressed as "D/N ratio".

However, the most interesting finding was the

difference between the anterior wall and the inferior wall. When there is an infracted area in the anterior wall, relative count on the SPECT images for every D/N ratios was lower than true radioactivity in the phantom. For example, when the D/N ratio was 60%, relative count for Tl-201 and Tc-99m in the anterior wall were 44.6% and 45.2%, respectively. On the other hand, when there is an infracted area in the inferior wall, relative count on the SPECT images for 20% and 40% of D/N ratio was higher than true radioactivity in the phantom. For example, for 20% of D/N ratio, relative count for Tl-201 and Tc-99m in the inferior wall were 38.9% and 31.1%, respectively and for 40% of D/N ratio, these was 47.9% and 45.4%, respectively. This finding is very important in visual interpretation of SPECT images. When there is an infarcted area in the anterior wall, SPECT images shows decreased perfusion more clearly. On the other hand, when there is an infarcted area in the inferior wall, SPECT images obscures decreased perfusion. In addition this finding is modified by the radioactivity in the lung, which acts as the background on SPECT images. As above, it was suggested that discrepancy on myocardial uptake between Tl-201 and Tc-99m might be induced by the difference for photopeak of both tracers. More study is needed to solve this problem.

In conclusion, we should be careful for the diagnosis of myocardial infarction, especially in the patients who had infarcted area in the inferior or whose tracer uptake in the lung increased due to poor cardiac function.

ACKNOWLEDGMENTS

This paper was presented at the 27th Hokuriku Nuclear Medicine Circulation Conference in Kanazawa, on December 7, 1996.

REFERENCES

1. Wackers, F.J. et al. : Technetium-99m hexakis 2-methoxyisobutyl isonitrile : Human biodistribution, dosimetry, safety, and preliminary comparison to thallium-201 for myocardial perfusion imaging. J. Nucl. Med., 30 : 301-311, 1989.
2. Sinusas, A.J. et al. : Quantitative planar imaging with technetium-99m methoxyisobutyl isonitrile : Comparison of uptake patterns with thallium-201. J. Nucl. Med., 30 : 1456-1463, 1989.
3. Clausen, M. et al. : The contraction fraction (CF) in myocardial studies with technetium-99m-isonitrile (MIBI)-Correlation with radionuclide ventriculography and infarct size measured by SPECT. Eur. J. Nucl. Med., 15 : 661-664, 1989.
4. Leppo, J.A. et al. : A review of cardiac imaging with sestamibi and teboroxime. J. Nucl. Med., 32 : 2012-2022, 1991.
5. Baillet, G.Y. et al. : Simultaneous Tc-99m MIBI angiography and myocardial perfusion imaging. J. Nucl. Med., 30 : 38-44, 1989.
6. Villanueva-Mayer, J. et al. : Simultaneous assessment of left ventricular wall motion and myocardial perfusion with technetium-99m-methoxy isobutyl isonitrile at stress and rest in patients with angina : comparison with thallium-201 SPECT. J. Nucl. Med., 31 : 457-463, 1990.
7. Maurea, S. et al. : Rest-injected thallium-201 redistribution and resting technetium-99m methoxyisobutyl isonitrile uptake in coronary artery disease : relation to the severity of coronary artery stenosis. Eur. J. Nucl. Med., 20 : 502-510, 1993.
8. Rigo, P. et al. : Technetium-99m-tetrofosmin myocardial imaging : a comparison with thallium-201 and angiography. J. Nucl. Med., 35 : 587-593, 1994.
9. Tartagni, F. et al. : Double injection of Tc-99m-methxy isobutyl isonitrile in tha same session : diagnostic accuracy in tomography compared with that of thallium-201 chloride. Cardiologia, 35 : 581-590, 1990.
10. Benoit, T. et al. : Quantitative evaluation of myocardial single-photon emission tomographic imaging : application to the measurement of perfusion defect size and severity. Eur. J. Nucl. Med., 23 : 1603-1612, 1996.
11. Kasalick, J. et al. : Myocardial scintigraphy using 99m-Tc-methoxyisobutyl isonitrile (Tc-MIBI) : Is it equivalent to 201-Tl?. Cas. Lek. Cesk., 130 : 688-691, 1991.
12. Tsukamoto, T. et al. : Usefulness of resting thallium-201 delayed imaging for detecting myocardial viability in patients with previous myocardial infarction. Ann. Nucl. Med., 7 : 79-86, 1993.
13. Bestetti, A. et al. : Fourier amplitude image circumferential profile analysis in the evaluation of the dipyridamole test. J. Nucl. Biol. Med., 37 : 185-190, 1993.
14. Gang, H. et al. : Rest distribution of Tc-99m-MIBI in patients with coronary artery disease assessed by SPECT : comparison with the distribution of [18F] FDG assessed by PET. J. Nucl. Biol. Med., 38 : 540-544, 1994.

15. Matsunari, I. et al. : Quantitative rest technetium-99m-tetrofosmin imaging in predicting functional recovery after revascularization : comparison with rest-redistribution thallium-201. J. Am. Coll. Cardiol., 29 : 1226-1223, 1997.
16. Li, ST. et al. : Quantitative analysis of technetium 99m 2-methxyisobutyl isonitrile single-photon emission computed tomography and isosorbide dinitrate infusion in assessment of myocardial viability before and after revascularization. J. Nucl. Cardiol., 3 : 457-463, 1996.
17. Tamosiunas, G. et al. : Myocardial contractility and viability. A radionuclide tomography study using technetium-99m labeled isonitriles. Rev. Esp. Cardiol., 48 : 473-479, 1995.
18. Soufer, R. et al. : Comparison of sestamibi single-photon emission computed tomography with positron emission tomography for estimating left ventricular myocardial viability. Am. J. Cardiol., 75 : 1214-1219, 1995.
19. Nordrehaug, JE. et al. : Physiological inverse relationship between heart rate and thallium-201 lung uptake, clearance and lung/myocardial uptake ratio. Eur. Heart J., 11 : 628-633, 1990.
20. Martinez, E.E. et al. : Lung and myocardial thallium-201 kinetics in resting patients with congestive heart failure : correlation with pulmonary capillary wedge pressure. Am. Heart J., 123 : 427-432, 1992.

SPECT 画像における心筋梗塞部の摂取率の評価 ：ファントム実験による Tl-201 と Tc-99m の比較

小野口昌久，丸野　廣大，高山　輝彦，村田　　啓

要　　旨

心筋梗塞部の放射能の集積低下が SPECT 画像で正確に評価されているかを検討するために，ファントムを用いた実験を行い Tl-201 と Tc-99m のカウント比について比較した。梗塞部のモデルとして，心筋の前壁，あるいは下壁の放射能濃度を正常心筋部の20，40，60%に設定した。また肺内の放射能の影響を評価するために，肺の放射能濃度を正常心筋部の10，30%に設定した。正常心筋部および梗塞部のカウントは，SPECT 画像の短軸像に円周性プロフィール曲線（circumferential profile curve）を適用して算出した。梗塞部が前壁にある場合には，肺の放射能濃度や梗塞の程度とは無関係に，SPECT 画像による梗塞部のカウント比は低い値を示し，Tl-201 と Tc-99m で有意差は認められなかった。梗塞部が下壁にある場合には，梗塞部の濃度比が20%と40%の時に SPECT 画像によるカウント比は Tl-201 と Tc-99m で共に高い値を示した。すなわち前壁の場合には梗塞による集積低下が画像上でより明瞭に表示されるのに対し，下壁の場合には集積低下が認めにくくなることが判明した。一方，肺の放射能の影響については，肺の集積が多い場合には前壁の梗塞の程度をより大きく評価するのに対し，下壁への影響は肺の集積が少ない場合と同程度に集積低下が認めにくくなった。以上より，下壁の梗塞や心機能の低下により肺の集積が増加した場合の梗塞の診断には十分な注意が必要と思われた。