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Assessment of myocardial viability in patients with myocardial infarction using twenty-four hour thallium-201 late redistribution imaging

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Background: Rest thallium-201 (^{201}Tl) myocardial perfusion imaging has been widely used for evaluation of myocardial ischemia/viability after myocardial infarction, but the ideal timing for imaging after injection to maximally estimate viability is not well established. ***Methods:*** Thirty-six patients with myocardial infarction underwent the initial, 3 h, and 24 h redistribution imaging after intravenous injection of 148–185 MBq ^{201}Tl. The initial and 3 h images, the initial and 24 h images, and the 3 and 24 h images were compared double-blinded. ***Results:*** Out of the 184 abnormal segments based on the initial imaging, 56 (30%) segments improved by at least 1 grade on the 3 h imaging while 78 (42%) segments improved by at least 1 grade on the 24 h imaging. The 24 h late imaging detected more viable myocardium than the 3 h imaging did, with a significant difference ($\chi^2 = 5.680$, $p = 0.017$). There were 158 abnormal segments on the 3 h imaging, with average 28% (44) segments improved by at least 1 grade on the 24 h imaging. There were 128 initial abnormal segments with no improvement on the 3 h imaging. Out of these segments, the 24 h late redistribution imaging detected additional redistribution in 26 segments, taking up 20%. ***Conclusions:*** Twenty-four hour late ^{201}Tl imaging will demonstrated additional redistribution in patients who have incompletely reversible defects on early redistribution imaging at 3h.

Key words: thallium-201, coronary artery disease, myocardial viability

INTRODUCTION

AN ACCURATE RECOGNITION of viable myocardium at high risk, including ischemic, stunned, hibernating and maimed myocardium, has provided the important basis for revascularization and prognosis in patients with coronary artery disease.[1] ^{201}Tl redistribution imaging has been widely used for identification of myocardial ischemia/viability after myocardial infarction. Previous studies showed that conventional 3–4 hour (h) early redistribution imaging underestimated a considerable proportion of viable myocardium,[2–4] and that the 24 h late redistribution imaging was superior to the 3–4 h redistribution imaging for detection of viable myocardium. However, the value of 24 h ^{201}Tl late imaging remains controversial. The purpose of this study was to evaluate the potential advantage of the 24 h versus 3 h redistribution imaging after the resting injection of ^{201}Tl in estimating viable myocardium in patients with myocardial infarction.

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METHODS AND MATERIALS

Patients

Thirty-six consecutive myocardial infarction patients, diagnosed on the basis of confirmatory case histories, clinical manifestations, electrocardiogram, cardiac markers and/or coronary angiogram, underwent imaging tests. All patients received the 3 h and 24 h imaging regardless of the results of the 3 h imaging. All antianginal medications were withheld on the morning of the imaging test

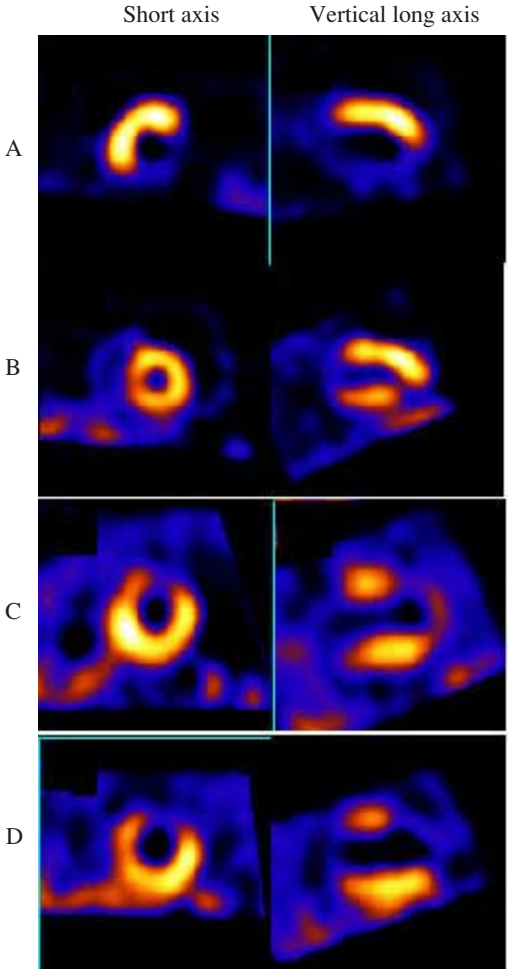

Fig. 1 Image quality analysis of the 3 h and 24 h images. A, excellent; B, good; C, fair; and D, poor.

and resumed after completion of the first imaging. Patients with significant valvular heart disease or cardiomyopathy were excluded. Written informed consent was obtained from all patients, and the ethics committee in this hospital approved the protocol.

Imaging study

All of the myocardial infarction patients with an injection of 148–185 MBq ^{201}Tl received resting imaging tests only. All patients underwent imaging using a two-head SPECT camera (Philips) equipped with low-energy coincidence circuit collimators, initially (10–15 min later), 3 h and 24 h, respectively, after injection of ^{201}Tl. Fat meal was encouraged to optimize the 3 h ^{201}Tl images after the completion of the first acquisition. Cathartics were encouraged to optimize the 24 h ^{201}Tl images after the completion of the 3 h acquisition. The acquisition was performed using ^{201}Tl energy windows of 75 ± 12.5% and 167 ± 5% at 3-degree intervals, with matrix 128 × 128 and zoom 2.0. The acquisition time was 30 seconds/view and 40 seconds/view for the first 2 times and for the last time, respectively. Myocardial images were reconstructed and displayed as a series of short axis, horizontal and vertical long axis slices. The slice thickness was 4 mm.

Table 1 Clinical characteristics

Characteristics	value, or number of patients
Age	66 ± 13 years; range 32–84
Gender	
Male	26
Female	10
Non-insulin dependent diabetes mellitus	6
Hypertension	16
Smoking*	14
Revascularization prior to imaging test	18
Myocardial infarction	
Acute	20
Old	16
Infarcted localizations	
Inferior or posterior	16
Anterior or anteroseptal	20
Coronary angiography	32
Abnormal findings	30
Normal findings	2
Culprit vessels	
LAD	20
LCX	4
RCA	10

*at least 10 cigarettes per day >10 years.

Image quality analysis

The semi-quantitative analysis of the 3 h and 24 h ^{201}Tl image quality was conducted independently by two nuclear medicine physicians using a 4-grade model: excellent, good, fair and poor (Fig. 1). Consensus was obtained after debate if any disagreement was apparent.

Image interpretation

Images were interpreted by 2 experienced nuclear doctors blinded to the clinical data. Pairs of study for each patient were read separately. Thus, the initial and 3 h images, the initial and 24 h images, and the 3 and 24 h images were compared. Readers, who were blinded to the timing of the imaging, did not know if they were comparing the initial and 3 h, the initial and 24 h or the 3 and 24 h images. The heart size was graded subjectively as enlarged or not enlarged. The left ventricle was divided into 17 segments at three levels of the myocardium: apical (anterior, lateral, inferior and septal), mid (anterior, anterolateral, inferolateral, inferior, inferoseptal and anteroseptal), basal (anterior, anterolateral, inferolateral, inferior, inferoseptal and anteroseptal) and apex.[5] Uptake of Tl-201 in each myocardial segment was scored on a 0–4 scale: 0, normal uptake; 1, mild; 2, moderate; 3, severe reduction in uptake; and 4, no uptake. Perfusion reduction in 3 consecutive slices at the same location in any 2 different axes was defined as positive segments. Segments scoring ≥1 in apex, anterior or lateral wall were considered as positive

Table 2 Image quality analysis of the 3 h and 24 h images (% of total patients)

Images	n	excellent	good	fair	poor	CMH	p
3 h	36	20 (56)	6 (17)	4 (11)	6 (17)	0.871	0.351
24 h	36	20 (56)	8 (22)	8 (22)	0 (0)		

Table 3 Results of initial thallium imaging

Result	Number of patients
Increased heart size	24
Initial global score	
≤13	10
14–18	12
19–23	6
24–36	8
Number of segments with score ≥3	
≤2	14
3	6
4–5	12
6–8	4

ones and those scoring zero as normal ones. Segments scoring ≥2 in septal or inferior wall were considered as positive ones and ≤1 as normal ones. Decreased ≥1 on the 3 or 24 h imaging was considered as (partially) reversible segments. Increased ≥1 on the 3 or 24 h imaging was considered as reverse redistribution segments. The initial global score was the sum of the segmental scores of the 17 short axis segments on the initial imaging.

Statistical analysis

All parameters were expressed as mean plus/minus standard deviation. Non-parameters were expressed as frequency. A Cochren-Mantel-Haenzsel Statistics was hired to test R × C contingency table of image quality analysis. Other frequencies were assessed by a χ^2 test. A p value <0.05 was considered statistically significant.

RESULTS

Clinical characteristics

The demographic data of the study subjects are presented in Table 1. The mean age of the study group was 66 years. Out of the 36 patients, 72% were men. Fifty per cent underwent revascularization prior to the imaging test, 56% was with acute myocardial infarction and 34 culprit vessels were found among 32 patients receiving coronary angiography with more than 1 culprit vessel per patient.

Image quality analysis

Of the 36 patients, 56% (20) were graded as excellent both on the 3 h and on the 24 h imaging, 17% (6) were graded as poor on the 3 h imaging and none was graded as poor on the 24 h imaging. Table 2 lists the image quality analysis of the 3 h and 24 h images.

The initial SPECT thallium results

Qualitative results for the initial thallium imaging are presented in Table 3. The initial global score was ≤13 in 28%, 14–18 in 33%, 19–23 in 17% and 24–36 in 22% of the patients. The number of segments scoring ≥3 was 6–8 in 11%, 4–5 in 33%, 3 in 17% and less than 2 in 39% of the patients. Increased heart size was found in 67% of the patients.

Three-hour images

The total number of abnormal segments on the initial study was 184, with average 30% (56) segments improved by at least 1 grade on the 3 h imaging. Out of 184 segments, there were 88 ones scoring ≤3, with 44 (50%) ones improved by at least 1 grade on the 3 h imaging, and there were 96 segments scoring 4, with 12 (13%) ones improved by at least 1 grade on the 3 h imaging. The 3 h redistribution imaging detected more viable myocardium from segments scoring ≤3 than from those scoring 4, with a significant difference ($\chi^2 = 31.235$, $p = 0.001$) (Table 4).

Twenty-four-hour images

There were 158 abnormal segments on the 3 h imaging, with average 28% (44) segments improved by at least 1 grade on the 24 h imaging. Out of 158 segments, there were 62 ones scoring ≤3, with 32 ones improved by at least 1 grade on the 24 h imaging, taking up 52%, and there were 102 segments scoring 4, with 12 ones improved by at least 1 grade on the 24 h imaging, taking up 13%. The 24 h redistribution imaging detected more viable myocardium from segments scoring ≤3 than from those scoring 4, with a significant difference ($\chi^2 = 28.682$, $p = 0.001$). Table 5 lists the number of segments with redistribution on the 24 h imaging according to their 3 h scores.

Out of the 184 abnormal segments based on the initial imaging, 56 (30%) ones improved by at least 1 grade on the 3 h imaging and 78 (42%) ones improved by at least 1 grade on the 24 h imaging. The 24 h late imaging detected more viable myocardium than the 3 h imaging did, with a significant difference ($\chi^2 = 5.680$, $p = 0.017$). Out of the 88 abnormal segments scoring ≤3 on the initial imaging, the 24 h late imaging showed an insignificant trend toward more redistribution compared to the 3 h imaging ($\chi^2 = 2.302$, $p = 0.129$). Out of the 96 abnormal segments scoring 4 on the initial imaging, the 24 h late imaging detected more viable myocardium than the 3 h imaging did, with a significant difference ($\chi^2 = 4.923$, $p = 0.027$) (Table 4).

There were 128 initial abnormal segments with no any

Table 4 Number of segments with redistribution on the 3 h and 24 h imaging in relation to their initial segment scores (% of total segments)

Initial abnormal segmental score	Number of segments	Number of segments with redistribution at 3 h	Number of segments with redistribution at 24 h
1	40	16 (40)	20 (50)
2	26	12 (46)	18 (69)
3	22	16 (73)	16 (73)
4	96	12 (13)	24 (25)
Total	184	56 (30)	78 (42)

Table 5 Number of segments with redistribution at 24 h in relation to their segmental score at 3 h (% of total segments)

Abnormal segment score at 3 h	Number of segments	Number of segments with redistribution at 24 h
1	30	8 (27)
2	22	16 (73)
3	10	8 (80)
4	96	12 (13)
Total	158	44 (28)

Table 6 Number of segments with redistribution at 24 h alone rather than at 3 h (% of total segments)

Initial abnormal segmental score	Number of segments	Number of segments with redistribution alone at 24 h
1	24	4 (17)
2	14	8 (57)
3	6	2 (33)
4	84	12 (14)
Total	128	26 (20)

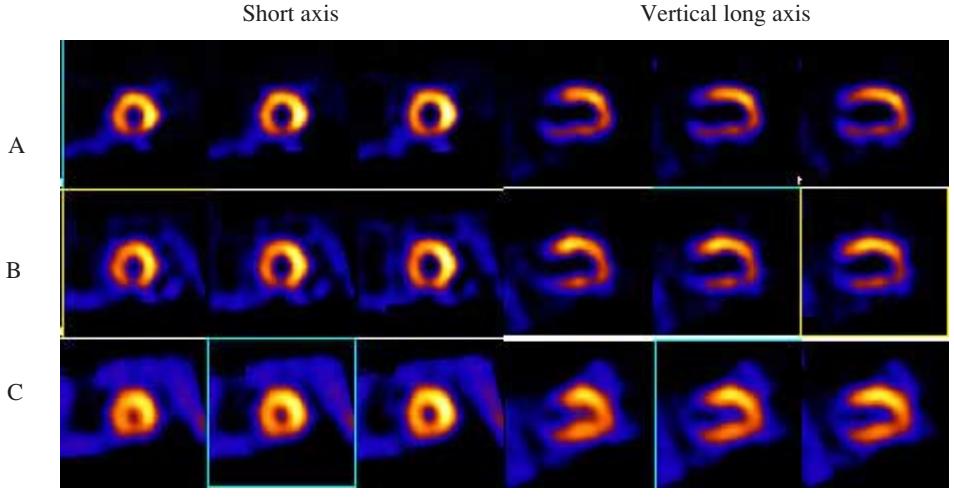

Fig. 2 A 58-year-old male with a chief complaint of persistent chest pain for 2 hours. The diagnosis was acute myocardial infarction and the emergent percutaneous coronary interventional therapy was performed successfully with reperfused right coronary artery. A, the initial images; B, the 3 h images; and C, the 24 h late images. Abnormal inferior segments on the initial images did not have evidences of improvement on the 3 h images, but recovered to normal on the 24 h images.

improvement on the 3 h imaging. Out of these segments, the 24 h late redistribution imaging detected additional redistribution in 26 segments, taking up 20% (Table 6 and Fig. 2).

Reverse redistribution on the 3 h or 24 h imaging in relation to the initial imaging

On the 3 h imaging relative to the initial imaging, 16 (44%, 16/36) patients showed reverse redistribution and a total of 44 (7%, 44/612) reverse redistribution segments were found. On the 24 h imaging relative to the initial imaging, 22 (61%, 22/36) patients showed reverse redistribution and a total of 76 (12%, 76/612) reverse redistribution segments were found.

DISCUSSION

The image quality analysis on the 3 h and 24 h imaging was evaluated using a 4-grade model. There was no significant difference in excellent, good, fair and poor rates between these 2 groups. It is interesting that none was graded as poor on the 24 h imaging and that 6 patients were graded as poor on the 3 h imaging. Factors affecting image quality are complex. The continued washout and decay of radiotracer in myocardial tissue with the passage of time leads to low blood ^{201}Tl levels and decreased count density, which ultimately discount the image quality and limit the clinical use of 24 h ^{201}Tl late redistribution imaging.[6] In the current study, a dose of 148–185 MBq ^{201}Tl, more than conventional dose of 74–111 MBq, was given intravenously. Additionally, a total of 68 frames on the 24 h late imaging were acquired for a prolonged acquisition time of 40 seconds/view with a 2-headed gamma camera and matrix 128 × 128 at 3-degree interval. The resultant increased ^{201}Tl blood levels and more acquisition information may contribute to satisfactory 24 h image quality in the present study. In addition, inferior or inferoseptal segments on the 3 h imaging were sometimes interfered with by increased liver uptake of the radiotracer, and inferior or inferolateral segments on the 24 h imaging were frequently interfered with by left colic flexure retention of the radiotracer. As to the former, a fatty meal was encouraged to facilitate the excretion of the radiotracer out of liver and gallbladder, and to the latter, cathartics were encouraged to facilitate defecation. In the current study, out of the 6 patients with poor image quality on the 3 h imaging, 2 patients had inferior, inferosetal and inferolateral segments interfered with by both the liver uptake and left colic flexure retention of ^{201}Tl, who improved to excellent grade on the 24 h imaging; 4 patients had inferior and inferoseptal (2 patients each) segments, respectively, interfered with by the liver uptake of ^{201}Tl, who improved to good grade on the 24 h imaging. These measures may contribute to satisfactory 24 h image quality, which seems even superior to the 3 h images in the present study. A separate study is required to clarify the factors responsible for 24 h image quality.

The 24 h late imaging, with more time for redistribution to occur, will contribute to detection of viable myocardium in theory because of the redistribution properties of ^{201}Tl. On a segmental basis, redistribution was seen on the 24 h and the 3 h redistribution images in 42% and 30% of abnormal segments, respectively, in relation to the initial images. More importantly, 20% of segments which did not demonstrate any redistribution on the 3 h imaging had redistribution on the 24 h imaging, consistent with previous reports.[7] The 24 h imaging detected a similar amount of viable myocardium among the abnormal segments scoring ≤3 on the initial imaging compared to the 3 h imaging. The 24 h imaging, however, detected more viable myocardium from the initial abnormal segments scoring 4 than the 3 h imaging did, with a significant difference. In addition, both the 3 h imaging and the 24 h imaging detected myocardial viability more easily from the initial abnormal segments scoring ≤3 than from those scoring 4. These results have reminded us that detection of myocardial viability by ^{201}Tl is dependent not only on the timing of the imaging, but also on the degree of myocardial perfusion reduction. Less time is required for redistribution to occur in abnormal segments scoring ≤3, from which the 3 h imaging is enough to detect viable myocardium. More time, however, is required for redistribution to occur in abnormal segments scoring 4, from which the 24 h imaging detects more viable myocardium compared to the 3 h imaging. Redistribution on the 24 h late imaging following stress studies has been attributed to more severe coronary stenosis.[8] The same mechanism may have been responsible for the occurrence of late redistribution in the current study. Thus, from the standpoint of the segmental changes, the 24 h late redistribution images provided information that was not available on the 3 h early redistribution images.

The implications of these findings for clinical rest thallium images are noteworthy. Redistribution imaging is required to determine the true size of the resting thallium defect, as the measurement obtained on the initial images will overestimate the defect obtained on the early redistribution images. Although the initial images may provide important clinical information regarding myocardial viability in patients with stunning or minimal decreases in resting blood flow, redistribution will be required to identify those segments with definite resting ischemia. Our findings suggest that late redistribution imaging will identify more segments with resting ischemia.

The potential value of 24 h late ^{201}Tl redistribution imaging has been studied with respect to stress or rest imaging, but remains an issue of controversy. Matsuno et al.[9] showed that the severity score in patients with old infarction decreased significantly from the early to the intermediate images, and decreased further on the delayed images. In patients with acute infarction, the score increased from the early to the intermediate images, but not on the delayed images. Regional uptake on the delayed images showed a better correlation with the fluorodeoxyglucose images than that on the early images. Redistribution on the delayed images was exclusively observed in the myocardial segments with less uptake than that estimated by fluorodeoxyglucose. Kiat et al.[7] showed that many segments with fixed defects on the basis of 4 h redistribution imaging improved following revascularization. They showed further that late redistribution imaging after 24 h was able to increase the yield for the detection of redistribution and that such redistribution was associated with improvement in regional wall motion following revascularization. Wagdy et al.[10] showed that 24 h late redistribution images detected additional

redistribution in 30% of the patients who did not have meaningful redistribution on 4 h images, and in 8% of the segments which were abnormal at 4 h. Thus, the 24 h late imaging was superior to the 3–4 h redistribution imaging in detection of myocardial viability. Different views were also present, however, in previous studies. Matsunari et al.[11] showed that when a threshold of 60% of peak activity was used as an index of myocardial viability, only a small fraction (3%) of the initial ^{201}Tl defects were additionally considered viable by the late images. The positive and negative predictive values of the early redistribution images for functional recovery were similar to those obtained by the late images. Thus, most of the clinically relevant information on myocardial viability may be obtained by conventional rest-early redistribution ^{201}Tl imaging when the defect severity is considered an index of tissue viability. The current study showed that the 24 h late ^{201}Tl imaging, with satisfactory image quality, detected considerable, additional amount of viable myocardium after myocardial infarction following rest injection.

Although reverse redistribution segments are frequently associated with myocardial viability as shown by functional recovery after revascularization, the implications remain controversial. It would be advisable to explore the reverse redistribution phenomenon in a separate study.

This study has a number of limitations, including the small number of patients, the absence of functional recovery data of post-revascularization, the potential impact of attenuation artifacts, and the absence of other imaging modalities such as positron emission tomography in these same patients. Nevertheless, the present study showed that the 24 h late redistribution imaging, with satisfactory image quality, would demonstrate additional redistribution in some segments that were abnormal on the 3 h redistribution imaging and in some segments that did not have any evidence of redistribution on the 3 h redistribution imaging. On the basis of these findings, we suggest that the 24 h late redistribution imaging should be performed, particularly, in those patients who have incompletely reversible defects on the 3 h early redistribution imaging.

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