Lung Thallium-201 Uptake During Exercise Emission Computed Tomography

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To test whether the analysis of lung uptake is worth adding to the interpretation of exercise thallium-201 (^{201}Tl) emission computed tomography (ECT), a lung/heart ratio of ^{201}Tl uptake was measured from an anterior image during ECT in 25 clinically normal (Group 1), 91 angiographically normal (Group 2), and 265 subjects with coronary artery disease (Group 3). The mean +2 s.d. of ratios in Groups 1 and 2 were the same (0.37). In Group 3, 80 subjects (30%) with increased ratios (>0.37) had higher frequencies of prior infarction and multi-vessel disease, more severe left ventricular dysfunction, and ^{201}Tl defects than 185 subjects with normal ratios. Subjects with markedly increased ratios (>0.45) had three-vessel disease more frequently than those with slightly or moderately increased ratios (67% versus 14% or 35%). Thus the measurement of lung/heart ratios may provide information regarding the severity of coronary artery disease and should be added to the routine interpretation of exercise ECT.

J Nucl Med 1991; 32:417–423

Exercise thallium-201 (^{201}Tl) myocardial scintigraphy is one of the most widely used techniques for the evaluation of coronary artery disease (CAD). It has been utilized not only to detect the presence of CAD, but also to determine high-risk patients. In planar ^{201}Tl imaging, increased lung ^{201}Tl uptake in multiple areas showing redistribution and multiple severe perfusion defects have been shown to be a marker of severe CAD and to predict adverse prognosis (*1–7*). Above all, the quantitatively assessed lung/heart ratio of ^{201}Tl activity has been reported to be the most important predictor of future cardiac events among electrocardiographic, scintigraphic, and angiographic variables in ambulatory symptomatic patients with CAD (*6*).

Exercise emission computed tomography (ECT) with ^{201}Tl is being increasingly used in the clinical setting. It has been shown to improve the accurate identification of CAD as compared to planar imaging (*8–11*). The value of analysis of lung ^{201}Tl uptake in ECT, however, has not been established. Recently, Kahn et al. (*12*) reported that the measurement of lung ^{201}Tl uptake from the anterior projection image obtained during ECT may not provide supplementary information regarding the extent of myocardial ischemia or ventricular dysfunction. Their observation in the ECT images is different from that in the planar images, which has been confirmed by many previous reports (*13–20*). It may require further investigation before the value of measurement of lung ^{201}Tl uptake in the ECT images can be denied. To examine whether the quantitative measurement of lung ^{201}Tl uptake is worth adding to the routine interpretation of exercise ECT with ^{201}Tl, we quantitatively evaluated lung ^{201}Tl uptake in subjects with and without CAD.

MATERIALS AND METHODS

Study Population

The following study groups were selected from 700 consecutive subjects who underwent exercise ^{201}Tl ECT in our nuclear cardiology laboratory. Group 1 consisted of 25 clinically normal subjects who were considered to have a very low probability (<5%) for CAD based on demographics and risk factors. The Group 1 subjects showed normal rest and exercise electrocardiography and did not undergo coronary angiography. Group 2 consisted of 91 subjects who had been referred to our hospital for evaluation of chest pain but who had no abnormalities in clinical evaluations including coronary angiography and left ventriculography. Group 3 consisted of 265 subjects with angiographically documented CAD. All subjects provided informed consent for the clinically indicated study.

Cardiac Catheterization

Group 2 and 3 subjects underwent coronary angiography and left ventriculography. Angiographically documented CAD was defined as a ≧75% luminal narrowing of one or more major coronary arteries or their major branches, based on the visual evaluation of two experienced angiographers. Left ventricular ejection fraction (LVEF) at rest was calculated by the area-length method and left ventricular end-diastolic pressure (LVEDP) was measured at rest.

Received April. 11, 1990; revision accepted Sept. 12, 1990

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Exercise Testing

All subjects underwent symptom-limited, maximal exercise testing on an upright bicycle ergometer in a fasting state. The exercise end points included moderate-to-severe chest pain, shortness of breath, leg fatigue, hypotension, or frequent ventricular arrhythmias. At peak exercise, 3.5 mCi of ^{201}Tl were injected intravenously and subjects were encouraged to continue exercising for an additional 30–60 sec. The ischemic depression of ST segments was defined as either horizontal or downsloping depression that was ≧0.1 mV below the baseline 0.08 second after the J point.

Image Acquisition

Myocardial images were obtained with a large field of view rotating gamma camera (ZLC 7500, Siemens Gammasonics, Inc., Des Plaines, IL) equipped with a high-resolution, parallel-hole collimator and interfaced with a computer system (Scintipac 2400, Shimadzu Corp., Kyoto, Japan). Thirty-two projections over 180° from the 45° right anterior oblique position to the 45° left posterior oblique position were acquired in a 64 × 64 matrix of a 38-cm field of view for 20 sec per image. Initial imaging was begun within 10 min after completion of exercise. Delayed images were obtained 4 hr after injection. No attenuation or scatter correction was used. Orthogonal images were generated by oblique-angle reconstruction producing vertical long-axis, short-axis, and horizontal long-axis slices each 6 mm thick.

ECT Analysis

Initial and delayed ^{201}Tl ECT were analyzed with previously reported methods (*21*). Briefly, the uptake score of ^{201}Tl in the initial and delayed images was visually determined for each of the total nine myocardial segments according to a four-point scoring system: 3 = normal, 2 = mildly reduced, 1 = moderately reduced, and 0 = markedly reduced. We defined initial and delayed scores of ^{201}Tl in each subject as the sum of uptake scores of total nine segments in the initial and delayed images, respectively. We also performed the circumferential profile analysis in the short-axis and vertical long-axis slices to calculate the washout rate of ^{201}Tl. An abnormal washout rate was defined as less than two standard deviations below the mean normal value that had been established from 15 normal subjects. In each subject, we calculated the Δ uptake score by subtracting the total uptake score of segments with an abnormal washout rate in the initial image from the total uptake score of the corresponding segments in the delayed image.

Lung Thallium Uptake

In the unprocessed anterior projection image (number 9 of 32) acquired as part of the initial imaging, the lung/heart ratio of ^{201}Tl activity was measured using a region of interest (ROI) method. Separate square ROIs of 5 × 5 pixels (3 × 3 cm) were defined for areas of the left upper lung and left ventricular myocardium (Fig. 1). The lung ROI was placed over the most intense lung activity in the region of which the base was five pixels above the basal anterolateral myocardial wall. The myocardial ROI was placed over the myocardial wall with the greatest count density. The lung/heart ratio was determined as the mean counts/pixel in the lung ROI divided by that in the myocardial ROI.

Interobserver variability of measurements of the lung/heart ratio were determined by two independent observers in 30 Group 3 subjects. To determine the relationship between the lung/heart ratio measured from the anterior ECT projection image and that measured from the conventional anterior planar image, an anterior planar image was obtained for 3 min immediately after the routine ECT acquisition in 25 subjects. During the conventional planar imaging, the gamma camera was placed as close as possible to the subject's chest. To determine the interval effect between the injection of ^{201}Tl and image acquisition, anterior projection images were obtained for 20 sec at 10 min and 20 min after the injection of ^{201}Tl in 24 subjects.

Statistical Methods

Data were expressed as either mean ± s.d. or as proportions. Proportions between two groups were compared by the chi-square test or the Fisher exact test. Mean data between two groups were compared by the Student's t-test. When test groups were not normally distributed, the nonparametric Wilcoxon t-test was applied. Differences between groups were considered significant at a p value of <0.05 (two-sided). Stepwise discriminant analysis was performed to determine which of the significant variables actually discriminated between subjects with CAD and an increased lung/heart ratio and those with CAD and a normal ratio.

RESULTS

Lung/Heart Ratio Measurements

Figure 2 demonstrates the correlation of lung/heart ratios measured by two independent observers. The lung/heart ratio was a highly reproducible measurement between observers ($r = 0.97$, $p < 0.001$, s.e.e. = 0.021). The mean absolute difference between ratios obtained by the two observers was 0.016 ± 0.014 with a range of 0.00–0.05.

Figure 3 demonstrates that the lung/heart ratios measured from the anterior ECT projection image correlated well with those from the conventional planar image ($r = 0.95$, $p < 0.001$, s.e.e. = 0.032). The mean absolute difference between the ratios measured from the anterior ECT projection image and from the conventional planar image was 0.022 ± 0.023 with a range of 0.00–0.10. The absolute counts in the lung and myocardial ROIs were 451 ± 113 and 1461 ± 419 counts/25 pixels on the 20-sec acquisition, and 3985 ±

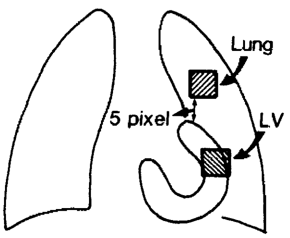

FIGURE 1
A schematic illustration of an anterior projection image. A square ROI (Lung) of 5 × 5 pixels is placed over the most intense lung activity in the region which is separated from the basal anterolateral myocardial wall by five pixels. Another square ROI (LV) is placed to cover the myocardial wall with the greatest count density.

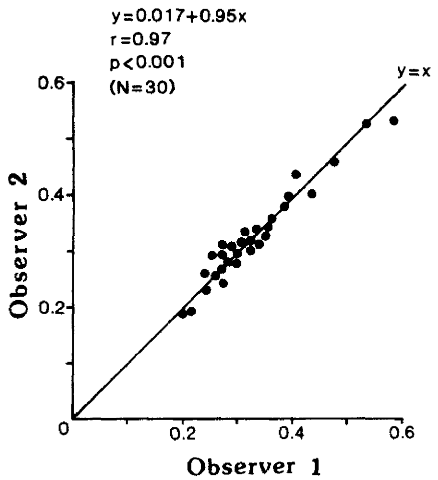

FIGURE 2
Correlation between the lung/heart ratios measured by two independent observers.

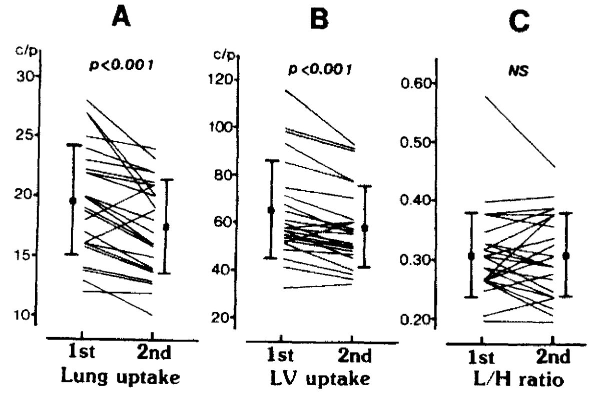

FIGURE 4
Changes from the first imaging (1st) obtained 10 min postinjection of ^{201}Tl to the second imaging (2nd) obtained 20 min postinjection. (A) Counts/pixel in the lung ROI (Lung uptake). (B) Counts/pixel in the heart uptake (LV). (C) Lung/heart ratio (L/H ratio). The vertical bars represent the mean ± s.d. c/p = counts/pixel; NS = not significant ($p > 0.05$).

971 and 12908 ± 3930 counts/25 pixels on the 3-min acquisition, respectively.

The comparison between measurements on the first anterior image (for 20 sec, 10 min after the injection of ^{201}Tl) and on the second anterior image (for 20 sec, 20 min after the injection) is shown in Figure 4. The absolute counts in the lung and myocardial ROIs were 490 ± 115 and 1627 ± 510 counts/25 pixels on the first acquisition and 439 ± 96 and 1470 ± 426 counts/25 pixels on the second acquisition, respectively. While both the lung and heart uptakes of ^{201}Tl decreased significantly from the first image to the second ($p < 0.001$, respectively), the lung/heart ratio was not significantly different between the first and second images ($p > 0.05$).

Lung/Heart Ratio in Subjects Without CAD

The lung/heart ratios were 0.279 ± 0.044 in Group 1 and 0.272 ± 0.048 in Group 2 (Fig. 5). There was no significant difference in the mean lung/heart ratios of Group 1 and 2 subjects ($p > 0.05$). Furthermore, the mean +2 s.d. of lung/heart ratios in Group 1 and 2 subjects were the same, i.e., 0.37. Therefore, the data combined from Group 1 and 2 subjects were analyzed as normals.

In these 116 subjects consisting of 25 clinically normal and 91 angiographically normal subjects, the lung/heart ratio was similar in 60 males and 56 females ($p > 0.05$) and did not correlate with age and peak systolic blood pressure during exercise testing ($p > 0.05$, respectively). On the other hand, the lung/heart ratio correlated weakly but significantly with peak heart rate (r =

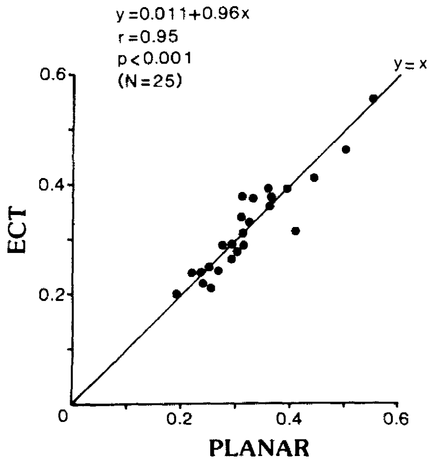

FIGURE 3
Correlation between the lung/heart ratios measured from a conventional planar image (PLANAR) and the anterior projection image acquired as part of the tomographic projection image set (ECT).

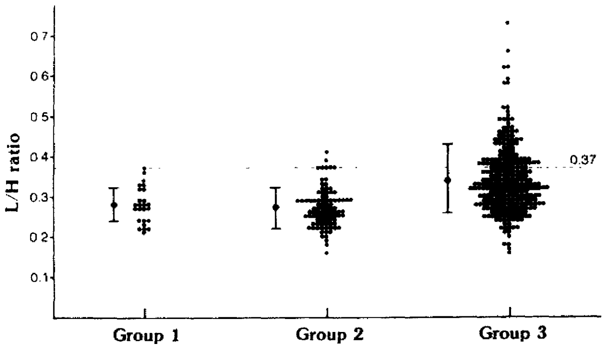

FIGURE 5
Individual lung/heart (L/H) ratios for 25 clinically normal subjects (Group 1), 91 angiographically normal subjects (Group 2), and 265 subjects with CAD (Group 3). The vertical bars represent the mean ± s.d. for each group. The dashed horizontal line represents a L/H ratio of 0.37 (mean ± 2 s.d. of Groups 1 and 2).

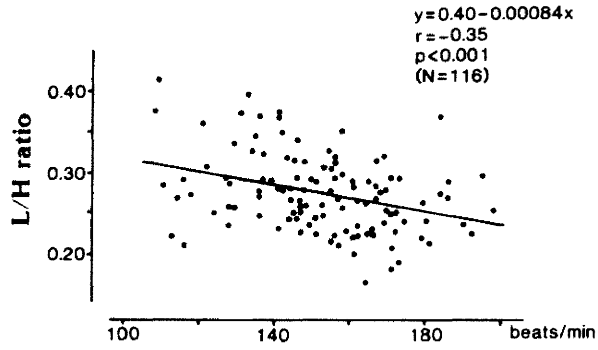

FIGURE 6
Correlation between the peak heart rate during exercise and the lung/heart (L/H) ratio in 116 subjects of Groups 1 and 2.

−0.35, $p < 0.001$) and peak rate-pressure product during exercise testing ($r = -0.33$, $p < 0.001$). However, the lung/heart ratio varied considerably at the same level of peak heart rate (Fig. 6).

Lung/Heart Ratio in Subjects with CAD (Tables 1 and 2)

The lung/heart ratio of Group 3 subjects was 0.342 ± 0.085 (Fig. 5) and was significantly higher than those of Group 1 and 2 subjects ($p < 0.001$, respectively). When the mean +2 s.d. of lung/heart ratios derived from 25 clinically normal subjects (0.37) was considered as the normal upper limit, 80 (30%) of Group 3 subjects showed an increased ratio. The highest ratio was 0.74 in a subject who had prior anterior and inferior myocardial infarctions with three-vessel disease and ventricular aneurysm (Fig. 7).

When 80 subjects with an increased ratio were compared to 185 subjects with a normal ratio, there were no significant differences in gender, age, and the frequency of ischemic depression of ST segment ($p > 0.05$, respectively). The frequency of prior myocardial infarction was significantly higher in subjects with an increased ratio than in those with a normal ratio ($p < 0.01$). The peak heart rate, peak systolic blood pressure, and peak rate-pressure product during exercise testing were significantly lower in subjects with an increased ratio than in those with a normal ratio ($p < 0.001$, respectively). The frequency of chest pain during exercise testing was significantly higher in subjects with an increased ratio than in those with a normal ratio ($p < 0.05$).

The number of diseased coronary vessels was significantly greater ($p < 0.01$), LVEF at rest was significantly lower ($p < 0.001$), and LVEDP at rest was significantly higher ($p < 0.001$) in subjects with an increased ratio than in those with a normal ratio. Multi-vessel and three-vessel diseases were significantly frequent in subjects with an increased ratio than in those with a normal ratio ($p < 0.05$ and $p < 0.01$, respectively). While the initial and delayed scores of ^{201}Tl myocardial uptake were significantly lower in subjects with an increased

TABLE 1
Comparisons of Means between Normal and Increased Lung/Heart (L/H) Ratios in Subjects with CAD

	Normal L/H (n = 185)	Increased L/H (n = 80)	p
Age (y.o.)	58.0 ± 11.9	59.8 ± 7.7	ns
Peak HR (per min)	138 ± 20	124 ± 23	<0.001
Peak sBP (mmHg)	182 ± 29	158 ± 31	<0.001
Peak RPP (×100)	252 ± 63	197 ± 58	<0.001
No. of diseased vessels	1.6 ± 0.7	1.9 ± 0.9	<0.01
LVEF (%)	62.4 ± 13.3	50.2 ± 16.1	<0.001
LVEDP (mmHg)	12.7 ± 5.3	16.7 ± 6.0	<0.001
Initial ^{201}Tl score	19.7 ± 5.2	15.4 ± 5.0	<0.001
Delayed ^{201}Tl score	22.4 ± 4.0	18.5 ± 5.2	<0.001
Δ uptake score	2.6 ± 3.2	3.0 ± 2.8	ns

Data are mean ± s.d.
HR = heart rate; LVEDP = left ventricular end-diastolic pressure; LVEF = left ventricular ejection fraction; ns = not significant ($p > 0.05$); sBP = systolic blood pressure; and RPP = rate-pressure product.

TABLE 2
Comparisons of Proportions Between Normal and Increased Lung/Heart (L/H) Ratios in Subjects with CAD

	Normal L/H (n = 185)	Increased L/H (n = 80)	p
Male	144 (78%)	69 (84%)	ns
Prior infarction	123 (66%)	72 (90%)	<0.01
Site of prior infarct			
Anterior	51 (28%)	31 (39%)	ns
Inferior	48 (26%)	20 (25%)	ns
Chest pain	48 (26%)	33 (41%)	<0.05
ST depression	76 (41%)	39 (49%)	ns
ST elevation	33 (18%)	21 (26%)	ns
Multi-vessel disease	76 (41%)	46 (58%)	<0.05
Three-vessel disease	27 (15%)	28 (35%)	<0.01

Data are numbers of subjects (proportions).
ns = not significant ($p > 0.05$).

FIGURE 7
Anterior projection image acquired as part of the tomographic projection image set from a 62-yr-old man with prior myocardial infarction. He showed the highest lung/heart ratio, 0.74.

ratio than in those with a normal ratio ($p < 0.001$, respectively), the Δ uptake score was similar in subjects with increased and normal ratios ($p > 0.05$).

Stepwise Discriminant Analysis

Using stepwise discriminant analysis, we analyzed the ten variables which were significantly different between 185 subjects with a normal lung/heart ratio and 80 with an increased ratio:

1. Presence of a prior infarction.
2. Chest pain during exercise testing.
3. Peak heart rate.
4. Peak systolic blood pressure.
5. Peak rate-pressure product.
6. Initial score of ^{201}Tl.
7. Delayed score of ^{201}Tl.
8. Number of diseased vessels.
9. LVEF.
10. LVEDP.

Only four variables discriminated between subjects with a normal lung/heart ratio and those with an increased ratio. The most important discriminator was LVEF ($F = 49.77$, $p < 0.0001$), followed by peak rate-pressure product ($F = 27.16$, $p < 0.0001$), initial score of ^{201}Tl ($F = 11.86$, $p < 0.001$), and LVEDP ($F = 6.74$, $p < 0.05$).

Severity of Increased Lung/Heart Ratio and Three-Vessel Disease

Global ischemia due to severe three-vessel disease could result in diminished ^{201}Tl uptake in all areas of myocardium so that it would be difficult to detect three-vessel disease by ^{201}Tl imaging. In patients with severe three-vessel disease, however, a lung/heart ratio may be markedly high even if multiple defects of ^{201}Tl do not exist in three vascular territories. We therefore studied the relation between the degree of increased lung uptake and three-vessel disease to evaluate the supplementary information of measurements of lung ^{201}Tl uptake. The degree of increased lung/heart ratios was classified into "slightly", "moderately," and "markedly." Slightly increased ratios were defined as >0.37 and ≦0.41; moderately increased ratios were defined as >0.41 and ≦0.45, and markedly increased ratios were defined as >0.45. The levels of 0.37, 0.41 and 0.45 were the mean +2 s.d., mean +3 s.d., and mean +4 s.d. of Group 1 subjects, respectively.

In 80 subjects with CAD and an increased lung/heart ratio (>0.37), 36 subjects (45%) had a slightly increased ratio, 20 (25%) had a moderately increased ratio, and 24 (30%) had a markedly increased ratio. Figure 8 demonstrates the incidence of three-vessel disease in three subgroups with slightly, moderately, and markedly increased ratios. The incidence of three-vessel disease of the subgroup with markedly increased ratios (67%) was significantly higher than those with slightly and moderately increased ratios (14%, $p < 0.001$ and 35%, $p < 0.05$, respectively).

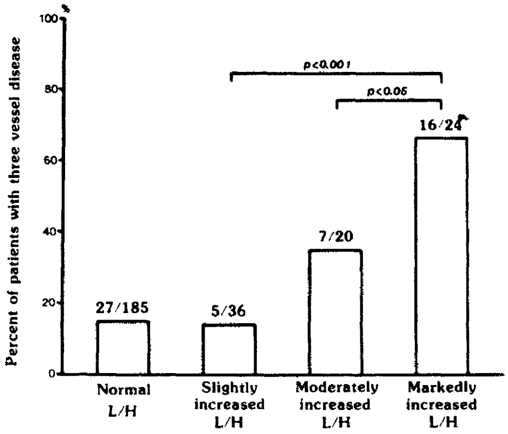

FIGURE 8
Comparison of the incidence of patients with three-vessel disease among normal, slightly increased, moderately increased, and markedly increased lung/heart (L/H) ratios in Group 3 subjects. A denominator and a numerator of the fractional number above each column represent the total number of subjects of each subgroup and the number of those with three-vessel disease in the subgroup, respectively. For example, the fractional number 16/24 above the far right column means that 16 of 24 subjects with a markedly increased L/H ratio have three-vessel disease.

DISCUSSION

The measurement of lung ^{201}Tl uptake from anterior projection images as part of ECT imaging in this study was reproducible and did not require more than 20 sec. As in planar imaging, the lung/heart ratio of ^{201}Tl activity in ECT imaging correlated with the peak heart rate during exercise testing in clinically or angiographically normal subjects. If the assessment of lung/heart ratio can provide information concerning the severity of CAD or left ventricular dysfunction in patients with CAD, it should be worth adding to the routine interpretation of exercise ^{201}Tl ECT as reported for planar imaging.

In this study, an increased lung/heart ratio was associated with a greater number of diseased vessels, a higher incidence of three-vessel disease, and more severe ^{201}Tl defect in the initial image. These findings suggest that the increased ratio may indicate more severe CAD. Furthermore, an increased ratio was associated with a lower LVEF, a higher LVEPP, and more severe ^{201}Tl defect in the delayed image. These findings suggest that the increased ratio may indicate more severe dysfunction of the left ventricle. As in planar imaging (*13–20*), the measurement of lung ^{201}Tl uptake in ECT imaging may therefore provide information about the severity of CAD or left ventricular dysfunction.

Because neither the frequency of ischemic ST depression nor the severity of transient defect (Δ uptake score) were significantly different between subjects with normal and increased lung/heart ratios in this study, lung ^{201}Tl uptake may not be related to the severity of exercise-induced myocardial ischemia. This finding is not consistent with previous reports (*16, 18, 20*). The difference may be due in part to the relatively higher percentage of patients with prior myocardial infarction in this study compared to the previous studies. Furthermore, diffuse subendocardial ischemia, which may occur in patients with three-vessel disease, may induce an elevation of the lung/heart ratio with no apparent multiple transient defects.

Our observations were different from those reported by Kahn et al. (*12*). First, the normal upper limit of lung/heart ratios in their study (0.33) is lower than that in our study (0.37). Values as the normal upper limit reported by earlier studies (*15, 17, 20, 22*) are similar to that of our study rather than to Kahn's study. Second, while 67% of subjects with CAD showed increased lung/heart ratios in their study, only 30% showed increased ratios in our study. Compared to earlier studies, the incidence of increased ratios in Kahn's study is markedly high while that in our study is relatively low. Furthermore, Kahn et al. reported that subjects with increased lung ^{201}Tl uptake did not differ from those with normal lung ^{201}Tl uptake with respect to the extent of CAD or left ventricular dysfunction. The explanation for these discrepancies may involve several differences between Kahn's and our studies. One is the method for delineating pulmonary and myocardial ROIs. While the lung ROI included 55 to 80 pixels and the myocardial ROI included 6 to 10 pixels in their study, both ROIs always included 25 pixels in our study. Another difference is the duration from ^{201}Tl injection to the acquisition of anterior projection image (*23*). They obtained the anterior projection image approximately 17 min after the injection of ^{201}Tl. We obtained it approximately 13 min after ^{201}Tl injection. This difference may explain the discordance in normal upper limits, but not in incidences of increased ratios in subjects with CAD. Furthermore, there are differences in the patient population in their study and in our study. For example, the percentage of patients with prior myocardial infarction in their study (60%) is lower than that of our study (74%). The percentage of patients with single-vessel disease in their study (61%) is higher than that in our study (54%). It should be noted that we studied a larger population of subjects with CAD (n = 265) than Kahn's study (n = 70).

It has not been reported whether the quantitative grading of increased lung ^{201}Tl uptake can provide any clinically useful information. Although Boucher et al. (*13*) graded the increased lung uptake of ^{201}Tl as "moderate" and "severe," their assessment of the lung uptake was qualitative and patients with severely increased lung uptake were not compared with those with moderately increased lung uptake. Kaul et al. (*6*) demonstrated that the quantitatively assessed lung/heart ratio of ^{201}Tl was the most important predictor of a future cardiac event in ambulatory patients with chest pain. Their study however did not include the grading of increased lung/heart ratios to be applicatory to the clinical assessment of a ratio of an individual patient with CAD. We graded increased lung/heart ratios quantitatively as mildly, moderately, and markedly increased ratios and observed that the quantitative assessment of the degree of increased lung ^{201}Tl uptake may be useful for detecting patients with three-vessel disease. This observation may add support to the clinical significance of quantitative assessment of lung ^{201}Tl uptake.

Rothendler et al. (*23*) reported that the delay in commencing imaging after exercise may decrease the ability to detect the increased lung uptake of ^{201}Tl. We acquired two anterior images equivalent to the anterior ECT projection image 10 min and 20 min after the injection of ^{201}Tl. No significant difference could be found between lung/heart ratios derived from the first image and those derived from the second image, although both lung and heart ^{201}Tl uptakes decreased significantly. In each individual subject, however, the change in the ratio was not negligible. For example, six subjects with a ratio of 0.27 measured in the first image showed markedly varied ratios of 0.21 to 0.38 in the second image. In the subject with a ratio of 0.27 in the first image and 0.38 in the second image, the ratio measured from the conventional planar image, which was acquired immediately after the second imaging, was 0.31. The ratio in the second image might be therefore overestimated due to the poor counting statistics associated with the short-duration acquisition (20 sec). In addition, the variability of lung ^{201}Tl clearance may cause the individual variability of lung/heart ratios. It may be essential for assessing individual lung/heart ratios to minimize the delay between exercise and initial imaging.

Recently, Mannting (*24*) reported a new method for quantification of lung ^{201}Tl uptake in ECT studies. He measured the lung ^{201}Tl uptake on the summation image of the eight frames from the anterior to the 45° right anterior oblique projections to overcome the poor counting statistics associated with the single anterior projection image. His unique method, however, did not improve the correlation between the lung/heart ratios measured from ECT and planar studies (r = 0.79–0.95) compared to that in our study (r = 0.95). Furthermore, his method may require too much time to be added to the routine interpretation of exercise ECT. It is important to shorten the time required for the analysis of lung ^{201}Tl uptake, since the analysis of myocardial perfusion in exercise ECT generally requires a long time and lung ^{201}Tl uptake is only a supplementary indicator for it.

In conclusion, the quantitative measurement of lung ^{201}Tl uptake may provide information regarding the severity of CAD or left ventricular dysfunction and, therefore, should be added to the routine interpretation of exercise ECT as reported for planar imaging. However, the application of lung/heart ratios for the identification of high-risk patients may require further investigation about the correlation of lung ^{201}Tl uptake and prognosis, which has been reported on planar imaging (*6, 25*).

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