MORPHOLOGICAL ASSESSMENT OF LEFT VENTRICULAR WALL AND VENTRICULAR ANEURYSM BY THALLIUM-201 MYOCARDIAL EMISSION COMPUTED TOMOGRAPHY

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To evaluate the influence of left ventricular (LV) aneurysm on non-infarcted ventricular wall, the shape of the left ventricular wall was assessed by thallium-201 single photon emission computed tomography (SPECT). From the morphology of the ventricular wall close to the apex, the rest images along the transaxis, horizontal long axis and vertical long axis were classified into 4 types: convergent, parallel, divergent and completely defective. LV aneurysm was detected by 2-dimensional echocardiography and/or contrast left ventriculography in 39 of 80 patients with previous myocardial infarction. Although convergence in the normal configuration of ventricular walls close to the apex, 4 of 39 patients with LV aneurysm showed this pattern. The divergent type was very specific (100%) and the most sensitive (56.4%) of the 4 for identifying LV aneurysm. Moreover, the parallel configuration indicated aneurysm in cases of inferoposterior infarction and all the completely defective cases exhibited this abnormality.

Thus, thallium-201 SPECT is suitable for observing the morphology of the ventricular wall and can provide highly reliable information for detecting postinfarction ventricular aneurysm with a sensitivity of 89.7%, a specificity of 87.8% and a diagnostic accuracy of 88.8%.

THE detection of left ventricular (LV) aneurysm has quite important prognostic implications for patients with myocardial infarction because congestive heart failure, malignant ventricular arrhythmia, thrombus formation or systemic embolism can result. An LV aneurysm can be defined by echocardiography or left ventriculography as a) either akinesis or dys-

kinesis; or b) a well-demarcated bulging from the left ventricular wall during systole.¹⁻⁹ On the other hand, thallium-201 myocardial scintigraphy is currently performed to evaluate infarction or myocardial ischemia in patients with known or suspected coronary artery disease. In addition, singlephoton emission computed tomography (SPECT) with thallium-201 has been established as the most reliable form of myocardial imaging because of its reproducibility and 3-dimensional visualization of myocardial perfusion.¹⁰⁻¹⁵ However there have been few reports of thallium-201 myocardial imaging of ventricular aneurysm

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TABLE I PATIENT POPULATION

	<i>n</i>	<i>Sex (M/F)</i>	<i>Age</i>	<i>LVEF (%)</i>
<i>LV aneurysm</i>	39	38/1	53 ± 2 (25–74)	32 ± 2 (9–58)
<i>No LV aneurysm</i>	41	38/3	54 ± 2 (32–79)	50 ± 1* (34–66)
<i>Total</i>	80	76/4	54 ± 1 (25–79)	41 ± 2 (9–66)

LVEF = left ventricular ejection fraction; *M* = male; *F* = female

* : $p < 0.001$ vs *LV aneurysm*

Fig.1. Left ventricular aneurysm by 2-dimensional echocardiography. The end-diastolic image on the apical 4 chamber view is shown from the patient with anteroapical and apical infarction accompanying apical thrombus. VA = ventricular aneurysm, Th = thrombus, LV = left ventricle, LA = left atrium.

because it is difficult to detect an aneurysm by the conventional planar scintigram with a poor spatial resolution.^{16–20}

This study was designed to analyze the influence of aneurysm formation on the shape of noninvolved ventricular walls in patients with previous myocardial infarction using thallium-201 SPECT and to estimate the clinical utility of this technique for detecting LV aneurysm.

MATERIALS AND METHODS

Subjects: This study comprised 80 patients (76 men, 4 women; age range 25–79 years, mean 54 ± 1 year) with previous myocardial infarction (Table I). The diagnosis of myocardial infarction was based on typical symptoms, electrocardiographic findings, and elevation of serum creatine kinase. All patients underwent 2-dimensional echocardiography (2DE) and/or contrast left ventriculography (LVG) to evaluate segmental

wall motions and to detect LV aneurysm. 2DE (Toshiba SSH 40A with a 2.4 or a 3.5 MHz transducer) was performed from multiple parasternal long- and short- axis views, apical long axis- and 4 chamber- views in all patients (Fig. 1). Fifty-four cases also underwent angiographic examinations. LVG was carried out in the 30° right anterior oblique and 60° left anterior oblique projections (Fig. 2). An aneurysm was defined as a demarcated bulge in the contour of the LV wall during both diastole and systole, demonstrating dyskinesia or akinesis.^{1,2}

Thallium-201 myocardial tomographic imaging: Within 2 weeks after the examinations with 2DE and/or LVG, rest thallium-201 myocardial imaging was performed using single-photon emission computed tomography (SPECT) for all patients. Thallium-201 chloride (4 mCi) was injected intravenously. Ten minutes after the injection, a large field of view (LFov) gamma camera with a high resolution parallel hole col-

Fig.2. Left ventricular aneurysm by contrast left ventriculography. End-diastolic and end-systolic images in a 30-degree right anterior oblique view are shown from the patient with anteroseptal and apical infarction.

limator (Simens ZLC 75) was rotated 180° around the long axis of the body from a 45° left posterior oblique to a 45° right anterior oblique projection with 36 views every 5° for 30 sec each in a total data acquisition time of 18 min. The data were input into 64×64 computer matrices and no attenuation correction was used.

Thallium-201 SPECT data were processed using a minicomputer system (Shimadzu Scintipac 2400) connected on-line to the gamma camera. Transaxial tomographic images were reconstructed first by a filtered back projection method with a Shepp and Rogan filter using a convolution reconstruction algorithm. Then, the short axis, vertical long axis and horizontal long axis tomograms were created with a one-pixel width (Fig. 3). All images were recorded on film.

Interpretation of thallium-201 SPECT imaging: The location of myocardial infarction was

detected by thallium-201 SPECT images. In addition, the morphology of the LV wall was evaluated in detail and classified into the 4 types, according to Morton et al²⁰ as follows: convergent; parallel; divergent; and completely-defective (Fig. 4). The first 3 types were recognized by the direction in which the anterior, septal, lateral and inferoposterior walls moved from the cardiac base to the apex. The views used for identifying the scintigraphic patterns were the transaxis, vertical long axis and horizontal long axis, but not the short axis. Convergence was taken to occur when all the ventricular walls approached the apex in each view of thallium-201 SPECT. Divergence was defined as an outward extension of the ventricular wall from the expected ventricular contour, and had to be observed in at least 3 continuous sections. The parallel type included a failure of configuration and divergence of the ventricular walls. If the infarcted area was so extensive that no scintigraphic view was able to reveal the ventricular wall morphology (and therefore could not be classified in any of the first 3 types), this was classified as completely defective.

Radionuclide ventriculography: To evaluate cardiac function, radionuclide ventriculography with technetium-99m as pertechnetate (20 mCi) was used for all patients. After the patient's red cells were labeled in vivo and the radioactivity had been equilibrated, the data were collected in a multiple gated mode of 500 cardiac cycles. The scintillation camera (Searle LFOV) was equipped with a low energy all purpose parallel hole collimator and positioned at an approximately 45° left oblique projection with a 5° to 10° caudal tilt. The gated blood-pool data were processed with the minicomputer system and the ejection fraction (LVEF) was calculated.

Data analysis: The detection of LV aneurysm by 2DE and/or LVG and the assessment of thallium-201 SPECT images were independently performed by 3 cardiologists and 2 radiologists, respectively. Discrepancies in each examination were resolved by discussion. All values are presented as the mean $\pm$ SEM. For statistical comparisons, the unpaired Student t-test or the chi-square test was used. A p value of 0.05 or less was considered as significant.

RESULTS

In 39 of 80 patients with myocardial infarction, LV aneurysm was detected by 2DE

Fig. 3. Schematic representation of thallium-201 tomographic images. The tomograms are derived from the four (transaxis, horizontal long axis, vertical long axis and short axis) views. The left ventricular walls are divided into 5 (anterior, septal, lateral, apical and inferoposterior) segments. A = anterior, S = septal, L = lateral, Ap = apical, P = posterior, I = inferior, IP = inferoposterior, AL = anterolateral.

Fig. 4. Demonstration of typical 4 scintigraphic patterns on thallium-201 SPECT images. (A) This convergence is from the patient with anterolateral infarction and a ventricular aneurysm was not detected by either echocardiographic or angiographic examinations. (B) The parallel type is from the patient with inferoposterior infarction and LV aneurysm. (C) This divergence is found in the same patient as shown in Fig. 2. (D) In this complete defect type, both the antero-septal and inferoposterior segments are thoroughly defected and an aneurysm is detected by 2DE and LVG.

TABLE II SUMMARY OF INFARCT SEGMENTS AND LVEF IN THE PATIENTS WITH AND WITHOUT LV ANEURYSM

Infarct segment		Antero-septal	Extensive anterior	Anterior + inferior	Infero-posterior	Pure posterior
LV aneurysm	<i>n</i>	17	7	6	9	—
	LVEF (%)	33 ± 2*	25 ± 3*	24 ± 3*	42 ± 5	—
No LV aneurysm	<i>n</i>	10	1	1	22	7
	LVEF (%)	49 ± 3**	44	34	50 ± 2	55 ± 7
Total	<i>n</i>	27	8	7	31	7

LVEF = left ventricular ejection fraction

* : $p < 0.05$ vs inferoposterior, ** : $p < 0.01$ vs LV aneurysmTABLE III ²⁰¹Tl-SPECT FINDINGS IN THE PATIENTS WITH AND WITHOUT LV ANEURYSM

Infarct segment	Antero-septal	Extensive anterior	Anterior + inferior	Infero-posterior	Pure posterior	Total
Convergence	1/5	1/1	0/1	2/22	0/7	4/36
Parallel	3/5	0/0	1/0	5/0	0/0	9/5
Divergence	12/0	5/0	3/0	2/0	0/0	22/0
Complete defect	1/0	1/0	2/0	0/0	0/0	4/0
Total	17/10	7/1	6/1	9/22	0/7	39/41

Values are presented by the number of cases as "with LV aneurysm/without LV aneurysm".

TABLE IV ANALYSIS OF THE RELIABILITY OF DETECTION OF LV ANEURYSM BY ²⁰¹Tl-SPECT

	True positive (%)	True negative (%)	Diagnostic accuracy (%)
Convergence	4/39 (10.3)	5/41 (12.2)	9/80 (11.3)
Parallel	9/39 (23.1)	36/41 (87.8)	45/80 (56.3)
Divergence	22/39 (56.4)	41/41 (100)	63/80 (78.8)
Complete defect	4/39 (10.3)	41/41 (100)	45/80 (56.3)
Divergence or complete defect	26/39 (66.7)	41/41 (100)	67/80 (83.8)
Divergence or parallel	31/39 (79.5)	36/41 (87.8)	67/80 (83.8)
Divergence, parallel or complete defect	35/39 (89.7)	36/41 (87.8)	71/80 (88.8)

and/or LVG (Table I). LVEF was significantly lower in the patients with LV aneurysm than in those without an aneurysm.

Table II lists features of the infarct segment and LVEF in all cases. The incidence of aneurysm formation was significantly higher in patients with an antero-septal infarction than in

those with an inferoposterior infarction in this series [17/27 (63.0%) vs 9/31 (29.0%); $p < 0.01$], while the inferoposterior infarct cases, where the apex was involved, were often accompanied by LV aneurysm. LV aneurysm caused a greater decrease in cardiac function in patients with an infarcted anterior segment than in those

without one.

The scintigraphic data by thallium-201 SPECT are shown in Table III. The convergent type, which is usually seen in a normal subject without any infarction, was more frequently observed in the patients without LV aneurysm than in aneurysm cases [36/41 (87.8%) vs 4/39 (10.3%); $p < 0.001$]. Only 14 of 80 patients (17.5%) had the parallel configuration, and no significant difference in the incidence of this pattern was found between patients with and without LV aneurysm [5/41 (12.2%) and 9/39 (23.1%), respectively]. However, the parallel pattern was more specific for aneurysms in inferoposterior infarct cases than those in anteroseptal infarct cases [5/5 (100%) vs 3/8 (37.5%); $p < 0.025$]. The divergent type was found only in patients having an LV aneurysm (22/39, 56.4%). Despite the low incidence (4/39, 10.3%), the completely defective type apparently indicated the possibility of aneurysm formation (4/4, 100%).

The clinical efficacy of the scintigraphic classification for detecting LV aneurysm is shown in Table IV. The divergence was the most sensitive (56.4%) of the 4 types and markedly specific (100%) for aneurysm patients. The parallel and complete defect types also had good specificity (87.8%, 100% respectively) despite their low sensitivity (23.1, 10.3%, respectively). Therefore, it seemed that the recognition of the parallel or completely defective types contributed to an improvement in sensitivity. As a result, thallium-201 SPECT was able to predict the presence of LV aneurysm with a sensitivity of 89.7%, a specificity of 87.8% and a diagnostic accuracy of 88.8%, by observing the scintigraphic patterns.

DISCUSSION

Thallium-201 myocardial scintigraphy is currently performed in patients with coronary artery disease because it is suitable for evaluating myocardial ischemia. However, little attention has been paid to determining the morphology of the ventricular wall. Moreover, the implications of the ventricular distortion that has often been observed in myocardial infarction cases is not always readily apparent, probably because conventional planar scintigraphy with thallium-201 has low spatial resolution and may therefore not be sensitive enough to detect the abnormality.¹⁸

In this respect, the application of single-photon emission computed tomography (SPECT)

to radionuclide techniques has contributed to more accurate and detailed analysis of regional abnormalities.^{10-15,21-24} Recently, Morton et al²⁰ reported that thallium-201 SPECT could detect an LV aneurysm with high reliability. The present study also revealed the importance of the failure of the ventricular walls to converge on the thallium-201 SPECT images. The results reported by Morton et al, however, seem to overestimate the findings as compared to those obtained in our study, possibly because the former study consisted of fewer patients with LV aneurysm (only 16 of 74) and only included one case with apical/inferior infarct with an aneurysm. The present study included all types of myocardial infarction (anterior, septal, lateral, apical, inferoposterior and their combinations) and 39 of 80 patients had LV aneurysm (Table I).

In this investigation, the morphology of a non-infarcted ventricular wall was evaluated by thallium-201 SPECT and classified into 4 scintigraphic patterns. The convergent type indicated a normal configuration at the apex (no ventricular distortion) and, therefore could not show the presence of ventricular aneurysm. However, 4 patients with LV aneurysm were classified as convergent. Although the reason is not clear, the marked dilatation of their left ventricles due to severe heart failure might weaken the influence of LV aneurysm. Despite its relatively mild distortion, the parallel pattern indicated the presence of LV aneurysm in patients with inferoposterior infarction with a specificity of 100%, but did not always do so in patients with other types of infarctions. This may be due to the lessened influence of LV aneurysm on the noninfarcted ventricular wall in the case of inferoposterior infarction because the septal or lateral involvement occurred in fewer cases and to a lesser extent, resulting in a smaller aneurysm. The other possible explanation is that the presence of the diaphragm near the inferoposterior segment might prevent the distortion due to LV aneurysm. The divergent type is most characteristic of LV aneurysm; its sensitivity and specificity were 56.4% and 100%, respectively. Divergence appeared as bulging and was often observed in patients with large aneurysms accompanying the infarction with anterior and apical involvement. The completely defective type was not direct evidence of aneurysm formation; however, all 4 cases had LV aneurysms in this series. This suggests a high probability of the presence of an aneurysm in the

completely defective case.

Diagnosis of postinfarction ventricular aneurysm by two-dimensional echocardiography or angiography with radionuclide or with contrast material is now well established.¹⁻⁹ Since the surgical resection of an aneurysm can improve survival, early detection is very important.^{2,5} If thallium-201 scintigraphy using SPECT is performed, the morphology of all the ventricular wall should be analyzed. In addition to observing myocardial infarction or ischemia, this assessment can contribute to predicting the presence of LV aneurysm.

Four points about thallium-201 SPECT imaging should be noted for the diagnosis of LV aneurysm: (1) the presence of apical involvement; (2) the extensive infarction (so-called completely defective type); (3) the parallel configuration in the case of inferoposterior infarction; and (4) the divergence pattern in all types of myocardial infarction. Considering these findings, the sensitivity and diagnostic accuracy of thallium-201 SPECT improved (89.7% and 87.8%, respectively) with a slight decrease in specificity (Table IV).

Thus, thallium-201 SPECT appears to be a good technique not only for evaluating myocardial ischemia, but also for observing non-involved ventricular walls in patients with myocardial infarction. It is likely that a more detailed study of the interpretation of thallium-201 tomographic images can provide important information about the presence of postinfarction ventricular aneurysm.

REFERENCES

1. GORLIN R, KLEIN MD, SULLIVAN JM: Prospective correlative study of ventricular aneurysm. Mechanistic concept and clinical recognition. *Am J Med* 42: 512, 1967
2. WEYMAN AE, PESKOE SM, WILLIAMS ES, DILLON JC, FEIGENBAUM H: Detection of left ventricular aneurysms by cross-sectional echocardiography. *Circulation* 54: 936, 1976
3. VISSER CA, KAN G, DAVID GK, LIE KI, DURRER D: Echocardiographic-cineangiographic correlation in detecting left ventricular aneurysm: a prospective study of 442 patients. *Am J Cardiol* 50: 337, 1982
4. LEE DCS, JOHNSON RA, BOUCHER CA, WEXLER LF, MCENANY MT: Angiographic predictors of survival following left ventricular aneurysmectomy. *Circulation* 56 (Suppl II): 12, 1977
5. SORENSEN SG, CRAWFORD MH, RICHARDS KL, CHAUDHURI TK, O'ROURKE RA: Non-invasive detection of ventricular aneurysm by combined two-dimensional echocardiography and equilibrium radionuclide angiography. *Am Heart J* 104: 145, 1982
6. HOPKINS GB, KAN MK, SALEL AF: Scintigraphic assessment of left ventricular aneurysms. *JAMA* 240: 2162, 1978
7. DYMOND DS, JARETT PH, BRITTON KE, SPURRELL RAJ: Detection of postinfarction aneurysms by first pass radionuclide ventriculography using a multicrystal gamma camera. *Br Heart J* 41: 68, 1979
8. FRIEDMAN ML, CANTOR RE: Reliability of gated heart scintigrams for detection of left-ventricular aneurysm: concise communication. *J Nucl Med* 20: 720, 1979
9. WEIZELBERG GG, STRAUSS HW, BINGHAM JB, MCKUSICK KA: Scintigraphic evaluation of left ventricular aneurysm. *Am J Cardiol* 46: 1138, 1980
10. HOLMAN BL, HILL TC, WYNNE J, LOVETT RD, ZIMMERMAN RE, SMITH EM: Single-photon transaxial emission computed tomography of the heart in normal subjects and in patients with infarction. *J Nucl Med* 20: 736, 1979
11. GOODWIN PN: Recent developments in instrumentation for emission computed tomography. *Semin Nucl Med* 10: 322, 1980
12. MAUBLANT J, CASSAGNES J, LEJEUNE JJ, MESTAS D, VEYRE A, JALLUT H, MEYNIEL G: A comparison between conventional scintigraphy and emission tomography with thallium-201 in the detection of myocardial infarction. *J Nucl Med* 23: 204, 1982
13. RITCHIE JL, WILLIAMS DL, HARP G, STRATTON JL, CALDWELL JH: Transaxial tomography with thallium-201 for detecting remote myocardial infarction. *Am J Cardiol* 50: 1236, 1982
14. MASSIE BM, WISNESKI JA, INOUE IK, HOLLENBERG M, GERTZ EW, HENDERSON S: Detection and quantification of previous myocardial infarction by exercise-redistribution tomographic thallium-201 scintigraphy. *Am J Cardiol* 53: 1244, 1984
15. NOHARA R, KAMBARA H, SUZUKI Y, TAMAKI S, KADOTA K, KAWAI C, TAMAKI N, TORIZUKA K: Stress scintigraphy using single-photon emission computed tomography in the evaluation of coronary artery disease. *Am J Cardiol* 53: 1250, 1984
16. YEH E: Thallium image of ventricular aneurysm. *Eur J Nucl Med* 7: 288, 1982
17. WINZENBERG A, GOODENDAY LS, LEIGHTON RF: Scintigraphic detection of ventricular aneurysm with thallium-201. *J Nucl Med* 24: 34, 1983
18. GERSON MC, VARMA DGK, NISHIYAMA H, GELFAND MJ: Evidence of left ventricular aneurysm by thallium-201 myocardial scintigraphy. *Clin Nucl Med* 8: 133, 1983
19. BREISBLATT WM, BROWN DL, WEILAND RL: Reversibility of longstanding left ventricular aneurysm predicted by thallium-201 imaging. *J Am Coll Cardiol* 7: 1162, 1986
20. MORTON KA, ALAZRAKI NP, TAYLOR AT, DATZ FL: SPECT thallium-201 scintigraphy for

- the detection of left-ventricular aneurysm. *J Nucl Med* 25: 168, 1987
21. MAUBLANT J, BAILLY P, MESTAS D, CAS-SAGNES J, LUSSEN JR, ZUROWSKI S, HUFFER E, VEYRE A, JALLUT H, MEYNIEL G: Feasibility of gated single-photon emission transaxial tomography of the cardiac blood pool. *Radiology* 146: 837, 1983
 22. BARAT JL, BRENDDEL AJ, COLLE JP, PELONNIER VM, OHAYON J, WYNCHANK S, LECCIA F, BESSE P, DUCASSOU D: Quantitative analysis of left ventricular function using gated single photon emission tomography. *J Nucl Med* 25: 1167, 1984
 23. NAKATA T, MURAKAMI H, INOUE M, HOSODA S, TANAKA S, KUMAOKA K, TSUDA T, KUBOTA M, MORITA K, IIMURA O: Qualitative determination of infarct segment by Fourier analysis using gated cardiac pool emission computed tomography. *J Cardiogr* 16: 331, 1986 (in Japanese)
 24. STADIUS ML, RITCHIE JL: Gated blood pool tomography. In *New Concepts in cardiac imaging -1986*, ed by POHOST GM, HIGGINS CB, MORGANROTH J, RITCHIE JL, SCHELBERT HR, Year Book Medical Publisher, Chicago, 1986, pp 137
 25. LOOP FD, EFFLER DB, NAVIA JA, SHELDON WC, GROVES LK: Aneurysm of the left ventricle: Survival and results of a ten year surgical experience. *Ann Surg* 178: 399, 1973