SPECT Thallium-201 Scintigraphy for the Detection of Left-Ventricular Aneurysm

Kathryn A. Morton, Naomi P. Alazraki,* Andrew T. Taylor,* and Frederick L. Datz

Nuclear Medicine Service, Veterans Administration Medical Center; and Department of Radiology, University of Utah School of Medicine, Salt Lake City, Utah

We have noted that the presence of left ventricular anterior/apical aneurysm on contrast ventriculography or echocardiography correlates well with the finding of failure of convergence of the left ventricular walls toward the apex on single photon emission computed tomography (SPECT) thallium-201 images. To assess this observation, we analyzed the SPECT thallium scans of 74 sequential patients who had SPECT thallium scintigraphy and contrast ventriculography and/or echocardiography for evaluation of coronary artery disease. Immediate post-stress and 4-hr redistribution thallium-201 SPECT images, obtained following i.v. administration of 2 mCi of thallium-201, were reconstructed with no attenuation correction using three-dimensional linear and nonlinear filters and displayed in short, vertical-long, and horizontal-long axes. Of the 74 patients, contrast ventriculography and/or echocardiography showed anterior/apical aneurysms in 15 and a posterolateral aneurysm in one. SPECT thallium scans detected 14 of the 16 aneurysms, based on the criterion of failure of convergence of the ventricular walls toward the apex. There were two false-positives. Thus SPECT thallium-201 scintigraphy for the detection of left-ventricular aneurysm in this series had a sensitivity of 94%, a specificity of 97%, and an accuracy of 96%.

J Nucl Med 28:168–172, 1987

Ventricular aneurysm is a common complication of transmural myocardial infarction (MI). Autopsy data show an incidence in post-myocardial infarction patients varying from 3.5 to 25% (*1,2*). The left ventricle is involved in 95% of patients with ventricular aneurysms and the right ventricle in 5%. Of all aneurysms, 80% involve the anterior wall and/or apex of the left ventricle and these are generally larger than those which involve other areas. Therefore, the greatest risk of aneurysm follows infarction in the distribution of the left anterior descending coronary artery.

Complications of left ventricular aneurysm are more common with large aneurysms. They include mural thrombus formation, calcification of the thrombus or aneurysm wall, arterial embolization, impaired ventricular function with chronic congestive heart failure and ventricular tachycardia. Although rupture of the aneurysm is rare, it can occur acutely or following reinfarction at the margin of the aneurysm (*2–4*). Surgical resection of aneurysms tends to be unsuccessful with very large aneurysms. Patient prognosis and treatment can therefore be affected by the presence and diagnosis of an aneurysm.

Many patients with coronary artery disease and previous histories of myocardial infarction are evaluated with thallium-201 (^{201}Tl) or radionuclide gated blood-pool imaging. Gated blood-pool studies have been reported as highly sensitive for detecting ventricular aneurysms (*5*). This study was undertaken to determine the reliability of single photon emission computed tomographic (SPECT) ^{201}Tl myocardial scintigraphy for the diagnosis of ventricular aneurysm.

PATIENTS AND METHODS

Patients

Seventy-four sequential male patients, ages 33 to 74 yr, who had exercise SPECT ^{201}Tl scintigraphy and either contrast ventriculography (69 patients) and/or echocardiography (eight patients) within 12 wk of their SPECT thallium studies for evaluation for coronary artery disease were included in the study. The patients were studied at our institution.

Received Jan. 8, 1986; revision accepted Sept. 4, 1986.

For reprints contact: Naomi P. Alazraki, MD, Co-Director, Nuclear Medicine, Emory University and VA Med. Ctr., 1364 Clifton Rd. N.E., Atlanta, GA 30322.

* Drs. Alazraki and Taylor are currently Co-Directors of Nuclear Medicine at Emory University and the VA Medical Center in Atlanta.

SPECT Thallium Imaging Protocol

Patients were instructed to take nothing by mouth, with the exception of medication, for at least 4 hr prior to the study to prevent excessive splanchnic thallium uptake and to minimize the risk of aspiration should complications occur during the examination. Medications, including beta-adrenergic blocking agents, were not discontinued prior to the study.

All patients were stressed with a multistage treadmill test either maximally, according to the Bruce protocol, or to a submaximal degree. Exercise was terminated when (a) the patient achieved 95% of his predicted maximal heart-rate, (b) he developed electrocardiographic or clinical evidence of myocardial ischemia or hemodynamic instability, (c) he was unable to continue exercise for reasons such as leg fatigue or shortness of breath, or (d) he was otherwise determined by cardiology to have reached the safe limit of stress. Patients were continuously monitored by electrocardiography and blood pressure determinations at each stage of exercise. One minute prior to completion of exercise, 2.0 mCi of [^{201}Tl] chloride* was injected intravenously.

Immediately after completion of exercise, "stress" images were acquired using single photon emission computed tomography (SPECT). With the patient supine, a 61 PM tube scintillation camera with a rotating head and a low-energy, general purpose collimator obtained 32 images for 45 sec each, over 180° of rotation from the 45° left posterior oblique to the 45° right anterior oblique projection for a total imaging time of 24 min. A symmetrical 15% window was centered at ~78 keV and images were acquired into a 64 × 64 computer matrix. "Redistribution" images were acquired in the same manner four hours after the completion of exercise. Between the stress and redistribution images the patients were permitted to ingest only water and noncaloric beverages.

SPECT thallium scan processing. Stress and redistribution images were recorded and processed on a dedicated nuclear medicine computer in the following manner: The center of rotation (calculated prior to each day's study) and a 30 million count technetium-99m or ^{201}Tl uniformity flood (acquired weekly) were applied to each acquisition. A transaxial tomographic reconstruction was then performed with 1-pixel wide slices, no Y-filtering and no attenuation correction, followed by a ramp-hanning filter with a cutoff frequency of 1.000. A three-dimensional nonlinear filter was applied to the transaxial images with a three standard deviation cutoff, followed by a linear three-dimensional filter with a cutoff of 0.5. One-pixel wide slices of the heart in the short, vertical long and horizontal long axes were finally created. All images were recorded onto film; manual intensity adjustments were made so that the stress and redistribution images were of similar intensities in the regions of best perfusion.

Interpretation of scans. The SPECT thallium scan images were analyzed for regional ischemia or infarction. The scans were read jointly by two nuclear medicine physicians (K.M., N.A.) without prior knowledge of the patient's history, physical findings, laboratory tests, ventriculographic, or echocardiographic results. Agreement was reached in all cases by discussion. Abnormal scans which showed apical/anterior infarction (deficient uptake on both stress and redistribution images in the left ventricular anterior wall/apex) by SPECT thallium scintigraphy were identified. The left ventricular walls were evaluated in short axis, vertical long axis, and horizontal long axis views for convergence, divergence, or parallel configurations as they approached the apex.

These scans were correlated with the contrast ventriculograms and/or echocardiograms for the presence or absence of an aneurysm. A ventricular aneurysm by either contrast ventriculography or echocardiography was defined as a convex sharply circumscribed segment of ventricular myocardium showing dyskinesis during systole relative to adjacent functioning myocardium. Sensitivity, specificity, and accuracy of the SPECT thallium studies in the diagnosis of left ventricular apical/anterior aneurysm using the criterion of failure of convergence of the left ventricular walls as they approach the apex were calculated.

RESULTS

Seventy-four patients had contrast ventriculography and/or echocardiography within 4 mo of their SPECT thallium study (80% had the studies within 3 wk of their SPECT thallium scan). Of these 74 patients, 11 had normal SPECT thallium studies and 63 had abnormal studies. Of the patients with normal SPECT thallium scans, none showed ventricular aneurysms by contrast ventriculography. Of the 63 patients with abnormal SPECT thallium scans, 22 had scan evidence of apical/anterior infarction while the remaining 41 had SPECT thallium scans which showed other types of abnormalities. Among the 74 patients studied, contrast ventriculography and/or echocardiography identified 16 ventricular aneurysms. All 16 patients had abnormal SPECT thallium scans. Of the 16 aneurysms, all but one (a large posterolateral aneurysm) occurred in the anterior wall and apex of the left ventricle in patients who showed apical/anterior infarction by SPECT thallium scan.

Analysis of the SPECT thallium scans in the 22 patients showing scintigraphic evidence of apical/anterior infarction showed three patterns: convergence of the ventricular walls toward the apex (six patients), parallel configuration of the ventricular walls as they approached the apex (four patients), and divergence of the ventricular walls toward the apex (12 patients). Convergence, divergence, or parallel configuration of the left ventricular walls was seen best on the vertical and horizontal long-axis projections (Fig. 1). The short axis view showed an enlarging ventricular diameter as slices approached the apex in patients whose vertical and horizontal long-axis projections showed diverging left ventricular walls. In eight of the 12 patients with the diverging pattern, divergence was more pronounced on the stress than on the redistribution images (Fig. 2). This suggests, as in the case of radionuclide ventriculograms, that increased cardiac work exaggerates wall motion abnormalities.

The presence or absence of an apical/anterior aneurysm by contrast ventriculography and/or echocardiog-

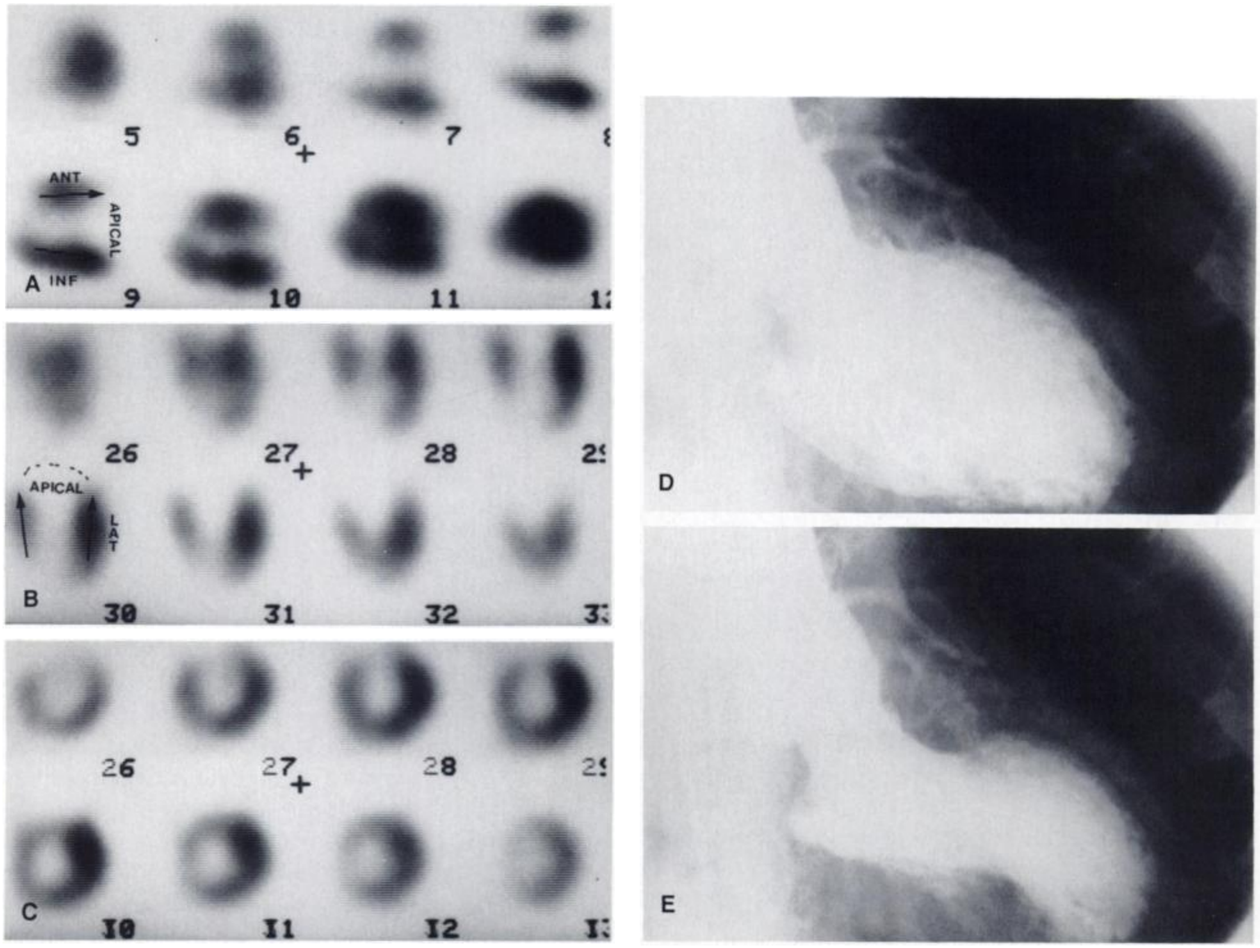

FIGURE 1
Ventricular aneurysm. Thallium-201 SPECT images show divergence of left ventricular walls as they approach the apex, instead of normal convergence. Contrast left ventriculogram apical aneurysm. A: Thallium-201 SPECT images in vertical long axis projection. Slices progress from lateral wall (5) to septal wall (12). Left ventricular anterior and inferior walls (labeled on slice number 9) diverge towards apical aneurysm. B: Thallium-201 SPECT images in horizontal long axis projection. Slices progress from inferior (26) to anterior (33). Left ventricular septal and lateral walls (labeled on slice 30) diverge towards apical aneurysm. C: Short axis views show a larger chamber at the apex (26) than at the base (33), reflecting aneurysmal dilatation at the apex. D: End-diastolic view from contrast left ventriculogram performed at cardiac catheterization. E: End-systolic view from left ventriculogram. Apical aneurysm is apparent.

raphy correlated well with the pattern of divergence or parallel configuration on the SPECT thallium scans (Table 1). Among the six patients whose ventricular walls converged normally toward the apex (Fig. 3), only one had contrast ventriculographic evidence of a small apical aneurysm. Of the four patients whose SPECT thallium scans showed parallel ventricular walls, two showed small but definite apical aneurysms by contrast ventriculography and the other two had akinesis in the infarcted apical/anterior left ventricular wall, but no definite aneurysms. All of the 12 patients whose SPECT thallium scans showed divergence of the left ventricular walls showed definite large apical/anterior aneurysms by contrast ventriculography and/or echocardiography. The single aneurysm which was not located in the apical/anterior portion of the left ventricle was easily identified on the SPECT thallium images as a large bulge in the posterolateral wall.

Table 2 summarizes the reliability of SPECT thallium scans in the detection of ventricular aneurysms in this series. For all patients, SPECT thallium scintigraphy detected ventricular aneurysms with a sensitivity of 94%, a specificity of 97%, and an accuracy of 96%. For just those patients with evidence of an apical/anterior infarction by SPECT thallium scintigraphy, the presence of divergent or parallel ventricular walls predicted the presence of an aneurysm with a sensitivity of 93%, a specificity of 71%, and an accuracy of 86%. In patients with any abnormality on SPECT thallium scan, aneurysms were detected by the scan with a sensitivity of 94%, specificity of 96%, and an accuracy of 95%.

DISCUSSION

The prognosis of a patient with a previous myocardial infarction can be altered by the presence of a ventricular

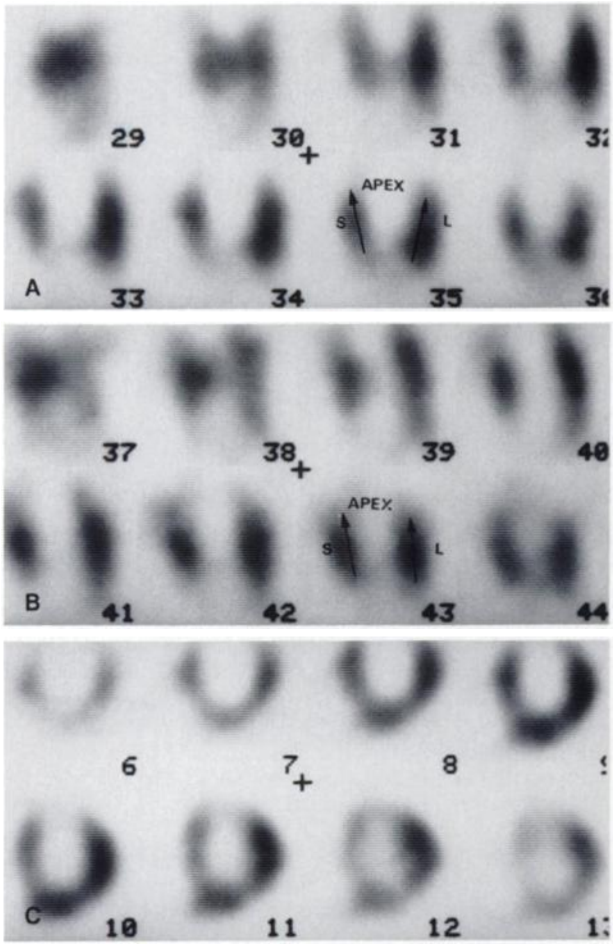

FIGURE 2
Horizontal long axis views from SPECT ^{201}Tl images performed at stress (2A) and redistribution (2B) septal (s) and lateral (l) show more exaggerated findings of divergence of ventricular walls as they approach the apex on stress images (compare angulation of arrows on slice 35 and slice 43). Redistribution images show septal and lateral walls to be more parallel than divergent, as they are on stress images (2A).

aneurysm. The prognosis then depends on the severity of the underlying coronary artery disease and the size of the aneurysm. If the aneurysm is small, involving <20% of the total area of left ventricle, stroke volume is maintained and patient survival is similar to that of post-MI patients without aneurysms (*6*). However, larger aneurysms significantly reduce survival; reports indicate that the 5-yr survival of post-MI patients is ~77% in the absence of aneurysm and ~27% in those with left ventricular aneurysm (*2,4*). A recent study has shown that the 1-yr survival in patients following acute transmural anterior wall myocardial infarction is significantly reduced in those patients who develop aneurysms compared with those who do not (61% versus 9%) (*12*).

There is evidence that resection of some ventricular aneurysms may improve survival. The Cleveland Clinic

TABLE 1
Correlation of Contrast Ventriculography and/or Echocardiography with SPECT Thallium-201 Images for Aneurysm Diagnosis

Contrast ventriculogram and/ or echocardiogram results	No.	SPECT ^{201}T1 imaging: Relationship of LV walls		
			Fail to converge	
		Converge to apex	Parallel	Diverge to apex
LV aneurysm	16	2*	2	12
Apical/ant aneurysm	15	1	2	12
No aneurysm	58	56	2	0
Total patients	74	2	2	23

* Includes one small apical aneurysm (false negative) and one posterolateral aneurysm identified as a bulge of the posterolateral wall on thallium images.

has reported a 5-yr survival for patients whose postinfarction aneurysms were surgically resected of 76% (about the same as that of post-MI patients without aneurysms), compared with 20% for patients with aneurysms who were treated with medical management alone (*7*). Surgical resection of left ventricular aneurysms is indicated when ventricular tachyarrythmias, refractory congestive heart failure or recurrent arterial embolization develop (*5*). Reported results of resection are less favorable for patients with unstable angina, papillary muscle, or septal involvement. Aneurysms involving more than 50% of the area of the ventricular myocardium are not amenable to resection, since the resultant ventricular chamber is too small to achieve an adequate stroke volume (*4,5*). It is therefore important that ventricular aneurysms be recognized early and followed in correlation with the clinical status of the patient, (*8–11,13*).

The diagnosis of ventricular aneurysm is classically made by the physical finding of a precordial systolic bulge (present in 10% of patients with anterior ventricular aneurysm), electrocardiographic findings of persistent ST segment elevation, inverted T waves and significant Q waves (present in ~65–79% of cases of anterior wall aneurysms), and the finding of an abnormal bulge on chest radiographs (present in ~15–25% of cases with aneurysms). However, as many as 30–40% of patients with aneurysms are overlooked based on these criteria (*4*).

In this study, the high incidence of abnormal thallium scans (63/74) and ventricular aneurysms (16/63) reflected the profile of the patient population evaluated for chest pain at our institution: most are late-middle-aged or elderly males who smoke. In addition, many patients with previous histories of myocardial infarctions who have continuing chest pain have thallium scans at our institution in the evaluation additional

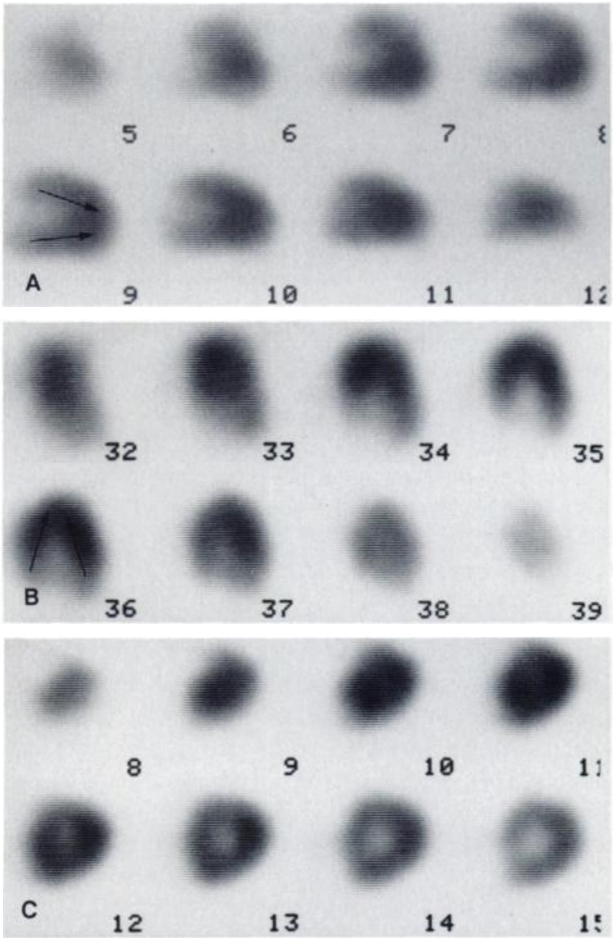

FIGURE 3
Normal SPECT thallium images. A: Vertical long axis images show convergence of anterior and inferior walls towards the apex (see slice 9). B: Horizontal long axis images show convergence of septal and lateral walls towards the apex (see slice 36). C: Short axis images show progressive enlargement of the circular myocardial wall outlines as the slices progress from apex (see slices 8, 9) towards the base (slices 13–15).

ischemic cardiac disease. Although the echocardiographic and contrast ventriculographic findings miss very few cases, these studies are not routine in immediate post-MI patients. Radionuclide ventriculography has been shown to be a highly reliable method for identifying aneurysms, with an overall accuracy of 96% in patients with coronary artery disease (*5*). This study shows that SPECT thallium scintigraphy is also a reliable diagnostic tool for the identification of ventricular aneurysm.

TABLE 2
Reliability of Detection of Left Ventricular Aneurysms by SPECT Thallium Scintigraphy

Patient population	Total	Sensitivity (%)	Specificity (%)	Accuracy (%)
All	74	94	97	96
Any abnormal thallium scan	63	94	96	95
Apical/anterior infarction by SPECT thallium	22	93	71	86

NOTE

* DuPont Company, No. Billerica, MA.

ACKNOWLEDGMENT

This research was supported by the Veterans Administration.

REFERENCES

1. Schlichter J, Hellerstein HK, Katz LM. Aneurysm of the heart: a correlated study of 102 proved cases. *Medicine* 1954; 33:43–86.
2. Dubnow MH, Burchell HB, Titus JL. Post-infarction ventricular aneurysm: clinicopathologic and electrocardiographic study of 80 cases. *Am Heart J* 1965; 70:753–760.
3. Abrams DL, Edlist A, Luria MH, et al. Ventricular aneurysm: a reapprisal based on a study of sixty-five consecutive autopsy cases. *Circulation* 1963; 27:164–169.
4. Hurst JW, Logue RB, Schlant RC, et al. The heart, arteries and veins. 4th ed. New York: McGraw Hill, 1978:1208.
5. Friedman MJ, Cantor RE. Reliability of gated scintigrams for detection of left-ventricular aneurysm: concise communication. *J Nucl Med* 1979; 20:720–723.
6. Hurst JW, Logue RB, Schlant RC, et al. The heart, arteries and veins. 4th ed. New York: McGraw Hill, 1978:1277.
7. Loop FD, Effler DB, Navia JA, et al. Aneurysm of the left ventricle: survival and results of a ten year surgical experience. *Ann Surg* 1973; 178:399–405.
8. Lillehei CW, Levy MJ, DeWall RA, et al. Resection of chronic post-infarction myocardial aneurysms. *Geriatrics* 1962; 17:786–801.
9. Lam CR, Gale H, Drake E. Surgical treatment of left ventricular aneurysms. *JAMA* 1964; 187:1–3.
10. Chapman DW, Amad K, Cooley DA. Ventricular aneurysms: fourteen cases subjected to cardiac bypass repair using the pump oxygenator. *Am J Cardiol* 1961; 633:633–648.
11. Effler DB, Wescott RN, Groves LK, et al. Surgical treatment of ventricular aneurysm. *Arch Surg* 1963; 87:249–257.
12. Meizlish JL, Berger J, Plankey M, et al. Functional left ventricular aneurysm formation after acute anterior transmural myocardial infarction. *N Eng J Med* 1984; 311:1001–1006.
13. Schimert G, Falsetti HL, Bunnell IL, et al. Excision of akinetic left ventricular wall for intractable heart failure. *Ann Intl Med* 1969; 70:437–445.