

PRELIMINARY NOTES

Quantitative Methods in the Evaluation of Thallium-201 Myocardial Perfusion Images

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Methods have been developed for on-line computer enhancement of a scintillation camera's myocardial images and for a graphical presentation showing relative thallium-201 activity in the myocardium. Enhancement uses fast Fourier transform techniques. The methods have been applied to multiple images obtained after stress and 4-5 hr rest. Patients with myocardial infarction and/or transient ischemia were evaluated and typical examples are presented.

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The purpose of this investigation is to develop quantitative methods to assist the observer in the evaluation of thallium-201 myocardial perfusion images. Two aspects are reported: a) on-line computer enhancement of the scintillation camera image using fast Fourier transform techniques; and b) a graphical presentation showing relative radionuclide activity as a function of location in the myocardium along a peripheral dimension. The enhancement technique provides the observer with an image that can be interpreted more easily. The graph permits him to make quantitative estimates, free from subjective bias, of the relative level and peripheral extent of a region exhibiting low activity. This is particularly important in attempts to distinguish transient ischemia from myocardial infarction by comparison of images obtained both after maximum exercise and at rest.

Myocardial imaging following administration of Tl-201 during stress has been shown to be useful in evaluation of the extent of both myocardial infarction and other kinds of ischemia. Pohost et al. (1) investigated the value of serial imaging after injection of Tl-201 in patients undergoing stress, and observed redistribution of the tracer into recently ischemic areas at rest, whereas there was no similar redistribution into old infarcts.

MATERIALS AND METHODS

In the present study, patients subjected to controlled myocardial stress by treadmill exercise or atrial pacing were injected with 1.5 mCi of carrier-

free Tl-201 at the time of maximum stress as determined by significant angina or an ST-segment depression greater than 2 mm (2). Stress was continued for 1 min after injection. Multiple views were recorded from 10 to 40 min after injection and repeated after 4-5 hr of rest.

Thirty-four patients, referred to the cardiac catheterization laboratory for evaluation of chest pain, were studied. Each was given a detailed clinical examination, chest x-ray, and standard 12-lead electrocardiogram. Left ventriculograms and selective coronary cineangiograms were obtained from all patients. Fifty percent or more narrowing of the coronary arterial lumen was considered significant. The diagnosis of previous myocardial infarction was based on history, standard electrocardiogram, and the presence of akinetic or dyskinetic segments as observed in the left ventriculogram.

The enhancement method is a modification of the technique previously developed for use on liver scintigrams (3). A PDP-12 digital computer is interfaced to the scintillation camera and programmed to perform on-line two-dimensional frequency-domain analysis and processing. In this method, a two-dimensional fast Fourier transform is generated, and a composite one-dimensional frequency spec-

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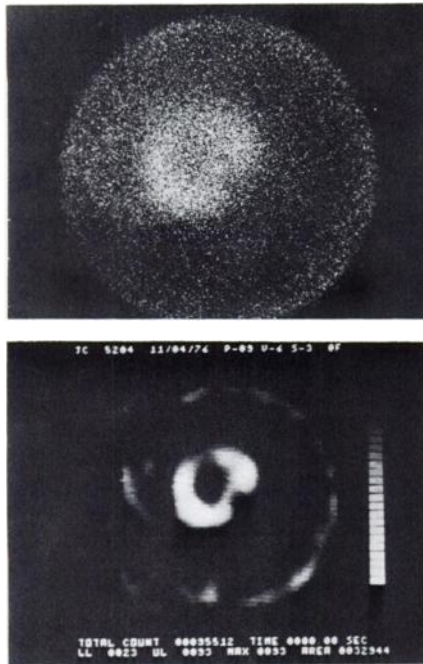


FIG. 1. (Top) Original Tl-201 myocardial scintiphoto. (Bottom) Computer-enhanced image.

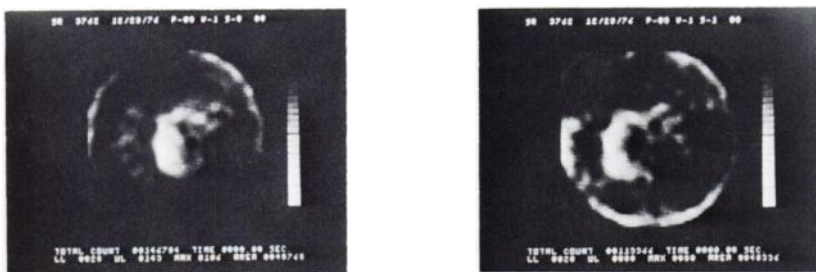
filter was optimized using the image of a known phantom. The band pass of this filter has been modified for use in the present studies.

RESULTS

Figure 1 shows a typical Tl-201 myocardial image as obtained directly from a scintillation camera, together with the corresponding computer-enhanced image. In the latter, a region of lowered activity in the inferior myocardium is clearly visible, but the defect is difficult to identify in the original image. Preliminary results indicate that the interpretation from the enhanced image is preferred by the diagnostician.

The graphical presentation showing relative radio-nuclide activity as a function of location in the myocardium uses data obtained from the enhanced image. To date, only the 45° left anterior oblique (LAO) view has been processed in this way. The interactive program permits the operator to select the "center" of the image. A computer algorithm then calculates the locus of points of maximum activity along the myocardium. This locus, superimposed on the image, is presented to the operator for verification of proper relationship to the myocardium. The computer then calculates the average activity along radial lines (spaced every 5°) emanating from the "center" of the image. The average is calculated over radial segments between points at which the activity is 50% of the maximum on that particular radial line.

trum is produced. An interactive program allows the operator to construct graphically a frequency-domain filter and apply it to the data matrix. An inverse Fourier transform produces an enhanced image in the spatial domain. In the liver-image study, the



STRESS

REST

COMPUTER GENERATED IMAGES - 45° LAO VIEW

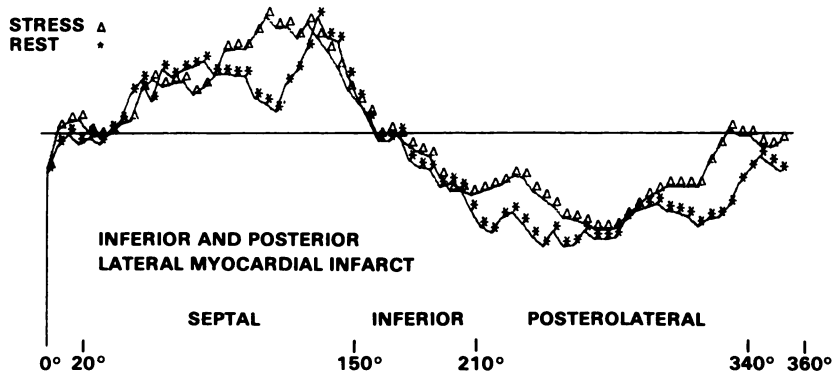


FIG. 2. Enhanced images and graphical presentation of myocardial infarction. Graphs present relative stress and rest values and mean stress value along radial axis from 0° to 360°, counterclockwise from 12 o'clock.

TABLE 1. COMPARISON OF ANGIOGRAPHIC FINDINGS AND COMPUTERIZED Tl-201 MYOCARDIAL IMAGES IN 34 PATIENTS

Angiographic findings	Computerized Tl-201 imaging		
	Infarction	Transient ischemia	Normal
Infarction (17)	13	2	2
Transient ischemia (10)	0	9	1
Normal (7)	0	1	6

the expected normal variation of $\pm 20\%$ suggested by Strauss (4). Ischemia is considered to exist if the stress curve falls below the rest curve, by at least 20% of the mean, over at least 2 cm of the myocardium. Of 17 patients demonstrating myocardial infarction by angiography, 13 showed infarction by computerized thallium imaging. Ten patients showed transient ischemia by angiography and nine by imaging. There were seven normal angiograms and six normal images. There was greater than 75% correspondence in all categories.

The ensemble of average count values is presented on a linear graph as a function of angle, the origin of which corresponds to the 12 o'clock position on the myocardial image (Figs. 2 and 3). The peak values of the curves thus derived from the stress and rest images are normalized to an arbitrary constant to facilitate comparison between the two curves. In order to facilitate comparisons between patients, the following regions of myocardium have been defined: a) septal, 30–150°; b) inferior, 150–210°; and c) posterolateral, 210–330°. In all cases, the angles are measured in a counterclockwise direction relative to an origin at 12 o'clock.

DISCUSSION

Preliminary work has been carried out with these quantitative methods in the evaluation of images from Tl-201 myocardial perfusion in order to improve the separation of temporary ischemia from infarction (5). Figure 2 shows the computer-enhanced images of a patient taken at 45° LAO immediately after maximum stress, and again after 4 hr rest. Also shown are the graphs of activity as a function of angle. Based on angiography, the clinical diagnosis was inferior and posterolateral myocardial infarction. There appears to be a significant decrease in activity in the inferior and posterior lateral areas both with stress and following rest. The lack of improvement is consistent with the diagnosis of myocardial infarction without coexistent transient ischemia. Figure 3 shows similar computer-enhanced images and a set of graphs for another patient diag-

In the graphical presentation of the rest image, a segment is taken to represent myocardial infarction if the activity is less than the peak, by at least 40% of the average activity around the periphery, over at least 2 cm of the myocardium. This corresponds to

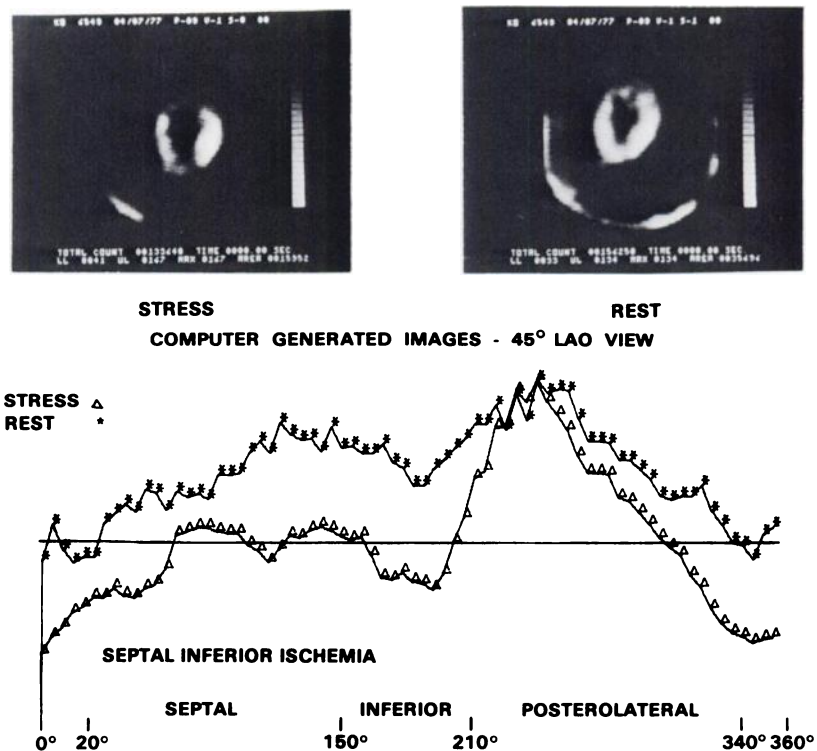


FIG. 3. Enhanced images and graphical presentation of transient myocardial ischemia. Procedure as in Fig. 2.

nosed clinically and angiographically as having transient ischemia in all three segments. The images and graphic presentation fit this diagnosis. In both the enhanced images and the graphic presentation there is decreased activity in the septal and inferior segments and in parts of the posterolateral segment.

In the preliminary study we have compared the results obtained from the graphical presentations, visual interpretations of the enhanced images, and clinical studies. With the clinical and angiographic results as a reference, the graphical presentation appears to be better, on the average, than the visual interpretations. There have been a number of instances in which the graphical presentation indicated ischemic or infarcted regions that were not recognized visually. In a group of eight patients who were studied under similar conditions on two different occasions, there was total agreement between the interpretations in five patients. In each of the remaining three there was agreement for two of the three myocardial segments examined.

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