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Technetium pyrophosphate myocardial scanning in acute myocardial infarction

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Technetium 99m pyrophosphate (99mTCPyP) accumulates in recently infarcted myocardium and can be detected by external imaging techniques. This study was performed to evaluate the ability of this isotope to identify the presence of acute myocardial infarction. In 82 patients admitted to a coronary care unit with chest pain of varying etiology, scan was positive in all 13 patients with acute transmural myocardial infarction and in 23 of 27 patients with nontransmural myocardial infarction. The scan was negative in 37 of 42 patients without evidence of recent infarction. Four of the remaining five patients in this group had unstable angina pectoris. The authors believe TCPyP myocardial scanning is an easy, noninvasive, and highly reliable test for detection of acute myocardial infarction when performed within seven days of the onset of chest pain. The method has particular significance when standard diagnostic aids are difficult to interpret. It was also extremely helpful in substantiating the diagnosis of nontransmural infarction.

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THE diagnosis of acute myocardial infarction by standard electrocardiographic and enzymatic criteria has proved difficult, if not impossible, in certain clinical situations such as in patients suspected of having a nontransmural infarction, in those with left bundle branch block, and in patients with previous myocardial infarction. With the exception of recently developed MB-CPK isoenzyme, cardiac enzyme elevation is not specific for myocardial damage and may occur secondary to congestive heart failure, hemolysis, liver, lung or brain damage, and following intramuscular injections or trauma of cardiac resuscitation. To improve diagnostic ability in these patients, a test which could reliably indentify the presence of infarction would be of help. In addition, more specific diagnostic parameters are required for evaluation of the significance of variable ST & T wave changes and transitory enzyme elevations in patients with chest pain with unstable angina or nontransmural infarction, since only a thin line exists between unstable angina pectoris and the diagnosis of subendocardial infarction.

A number of investigators[1-4] have recently shown that technetium 99^{m} stannous pyrophosphate (99^{m}TcPyP) accumulates in recently infarcted myocardium and can be detected by external imaging techniques in humans. Bonte et al[5] observed that calcium labeled with 99^{m} technetium stannous pyrophosphate became localized within the mitochondria of necrotic myocardial cells and can be imaged with scintillation cameras. The present study was performed 1) to evaluate the ability of this isotope to indentify the presence of acute myocardial infarction in patients admitted to a coronary care unit with chest pain of varying etiology, and 2) to further define the presence or absence of infarction in intermediate coronary syndrome.

Material and methods:

Myocardial scintigrams were obtained in 82 patients who were admitted to the coronary care unit as myocardial infarct suspects within 2-7 days of the onset of their symptoms. The patients represented a broad and heterogenous group admitted to the coronary care unit of this 1,000-bed hospital. The patients were collected serially over a five-month period between January 1 and June 1, 1974. We excluded from the study patients who did not wish to participate in the study and those whom it was deemed inadvisable to move from the coronary care unit to the Nuclear Medicine Department for imaging. Serial daily electrocardiograms and serum glutamic oxalacetic transaminase (SGOT), creatinine phosphokinase (CPK), and lactic dehydrogenase (LDH) levels were obtained. Upper limits of normal in our laboratory for SGOT are 35, for CPK 40 and for LDH 180 iu. All studies were performed using a scintillation gamma camera. Imaging was performed within 60-120 minutes after intravenous injection of 15 millicuries of 99^{m}Tc tagged to 5 mg of stannous pyrophosphate. Patients were then transferred by stretcher under medical supervision to the Nuclear Medicine Department and connected to a portable monitor defibrillator. Only stable patients were selected for imaging. Neither arrhythmia nor other obvious side effects were observed from either injection of the isotope or from imaging. The imaging time was approximately 15 minutes. Images of 300,000 counts were recorded on film in anterior, left anterior oblique and left lateral views over approximately 30 seconds. Anatomic landmarks were readily identifiable in most images because of the accumulation of the isotope in the bones of the chest wall. Standard computer processing and contrast enhancement was done in most cases.

The scintigrams were graded as negative, intermediate, and definite positive depending on the activity over the cardiac area without knowledge of the clinical diagnosis of the patient. The following grading was used: *Negative* scans represented either no activity (Figure 1) or faint activity in one view. *Intermediate positive* represented moderate activity in at least two views (Figure 2).

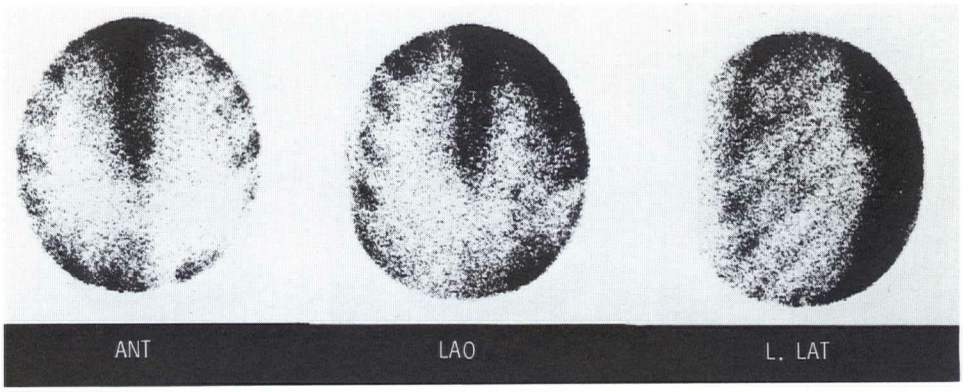

Figure 1

In this negative TcPyP scan in a 69-year-old patient with aortic stenosis, note the isotope uptake in the skeleton of the chest wall. There is no activity in the area of the heart.

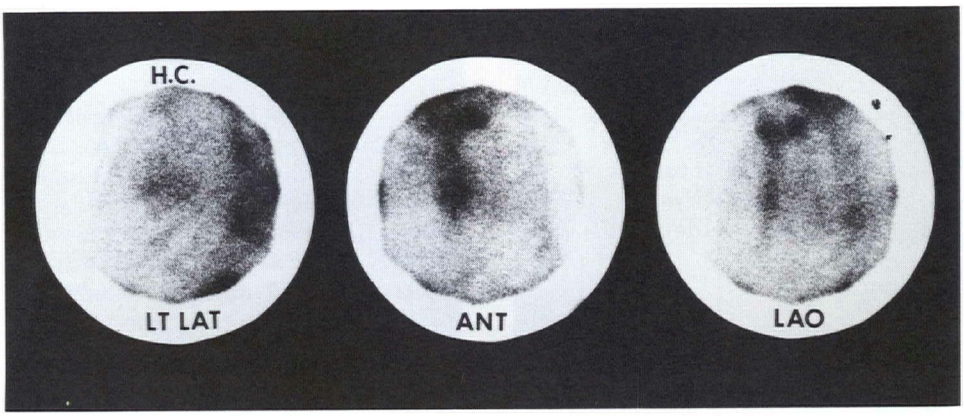

Figure 2

An intermediately positive TcPyP scan with moderate activity in a 44-year-old patient with nontransmural myocardial infarction.

Definite positive scan was represented by localized intense activity within the myocardial boundaries (Figure 3). Among the 82 patients who had Tc 99^{m} stannous pyrophosphate myocardial scintigrams, the average age was 58 years. There were 57 males and 25 females. The patients were divided into three groups (See Table 1).

Group I: consisting of patients with clinical evidence of acute transmural myocardial infarction as defined by the appearance of new Q waves, evolving ST&T wave changes associated with rises in CPK, LDH, and SGOT.

Group II: consisting of patients with clinical evidence of acute nontransmural myocardial (subendocardial) infarction as defined by the presence of prominent ST depression and T wave inversion without new Q waves and subsequent return of these abnormalities to base line associated with either typical elevation above normal limits

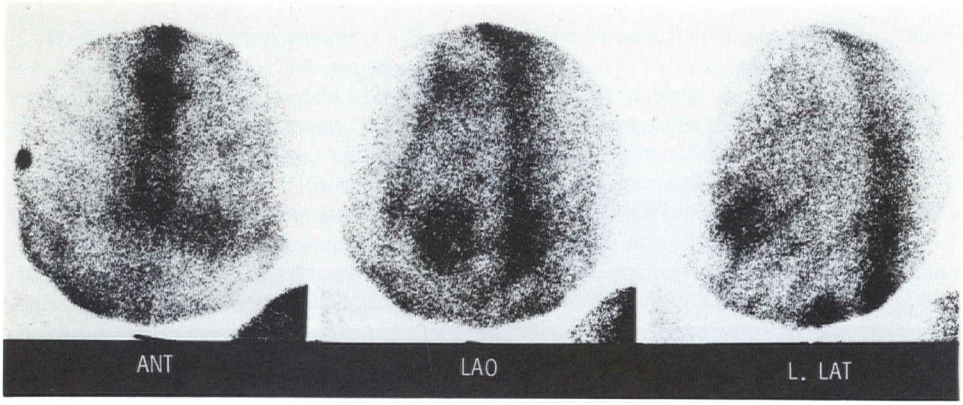

Figure 3

A definitely positive TcPyP scan with localized and intense activity projected anteriorly over the cardiac area in a patient with acute anterior myocardial infarction. Scan was obtained four days after the onset of symptoms.

of CPK, LDH, and SGOT or a fall in serum CPK from high normal to low values.

Group III: consisting of patients who did not develop clinical, enzymatic or electrocardiographic evidence of acute infarction.

Results

There were 13 patients in Group I with acute transmural myocardial infarction. Of these, seven had inferior, five anterior, and one true posterior infarction as localized by electrocardiograms. All 13 patients in these groups had a definitely positve scintigram. The area of infarction on the scans correlated well with the ECG localization of infarction (Figure 3).

There were 27 patients in Group II with clinical evidence of acute nontransmural myocardial infarction. Twenty-three had a positive scan. Eighteen of these 23 patients showed intermediate activity and the rest showed a definite activity. Four patients in this group had negative studies, obtained between 4 and 7 days after the onset of symptoms. This may have been too late to visualize the acute changes with TcPyP in the setting of small areas of infarction. Figures 4A and 4B represent one patient in Group II with nontransmural infarction characterized by deep T wave inversion and a positive scan (shown in Figure 2) with intermediate activity. Angiography demonstrated localized hypokinesis which became normal as did EKG and scan after successful bypass surgery.

TABLE I

Technetium 99 Pyrophosphate Scintigram Correlation In Clinical Subgroups With Acute Chest Pain

	Total patients	Definite positive	Intermediate positive	Negative
I Acute transmural infarction	13	13	0	0
II Acute non-transmural infarction	27	5	18	4
III No acute infarction	42	1	4	37
	82	19	22	41

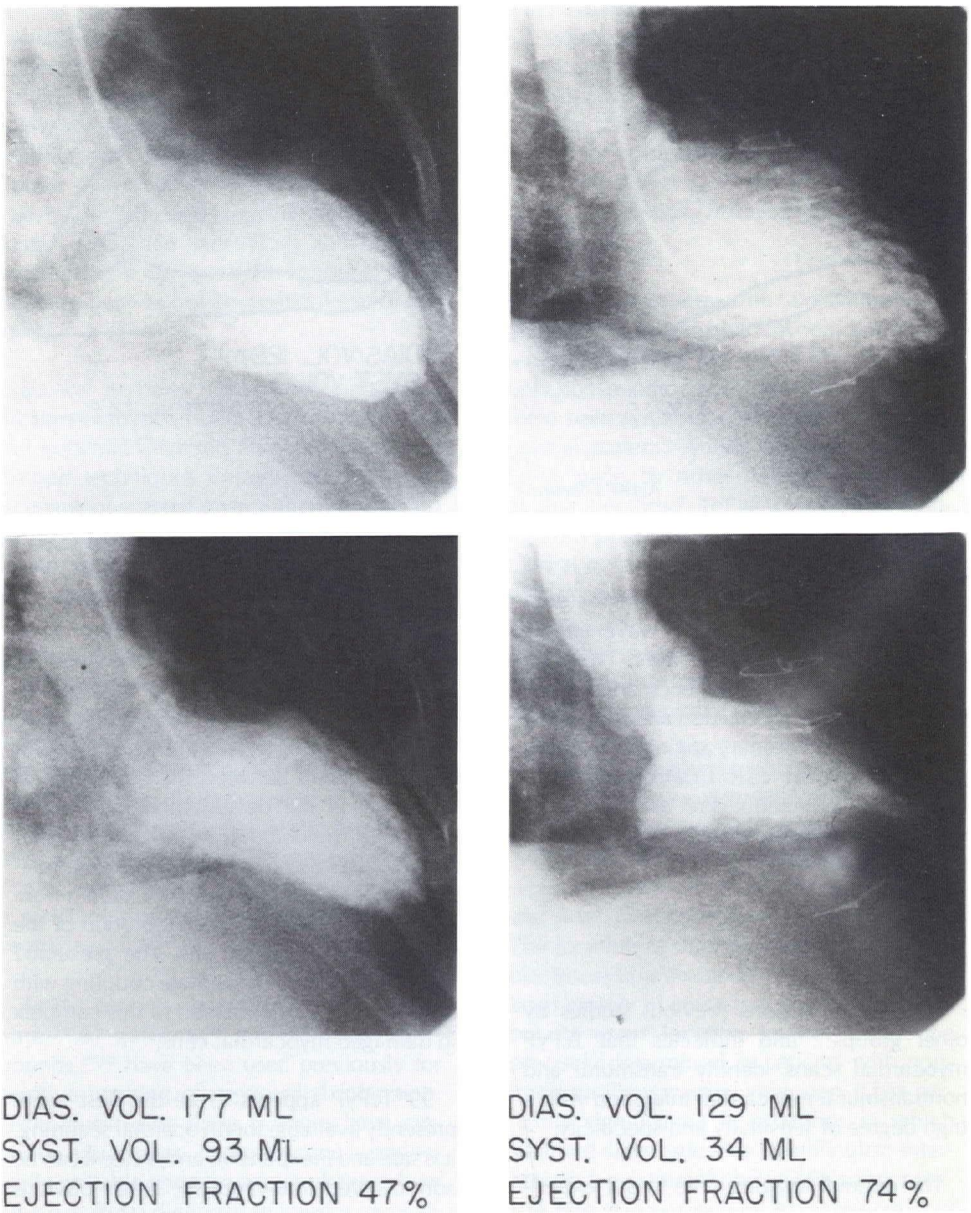

Figure 4A

Pre- and postoperative left ventricular angiograms of a patient with subendocardial infarction whose myocardial scan is shown in Figure 2. Note the localized antero-apical hypokinesis which became normal after bypass surgery, with marked improvement in the ejection fraction.

None of the 42 patients in Group III developed clinical, enzymatic, or electrocardiographic evidense of acute myocardial infarction. Thirty-seven of these patients had negative scans. Four of the remaining five patients with seemingly false positive

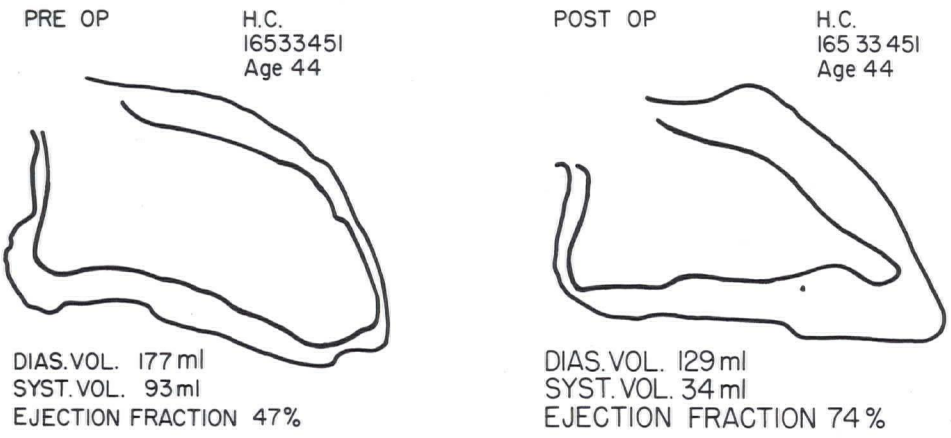

Figure 4B
Artist's drawing of views in Figure 4A

scans, clinically, had "unstable angina pectoris" with variable ST & T wave abnormalities and normal enzymes. The fifth patient had aortic insufficiency and underwent cardiac catheterization and was found to have normal coronary angiograms. There was no valvular calcification on fluoroscopic examination. We are unable to explain the positive scan in this particular patient.

Discussion

This study supports previous studies by other groups[1-4] and indicates that TcPyP myocardial scans identify transmural and nontransmural myocardial infarction with a high degree of sensitivity and specificity.

The optimal imaging time in our experience is between 60-120 minutes after injection of isotope. Although the images are positive as early as 12 hours after myocardial infarction, maximum localization seems to occur between 24-72 hours after infarction. Positive images can be obtained with decreasing sensitivity up to one week following infarction, although in some patients we were able to obtain positive images up to two weeks. Studies obtained between 12 hours and after seven days may be negative. Studies in dogs by Buja[6] and others have suggested a strong temporal and topographical relationship between the deposition of calcium and the development of positive ^{99m}TcPyP myocardial scintigrams. Their studies have also suggested a strong correlation between the resorption of calcium from the area of infarction and resolution of the positive TcPyP scintigrams. The presumed mechanism is pyrophosphate coupling with calcium and the deposition of this complex in damaged myocardial cells.[5]

^{99m}TcPyP appears to be the best agent presently available for myocardial scanning. It is safe and inexpensive and, since it can be administered intravenously, it has obvious advantages over other agents which require intracoronary injection. Because of its relatively short half life of approximately six hours, scans can be repeated at 24-48 hour intervals if deemed necessary and thus may be able to identify extension of a myocardial infarction, should it occur. The scan is posi-

tive as early as 12 hours after myocardial infarction, allowing an early and precise diagnosis in patients with chest pain of varying etiology. This isotope has been used safely for several years for bone scanning without any reported side effects.[7,8] The uptake of 99^{m}TcPyP in the skeleton of the chest wall provided good anatomic landmarks. Computer processing and contrast enhancement improved the images in some patients, but was not an essential part of this study.

Several isotopes have been used as indicators of myocardial perfusion and to detect ischemic infarcted myocardium. These isotope techniques depend on failure of ischemic or scarred myocardium to pick up the isotope, thereby producing a negative image. Isotopes producing negative perfusion images include 42K,[9] 43K,[10-12] 129 cesium,[13] 131 cesium,[14] 81 rubidium,[15] 13 nitrogen,[16] and most recently 201 thallium.[17] The disadvantage of these techniques includes failure to distinguish recent from older infarction, poor physical characteristics, and general unavailability of the radionuclides for clinical studies. The other major disadvantage of a negative image is loss of sensitivity from superimposition of "cold" over normal areas of myocardium as a result of the spherical geometry of left ventricle.

$Tc99^{m}$ tetracycline,[18] Tc glucoheptonate,[19] 67 gallium,[20] and mercury compounds,[21,22] have been used previously for positive imaging of myocardial infarction. Techniques using these isotopes have certain disadvantages. Tc tetracycline is biologically unstable and also accumulates in liver which makes a diagnosis of inferior myocardial infarction difficult. There is also need for a 24-hour delay between administration and optimal imaging. Tc glucoheptonate has been found to be less sensitive and also accumulates in the liver. Mercury compounds have a risk of renal complications and have not been used in humans. Gallium 67, which accumulates in tumors and abscesses, also labels recent infarction because of associated inflammation. It will also give a positive scan with acute pericarditis or inflammatory disease in liver or gall bladder. In animal experiments 99^{m}TcPyP has been shown to identify infarcts larger than 5 gms.[23]

Four of our patients with "unstable angina pectoris" had positive myocardial scans with intermediate activity. In these patients only nonspecific ST & T wave abnormalities were seen with serial enzymes showing a normal pattern. Similar observations have been made by other authors in unstable angina pectoris.[3] TcPyP myocardial scintigraphy possibly detects small areas of myocardial necrosis occurring in some patients with unstable angina pectoris. However, it is also possible that myocardial scintigraphy may label severely and chronically ischemic, but not necessarily irreversibly damaged, myocardial cells in such a setting.

These observations support previous studies[1-4] that indicate that 99 TcPyP scans are positive in patients with acute transmural and nontransmural myocardial infarction, when scans are obtained between 12 hours and seven days after myocardial infarction. The location of the myocardial damage on electrocardiogram and TcPyP scans correlated closely in acute transmural infarction, but its exact location cannot always be precisely determined in patients with nontransmural myocardial infarction. It has particular significance in situations in which standard diagnostic aids are difficult to interpret and is extremely helpful in substantiating the diagnosis of nontransmural infarction. Not only has this technique been an aid to diagnosis, but it has also added to our clinical understanding of the process of ischemia and infarction taking place in patients with nontransmural myocardial ischemic syndromes.

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