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Use of technetium^{99} myocardial scanning for identification of intraoperative myocardial infarctions

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Technetium 99m stannous pyrophosphate (TcPyP) myocardial scans were obtained in 42 selected nonconsecutive patients within 12 days following open heart operations for both valve replacement (19 patients) and coronary bypass (23 patients) procedures. The scans were correlated with elevation of serum lactic dehydrogenase, glutamic oxalocetic transaminase and the electrocardiograms obtained serially in the postoperative period. TcPyP scan was more specific than enzyme studies and it was more sensitive than the electrocardiogram. All new Q waves were associated with a positive scan but there were five positive scans which were not associated with new Q waves. Myotomy and direct surgical trauma to the left ventricle did not cause positive scanning. Evidence for infarction by myocardial scan was observed in both valvular and coronary bypass patients. The technique has improved understanding of the occurrence of intraoperative myocardial infarctions.

THE occurrence of myocardial infarction during open heart surgery of any type is a significant cause of postoperative mortality and morbidity and is an important variable in the consideration of medical or surgical therapy for coronary artery disease. The detection of infarction during surgical operation is difficult and has been based upon elevation of serum enzymes such as serum glutamic oxalacetic transaminase (SGOT), and lactic dehydrogenase (LDH) and appearance of new Q waves in the electrocardiogram.[1-14] The difficulty in evaluating serum enzyme elevation in the intra- and postoperative period is obvious.[7,8,15] Although the appearance of new Q waves is a strong indication of recent infarction,[14] the significance of their appearance has been questioned by some authors.[16] Although previously ascribed to pericarditis and electrolyte disturbance, it is most probable that some of the ST and T wave changes that occur in the postoperative period may, in fact, represent subendocardial myocardial infarction.

Parkey and others[17-21] have shown that technetium 99m stannous pyrophosphate (99m TcPyP) accumulates in recently infarcted myocardium and can be detected using external imaging technique. They showed this to be a simple and reliable indicator of both transmural and subendocardial infarction. In the present study we used this technique to measure the frequen-

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cy of occurrence of intraoperative infarction in patients undergoing open heart surgery for both valve replacement and coronary bypass procedures. We compared the sensitivity of this technique to the serum enzyme elevation and new Q wave occurrence in a nonconsecutive series of selected patients.

Materials and methods

A prospective study was carried out to detect the occurrence of intraoperative myocardial infarction using TcPyP myocardial scintigram in 42 selected adult patients undergoing open heart surgery at Henry Ford Hospital, Detroit, Michigan. Selection was based primarily upon the ability to transfer the patient to the Nuclear Radiology Department and the availability of the radioisotope within 2-12 days of operation. The technique had previously been shown to be diagnostic in this time period. The 42 patients represented approximately one-half of all the adult open heart surgical procedures performed in this period. All of the patients were judged to have stable angina pectoris. Patients with unstable angina pectoris were excluded from the study. There was no clinical evidence of acute myocardial infarction in the preoperative period.

The cardiopulmonary bypass technique employed at operation consisted of Ringer's lactate, mannitol, sodium bicarbonate prime using bubble oxygenator, moderate total body hypothermia of 28-30 degrees centigrade and local myocardial cooling using pericardial well of cold Ringer's lactate. No coronary artery perfusion or cannulation was performed and aortic cross clamp and anoxic time was kept to minimal interval.

The serum glutamic oxalacetic transaminase (SGOT) and lactic dehydrogenase (LDH) determinations were performed a day before surgery and daily thereafter for 3-5 days. The upper limits of normal values in our hospital were: SGOT 21 IU and LDH 290 IU. Creatine phospho kinase (CPK) determinations were much too variable to be considered in the comparison. The twelve lead electrocardiogram was recorded preoperatively and post-operatively for 3-5 days. The tracings were evaluated independently by three of the authors (S.G., D.M., and V.P.). The criteria for diagnosis of definite transmural infarction were based on the occurrence of a new Q wave in postoperative electrocardiogram or the development of left bundle branch block. One patient developed left bundle branch block after myotomy for hypertrophic subaortic stenosis. The Q wave criteria were based on Class I-1 and I-2 of Minnesota Code.[22] ST&T wave changes of themselves were not accepted as evidence of myocardial infarction.

Myocardial scintigrams were performed 60-120 minutes following IV injection of 15 mCi of 99m TcPyP. Each patient was imaged in the anterior, left lateral and left anterior oblique projection using a Nuclear Chicago Pho-Gamma HP scintillation camera with a high resolution collimator. Each scintigram was graded *negative, intermediate* and *definite* depending on the activity over the myocardium. We considered activity *intermediate* when there was definite but diffuse uptake in at least two of the three views (Figure 1). *Definite* activity was defined as localized uptake seen on the three views (Figure 2). The scintigrams were read "blind" by two observers separately (S.G. and D.M.). Where discrepancies occurred in the two readings, an independent arbiter was used.

Results

Forty-two patients were studied and were divided into two groups as shown in Table I. The miscellaneous group included one patient who had a repair of ventricular (traumatic) septal defect, one who had a removal of a left atrial myxoma, and one who had a left ventricular myotomy for hypertrophic subaortic stenosis. Analysis of the serum enzyme changes was performed by identifying the patients who exhibited a rise in serum

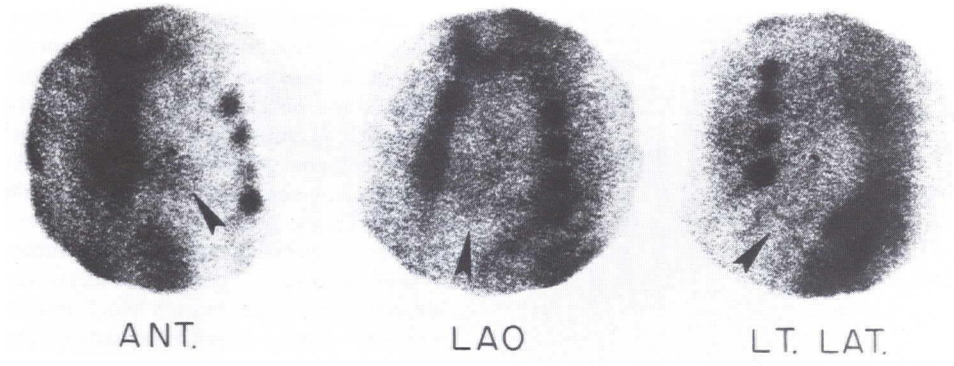

Figure 1
TcPyP image in the anterior (ant) left anterior oblique (LAO) and left lateral (Lt. Lat) projection showing an example of intermediate uptake in the apex of the left ventricle. There is no evidence of uptake in the Lt. Lat. projection but uptake can be seen in the other two projections (Patient 4 — Table III).

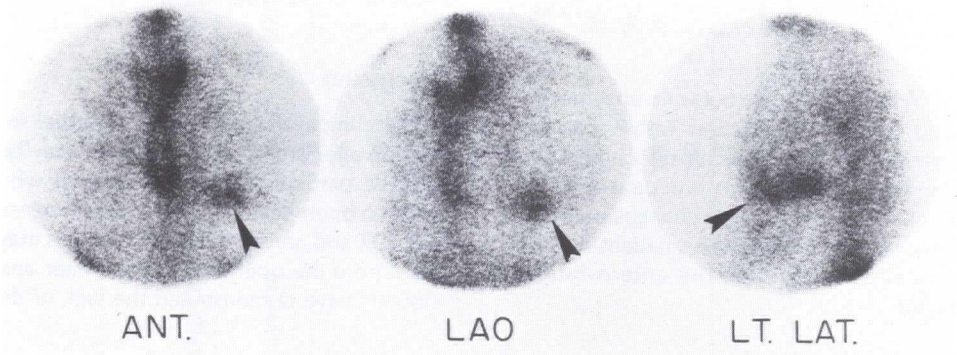

Figure 2
TcPyP image showing an example of definite uptake of isotope in the inferior apical region of the left ventricle (Patient 9 — Table III).

enzymes above a level that might be expected to occur as a normal response to cardiopulmonary bypass procedure in the absence of myocardial infarction. The levels selected were SGOT above 90 IU and LDH over 900 IU. Levels selected were based on previously published data, so that our observations could be compared to previous studies.[3] The correlation of the three diagnostic techniques is shown in Table II. Elevation of SGOT exceeding 90 units occurred in 13 of the 42 patients. The highest levels were present in the second postoperative day with subsequent gradual decline. LDH elevation exceeding 900 units was found in nine patients. New Q wave changes appeared in only six patients. Left bundle branch block occurred in one patient who had no direct trauma to the left bundle as did the patient with a ventricular myotomy. The TcPyP myocardial scan was positive in 11 of the 42 patients.

TABLE I

SURGICAL CHARACTERISTICS OF PATIENTS STUDIED

	Patients	
GROUP A		
Aorto-coronary bypass	21	
Aorto-coronary bypass and mitral valve replacement	2	
		23
GROUP B		
Mitral valve replacement	11	
Aortic valve replacement	4	
Mitral and tricuspid valve replacement	1	
Miscellaneous	3	
		19
TOTAL		42

The best correlation between enzyme elevation, new Q waves and TcPyP scan occurred in the definite localized scan groups. The only exception was one patient (Table III, patient 2) with ST&T changes and borderline rise in enzyme. This patient showed a localized uptake in the antero-lateral region.

In the intermediate scan group, no patients satisfied the enzyme elevation criteria, although two patients with new Q waves had intermediate positive TcPyP scans. In the negative scan groups there were 12 instances where enzyme criteria were satisfied. All new Q waves were associated with a definite or intermediate positive scan. One patient, in whom a septal myotomy was performed for hypertrophic subaortic stenosis, developed left bundle branch block but his scan was negative. In one other patient who had a negative scan, preoperative Q waves in II, III and AVF became noticeably deeper. The correlation of serum enzymes, ECG and myocardial scanning in the 11 patients who had positive myocardial scans is shown in Table III. In this group, six patients developed new Q waves. Left bundle branch block occurred in one other.

Discussion

The clinical diagnosis of myocardial infarction after any type of operation may be difficult, particularly in those patients who undergo open heart surgery. Minor increase in SGOT and nonspecific ECG changes may result from the operative trauma. Baer and Blount[15] have demonstrated the lack of di-

TABLE II

RELATIONSHIP OF POSITIVE $TcPyP^{99}$ SCAN TO ENZYME AND ECG ABNORMALITIES

Myocardial Scan Interpretation	No. of pts. in each group	SGOT > 90 IU	LDH > 900 IU	ECG Abnormal
Definite	6	5	5	5
Intermediate	5	0	0	2
Negative	31	8	4	0
Total	42	13	9	7
% of total group considered abnormal by each technique	26.2%	30.9%	21.4%	16.6%

TABLE III

POSITIVE SCAN AND ITS CORRELATION WITH ECG AND ENZYME ABNORMALITIES

	Age / Sex	No. of vessels bypassed	LDH	SGOT	ECG	Myocardial scintigram
Group A						
1.	51 / m	3	1475	191	ASMI	Definite-antero-lateral region
2.	52 / f	2	560	87	ST-T changes	Definite-antero-lateral region
3.	63 / m	2	435	65	ST-T changes	Intermediate-lateral wall
4.	57 / m	2	725	69	ST-T changes	Intermediate-apical region
5.	53 / f	2	1300	119	ILMI	Definite-inferior lateral
6.	49 / m	1	405	66	ST-T	Intermediate-diffuse
7.	61 / m	1+MVR	1120	139	LBBB	Definite-antero-lateral region
Group B						
8.	70 / m	MVR	655	53	IMI	Intermediate-inferior wall
9.	42 / f	MVR	1432	256	IMI	Definite-inferior apical region
10.	50 / m	AVR	625	60	IMI	Intermediate-diffuse
11.	57 / f	AVR	1048	113	ALMI	Definite-antero-lateral

MVR = mitral valve replacement; AVR = aortic valve replacement; ASMI—antero-septal myocardial inf. ILMI = inferior-lateral myocardial infarction; LBBB = left bundle branch block; IMI = Inferior myocardial infarction; ALMI = antero-lateral infarction. Normal value for LDH = 140-290 i.u.; SGOT = < 21 i.u.

rect correlation between the degree of mechanical trauma to the heart and the SGOT increases in the postoperative period. Neutze[10] studied 172 patients after open heart surgery and found SGOT and LDH elevation in all patients, with the highest values observed in patients with aortic and multiple valve replacements. They concluded that the postoperative elevation of serum enzymes is in part an inevitable consequence of cardiopulmonary bypass, but exceptionally high levels usually indicate myocardial infarction. Neutze[10] concluded that ST-T changes in the postoperative period should be used diagnostically with extreme caution.

In our experience, ST-T changes were very common in postoperative electrocardiograms and were related to pericarditis, electrolyte disturbances and the effects of digitalis. Therefore, we chose to use the occurrence of a new Q wave as indication of an intraoperative infarction. Even this criterion has been challenged by Bassan and associates,[16] who suggested that a new Q wave could be due to a rearrangement of the initial .04 seconds of the QRS complex due to improve contractility and electrical activity of previously ischemic and electrically inert tissue. More recently the diagnostic specificity of postoperative new Q waves has been confirmed.[14] This information presented here further confirms the pathologic significance of the new Q wave.

Previous studies have estimated the incidence of intraoperative myocardial infarction varying from 7% to 35%.[9,11,23-26] Brewer and associates[27] reported the incidence to be 17% in 220 patients surviving coronary bypass surgery. When autopsies were performed, the overall prevalence was 20%. Dixon and associates[28] noted infarction in 20% of 40 patients undergoing aorto-coronary saphenous vein bypass. Anderson and associates,[28] using ECG and VCG criteria, reported 17% of 46 patients undergoing AC bypass. Rossiter and associates[13] noted that myocardial infarction occurred relatively often in aortic and mitral valve replacement, although not as frequently as in coronary bypass surgery.

No doubt in most cases the demonstrated myocardial lesions played no discernible role in the postoperative process; indeed, most would escape detection because of varying criteria used for their diagnosis. Due to these difficulties, we suggest the usefulness of myocardial imaging techniques in detecting or determining the true incidence of myocardial infarction. The specificity and sensitivity of technetium pyrophosphate myocardial scintigram to detect infarcted myocardium in patients with acute myocardial infarction has been demonstrated by Parkey[17] and others.[18-21] They have shown that 99m TcPyP radionuclide is taken up by infarcted myocardium and can be detected by external imaging techniques between 2-10 days following infarction and in both transmural and nontransmural infarction. The definite localized scans are typical of those scans with transmural infarction whereas the intermediate scans are associated, both in our studies and those of Parkey, with subendocardial infarction. Buja and associates[30] have shown good morphological correlation of 99m TcPyP imaging to experimental myocardial infarction in dogs. Botvinick and associates[31] attempted to quantitate the size of the myocardium infarcted by using 99m TcPyP in mongrel dogs. They were able to identify all but two infarctions out of 12 produced. Both were the smallest sized infarcts, weighing 3.1 and 5.1 grams respectively. A number of reports show good correlation between the site of infarction and localization of radionuclide. It is clear from this study that surgical trauma to the left ventricle, including a myotomy, will not give a false positive scan.

Our study indicates that TcPyP scan is quite specific and appears to be slightly more sensitive than ECG and more specific than serum enzyme elevation. In all patients with new Q waves the scan was positive. The scan identified infarction that would have

been missed by electrocardiographic criteria alone in one patient. Platt and associates[32] studied 48 patients pre- and postoperatively by TcPyP myocardial imaging and similarly observed that this technique was more sensitive than ECG criteria. Most of these would probably be classified as subendocardial infarction and their clinical significance might be challenged. The importance of these abnormalitites over the long term will require further studies but they represent an important consideration when surgical and medical therapy are compared in coronary artery disease. Various studies[33-35] recently recognize this new tool in detection of perioperative myocardial infarction.

One major difficulty is the availability of pre- and post operative scans. The clinical material selected for this study was such that an abnormal preoperative scan was quite unlikely since all patients had stable angina pectoris. Unstable and pre-infarction angina patients in whom an abnormal scan would likely be found were excluded. This was also true in the patients with valvular heart disease. This was supported by four patients in whom we were able to obtain pre- and post operative studies. These observations also further indicate that enzymatic changes alone that occur in the post operative period have no importance if they are not associated with either ECG or scan abnormalities. These criteria had been used in the past as evidence of myocardial ischemia. We, therefore, believe that the scanning technique has added to our understanding of the importance and frequency of myocardial infarction occurring during cardiac surgery.

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