Diagnosis of Acute Myocardial Infarction in Patients Undergoing Open Heart Surgery: A Comparison of Serial Myocardial Imaging with Cardiac Enzymes, Electrocardiography, and Vectorcardiography

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In 44 consecutive patients undergoing elective open heart surgery (OHS), serial electrocardiograms (ECG), vectorcardiograms (VCG), serum CPK, cardiac isoenzymes (CPKMB), and myocardial images using Tc-99m pyrophosphate were obtained, before and after the operation, for the detection of acute myocardial infarction (AMI). Twenty-nine patients developed one or more positive tests postoperatively. Two patients had positive myocardial scintiscans; both had other evidence of infarction. Conversely, the appearance of CPKMB, or new ECG and VCG changes, occurred frequently without evidence of infarction, and were not associated with the development of a positive scintiscan. The results show that false-negative results are infrequent in patients imaged early after OHS, and that cardiac surgical procedures do not cause a high incidence of false-positive scintigrams. Consequently, radionuclide imaging for AMI offers an important adjunct for excluding acute infarction following open heart surgery.

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Although the diagnosis of acute myocardial infarction (AMI) is usually not difficult, reliable diagnosis may be problematical in the perioperative period of open heart surgery. The reported incidence of AMI in this setting varies from 6 to 35% (*1–9*) with no apparent difference in incidence whether patients underwent coronary artery bypass surgery or valve replacement (*8,10*).

This large variation in the incidence of AMI must in part be due to the selection of diagnostic criteria. Postoperatively, nonspecific electrocardiographic (ECG), vectorcardiographic (VCG), and serum-enzyme changes occur frequently. Acute ECG changes may be due to pericarditis and even noncardiac problems (*2–4,6–9*). Routine serum enzymes and isoenzyme patterns are altered by trauma and factors other than infarction (*11–15*). Since surgically related infarction can adversely affect the long-term results of patients surviving operation, and may occur because of technical factors at the time of surgery (*1*), it is important to find a more reliable means of confirming or excluding the diagnosis.

In nonsurgical patients, radionuclide imaging with technetium-99m pyrophosphate has been reported to be a reasonably specific and sensitive means of detecting transmural as well as subendocardial myocardial infarction (*16–20*). The infarcted area becomes visible scintigraphically within 12 hr after injury and fades away after 1–2 weeks. The role of imaging in the diagnosis of AMI in surgical patients

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during the perioperative period of open heart surgery is less well established. Tissue handling during surgery may lead to positive findings.

The present study was designed to evaluate the sensitivity and specificity of myocardial imaging in detecting AMI during the perioperative period in patients undergoing open heart surgery.

METHODS AND MATERIALS

Patients. Forty-four consecutive patients (43 male, 1 female) undergoing elective open heart surgery between January and June of 1975, were included in the study. The types of surgical procedure performed are listed in Table 1. All patients were on total hemodilution during bypass, with bubble oxygenator and roller pumps, and had moderate hypothermia (29–30°C) during bypass. Informed consent was obtained from all patients. All survived surgery.

Procedures. *Electrocardiograms.* Twelve-lead scalar electrocardiograms were obtained for the 2 days preceding surgery, and daily following surgery for 3–7 days. They were interpreted independently by two observers and classified as: (A) diagnostic of acute transmural infarction, i.e., new pathologic Q waves of 0.04 sec in two or more corresponding leads; (B) acute change compatible with ischemia or injury but not specific for infarction, i.e., flat ST-segment depression of greater than 2 mm in the left-ventricular leads lasting more than 48 hr, and deep T-wave inversions persisting for more than 48 hr; or (C) no abnormality suggesting acute infarction or ischemia.

Vectorcardiograms. Using the Frank lead system, vectorcardiograms were recorded within 72 hr before surgery and were repeated postoperatively 2–5 days following surgery. Using the criteria of Eddleman and Pipberger (*2*), pre- and postoperative vectorcardiograms were analyzed and compared for the development of: (A) a Q:R ratio, and (B) a Q duration indicative of acute infarction. The specific criteria were an abnormally low QR_z ratio (less than 0.10) for anterior MI; and a Q/R_x ratio greater than 0.17 for lateral MI. For inferior MI, the Q/R_y ratio must exceed 0.22 and Q_y duration be greater than 30 msec.

Enzymes. LDH and CPK isoenzyme determinations were performed 48 and 24 hr before surgery. Postoperatively, samples for determination of LDH and CPK isoenzymes were obtained 24 and 48 hr following surgery, and at the time of imaging if this was later. LDH and CPK isoenzymes were separated electrophoretically. LDH isoenzymes were determined by the method of Nerenberg (*22*). The detection method for CPK isoenzymes was based on that

TABLE 1. OPEN HEART SURGICAL PROCEDURES

Procedure	No.
Coronary artery bypass	18
Replacement of aortic valve	14
Replacement of mitral valve	8
Replacement of aortic and mitral valves	2
Mitral valvuloplasty	1
Repair of dissecting aortic aneurysm	1
Total	44

of Roe (*13*). The cardiac-specific MB band was determined qualitatively to be present or absent.

Myocardial imaging. All patients were imaged within 72 hr before surgery and within 5 days following surgery. Imaging was performed immediately, and again 3 hr after, injection of 5 mg of stannous pyrophosphate labeled with 15 mCi of Tc-99m. Distribution studies of the labeled pyrophosphate indicated that less than 10% of the injected dose remained in the circulation after 3 hr. Patients were imaged in the anterior and LAO positions and 750,000 counts were collected in each position. In addition, radionuclide tomograms were made in the anterior position with 1-in. depth separation, using a point between the anterior and midaxillary line as the focal point. The tomograms were obtained from a scintillation camera with rotating, slanted-hole collimator and circulating patient support* (*23*). They were read independently by two observers. The postoperative scintiscan was compared with the preoperative study and called positive if radioactivity unrelated to skeletal uptake or cardiac blood-pool developed on both anterior and LAO views. The tomographic views helped to identify masking skeletal and/or blood-pool radioactivity.

RESULTS

Preoperative studies indicative of acute myocardial infarction were not present in any patient. Following surgery, 21 of 44 patients developed altered LDH isoenzyme patterns indicative of infarction. Because of the difficulty in distinguishing the LDH isoenzyme pattern of infarction from that due to hemolysis occurring during extracorporeal circulation, the LDH findings are disregarded.

Twenty-nine patients developed acute changes postoperatively in at least one of the other tests, namely, ECG, VCG, the appearance of CPK-MB isoenzyme, or myocardial imaging. Fifteen patients had no acute postoperative changes by any test. The results are shown in Table 2 and Fig. 1.

Electrocardiogram. Postoperatively, 24 patients developed changes in the ECG patterns. One pa-

TABLE 2. RESULTS OF TESTS IN 44 PATIENTS

No. of Positive Tests	No. of Patients
0	15
1	19
2	8
3	1
4	1

tient after a coronary artery bypass, developed new Q waves indicating anterior myocardial infarction, and had a positive scintiscan, corroborative VCG changes, and the appearance of CPK-MB isoenzyme. Two other patients undergoing coronary artery bypass developed Q waves, suggesting inferior myocardial infarction following surgery. Both had confirmatory VCG changes, but only one produced the CPK-MB isoenzyme; both had normal scintiscans.

Twenty-one patients had only ST and T-wave changes on their postoperative ECGs. Fifteen of these had no other positive test (Fig. 1). Of the six patients with other positive tests, two had changes of infarction by VCG, and the other four showed the appearance of CPK-MB isoenzyme. None had scintiscans suggestive of acute myocardial infarction.

Vectorcardiogram. Six patients had postoperative VCGs indicating acute MI, three of whom had associated ECG evidence of infarction, as mentioned above. One had a positive scintiscan. Two of the others developed nonspecific electrocardiographic ST and T-wave abnormalities with no other evidence of infarction. The remaining patient with VCG evidence of infarction had no other positive test.

CPK-MB isoenzyme. Postoperatively, ten patients showed the appearance of CPK-MB isoenzyme. Four had associated nonspecific ST and T-wave changes on ECG. None of these had VCG changes or positive scintiscans. Two other patients had diagnostic ECG and VCG changes—one with the ECG and VCG indicating anterior infarction had a positive scintiscan; the other, with ECG and VCG evidence of inferior infarction, had no change on the postoperative scintigram. One other patient, with the appearance of CPK-MB isoenzyme following aortic-valve replacement, also had a positive scintiscan but no postoperative ECG or VCG changes. In the remaining three patients, the appearance of CPK-MB isoenzyme was the only positive postoperative finding.

Myocardial scintiscans. Preoperatively, scintiscans were normal in all of the patients. Postoperatively, two patients developed positive scintiscans. One of these had ECG and VCG evidence of anterior infarction, as well as the appearance of CPK-MB isoenzyme (Fig. 2). The other developed CPK-MB isoenzyme but did not have postoperative ECG or VCG changes (Fig. 3).

Thirty-six scintiscans (twenty-three preoperative and thirteen postoperative) suggested localized radioactivity in the region of the heart on one or both views, but by tomography it was shown to be in the blood pool or the ribs.

DISCUSSION

An important basis for assessment of a new method of detecting myocardial infarction is agreement of its results with those of other standards of diagnosis. In this way, the results of Tc-99m pyrophosphate scintigrams have been shown to correlate well with electrocardiographic findings and serum enzyme changes in nonsurgical patients felt to have acute myocardial infarction. Recent reports suggest that Tc-99m pyrophosphate imaging may also help in diagnosing acute myocardial infarction during the perioperative period of open heart surgery (*24–30*). In this situation the diagnosis becomes considerably more difficult because the usefulness of electrocardiographic and serum enzyme changes is diminished (*1–5,8,9*).

In the present study, if the appearance of a new Q wave on the electrocardiogram is chosen as the *sole* criterion for the diagnosis of acute transmural myocardial infarction, three patients in our series of 44 had acute infarction postoperatively. Scinti-

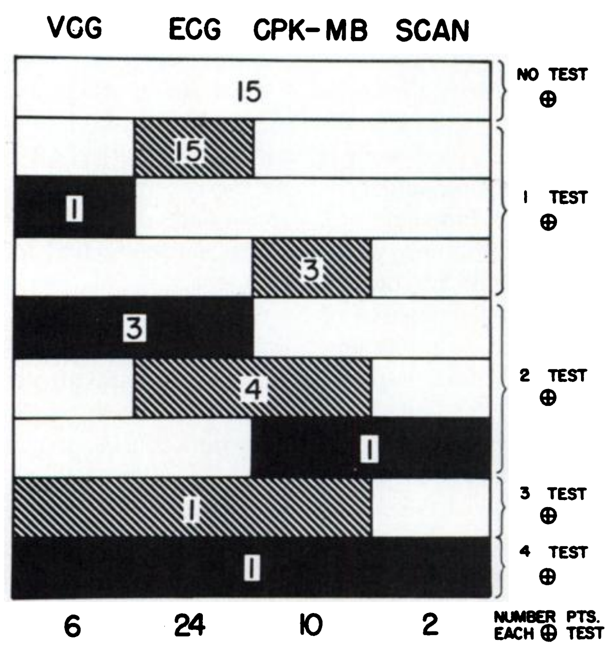

FIG. 1. Results of VCG, ECG, CPK isoenzyme, and myocardial imaging, and their correlations in 44 patients. Shaded area corresponds to positive test. Numbers are patients in each category. Alternate hatched and dark shades are used for easy recognition.

graphically, there was one true-positive and one false-positive result. Two scintiscans would be considered falsely negative, resulting in a sensitivity of 33% (1/3), a specificity of 98% (40/41), and an overall accuracy of 93% (41/44).

While the criterion of a new Q wave is reasonably specific, it is clearly an insensitive index of infarction, since a diagnosis of nontransmural infarction is often made in its absence. In patients undergoing open heart surgery, the diagnosis of nontransmural infarction may not be possible because nonspecific ST and T-wave changes often arise due to surgical trauma and/or pericarditis. In the absence of new Q waves on the electrocardiogram, positive scintigrams have been demonstrated to accompany new ventriculographic wall motion abnormalities, presumably secondary to infarction, in patients after open heart surgery (*25*). Furthermore, even the specificity of a new Q wave for the diagnosis of acute myocardial infarction is diminished somewhat in patients undergoing open heart surgery, since abnormal Q waves may appear due to factors other than infarction (*2,8,31–36*).

This study shows that tissue handling during open heart surgery does not lead to nonspecific cardiac localization of the administered radiopharmaceuticals. Of the two patients with positive scintiscan, one had a relatively large area of anterior infarction scintigraphically and had all the other corroborative clinical data. The other patient, who had the appearance of CPK-MB isoenzyme but no ECG or VCG changes, had a smaller scintigraphic area of infarction. In a series of autopsy proven cases, most electrocardiographically occult infarction has been related to small nontransmural infarcts (*37*). Positive myocardial images occurring in conditions other than AMI have, until now, been reported to occur only in patients with unstable angina (*20*), ventricular aneurysms (*38*), heavy valvular calcification (*29*), and following cardioversion (*39*), cardiac contusion (*40*), and—late—at the site of the ventriculotomy scar after cardiac surgery (*41*). Such occurrences were likely to be recognized in the present study because of the availability of the preoperative baseline scintigram for comparison. In addition, overlying skeletal or cardiac blood-pool activity could be differentiated from myocardial uptake by the use of radionuclide tomograms. Postoperatively, the patient with scintigraphic as well as ECG evidence of AMI required intra-aortic balloon pump support. This patient, and the other with a positive scintiscan but negative ECG, had to be treated for congestive heart failure.

Myocardial imaging was normal after surgery in all but the two patients discussed. Two patients had

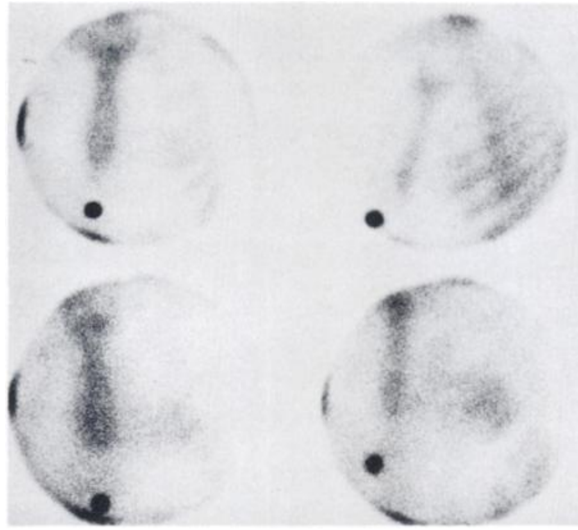

FIG. 2. Top row (left to right): Normal anterior and LAO presurgical myocardial images. Bottom row: Same views after surgery. Note relative lack of skeletal uptake in presence of large infarct.

ECG and VCG evidence of inferior myocardial infarction after coronary artery bypass, but uninformative scintiscans. Klausner et al. have questioned the diagnosis, after coronary artery bypass, of acute inferior myocardial infarction by ECG changes without other evidence of infarction; they feel that such changes are falsely suggestive of myocardial infarction (*27*). Our two patients with electrical evidence of inferior infarction, but normal scintigrams, are consistent with these observations. False-negative scintigrams are infrequent even in nontransmural

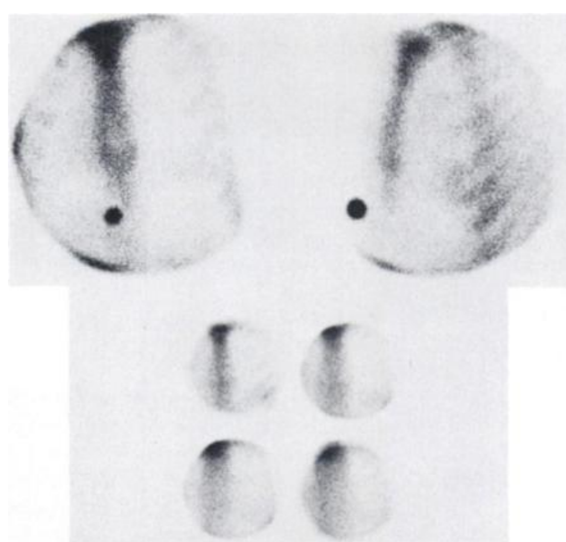

FIG. 3. Top row (left to right): Postsurgical anterior and LAO myocardial images indicate a small infarct. Bottom two rows: Anterior tomography, with 1-in. separations. Infarct is best seen on second plane (right-hand figure of middle row).

infarction when imaging is performed within 5 to 6 days (*16,17,19,20,30*). In the present study, all patients with normal scintiscans had an uncomplicated postoperative course.

Overall, the results are consistent with the sensitivity and specificity of myocardial imaging reported by others in nonsurgical patients (*16–20*). The present study suggests that myocardial imaging with Tc-99m pyrophosphate is a useful adjunct in the diagnosis of acute myocardial infarction following open-heart surgery. False-positive scintiscans are clearly infrequent and do not appear to be caused by the handling of the heart at surgery. While false-negative tests may be slightly more frequent, they do not appear to be associated with a difficult early postoperative course.

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FOOTNOTE

* Searle Pho Gamma HP.

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