Myocardial Perfusion Scintigraphy as an Adjunct to Selective Coronary Arteriography: A Preliminary Report

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A study is presented of 50 patients who underwent both selective coronary arteriography and myocardial perfusion scintigraphy following intracoronary injection of ^{99m}Tc-labeled human albumin microspheres (HAM). Myocardial perfusion scintigraphy was used as an adjunct to coronary arteriography in order to provide a more comprehensive assessment of the degree of ischemia present in the myocardium. Technetium-99m-labeled HAM was injected directly into the coronary circulation of these patients at the completion of coronary arteriography. From the scintigraphic images subsequently obtained, conclusions were drawn as to the relative blood flow to the myocardium. The patients were monitored throughout the procedure and no significant changes in heart rate, electrocardiogram, or blood pressure could be attributed to the intracoronary injection of HAM.

Despite the millions of dollars spent annually on research, coronary artery disease remains the number-one cause of death in the United States. Numerous attempts to determine the etiology and hence the treatment of coronary artery disease have been made. Although significant advances have been achieved, the mortality rate still remains disproportionately high at the present time.

Coronary bypass surgery is being used more and more frequently to restore the blood flow to the myocardium when the coronary vessels have been stenosed or occluded. Cardiac catheterization and coronary arteriography have long been used to determine the functional state of the myocardium and the degree of occlusion in the coronary vessels. A method for evaluating whether or not the myocardium has been severely scarred is needed since it is useless to perform bypass surgery on an area of the myocardium that has been irreversibly damaged.

Myocardial perfusion scintigraphy is based on the fact that viable myocardium must have circulation at the capillary and precapillary levels. An absence of this circulation implies a heavily scarred myocardium.

Quinn and coworkers *(1)* were among the first to directly inject radioactive ^{131}I-labeled macroaggregated albumin (MAA) particles into the coronary vessels of dogs.

Quinn's original research prepared the way for numerous other investigators. Endo *(2)*, Ashburn *(3)*, and Jansen *(4)* joined in the search for safe radioactive particles that could be injected into the coronary arteries after the completion of cardiac catheterization.

In animal studies, Ashburn found that there was a large margin of safety when the number and size of the particles injected were carefully controlled.

Jansen and associates reported only one case in their first 400 patients that exhibited electrocardiographic changes differing from the electrocardiographic changes seen after injection of the radiographic contrast media.

We decided to use a single isotope technique since we were interested in myocardial perfusion or the lack of it, and we felt able to distinguish anatomically which of the arteries supplied a particular area of the myocardium.

We elected to use ^{99m}Tc-labeled human albumin microspheres (HAM) over ^{99m}Tc-labeled MAA since we felt that the size of the particles could be controlled more easily, which we agreed was of prime importance.

Materials and Methods

The percutaneous Seldinger technique was used to perform both the left ventriculogram and the

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selective coronary arteriograms using Ducor® (Cordis Corp., Miami, Fla.) catheters of the Judkins (Melvin P. Judkins, Loma Linda, Calif.) type.

The patient was continously monitored by means of electrocardiographic equipment and pressure transducers. The femoroventricular catheter was positioned in the midchamber of the left ventricle using fluoroscopic control and pressure monitoring. A ventricular cineangiogram was taken in the right anterior oblique position and in the left anterior oblique position if clinically indicated. Post-angiographic pressures were taken as the catheter was pulled out of the left ventricular cavity to the ascending aorta. The femoroventricular catheter was replaced with the selective left coronary catheter. The catheter tip was positioned in the orifice of the left coronary artery and serial cine-arteriograms were taken in varying degrees of obliquity. Prior to the removal of the catheter, ^{99m}Tc-labeled HAM was injected. The catheter was removed and replaced with a selective right coronary catheter and the procedure repeated.

Microspheres were labeled with ^{99m}Tc-pertechnetate according to 3M Corp. (St. Paul, Minn.) standard procedural instructions. The size of the particles was strictly controlled by measurement in a hemocytometer chamber using a microscope. If the diameter of the microspheres exceeded 50 microns, the preparation was discarded. The particle size in our experience has not exceeded this diameter.

We limited each patient to less than 50,000 particles per study and normally injected a maximum of 0.5 mg of albumin. The injections were made selectively into the coronary arteries following the contrast studies. A suspension of 0.6 ml of microspheres was injected into the left coronary artery and two-thirds of that amount (0.4 ml) was injected into the right coronary artery. The individual doses were diluted with heparinized saline to equal the volume of the contrast injections. The radioactivity injected was not constant but varied according to the time that elapsed after labeling the microspheres. A patient on whom a perfusion study was performed immediately after labeling might have been injected with a total of 6 mCi of ^{99m}Tc-labeled HAM whereas a patient whose study was performed 8 hr after labeling would have received only approximately 2 mCi. Each isotope study was individualized according to whether one or two coronary arteries were injected by information gained from the preceeding contrast study.

After all catheters had been withdrawn and arterial bleeding controlled, the patient was sent to the nuclear medicine department and scintiphotos of the heart were obtained. The time that elapsed varied between 1/4 and 3/4 hr. We normally take at least six views of varying obliquity to correspond with the radiographic contrast studies. Images are obtained with a scintillation camera with a low energy high resolution collimator.

TABLE 1. Case 1 Laboratory Findings

Study	Results
Electrocardiogram	Nonspecific ST–T-wave changes
Vectorcardiogram	Borderline abnormal T-wave changes
Chest and cardiac series	Normal
Angiography	
Left ventriculogram	Normal
Selective coronary cinearteriograms	Left: Revealed 75–80% lesion of the midportion of the left anterior descending artery and 80% stenotic lesion at the origin of the first diagonal artery; the circumflex artery revealed a 20% stenotic lesion in its midportion Right: There are two areas of stenosis, both 75% in size: the first is located in the proximal portion and the second in the distal posterior descending branch
^{99m}Tc-labeled HAM perfusion scan	Normal

Case Histories

Case 1. I R, a 50-year-old male, weighing 160 lb and 5 ft, 8 in. tall, had a long history of heart murmur without definite diagnosis. He had noted anterior chest pain of 30 years' duration and tightness of the anterior chest for 1 year, which was precipitated by emotional crises and not related to physical activities. This patient was admitted to the hospital for elective cardiac catheterization and coronary angiography for evaluation of the chest pain. A summary of his laboratory findings is included in Table 1.

Case 2. E S, a 58-year-old female, weighing 98 lb and 5 ft, 2 in. tall, had noted moderate-to-severe difficulty in breathing on exertion and shortness of breath in emotional crises. The patient was admitted to the hospital for elective cardiac catheterization and coronary angiography. The laboratory findings are summarized in Table 2.

Case 3. F P was a 49-year-old male, weighing 149 lb and 5 ft, 9 in. tall, with a past history of arteriosclerotic heart disease resulting in an aorto-coronary saphenous vein bypass graft in 1970. The

TABLE 2. Case 2 Laboratory Findings

Study	Results
Electrocardiogram	Revealed advanced left bundle branch block
Vectorcardiogram	Confirmed left bundle branch block
Echocardiogram	Showed decreased generalized myocardial contractions with marked chamber enlargement; a markedly thickened septum and posterior ventricular wall was also noted
Chest and cardiac series	Moderate-to-severe cardiomegaly involving the left ventricle
Angiography	
Left ventriculogram	Revealed marked left ventricular dilatation with generalized hypokinesis
Selective coronary cinearteriograms	Left: Normal Right: Normal
^{99m}Tc-labeled HAM perfusion scan	Large perfusion defect occupying the apical portion of the left ventricle coinciding with the aneurysmal dilatation depicted angiographically

patient was admitted to the hospital due to increasing moderate-to-severe chest pain unrelieved by nitroglycerine. The laboratory findings are summarized in Table 3.

TABLE 3. Case 3 Laboratory Findings

Study	Results
Electrocardiogram	Consistent with anterior wall myocardial infarct
Vectorcardiogram	Confirms the EKG with probable inferior wall infarct
Chest and cardiac series	Consistent with left ventricular aneurysm
Angiography	
Left ventriculogram	Akinesis and hypokinesis involving anterolateral and inferoapical portions of the left ventricle
Selective coronary cinearteriograms	Left: Revealed total occlusive disease of the left anterior descending artery and a 20% stenotic area of the circumflex artery; the obtuse marginal branch of the diagonal artery was totally occluded Right: A 75% stenotic lesion was noted in the proximal segment
Graft injection	Demonstrates a patent right coronary artery
^{99m}Tc-labeled HAM perfusion study	A large perfusion defect was noted in the left anterolateral myocardium consistent with the area of the left anterior descending artery

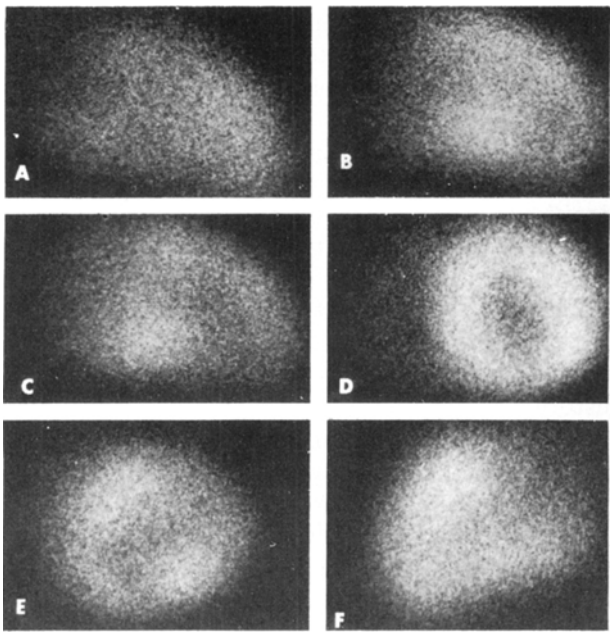

FIG. 1. Normal myocardial perfusion scan in varying degrees of obliquity. (A) RAO, 60°; (B) RAO, 40°; (C) RAO, 20°; (D) LAO, 40°; (E) LAO, 60°; and (F) left lateral. Note homogenous filling of entire myocardium.

Results and Discussion

An example of a normal myocardial perfusion scintigram is shown in Fig. 1 and an abnormal

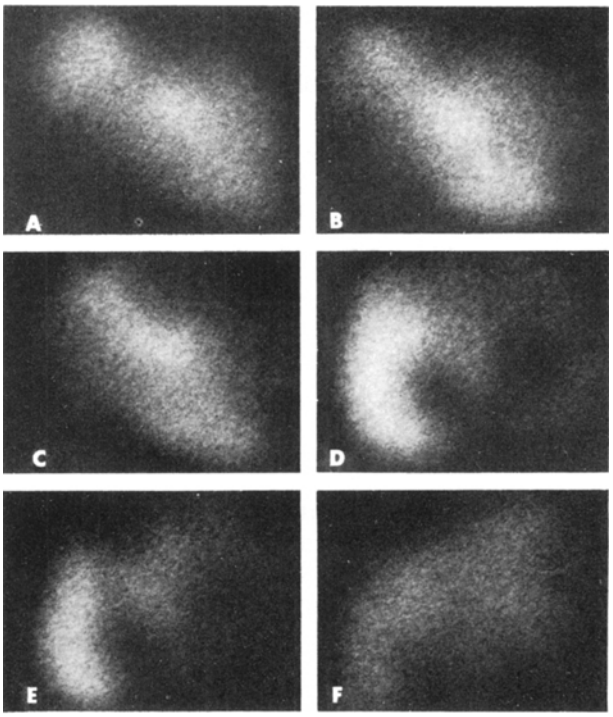

FIG. 2. Abnormal myocardial perfusion scan in varying degrees of obliquity. (A) RAO, 60°; (B) RAO, 40°; (C) RAO 20°; (D) LAO, 40°; (E) LAO, 60°; and (F) left lateral. Note filling defects in superior and inferior apical regions. Trapping of HAM in right system indicates total occlusion.

myocardial perfusion scintigram is shown in Fig. 2. None of the 50 patients undergoing these studies exhibited any unfavorable reactions.

Electrocardiographic changes were observed following the introduction of ^{99m}Tc-labeled HAM into the coronary arteries but they were of less significance than the electrocardiographic changes observed during the introduction of radiographic contrast media.

Eighteen of the 50 patients had normal perfusion scans. Thirteen of these patients had no history of myocardial infarction; however, 5 patients with a history of myocardial infarction had normal scans. This suggests revascularization or collateralization of the area that had previously been infarcted. Fifteen of these 18 normal perfusion studies had significant stenosis or complete occlusion to one or more arteries. All except 3 of the remaining 32 patients with abnormal perfusion scans had severe arterial stenosis or occlusion.

Conclusions

A study complementary to selective coronary angiography and ventriculography is needed to provide evaluation of the vascularity of the capillary bed at the site of injury. Myocardial perfusion scintigraphy seems to be a promising technique in visualizing the regional distribution of blood flow at the capillary and precapillary levels. We use ^{99m}Tc-labeled HAM because it is completely biodegradable, has a biologic half-life of 4–8 hr, and has an ideal gamma energy level for imaging on a scintillation camera.

We have shown from the studies undertaken to date that myocardial perfusion scintigraphy could become a valuable aid in determining the selection of candidates for bypass surgery and assessing the degree of myocardial damage following coronary occlusion.

Re-examination of postoperative patients to detect alteration in the degree of myocardial perfusion will be of value in assessing the usefulness of bypass surgery.

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