A PHANTOM STUDY OF THE VARIABLES IN MYOCARDIAL SCANNING WITH ^{131}Cs

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Cesium-131 has been suggested as a promising radiopharmaceutical for detecting myocardial infarcts because of the selective concentration of cesium by the myocardium (*1*). Several investigators have reported varying degrees of success with this radionuclide in scanning both dog and human myocardia; the obstacles encountered in these studies have also been related (*2–4*). Photoscanning of the heart with ^{131}Cs is hampered by its inherent low-energy, 29.4-keV x-ray, resulting in some tissue absorption by the structures of the chest wall. Also the interpretation of myocardial scans may be complicated by cardiac contraction and chest-wall respiratory movement.

MATERIALS AND METHODS

A phantom preparation was designed to simulate some of the factors outlined above which interfere with myocardial scanning both singly and in combination. Commercially available cast polystyrene heart models from Merck, Sharp and Dohme Drug Co. were used because of their anatomical accuracy. Each heart model consisted of two sections, anterior and posterior, and was constructed with sealed atrial and ventricular chambers, enclosed by the septum and the atrial and ventricular walls. When opened, the position of the septum and the shape of the ventricles were seen to be reproduced accurately (Fig. 1). This arrangement enabled an approximation of *in vivo* conditions. These models were modified by drilling out entry ways into the hollow myocardial wall area to instill a ^{131}Cs solution, leaving the ventricles empty. In one heart model selected areas were filled with solid plastic. These areas corresponded to a distribution of myocardial infarcts secondary to the occlusion of the anterior descending and circumflex coronary artery branches. Klemperer has shown that coronary thrombosis occurs in order of decreasing frequency in the left anterior descending artery, the right coronary artery and the left circumflex artery (*5*). Almost all infarcts occur in the left ventricle, and the most frequent site is the anterior region of the left ventricle near the apex (*6*). This model was used to represent an infarcted heart with the defects in the following locations: (1) a small lesion 2.5 cm in dia in the anterior aspect of the left ventricle, (2) a large area approximately 6×3 cm in the anterior apex of the heart and (3) a small lesion 2 cm in dia in the posterior aspect of the right ventricle (Fig. 2). The myocardial area in the second model was not filled with plastic so that a normal heart would be simulated.

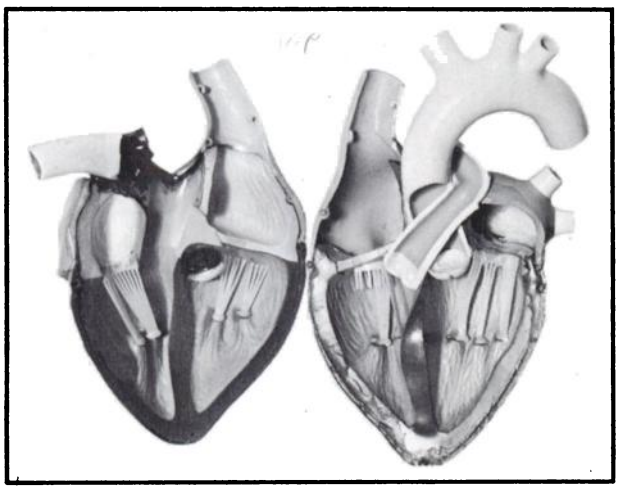

FIG. 1. Open-heart model showing interior cavities which remained free of radioactive solution.

The solution used for the study contained approximately 12.5 μCi of ^{131}Cs. This activity is based on available calculations concerning cesium accumulation in heart muscle and is approximately 1% of administered patient dose reported (*2–4,7*). After the diagnostic use of 1 mCi of ^{131}Cs, the highest nuclide concentration found in the heart is 0.05 μCi/gm (*8*). In a 250-gm heart the resulting activity of ^{131}Cs would be 12.5 μCi. At a scan time of approximately 2¾ hr ^{131}Cs has localized *in vivo* so that there is a myocardial-to-blood ratio of about 20:1 (*2*). This dose level was followed throughout the study with some minor variation.

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In addition to the phantom heart, an autopsy specimen including the sternum, ribs and intercostal muscles overlying the heart was obtained from a 5 ft 10 in., 170-lb male cadaver to study the attenuating effects of the chest wall. A roentgenogram of the specimen with the phantom heart in place was taken to determine the exact location of these structures to assure correct positioning in those studies using the heart model and the specimen together (Fig. 3). On all scans the following landmarks were used for later reference: (1) the area between the superior vena cava and the pulmonary artery, (2) the junction of the left atrium and left ventricle, (3) the apex of the heart and (4) the junction of the right atrium and right ventricle.

Scans were then performed using a Picker Magnascanner with a 1 × 3-in. NaI(Tl) crystal and the following collimators: (1) a standard Picker 19-hole, 3-in. medium-focus collimator, (2) a standard Picker 73-hole, 3-in. low-energy medium-focus collimator and (3) the specially constructed 1,045-hole, low-energy, medium-focus Brookhaven collimator. Specifications of these collimators are listed in Table 1. All three collimators were used in conjunction with the standard Picker small light aperture of 2 mm in dia for the phantom studies. A 25-keV analyzer window was used, and scanning factors were selected to obtain a statistically satisfactory ratio of counts/cm^2 over the area of maximum counting rate. For these studies, a ratio of 250 counts/cm^2 was considered optimum for the low counting rate obtained and was also the most feasible with regard to time required to complete a scan. Counting statistics were consistent throughout the experiment on those studies performed for comparative purposes. Scanning time for each picture was adjusted to keep the statistics approximately the same.

RESULTS AND DISCUSSION

Scans of the "normal" heart model were made first using the 73-hole collimator. Uptake corresponded well to the distribution of myocardium including the ventricular septum, and negative areas corresponding to the ventricular chambers could be distinguished. In the first scan, using the heart model alone, the counting rate obtained was 1,200/min. When the model was rescanned with the sternal structures positioned above it, the counting rate was reduced by approximately 50%. In comparing these two studies, it was observed that attenuation from the overlying anatomical specimen did not preclude the procurement of a satisfactory scan (Fig. 4A, B).

TABLE 1. COLLIMATOR SPECIFICATIONS

Collimator	Picker catalog no.	Focal length (in.)	Full width at half maximum of line spread function (in.)
19 hole medium focus	2107	3.0	0.50 @ 360 keV
73 hole low energy, medium focus	2113	3.0	0.25 @ 140 keV
1,045 hole low energy medium focus	—	3.5	0.23 @ 140 keV

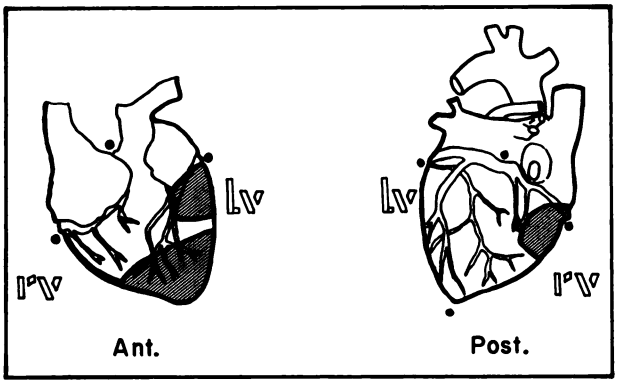

FIG. 2. Diagram indicating location of simulated infarcts placed between inner and outer walls of model. Anatomical landmarks used on scans are also shown.

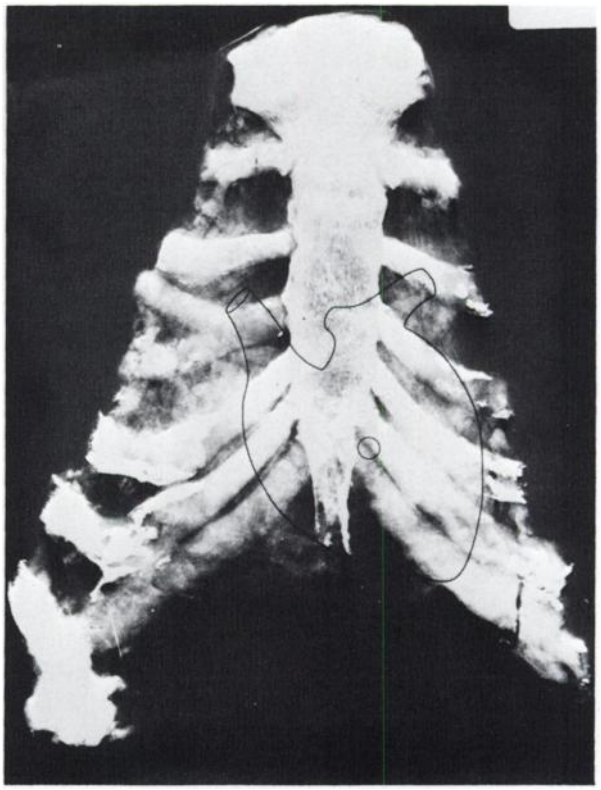

FIG. 3. Radiograph of cadaver chest section obtained for duplicating attenuation and scatter conditions. Position of phantom heart underneath specimen is outlined.

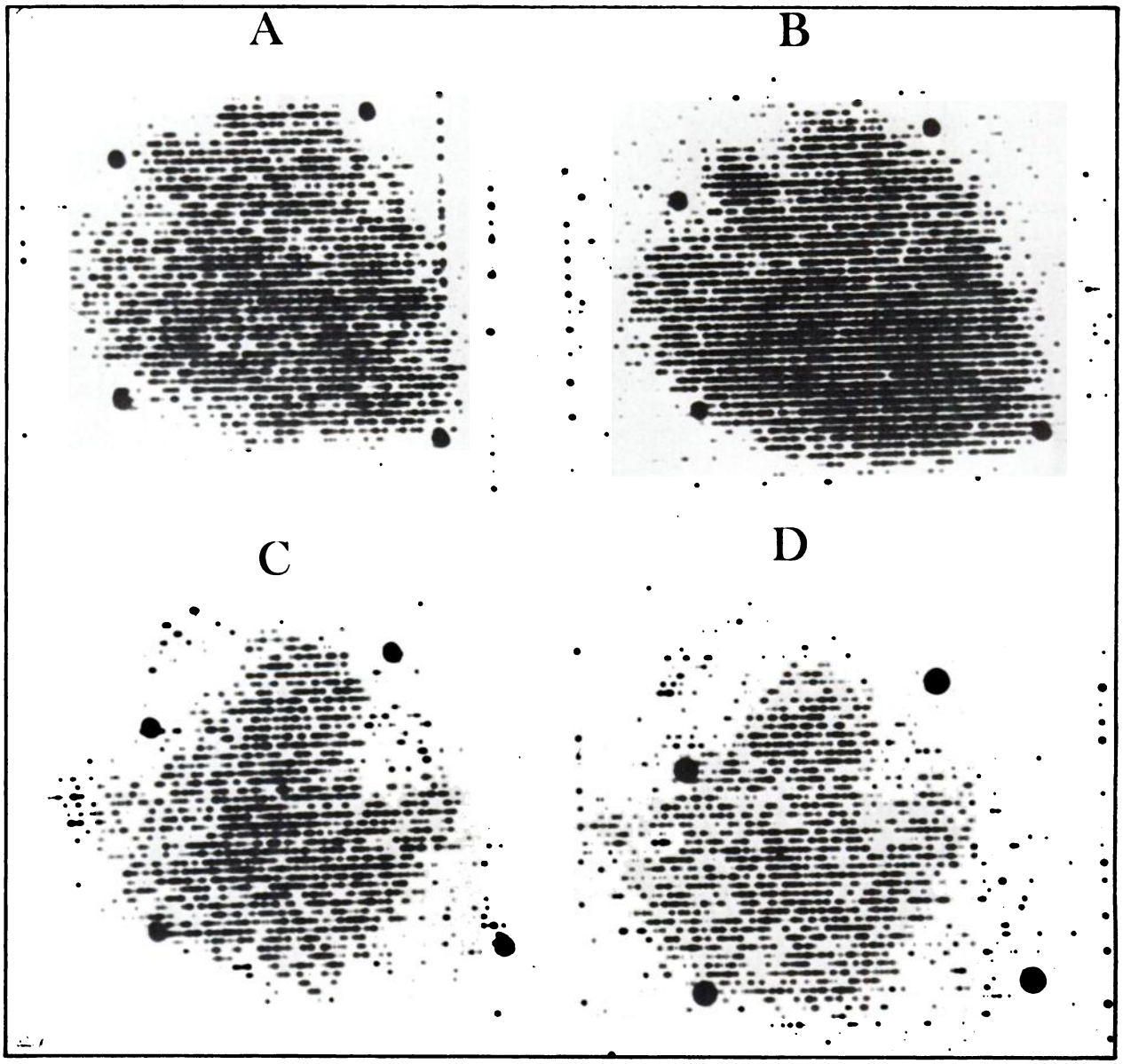

FIG. 4. Comparison scans showing appearance of (A) normal model without superimposed cadaver specimen, (B) specimen overlying normal model, (C) model containing lesions described in text without superimposed specimen and (D) predescribed model with specimen superimposed.

Studies of the infarcted heart model were then performed using the 73-hole collimator. A scan of the model alone was obtained at a counting rate of 1,000/cpm, and the locations of the artificial infarcts in the anterior aspect were demonstrated as areas of lesser activity. The defect in the posterior right ventricle was not as well visualized, probably because of the overlying activity in the anterior half of the model. On the second scan, although the counting rate was reduced by 50% with the addition of the specimen, the underlying heart model with its anterior defects was again clearly visualized without appreciable decrease in quality of the scan (Fig. 4C, D).

Several comparative studies—scans obtained first without and then with the specimen—led to the conclusion that attenuation from the overlying chest wall had little effect upon visualization of the infarcts in the phantom heart. However, potential uptake of ^{131}Cs by the intercostal muscles of a living subject could not be approximated in an autopsy specimen. Although bone absorption of the 29.4-keV x-ray of ^{131}Cs is of little significance in myocardial scanning, activity in the overlying intercostal muscles may cause difficulty in patient studies (especially if respiratory motion is marked).

Chest-wall movement and cardiac contraction were considered as two possible sources of confusion in interpreting myocardial scans. Because these factors were difficult to evaluate with a solid

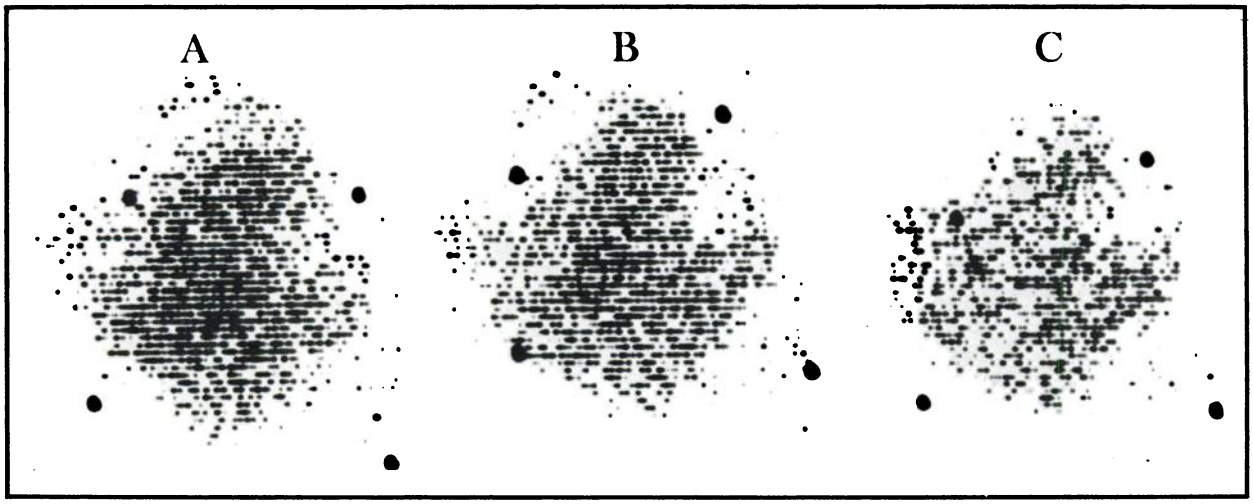

FIG. 5. Intercomparison study of effect of various collimators on image quality: A made with Picker 19-hole, 3-in. medium-focus collimator, B with Picker 73-hole, 3-in. medium-focus collimator and C with Brookhaven 1,045-hole, medium-focus collimator.

phantom and an autopsy specimen, this area of concern was not specifically investigated. However, it was noted from observing chest fluoroscopy that in the supine position movement due to normal diaphragmatic excursion was surprisingly small. In an attempt to evaluate the effect of cardiac contraction, Carr (*2*) compared cardiac silhouettes obtained from chest x-ray films to cardiac scan images of the same patient. He reported only minor discrepancies which were not considered significant.

Comparative scans were also performed to study the effect of various collimators on counting rate, scan quality and image sharpness (Fig. 5). The scan in Fig. 5A was done with a 19-hole, 3-in., medium-focus collimator in conjunction with the small light aperture to optimize results with this collimator. In the scan in Fig. 5B, the counting rate was reduced approximately 40% by using the 73-hole, 3-in., medium-focus collimator. The scan in Fig. 5C was obtained with the 1,045-hole Brookhaven collimator at a counting rate reduction of about 55% of that obtained with the 19-hole collimator. These changes in counting rate required adjustment of scan speed to maintain the same number of counts/cm^2. Relationships between these and previously discussed scans are given in Table 2.

In each of these scans (Fig. 5) of the infarcted model alone, the defects in the anterior aspect were well visualized and distinct from areas of greater activity. Again, the lesion in the posterior half was not as well demonstrated. The 19-hole collimator produced an adequate scan image of the heart and areas of infarction. Although the cold areas were not as clearly delineated as with the 73- and 1,045-hole collimators, this relatively small decrease in definition permitted far less scanning time—an important consideration in patient studies. The heart model was visualized well with the low-energy collimators in spite of the lower counting rates. A somewhat less homogeneous image was produced, but the infarcted areas were more sharply defined. The scan images obtained with the 73-hole and the Brookhaven collimators were so close in appearance that it was difficult to identify them consistently. Because of its wider availability, the 73-hole collimator was considered to be the more practical means of obtaining optimum image sharpness and scan quality and was therefore used to obtain the major portion of the phantom scans. It would therefore also be the preferable collimator for patient studies whenever scanning time is not of major importance.

SUMMARY

In conclusion, visualization of myocardial infarcts with ^{131}Cs appears to be a promising method. Studies

TABLE 2. SCANNING FACTORS USED

	Counting rate (cpm)	Counts/ cm^2	Scan speed (cm/min)	Approximate scan time (min)
Normal model				
without specimen	1,200	250	23	35
with specimen	600	250	12	70
Infarcted model				
without specimen	1,000	250	19	45
with specimen	500	250	10	80
Infarcted model without specimen				
19-hole collimator	1,600	250	30	25
73-hole collimator	1,000	250	19	45
1,045-hole collimator	750	250	14	60

of the phantom heart have shown the following: (1) lesions can be well visualized if they are on the anterior wall, (2) attenuation from bony structures of the overlying chest wall has little effect upon scan quality if scan time is increased to maintain good statistics and (3) the use of low-energy collimators aids in obtaining scans of good quality. Although studies of the effects of respiration and cardiac contraction were not included in this experiment, it is felt that these factors would not significantly alter the scan image. The effect of biological distribution of ^{131}Cs in the intercostal muscles was not determined. Further evaluation of the effectiveness of this radionuclide will be pursued in future patient studies.

ACKNOWLEDGMENT

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