The Importance of Technical Aspects in the Evaluation of Supplementary Indicators on Thallium-201 Myocardial Perfusion Scintigraphs Using Planar Imaging

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We previously evaluated the usefulness of visual abnormalities on myocardial stress-perfusion scintigraphy (SPS) not related to the pattern of cardiac perfusion (1). These supplementary indicators (SI) included: increased lung and ventricular basal uptake and a stress related increase in left ventricular size. In a study population of 72 randomly selected patients, artifactual production of SI was achieved by changes in our imaging parameters. Through increases in imaging intensities and time of acquisition, all SI were created. Similar effects were observed with increased count rates. Acquiring images at greater distances than direct patient contact affected ventricular size and basal uptake. Angulation differences affected both these SI and the interpretation of the extent of existing perfusion defects. Ventricular size differences were seen when comparisons of stress images were done with the same redistribution projections acquired on a different camera system. Unless technical accuracy is assured there is risk in using SI to help identify patients with coronary artery disease (CAD).

The diagnostic value of thallium-201 (^{201}Tl) stress-redistribution scintigraphy for the detection of coronary artery disease (CAD) has been well established. With quantitative single-photon emission computed tomography (SPECT) methods, a greater understanding of the full extent of coronary involvement has been achieved (*2,3*). Although tomographic methods only have a documented advantage in portraying distribution of the left circumflex artery (*4*), they do appear to objectify defect interpretation. Planar perfusion imaging, however, is still widely performed, alone or in association with SPECT. The performance of planar perfusion imaging is extremely important to those patients who cannot undergo tomography. In those patients that can undergo SPECT, planar imaging helps to clarify findings of tomography since the principles of planar imaging are well applied to SPECT. The results observed on planar imaging are similar to those seen on SPECT when the imaging parameters are altered.

Frequently, there has been an underestimation of the extent of CAD by the visual assessment of planar images (*5*) despite computer enhancement. Some of this underestimation may be physiologic, and related to the level of exercise and coronary ischemic threshold. Quantitative methods have improved sensitivity (*6–10*) but additional indicators should be utilized in order to extract as much useful information as possible from planar perfusion images. Such additional indicators include stress-related left ventricular enlargement, lung uptake, and ventricular basal uptake (Fig. 1).

Our previous study (*1*) documented the importance of these SI of CAD. The study showed that the presence of SI on stress-perfusion scintigraphy (SPS) images suggested that more extensive disease was present than what was indicated by the distribution of perfusion defects. In the absence of SI, multivessel disease seemed very unlikely in those patients who also had a negative treadmill test or no perfusion defects. These indicators may, however, be seriously influenced by technical factors. Only one study notes the influence of display varying patterns upon the visual interpretation of acquired images (*11*). Unless images are technically correct, there is considerable risk (false-positive or false-negative reading) during interpretation, since apparent SI may come and go with technical alterations. This evaluation was undertaken to report the technical alterations that could artifactually produce SI.

MATERIALS AND METHODS

Our previous study group (*1*) in which SI were assessed consisted of 172 patients. There were 126 males and 46 females with a mean age of 56 yr (range 24–96). Conditions of ischemia and infarction were assessed by the evaluation of the relative presence or absence of activity between stress and redistribution images. In 39 of these patients, we further examined the extent of CAD by selective coronary angiography. A separate population of 72 randomly selected patients, who underwent our standardized method of SPS had additional images acquired to produce artifactual SI through changes in our imaging procedures.

Thallium-201 Stress Imaging

An indwelling venous catheter was inserted into an antecubital vein prior to the exercise test. Patients were then exercised on a treadmill according to the Bruce Protocol (*12*). When the patient reached the maximally predicted heart rate, 1.5–2.0 mCi of ^{201}Tl was injected. (In the state of California, 1.5-2.0 mCi is the standard maximum allowable dose of ^{201}Tl

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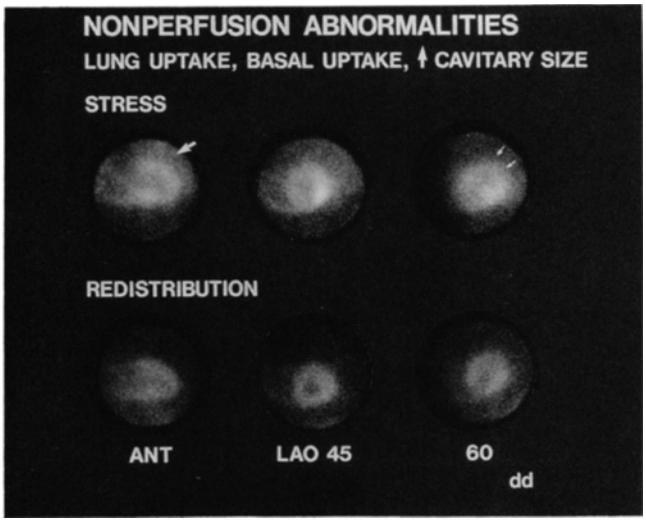

FIG. 1. Supplementary indicators seen on stress and redistribution scintigrams. Lung uptake (large solid arrow) in the anterior view and basal (myocardial) uptake (small arrows) in the 60° LAO view are displayed. An inferoapical perfusion abnormality is seen on the 60° LAO projection. The left ventricular outline also appears larger at stress than at redistribution.

for planar imaging. We now use 3.0-3.5 mCi with SPECT, however, the principles involved are not dependent on dose.) Patients were encouraged to exercise 30–60 sec past injection and imaging began after a 7-min rest period. During exercise, patients were monitored for EKG changes indicative of ischemia. Duration of exercise, peak heart rate and percent of maximally predicted heart rate, blood pressure, and any evidence of stress-induced pulmonary congestion, hypertension and arrhythmias were also monitored.

A small field of view (SFOV) scintillation camera* was employed, which was equipped with a high-sensitivity parallel-hole collimator. A high-sensitivity collimator was used since we found that we lost little in acquisition with a LEAP collimator. Moreover, we saved valuable time in imaging the temporarily dependent distribution of ^{201}Tl. A 20% window centered at the 80 keV mercury X-ray peak of ^{201}Tl was used. A thin lead shield was placed upon the collimator face to limit counts from the adjacent pulmonary and subdiaphragmatic regions.

An anterior projection was acquired for 300,000 counts and succeeding images of left anterior oblique (LAO) projections (30°, 45°, 60°) and left lateral projections were taken for the exact acquisition time of the anterior view.

A repeat anterior view was taken with the lead shield removed to demonstrate the full extent of lung uptake of ^{201}Tl. Initial anterior images, however, were evaluated for lung uptake.

Analog images were taken with a Polaroid camera equipped with lenses of varying apertures that recorded images at three different intensities. Digital images underwent our standard algorithm of contrast enhancement, background subtraction, and smoothing to eliminate the effects of scatter and collimation (*13*).

Scintigraphic Interpretation

Analog images were assessed not only for classical perfusion patterns of ischemia and infarction, but also for the presence of SI. A stress view that revealed a defect not present at redistribution was considered positive for ischemia, whereas a defect in the stress image that persisted on the redistribution view was considered positive for infarction.

The scintigraphic defects that related to the distribution of coronary involvement were: defects in the anterior or septal wall related to the left anterior coronary distribution, inferior defects related to the right coronary distribution, and lateral defects related to left circumflex disease. Apical abnormalities could relate to the distribution of any of the major coronary vessels.

The initial anterior view was visually assessed for lung uptake when radioactivity appeared to be higher, superior, and lateral to the myocardium than that below the diaphragm and in the mediastinum region. This apparent increase in lung uptake appeared to decrease on redistribution. Basal uptake was assessed by noting ^{201}Tl uptake in the mitral valve plane, equivalent or greater than that of the adjacent walls. The third SI was an apparent stress-related increase in the left ventricle as compared to the same redistribution image. The same criteria were used in assessing actual and artifactually produced SI.

Artifactual Production of Supplementary Indicators

To test the effects of changing imaging patterns on SI, we intentionally experimented with several variables during the acquisition of images. Normally the same acquisition intensities are used in acquiring stress and redistribution images. This is done so differences in images can be attributed to ^{201}Tl washout rather than intensity differences. During this study, a wide range of intensities were used in order to determine their effect upon SI. The intensities ranged from settings ~50 units below to 100 units above normal settings.

Variations in the length of acquisition and number of counts acquired were also done in this study. During standardized testing, the initial anterior view was acquired for 300,000 counts and proceeding views set to this time of acquisition. We acquired the same stress view at 90 sec, 180 sec, and 540 sec. We also evaluated the effect of varying the number of counts that were acquired for the same view. We acquired additional views of the same projection at increments of 100,000 counts. The same stress projection was acquired at a count rate of 100,000K, 400,000K, and 500,000K.

Normally the camera head was positioned parallel to the patient profile when acquiring images and adjusted to the desired LAO angle. To test the effects of angulation upon SI, normal LAO projections were angled at 5° increments in either the cephalic or caudal direction.

All stress images in this study were acquired on a SFOV camera*. Routine redistribution images were always done on this same camera system. To assess artifactually produced SI, identical redistribution projections were acquired on a LFOV camera system[†]. Intensities were approximated and the same type of high sensitivity parallel-hole collimator was employed in acquiring both sets of images. Evaluated differences between stress and redistribution could not be attributed to the resolution of the two camera systems. Magnification, intensity, and collimation remained constant. Indeed, the specifications for both camera systems are quite similar; however, the differences we note here relate to extreme size changes when comparing standard and LFOV images. These are not related to the collimators.

The effects of collimation upon image quality and portrayal of SI was also sought. To illustrate this, a general all-purpose collimator (GAP) was replaced with a high-resolution collimator, and a diverging collimator with a converging collimator. An attempt was made to approximate intensities and to acquire images for the same length of time.

Varying acquisition distances were applied ranging from direct patient contact to a distance of 60 cm. Increments of 10 cm, 20 cm, 30 cm, and 60 cm were used. Images were acquired at the same intensity and number of counts.

RESULTS

Table 1 summarizes the effects that certain technical variations had upon images. Variations in intensities, number of counts acquired, or time of acquisition had the effect of portraying all three SI (Fig. 2). To effect the changes in ventricular size an increase of up to 100 units of intensity was sufficient. An increased intensity gives the appearance of an enlarged ventricle while obscuring the cavity as compared to the same image acquired at a lower intensity. Increasing the intensity on the initial image also showed apparent lung and basal uptake. With each increase in intensity, the greater the probability of portraying SI. However, at an intensity of 100 units or above, even though lung uptake was unmistakable, the left ventricle could not be seen. For this reason, an assessment of basal uptake or enlargement was not possible. Intensities set below optimal had the opposite effect in portraying SI. The portrayal of actual or artifactually produced SI was reduced with lowered intensity settings. Assessment of any kind was not possible if intensities were set too low. The relationship of artifacts to conditions producing them is shown in Table 1. These conditions will always generate the noted artifacts. The frequency of their occurrence in a clinical setting was not tested, however, we expect the figure to be very low, expecially if one applies the information presented here.

Longer acquisition times of the same projection yielded images with greater count densities. Images that had a greater number of counts portrayed the same type of artifactually produced SI as images in which intensity changes had oc-

TABLE 1. Effects of Technical Variations on Perfusion Imaging

Technical variables	Effects
Intensity	Ventricular size, basal uptake, lung uptake
Time/Counts	Ventricular size, basal uptake, lung uptake
Angulation	Ventricular size, basal uptake
Camera	Ventricular size
Collimation	Ventricular size
Distance	Ventricular size, basal uptake

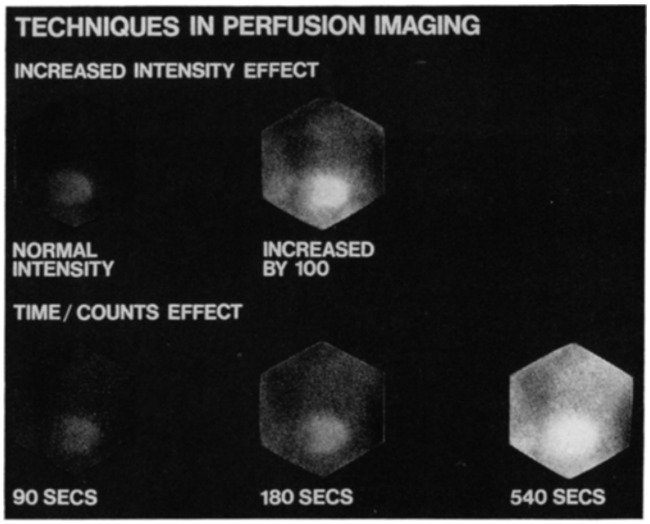

FIG. 2. Artifactually produced lung uptake, basal uptake and dilation of the left ventricle in the anterior projection. The images were taken without the lead "doughnut" to permit apparent lung uptake. An increase in the intensity by 100 units is represented in the upper images. The bottom images show effects of increasing acquisition times from 90 sec to 180 sec and 540 sec.

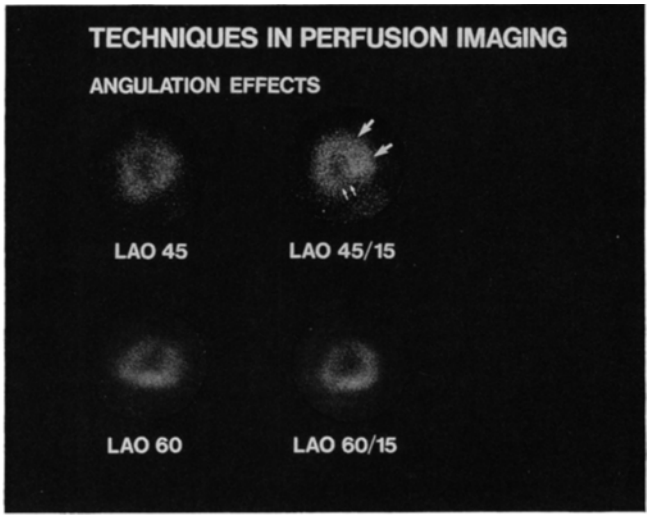

FIG. 3. Angulation effect of producing basal region uptake. A 15° caudal tilt is added to the LAO 45° and 60° projection. Evidence of regional uptake is demonstrated (large arrows) in the LAO 45°/15° view. In addition, an inferoapical defect (smaller arrows) is also seen to enlarge in this same view when compared to the normal LAO 45° projection.

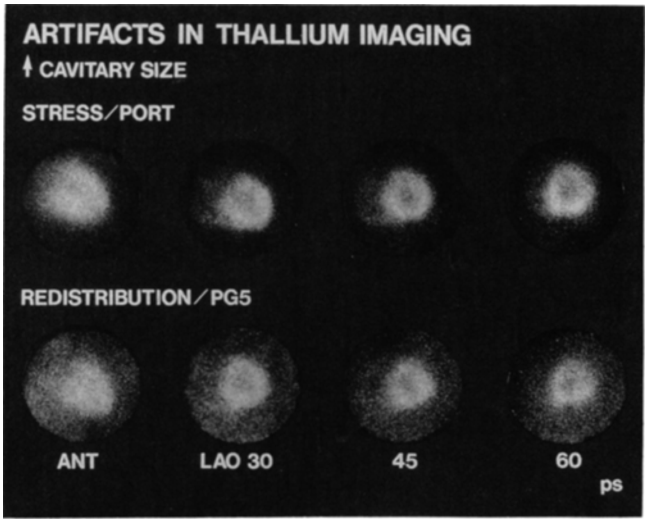

FIG. 4. SFOV camera* images are compared with the same redistribution images taken by a LFOV camera system†. Artifactually produced differences in left ventricular size are seen when comparing stress and redistribution images. ANT = anterior; LAO = left anterior oblique.

curred. Again, thresholds had to be realized, otherwise acquired images yielded no useful information. Images acquired at the same intensity for more than 500,000 counts even though portraying lung uptake very well, obscured assessment of ventricular enlargement or basal uptake.

Angulation of the camera head from parallel to the patient profile in either the cephalic or caudal direction had the effect of artifactually producing apparent cavitary dilation and basal uptake (Fig. 3). Even slight changes in this angulation could produce these effects. The extent of existing perfusion defects could also be influenced by this variation.

The use of different camera systems (Fig. 4) had the effect of portraying size differences of the left ventricle between stress and redistribution. All stress projections were acquired on a SFOV camera*. When the same redistribution views were acquired 4 hr later on a different camera system,† there appeared to be no difference in image quality. However, magnification differences produced apparent cavitary dilation.

Using different collimators produced artifactual differences in left ventricular size. If a GAP collimator was later replaced with a high-resolution collimator for redistribution images, less counts would be acquired at imaging. This effect is similar to decreasing count rates or time of acquisition since a similar reduction in counts gives the illusion of decreased left ventricular size at redistribution. The effects of using diverging or converging collimators is obvious, since they are designed to decrease or increase images respectively.

The distance at which an image was acquired had the effect of varying the size of the left ventricle and the extent of basal uptake. The further an image was acquired from the patient, the greater the count loss with a resultant loss in resolution. This effectively reduced apparent left ventricular size and the appearance of basal uptake, upon visual assessment of comparable images. Beyond 60 cm, image quality was too poor for evaluation.

DISCUSSION

If supplementary indicators are used to help identify patients with CAD by either planar or tomographic methods, technical accuracy must be assured. In this study, artifactual production of SI was achieved by even slight changes in normal patterns of acquiring images. Interpretation of images for SI is risky if images are not technically correct. In assessing images for lung uptake, interpreters must be sure that images were not acquired at greater intensities, number of counts, or time of acquisition. We have shown in this study that variations in these parameters have the possibility of artifactually representing lung uptake of ^{201}Tl. Basal uptake was also artifactually produced by these same variations. Differences in distance of acquisition and angulation of the camera head could also produce basal uptake. Changes in the size of the left ventricle between stress and redistribution could be achieved by all the variations that were attempted during this study. To help prevent the artifactual production of SI, the same camera and type of collimation should be used. Intensity settings should be standardized and approximately the same number of counts should be acquired for the same stress and redistribution view. Images should also be acquired as close to the patient as possible. Direct patient contact is preferred, since this will not only give the best resolution, but will also protect against artifactual changes in left ventricular size and basal uptake. This study stresses the importance of technical accuracy in order to prevent the artifactual production of SI. This is important to the correct diagnosis of CAD if SI are to be used as further indicators of coronary disease.

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NOTES

* Ohio Nuclear Series 120 Gamma Camera, Ohio Nuclear, Solon, OH.

† Siemens Gammasonics, Pho Gamma 5 Camera, Schaumburg, IL.

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