How to Detect and Avoid Myocardial Perfusion SPECT Artifacts

E. Gordon DePuey III

Division of Nuclear Medicine, Department of Radiology, St. Luke's-Roosevelt Hospital, and Columbia University College of Physicians and Surgeons, New York, New York

Although myocardial perfusion imaging with SPECT is an accurate and reliable diagnostic study, artifacts must be avoided, or detected and corrected, to minimize the rate of false-positive results. Common sources of artifacts are nonuniformity in gamma camera detectors, center of rotation errors, misaligned cameras on multidetector scanner systems, errors in image reconstruction, patient motion, radiotracer uptake in nontarget organs and attenuation. Some of these artifacts can be avoided by quality control of instrumentation and by imaging the patient in a prone rather than supine position to separate radiotracer activity from the target and nontarget organs and to reduce the effect of inferior wall attenuation. Other artifacts can be detected by careful image inspection and corrected by reprocessing. The best way to avoid artifacts is to pay very close attention to the technical factors of image acquisition and processing, and to be aware of attenuation factors.

Key Words: myocardial perfusion imaging; SPECT artifacts

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SPECT myocardial perfusion imaging with radiotracers can detect coronary artery disease (CAD) with approximately 90% sensitivity and nearly 80% specificity. Although this accuracy is acceptably high for a diagnostic test, the reality is that sensitivity and specificity are not 100%.

Unless referring physicians understand the ramifications of 80% specificity, they may become discouraged when some of their patients with positive myocardial perfusion studies undergo the pain and expense of cardiac catheterization on a regular basis, only to discover that their angiograms are normal.

As nuclear medicine imaging specialists, we need to be vigilant about improving the specificity of our studies by eliminating the known sources of false-positive scans. The best way to improve specificity is to detect and eliminate artifacts (*1–3*).

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For correspondence or reprints contact: E. Gordon DePuey, MD, Division of Nuclear Medicine, St. Luke's-Roosevelt Hospital, Amsterdam Ave. at 114th St., New York, NY 10025.

SPECT SYSTEM QUALITY CONTROL

When attempting to eliminate artifacts, the first area on which to focus is quality control of the SPECT imaging system. When image data are analyzed quantitatively, as in bull's-eye reconstruction, artifacts are more difficult to distinguish from true perfusion defects. Multidetector SPECT cameras present even more quality control problems and consequent artifacts. With advances in technology, image data are processed in more sophisticated ways which camouflage artifacts more easily recognized in raw images.

As physicians who interpret these images, we must remain close to our technology so we can detect these errors. As a rule, bull's-eye reconstructions and other quantitative analyses should be interpreted only after careful inspection of raw SPECT images. Similarly, a SPECT study should never be read without first looking at the rotating planar projections on the computer display monitor.

Uniformity

Flood fields must be tested daily for uniformity. Nonuniform flood fields can cause major problems. When the hot and cold areas of a nonuniform flood field are backprojected, ring artifacts occur in transaxial slices (Fig. 1). Concentric ring artifacts similarly can occur in bull's-eye (polar map) displays. If the interpreter is not aware of these artifacts, such studies can be misinterpreted as multivessel disease. When ring artifacts are observed, discontinue SPECT imaging with that camera, reacquire the flood field and correct the cause of nonuniformity.

Center of Rotation

The center of rotation is not always stable; it must be checked routinely and, when necessary, corrected. When the center of rotation is not stable, line sources that should create an image of discrete dots become deformed or blurred due to mispositioning of the backprojected points. If the center of rotation is off by just one or two pixels, the misaligned data can create artifactual defects in the SPECT image and the bull's-eye reconstruction. As mentioned previously, the defect is more difficult to recognize as an

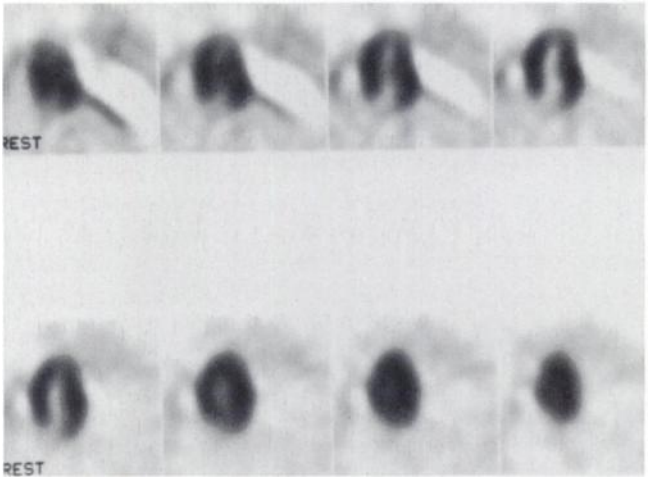

FIGURE 1. Ring artifact in horizontal long-axis slices due to a defective photomultiplier tube in a region of the scintillation crystal overlying the left ventricle.

artifact on the bull's-eye image than on the tomographic slices.

Multidetector Alignment

With dual- and triple-headed SPECT cameras, misalignment of detector heads can create artifacts that resemble perfusion defects. An error in one detector of a triple-headed SPECT scanner can translate into multiple defects on the SPECT image.

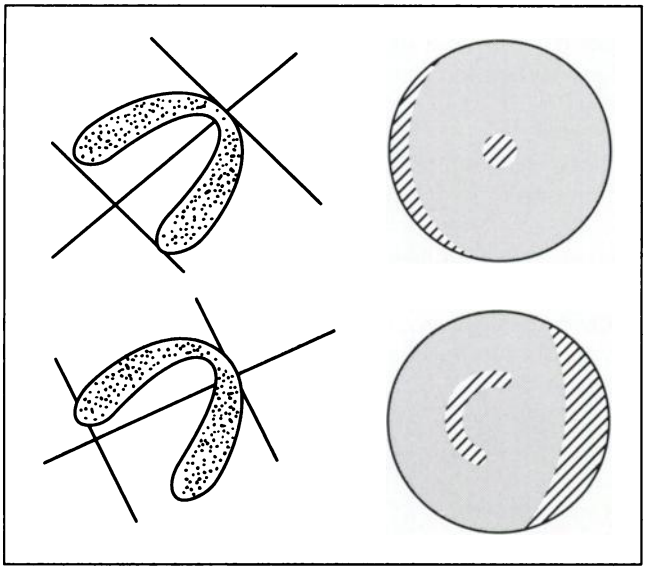

FIGURE 2. Correct long-axis selection from the diagrammed transaxial tomographic slice results in a bull's-eye image with regions of physiologically decreased count density (cross-hatched areas) at the base of the septum due to the membranous septum, and at the apex due to anatomic thinning. With incorrect long-axis selection a semilunar artifact is created at the periphery of the lateral wall. The apex is shifted anteriorly, creating a comma-shaped artifact in the septum, corresponding to the region of physiologic apical thinning.

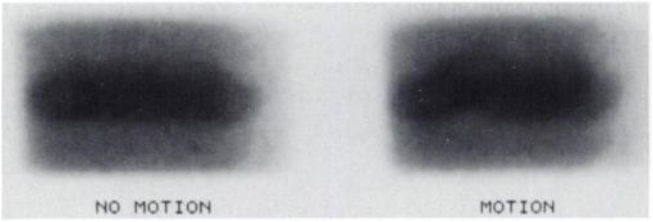

FIGURE 3. Summed planar projection images without (left) and with (right) patient motion.

Bull's-Eye Reconstruction

Incorrect slice selection in bull's-eye processing can eliminate crucial diagnostic data in the quantitative analysis, particularly at the apex or base of the left ventricle. Incorrect axis selection can create a more subtle problem.

When selecting the long-axis of the ventricle, for example, the axis should exactly bisect the ventricular cavity. Incorrect axis selection may: (a) foreshorten normal ventricular walls, creating apparent basal defects; (b) displace the apical "dimple," creating an apparent peri-apical perfusion defect; (c) or misplace true perfusion defects (Fig. 2), causing the interpreting physician to identify the involved vascular territory inaccurately. Two other operator-dependent steps—selection of the left-ventricular center on short-axis slices and assignment of the radius of search to determine the maximum count pixel—can result in improper sampling of the myocardium, compromising determination of defect extent. Even skilled and experienced technologists can, on occasion, make processing decisions that result in these artifacts.

PATIENT MOTION

Motion as little as one pixel in magnitude can create SPECT perfusion scan abnormalities that can be misconstrued as perfusion defects (*4*). Restricting patient motion is an ongoing challenge. Making sure that the patient is comfortable and immobile is an extremely important job for the technologist. When patients are confused or uncooperative, however, this job is difficult. The best way to detect patient motion artifacts is by looking for vertical, horizontal or rotational motion in rotating planar images on the computer's display monitor.

The summed planar images in Figure 3 are from a patient who slid down on the table about 3 pixels halfway through the acquisition. When this image is reconstructed, the problem is similar to a center of rotation error. The front and back of the heart are backprojected on different points in the reconstruction matrix, resulting in misalignment of the two myocardial walls. Such misalignment can create artifacts that resemble anterior and inferior perfusion defects (Fig. 4). Fortunately, when this type of motion artifact is detected, it can often be corrected by shifting image frames to eliminate the artifact.

On Figure 4, note the curvilinear "tails" of activity that extend from the defects, which are characteristic of a motion artifact on SPECT. Similar tails can be observed with

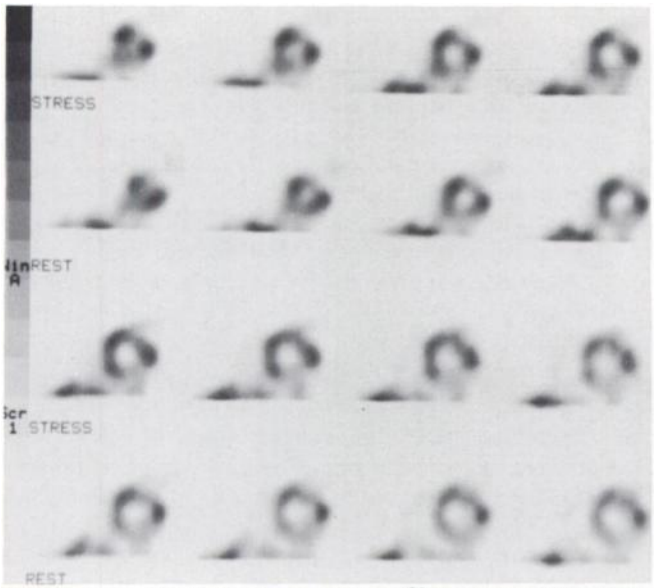

FIGURE 4. Short-axis stress and rest ^{99m}Tc-sestamibi SPECT images from a patient who moved approximately two pixels in the vertical direction during both image acquisitions.

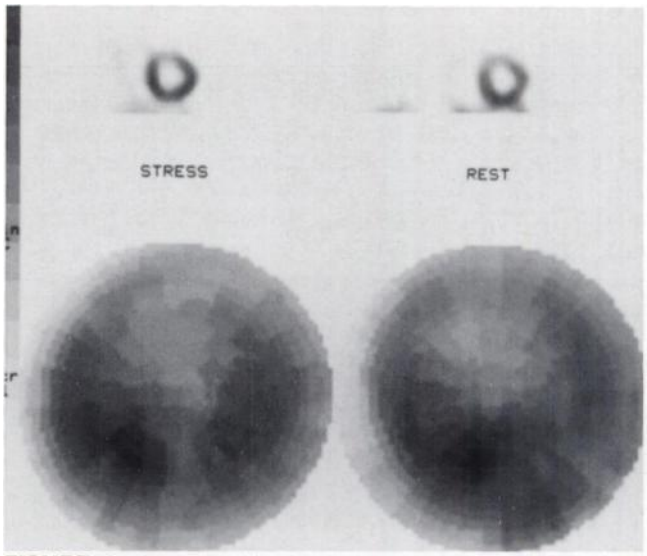

FIGURE 6. Tomographic short-axis stress and rest slices (top) and polar maps (bottom) from a female patient with large breasts. Fixed breast attenuation artifacts are present in the anterior wall. Reprinted with permission from Raven Press, New York, NY, from *Cardiac SPECT* 1994: in press.

center of rotation errors (Fig. 5). When imaging with ^{201}Tl, this type of motion artifact is easy to overlook because it only makes the image a bit more blurry. With ^{99m}Tc-labeled perfusion agents, however, this type of motion artifact is more clearly defined.

RADIOTRACER UPTAKE IN NONTARGET ORGANS

Overlapping bowel or liver activity in resting images, with either ^{201}Tl or ^{99m}Tc perfusion radiotracers, can create "pseudo-redistribution," making a fixed defect look reversible. On the tomographic slices, a recognizable loop of bowel or liver activity may be adjacent to the heart. If the activity from nontarget organs is mistakenly included in the radius of search for bull's-eye reconstruction, the bowel or liver activity is backprojected onto the heart and is included in the polar map as myocardial activity. If this activity overlaps a fixed defect, it appears as if the defect has "filled in," resulting in misdiagnosing ischemia where only infarction is present. One way to help prevent this problem is to image patients in a prone rather than supine position, which moves the bowel and liver further away from the heart.

In some cases, excreted ^{99m}Tc-sestamibi in the duodenum may reflux into the stomach, particularly in patients with hiatal hernias. Radiotracer activity in the stomach is often particularly difficult to separate from myocardial uptake.

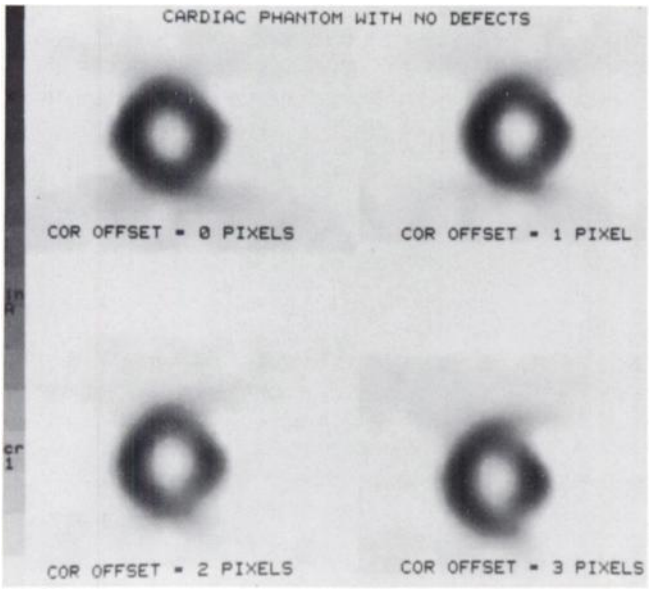

FIGURE 5. Short-axis tomographic slices of a cardiac phantom with no true defects. Center of rotation errors of one, two and three pixels are simulated. Opposed anterior and inferior artifacts are created as well as curvilinear "tails" of activity extending from the edges of the defects. Reprinted with permission from Raven Press, New York, NY, from *Cardiac SPECT* 1994: in press.

ATTENUATION

Attenuation artifacts can cause problems with both ^{201}Tl and ^{99m}Tc myocardial perfusion imaging, although they are less frequent with sestamibi than with thallium. Planar projection images from female patients with large breasts can show photopenic artifacts overlying the anterior wall of the left ventricle. When these data undergo SPECT reconstruction, it can be difficult to differentiate scar tissue from an attenuation artifact (Fig. 6).

The left hemidiaphragm, the position of which usually can be detected in rotating planar images, often causes attenuation artifacts. This problem can sometimes be avoided by imaging the patient in a prone position, which

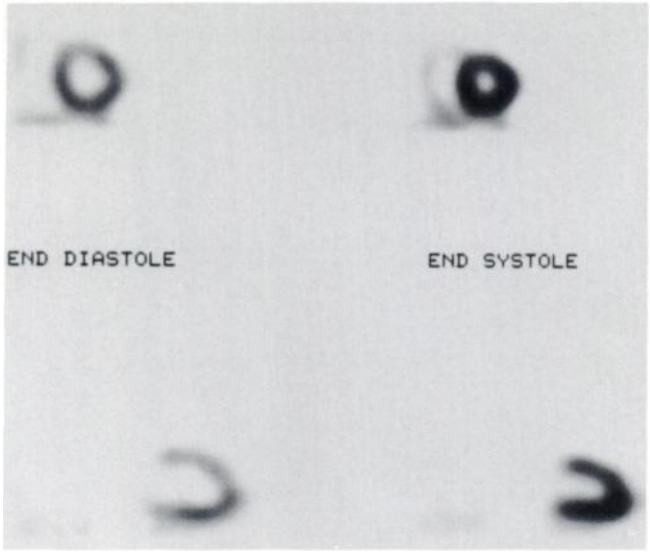

FIGURE 7. End-diastolic and end-systolic mid-ventricular short-axis (top) and vertical long-axis (bottom) slices from the patient in Figure 6. Note normal wall motion and thickening (intensification) of the anterior defect, favoring attenuation artifact rather than scar. Reprinted with permission from Raven Press, New York, NY, from *Cardiac SPECT* 1994: in press.

moves the diaphragm down and the heart up, minimizing diaphragmatic attenuation.

Another method to recognize attenuation artifacts is to perform gated myocardial perfusion studies, which can be done with ^{99m}Tc-sestamibi (*4*). When a perfusion defect is not visible consistently at both diastole and systole, it is more likely an attenuation artifact than a true defect (Fig. 7). Gated SPECT data, however, should be interpreted in light of the patient's clinical history and electrocardiogram, both of which are also useful in increasing diagnostic certainty with regard to the presence or absence of prior myocardial infarction.

CONCLUSION

Although myocardial perfusion imaging with SPECT is an accurate and reliable diagnostic study, artifacts must be avoided, or detected and corrected, to minimize the rate of false-positive results. Common sources of artifacts are nonuniformity in gamma camera detectors, center of rotation errors, misaligned camera heads, errors in image reconstruction, patient motion, radiotracer uptake in nontarget organs and attenuation. The best way to avoid artifacts is to pay very close attention to the technical factors of image acquisition and processing and to be aware of attenuation factors.

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