Electronic Off-Peak Status of One Head of a Dual-Head Gamma Camera Resulted in Bone Scintigraphy Artifacts and Faulty Findings on Gated Myocardial SPECT

Wei-Jen Shih, MD[1,2]; Tom Schoenstra, CNMT[1]; Kelly Gross, CNMT[1]; Becky Wierzbinski, BS, CNMT[1]; Vickie Kiefer, CNMT[1]; and Judith Collins, CNMT[1]

[1]Nuclear Medicine Service, Lexington VA Medical Center, Lexington, Kentucky; and [2]Department of Diagnostic Radiology, College of Medicine, University of Kentucky, Lexington, Kentucky

Objective: Gamma cameras contain energy discriminators that allow only those photons within a specified energy range to be recorded. A spontaneous shift in peak of 1 head of a dual-head gamma camera may cause artifacts. We present our experience with the incidental occurrence of off-peak status in 1 head of a dual-head gamma camera that resulted in subsequent artifacts and poor-quality images.

Methods: Four patients had been scheduled to undergo imaging on a newly installed dual-head gamma camera on the same morning. The first patient underwent ^{201}Tl-chloride anterior and posterior total-body imaging to check for metastatic thyroid cancer, and the images were of adequate quality for interpretation. The next 2 patients underwent dual-isotope rest ^{201}Tl-chloride and gated dipyridamole ^{99m}Tc-tetrofosmin myocardial SPECT. The rest ^{201}Tl myocardial SPECT images of both patients showed normal perfusion in the left ventricular wall, but the dipyridamole ^{99m}Tc SPECT images showed virtual absence of perfusion in the apical, anterior, and lateral walls. These findings might suggest myocardial ischemia. In addition, 1 of 2 patients' cardiac gated SPECT findings led to inaccurate left ventricular ejection fractions. Technologists did not become aware of the artifacts until the fourth patient underwent total-body bone scanning, which showed faint activity with loss of contrast in the entire anterior body. One of the camera heads was then found to have off-peak status. Thus, we abandoned use of 1 detector of the dual-head gamma camera and repeated the anterior bone scanning of the 4th patient and the dipyridamole SPECT of 1 of the 2 cardiac patients.

Results: Gated cardiac SPECT abnormalities resulting from off-peak status were difficult to identify and included abnormal left ventricular wall perfusion and an inaccurate left ventricular ejection fraction. It was determined later that the off-peak status was caused by malfunction of a photomultiplier tube.

Conclusion: Degraded planar images resulting from the off-peak status of a camera head are easily identified. The presence of the same pattern of abnormalities in 2 consecutive myocardial SPECT examinations should alert technologists to the possibility that the abnormalities are, in fact, artifacts.

Key Words: gamma camera; quality control; electronic off-peak; cardiac SPECT; bone scintigraphy; artifact

J Nucl Med Technol 2003; 31:165–169

Daily quality control checks of gamma camera performance are essential to ensure reliable images. Gamma cameras contain energy discriminators that allow only those photons within a specified energy range to be recorded. The process of setting this energy window is called "peaking" the camera. A spontaneous shift in the peak of 1 head of a triple-head gamma camera was reported to cause an artifact that mimicked ischemia on ^{201}Tl-chloride myocardial SPECT (*1*). We present our experience with 4 patients who were imaged on the same morning, when off-peak status occurred incidentally in 1 head of a dual-head gamma camera and resulted in subsequent artifacts and poor-quality images.

MATERIALS AND METHODS

The instrumentation used to image the 4 patients was a newly installed 2-head gamma camera (Axis; Marconi/Philip).

For correspondence or reprints contact: Wei-Jen Shih, MD, Nuclear Medicine Service, Lexington VA Medical Center, 1101 Veterans Dr., Lexington, KY 40502.
E-mail: wei-jen.shih@med.va.gov

The window settings were 20% and 40% for ^{201}Tl-chloride and 15% for ^{99m}Tc-tetrofosmin and ^{99m}Tc-hydroxylmethylene hydroxy-diphosphonate (HMDP). ^{201}Tl-Chloride was used in the first patient for total-body images to detect metastases of Hürthle cell carcinoma because of negative ^{131}I findings and an elevated serum thyroglobulin level. ^{201}Tl-Chloride and ^{99m}Tc-tetrofosmin were used in 2 patients undergoing dual-isotope rest and dipyridamole gated myocardial SPECT. Rest SPECT was performed after intravenous injection of ^{201}Tl-chloride; the patients were then given an intravenous injection of dipyridamole and underwent ^{99m}Tc-tetrofosmin gated SPECT 60 min later. The fourth patient underwent total-body anterior and posterior bone scanning using ^{99m}Tc-HMDP as the bone-imaging agent. In the first and the fourth patients, 1 head-detector (head I) above the patient recorded the anterior view, and a second head-detector (head II) simultaneously recorded the posterior image from below the imaging table.

RESULTS

The first patient's ^{201}Tl-chloride total-body images for Hürthle cell thyroid carcinoma were of adequate quality (Fig. 1); the scanning did not need to be repeated. For the second and third patients, rest ^{201}Tl-chloride myocardial SPECT provided readable images (Figs. 2A and 2B), and ^{99m}Tc-tetrofosmin gated SPECT showed an identical pattern of abnormalities for both patients. When the anterior and posterior total-body bone images were printed out (Fig. 3A), the posterior total-body image had adequate quality for bone interpretation, but the anterior image appeared to be blurred and was uninterpretable. One of the technologists suggested that 1 head of the dual-head gamma camera must be out of order. Head I was found to be off-peak, secondary to malfunction of a photomultiplier tube. The malfunctioning photomultiplier tube was replaced, and the function of the dual-head camera returned to normal the next day.

In reviewing the 2 myocardial SPECT studies, we found that the abnormalities involving the left ventricular lateral wall showed the same pattern. In examining the timing of the photopeak shift of head I, we found that the apparent malfunction had occurred after the second patient's ^{201}Tl SPECT study but before the first patient's dipyridamole ^{99m}Tc-tetrofosmin study. The off-peak period of head I had occurred during the ^{99m}Tc-tetrofosmin gated SPECT portion of the dual-isotope acquisition and before the bone scanning was performed. Artifacts were present in the individual images of all 3 consecutive patients. All artifacts resulted from the spontaneous off-peak status of head I, and the cardiac patients were later reimaged with ^{99m}Tc-labeled compounds—tetrofosmin or HMDP.

We again obtained multiple anterior images of the 4th patient soon after we found the artifacts in the anterior view.

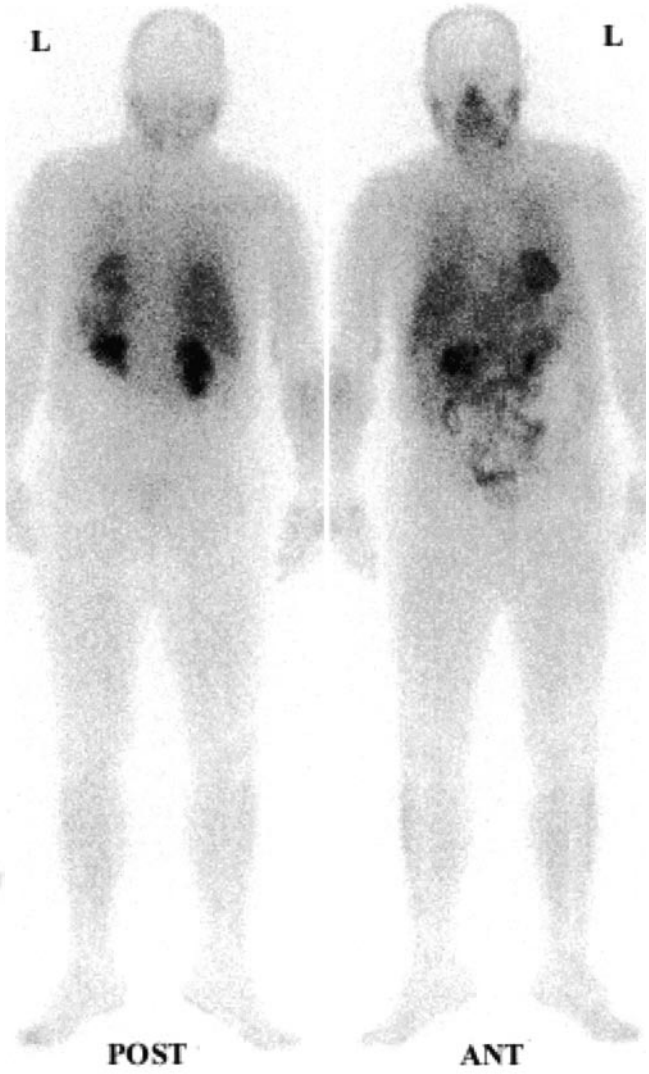

FIGURE 1. Total-body ^{201}Tl-chloride anterior (ANT) and posterior (POST) images. Small defect is in inferolateral aspect of right kidney; physiologic distribution of ^{201}Tl-chloride in body is normal.

These images were obtained by the normal (head II) detector and were readable (Fig. 3B). The second patient of the day (and the first patient for dual-isotope SPECT) was still in the hospital and underwent dipyridamole SPECT with the normal head (head II) of the dual-head gamma camera; the images showed normal perfusion of the left ventricular walls (Fig. 4A). The third patient of the day (the second patient for dual-isotope SPECT) had gone home already, and we repeated this patient's ^{99m}Tc-tetrofosmin gated SPECT 9 d later (Fig. 4B).

For the ^{99m}Tc-tetrofosmin gated studies, the left ventricular ejection fraction (LVEF) for the first cardiac SPECT study was calculated at 40% (normal value is $\geq$50%) at off-peak status and 60% at on-peak status using head II. The LVEF for the second cardiac SPECT study was calculated at 20% at off-peak status and 20% using the normal-functioning head; for this patient, rest SPECT images showed

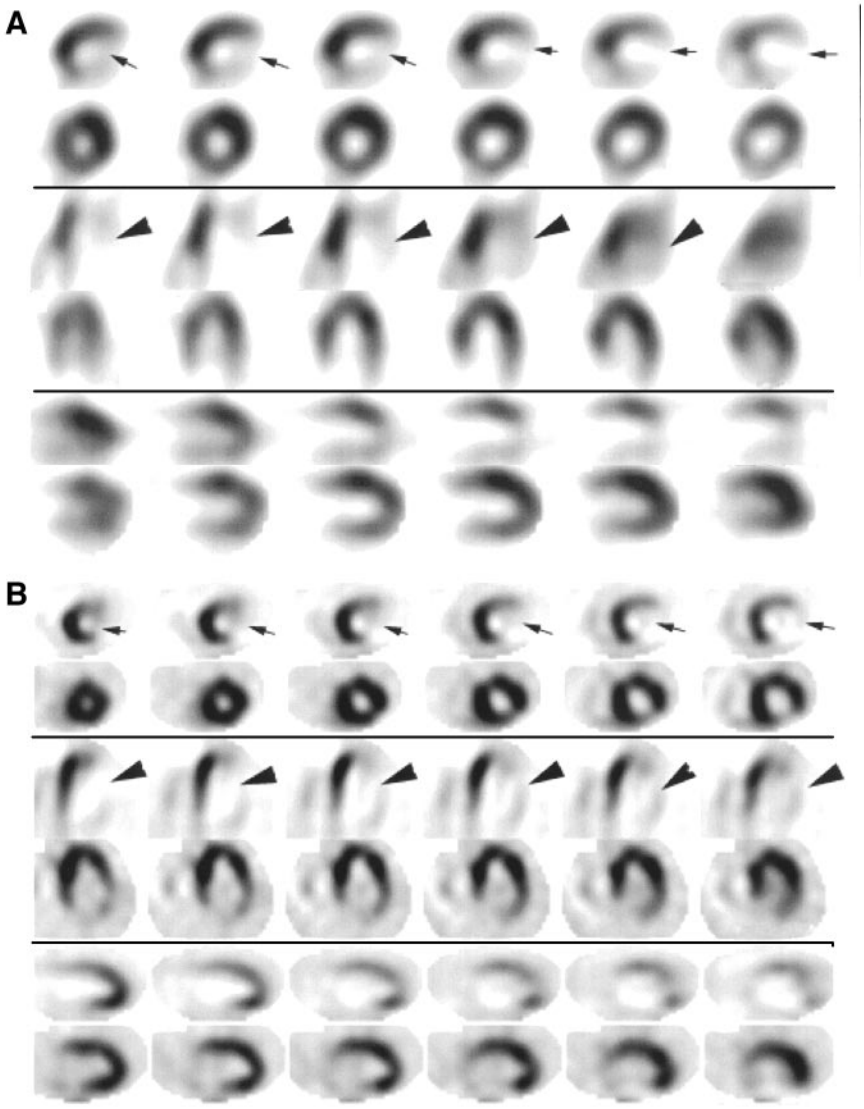

FIGURE 2. (A) Dual-isotope dipyridamole ^{99m}Tc-tetrofosmin (top images in each row) and rest ^{201}Tl (bottom images in each row) myocardial SPECT images from first myocardial SPECT examination. Uptake is virtually absent in apical, lateral, and inferior walls and is decreased in anterior wall on ^{99m}Tc-tetrofosmin SPECT images; perfusion of these walls on ^{201}Tl SPECT images is normal. Absence of perfusion in lateral wall is indicated by arrow on short-axis image and by arrowhead on horizontal longitudinal-axis image. Accordingly, LVEF was calculated as 40%. (B) Dual-isotope dipyridamole (top images in each row) ^{99m}Tc-tetrofosmin and rest ^{201}Tl (bottom images in each row) myocardial SPECT images of second myocardial SPECT examination. Again, uptake is virtually absent in apical, lateral, and inferior walls and is decreased in anterior wall on ^{99m}Tc-tetrofosmin SPECT images. ^{201}Tl SPECT images show normal perfusion in apical, lateral, and anterior walls; defect remains in most-inferior wall. Top 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) short axes; middle 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) horizontal axes; bottom 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) vertical axes.

left ventricular lateral and inferior perfusion abnormalities as shown in Figure 4B.

DISCUSSION

If the 4th patient's planar anterior bone scan had not been of poor quality because of scatter obscuring the bone margins or lesions, we might have failed to discover the off-peak status of the camera head. Planar images of inadequate quality or with reduced contrast, such as was seen on the anterior whole-body bone scan of the 4th patient, were easy to detect. We did not find the SPECT images to be sufficiently degraded to prompt further investigation; however, if the same pattern of perfusion abnormalities involving the lateral and inferior wall were to be seen in 2 consecutive patients, suspicion might be raised that the camera is malfunctioning.

After a gamma camera has correctly been peaked, daily tests of uniformity, resolution, and linearity should be performed as a quality control check. Images of inadequate or poor quality can result from too few counts (*2*,*3*). As the counts or information densities increase, the quality of the

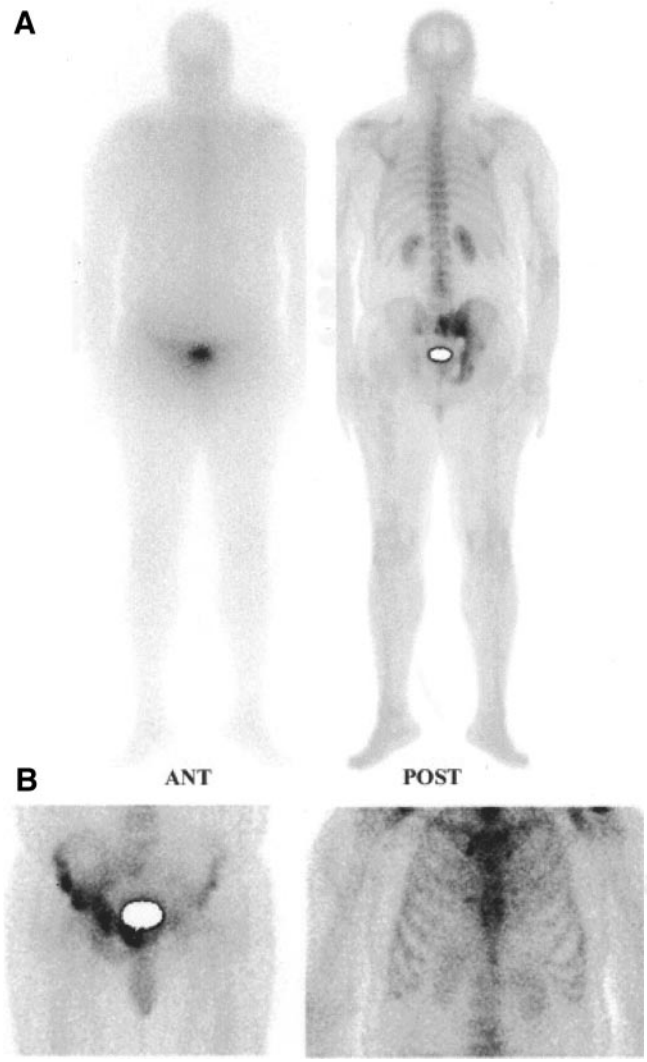

FIGURE 3. (A) ^{99m}Tc-HMDP anterior (ANT) and posterior (POST) total-body bone images. Markedly decreased activity and loss of contrast in bone structures are noted in anterior image. Posterior image shows abnormally increased activity in right hemipelvis, especially in sacrum and lower portion of right sacroiliac joint; this patient was known to have Paget's disease of bone and was followed up by bone scanning. (B) Anterior images of chest, abdomen, and pelvis obtained by head II show increased uptake in right pelvis.

images also increases, the image becomes more formative, and thus the diagnosis is easier (*2*,*3*). The production of artifacts by off-peak status has been well described (*4*). Images acquired during an off-peak period may show various types of artifacts: If the energy window is set too high, it may exclude most or all of the available photons. If the window is shifted too low, the images contain increased scatter. As a result, image quality becomes degraded, with blurring instead of sharp image detail and good contrast (*4*). Degraded images secondary to off-peak status were easily detectable for planar studies but not for SPECT studies.

There has been 1 case report describing a similar abnormality with spontaneous off-peaking, which mimicked myocardial ischemia, in myocardial SPECT (*1*). In that report, stress–rest ^{201}Tl-chloride myocardial SPECT showed significantly reversible redistribution because of a spontaneous shift in the peak of 1 head of a 3-head Picker camera (*1*). After adjustment of the photopeak of the head, SPECT was repeated and showed normal left ventricular activity (*1*). Likewise, our 2 patients' dual-isotope myocardial gated ^{99m}Tc-tetrofosmin SPECT studies (Figs. 2A and 3A) gave artifacts in the lateral and inferior walls that mimicked hypoperfusion and resolved on acquisition repeated using the normal head of the dual-head camera or repeated after the head was adjusted or fixed.

In addition to artifacts such as the perfusion abnormalities of the left ventricular wall that have been reported previously (*1*) and here, the off-peak status of the camera might result in lower LVEF and abnormal motion in gated cardiac SPECT studies. It is understandable that artifacts caused by an off-peak camera leading to inaccurate wall-motion signals and inaccurate LVEFs have not been previously reported.

Retrospective analysis of the off-peak status of head I showed that the off-peak status occurred after all ^{201}Tl-chloride imaging had been completed and before ^{99m}Tc-tetrofosmin SPECT had begun. Older gamma cameras should be peaked before a switch to a new radionuclide. However, our camera is peaked automatically; therefore, manual peaking is not required before a switch to a new radionuclide. Incidentally, the off-peak status of the camera head occurred when ^{201}Tl was switched to ^{99m}Tc.

CONCLUSION

Four patients were scheduled to undergo imaging on a dual-head gamma camera on the same morning. An off-peak status of 1 head of the dual-head camera occurred with ^{99m}Tc-labeled compounds and resulted in artifacts on myocardial gated SPECT images. The artifacts resembled left ventricular perfusion abnormalities and an inaccurate LVEF in 1 of the 2 patients who underwent gated SPECT and a degraded planar anterior image in the patient who underwent bone scanning. Soon after the electronic off-peak status was found, we repeated imaging of the patient who had the degraded bone image and the patient who had left ventricular wall abnormalities. The off-peak status was caused by a malfunction of a photomultiplier tube, and the tube was replaced. Degradation of planar images, such as our bone scans, because of off-peak status appears to be easily identifiable. Gated cardiac SPECT findings resulting from off-peak status, including reversible defects, left ventricular wall motion abnormalities, and faulty LVEF, were not easy to discover and have not, to our knowledge, been previously reported. When one observes the same pattern of SPECT perfusion abnormalities in consecutive patients, one should be alert to the possibility that the abnormalities may, in fact, be artifacts.

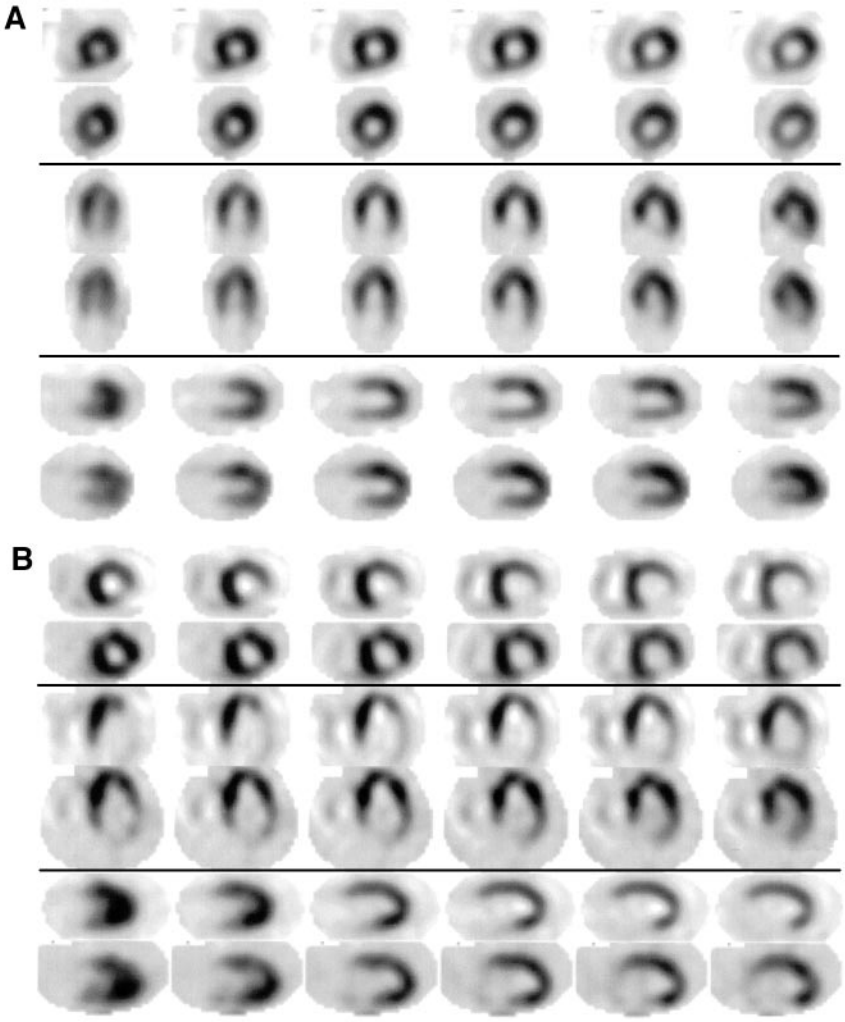

FIGURE 4. (A) Dual-isotope dipyridamole ^{99m}Tc-tetrofosmin (top images in each row) and rest ^{201}Tl (bottom images in each row) myocardial SPECT images from SPECT examination repeated using head II. Previously noted perfusion defect in left ventricular walls on ^{99m}Tc-tetrofosmin images is no longer seen; SPECT images are interpreted as showing normal myocardial perfusion with no ischemia. This patient's LVEF was calculated as 60%. (B) Dual-isotope dipyridamole (top images in each row) ^{99m}Tc-tetrofosmin and rest ^{201}Tl (bottom images in each row) myocardial SPECT images obtained 9 d later. ^{99m}Tc-Tetrofosmin SPECT images show absence of or decreased uptake in lateral wall (instead of absence of perfusion, as in Fig. 2B) and absence of perfusion in inferior wall. ^{201}Tl-Chloride SPECT images show redistribution in lateral wall and unchanged inferior defect. Top 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) short axes; middle 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) horizontal axes; bottom 2 rows = stress (^{99m}Tc-tetrofosmin) and rest (^{201}Tl-chloride) vertical axes.

REFERENCES

1. Nitke SJ. Off-peak detector mimicking ischemia on myocardial scan. *Clin Nucl Med.* 1999;24:276.
2. *Basic Instrumentation in Essentials of Nuclear Medicine Imaging*. 3rd ed. Philadelphia, PA: WB Saunders; 1991:15–36.
3. Early PJ, Miller WH. Considerations of counting and imaging. In: Early PJ, Sodee DB, eds. *Principles and Practice of Nuclear Medicine.* 2nd ed. St Louis, MO: Mosby; 1995:177–189.
4. Instrumentation and radiopharmaceuticals. In: *Practical Nuclear Medicine.* Philadelphia, PA: W.B. Saunders Co., Harcourt Brace Jovanovich, Inc.; 1992:27–69.