Simulated Frame-Loss Artifacts in Myocardial Perfusion SPECT Imaging: The Difference Between Single- and Dual-Headed Systems

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Objective: Right-angle dual-headed tomography has increased cardiac SPECT utility by cutting acquisition time in half which enhances gating capabilities. When gating, however, a deceleration in heart rate, due to a return to baseline rate after stress or lessened anxiety at the end of a study, may significantly affect the last step(s) of a gated study with possible frame or information loss. The purpose of this study was to illustrate the artifacts produced in myocardial perfusion studies when a frame or frames are lost in single- and dual-detector SPECT imaging methodologies.

Methods: A near-normal ^{99m}Tc-sestamibi study was obtained using a dual-headed camera system fitted with high-resolution, long-bore collimators. The normal study was processed including all frames (1–32). To demonstrate the effect of losing frames on a dual-headed system, the study was processed three different ways to simulate frame loss.

Results: Loss of frames at the end of a SPECT acquisition results in significant inferoseptal wall defects, left ventricular lumen narrowing, as well as thinning of the anterior and lateral walls. The overall appearance of the heart is a more oval-shaped heart with decreased perfusion. The effect of losing the last frame in a dual-headed camera system as opposed to losing the last frame in a single-headed camera system is more substantial.

Conclusion: A scan resulting in the loss of a frame in either a single- or a dual-headed camera system creates artifacts in the myocardial wall and should always be repeated. It is significant to note that artifacts present in a dual-headed system are much more prevalent than in a single-headed system due to the nature of dual-headed acquisition parameters.

Key Words: artifacts; single-photon emission computed tomography; frame loss; myocardial perfusion

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Myocardial perfusion imaging with SPECT radionuclides has increased the sensitivity and the specificity of coronary artery disease detection to approximately 90% and 80%, respectively (*1,2*). SPECT imaging provides the capability of viewing organs and systems in three dimensions. In addition, SPECT produces high-contrast images and quantitative information (*3*). Also, with the advent of multidetector systems, scan time has decreased resulting in increased patient comfort and increased patient load capabilities (*4*). With the increasing complexity of image acquisition, however, comes a wide range of system-related artifacts (*5–8*), in addition to patient-related artifacts such as motion and heart creep (*9–18*).

This study demonstrated the types and severity of artifacts created when dropping the last frame or frames in a dual-detector system as compared to frame losses in a single-detector system. Among the causes of frame loss are system malfunction and the dropping of a frame(s) at the end of a gated study because the patient's R-R interval dropped below the preset window of an acceptable R-R interval.

Gated SPECT is the regulation of the framing rate with electrocardiograph signals from the patient, which allows the calculation of the left ventricular ejection fraction and views of myocardial wall motion (*19*). Before scanning, approximately a 10% window is centered around the average R-R interval determined by the patient's electrocardiograph signals. The R-R interval is the average time between R-waves, which is calculated from the heart rate in beats per second (*20,21*).

When frames are dropped at the end of a study, or if a camera malfunction occurs and frames are not acquired, the resulting image is incomplete. The camera stops acquiring counts for the study when the patient's heart rate or R-R interval drops below the preset window during acquisition. This drop in the R-R interval typically occurs toward the end of a study as the patient is cooling down from a stress test or as the anxiety of the exam wears off. Often a patient cannot tolerate additional scanning. Thus, the incomplete scan is rendered satisfactory and is dictated without any serious consideration to the artifacts associated with the frame(s) lost.

Frame-loss artifacts can have important implications in patient coronary artery disease detection. The implications include false-positive disease findings and unwarranted medical care costs.

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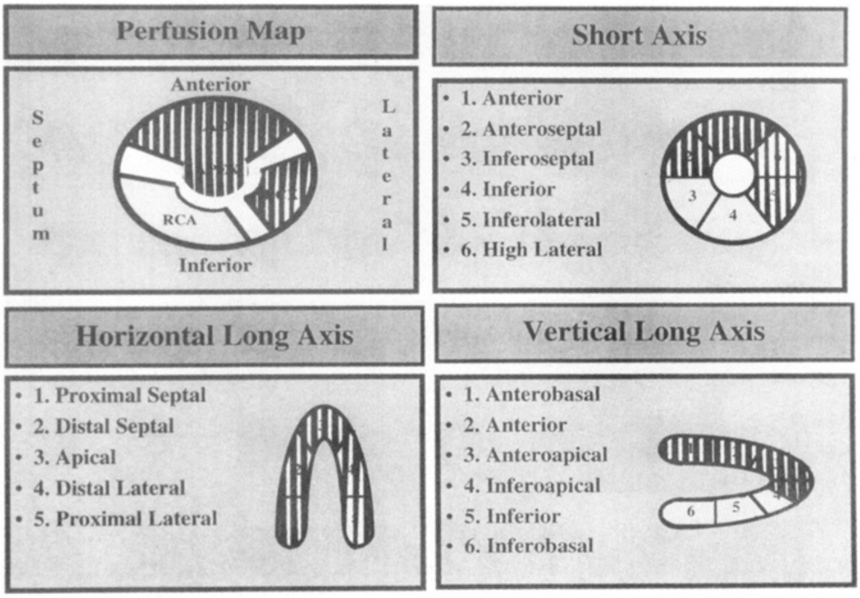

FIGURE 1. Myocardial segments.

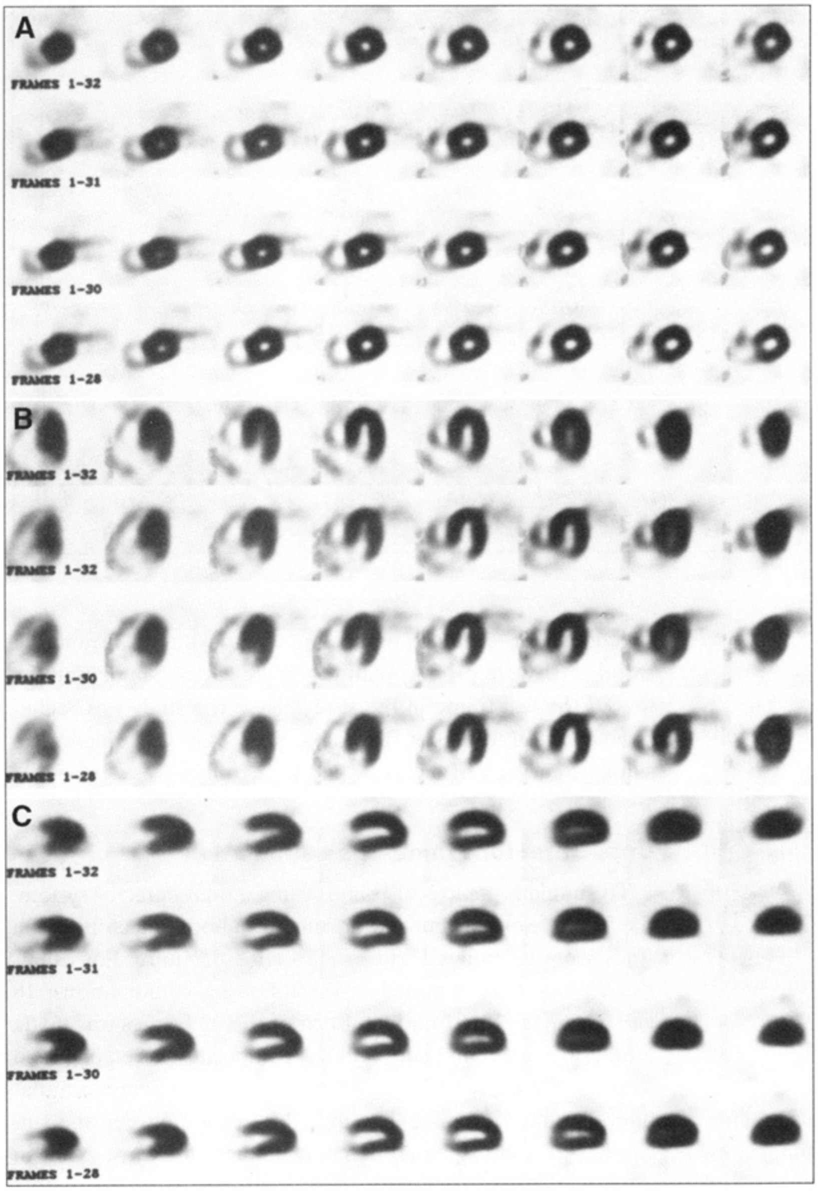

FIGURE 2. Single-detector system. Comparisons of a normal ^{99m}Tc-sestamibi SPECT study to studies in which frames were dropped. The three views depicted include: (A) the short axis; (B) the horizontal long axis; and (C) the vertical long axis. Each of the three views includes a normal study containing Frames 1–32 and three incomplete studies. The incomplete studies depict studies in which one, two and four frames, respectively, are subtracted from the studies.

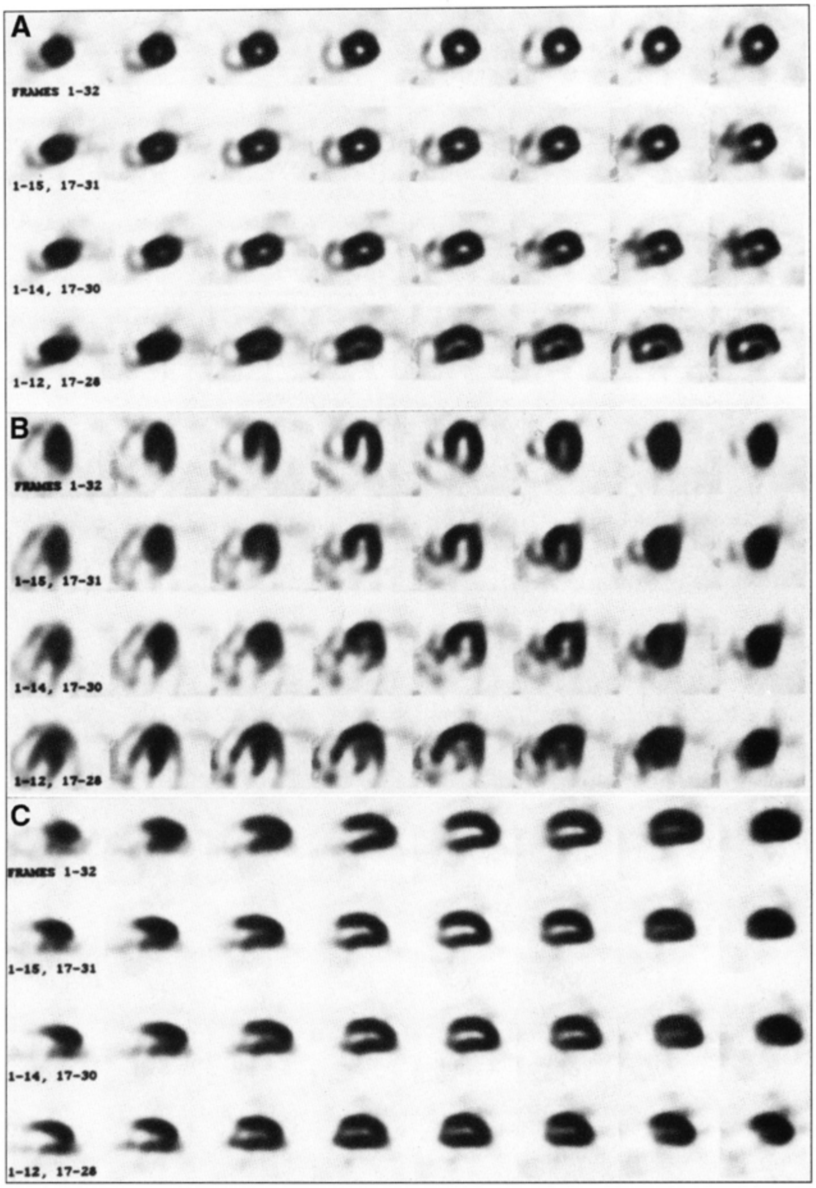

FIGURE 3. Dual-detector system. Comparisons of a normal ^{99m}Tc-sestamibi SPECT study to studies in which frames were dropped. The three views depicted include: (A) the short axis; (B) the horizontal long axis; and (C) the vertical long axis. Each of the three views includes a normal study containing Frames 1–32 and three incomplete studies. The incomplete studies appear in the following order after the normal study: a study in which Frames 1–15 and 17–31 were added together; a second incomplete study in which Frames 1–14 and 17–30 were added together; and a third study in which Frames 1–12 and 17–28 were added together.

MATERIALS AND METHODS

Image Acquisition and Processing

At peak exercise a patient was injected with approximately 30 mCi ^{99m}Tc-sestamibi and stressed for an additional minute. After the treadmill exercise, the patient was imaged. SPECT imaging was performed using a dual-headed camera system fitted with high-resolution, long-bore collimators, positioned at a 90° angle. A 64 × 64 word matrix was used, with 16 frames on each detector head for a total of 32 frames (40 sec/frame). The designated start angle was 315°. On completion of the acquisition, the resulting image was checked for motion, reconstructed and reoriented.

Single-Detector Frame-Loss Simulation

To simulate frame losses using a single-headed detector, each of the 32 frames was made into 32 individual composites. The composites were joined together using a frame append function. For example, individual composites of Frames 1 through 31 were produced and then appended, simulating the loss of the last frame in the study. Then the study was reconstructed and reoriented. The same procedure was followed to simulate the loss of one, two and four frames.

Dual-Detector Frame-Loss Simulation

To simulate the loss of frames using a dual-detector system, the frames were dropped uniformly from both detectors as if a study were terminated with frames left to acquire. For example, frames were dropped in the following combinations: 16 and 32; or 15, 16, 31 and 32. Each of the 32 frames was made into individual composites and the composites were appended with the append function, as with the single-detector simulation of frame dropping. The only difference between the single-detector and the dual-detector methodologies was that in the dual-detector simulation there were frames in the middle that were dropped because of the nature of 90° SPECT acquisition. For example, the individual composites of Frames 1–15 and 17–31 were appended together, reconstructed and reoriented. The same procedure was followed to simulate the loss of Frames 15, 16, 31 and 32 in a study. To exaggerate the effects of frame loss on a dual-headed system, the procedure was followed with Frames 13–16 and 29–32 missing.

Note that all of the studies were reconstructed and reoriented with the same filters, x-offsets and reorienting parameters for both the single- and dual-detector studies. All images were visually interpreted for analysis according to Figure 1.

RESULTS

These simulations showed that the inferior and septal walls were affected the most by the loss of frames at the end of a myocardial perfusion study. Furthermore, the results demonstrated that the inferoseptal wall defects noted in the comparison of single- and dual-headed detector systems are more prevalent in the dual-headed system. The results are depicted in Figures 2 and 3. The short, horizontal-long and vertical-long axes are depicted in these figures for both the single- and dual-detector systems. Other effects of dropping frames included an artificial narrowing of the myocardial lumen and visual distortions of the myocardium. The anterior and lateral walls were thinned, having less perfusion in the abnormal studies as compared to the normal acquisition. The apex was least affected by frame loss, demonstrating no significant difference between normal studies and studies with frame loss.

DISCUSSION

Artifacts in SPECT imaging are accentuated in comparison to planar imaging. In addition, artifacts due to frame loss in multidetector systems are greater and more prominent than artifacts due to frame loss in single-detector systems. This study illustrates the importance of repeat imaging of patients when frames are lost with either single- or dual-detector systems. It is important to note that this study was done on a normally perfused myocardium, and it is suggested that abnormal studies would yield greater defects. Thus, patients could be mismanaged and could undergo unnecessary procedures after an inaccurate interpretation of their perfusion scan.

CONCLUSION

Artifacts are introduced by losing frames during a ^{99m}Tc-sestamibi myocardial perfusion gated SPECT study. Specifically, the false-positive artifacts occur in the inferoseptal region and, to a lesser degree, in the anterior and lateral walls. The severity of the effect depends on the number of frames and the number of detectors in the system. The artifacts increase in severity with each frame lost, and the effects are accentuated with dual-headed detection systems as compared to single-headed detection systems.

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