

SPECT Quality Improvement

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Objective: Obtaining quality SPECT data is a vital component of the total SPECT procedure. A patient study was undertaken to document the various causes of artifacts in order to pinpoint methods that will lead to an improvement in the quality of SPECT images.

Methods: My institution's laboratory monitored 1,000 stress/reinjection SPECT thallium patient studies to determine how to improve SPECT imaging.

Results: Patient motion was identified as a major potential cause of imaging artifacts. Heart shift due to patient motion may result in false-positive studies.

Conclusion: Large improvements in SPECT imaging quality can be obtained by adherence to a few meaningful technical points and maneuvers.

Key Words: SPECT, quality control, artifacts.

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Single-photon emission computed tomography (SPECT) quality control should commence before a patient study is acquired. Obtaining quality SPECT data during the study is a critical component of the total SPECT procedure. My institution's laboratory monitored 1,000 stress/reinjection SPECT thallium patient studies to determine how to improve SPECT imaging. We looked for potential imaging artifacts, helpful techniques, and ways to improve SPECT quality.

Patient motion was identified as a major potential cause of imaging artifacts. Heart shift due to patient motion may result in false-positive studies (1-2). Heart shift occurred in patients through arm movement, coughing, deep tidal breathing, shivering, leg shifting due to hip pain or leg cramps, jerking awake from sleep, upward creep, or talking.

Other variables besides patient motion can affect SPECT quality. Collimators that shift during imaging, pallet attenuation, and upright versus supine injection were also identified as potential causes of artifacts.

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PATIENTS AND METHODS

Material

The study material consisted of planar and SPECT thallium-201 (^{201}Tl) stress/reinjection studies performed on 1,000 consecutive patients. Seven hundred sixteen patients underwent symptom-limited treadmill exercise testing utilizing the Bruce protocol. Two hundred eighty-four had pharmacologic stress testing with intravenous dipyridamole (0.258 mg/kg over 4 min).

Imaging Protocol

Approximately 3 mCi of ^{201}Tl was intravenously injected at peak exercise or 4 min after completion of dipyridamole injection. The patient continued exercise for 1 min postinjection during the Bruce protocol.

Planar myocardial imaging was begun within 5 min of ^{201}Tl injection, using a single-crystal gamma camera equipped with a low-energy all-purpose collimator, connected on line to a computer.

The planar study consisted of a 10° right anterior oblique (RAO) view and a 35° left anterior oblique (LAO) view acquired in a 128 × 128 word matrix with a 1.5 zoom. Each planar view was acquired for 5 min. SPECT imaging was started immediately following the planar imaging. The SPECT images were acquired over 180° starting at the 45° RAO projection. SPECT data were acquired for 32 views at 40 sec/view in a 64 × 64 word matrix. The camera pulse height analyzer was set with a 20% window centered on 70 keV and a 10% window centered on 166 keV. The patient was reinjected with approximately 1 mCi of ^{201}Tl at 3.5 to 4 hr postinjection. The same sets of planar and SPECT images were acquired after reinjection. The patient was observed during the stress and reinjection SPECT imaging. If patients moved, they were reminded to remain still.

The SPECT images were corrected for the mechanical center of rotation, flood-field uniformity, and heart motion. To detect heart motion, single lines were drawn above and below the heart on the raw projected data. The image was shifted after observing heart shift by concomitantly viewing the cine of the raw projected data and the two lines. The number of pixels shifted in the Y-axis were recorded, along

with the frame number during motion correction. The transaxial slices were reconstructed using a fifth order Butterworth with a 0.40 Nyquist cutoff frequency on the ramp filter. The standard vertical long, horizontal long, and short-axis views were reconstructed from the transverse slices.

RESULTS

We corrected 170 stress studies (17%) and 127 reinjected studies (12.7%) for heart shift or 14.85% out of 2,000 studies. Forty-nine patients (4.9%) were corrected on both the stress and reinjection images. These patients could not remain still due primarily to arthritic or generalized left shoulder pain. Other reasons included hip pain, back pain, or nervousness due to claustrophobia or anxiety. We found that patients tended to move their arms more when they were not set up in a comfortable position. Patients who had their left arms above their heads and right arms by their sides usually had the most difficult time since their left arms were not supported as easily. These patients tended to move their arms more, causing a slight shift in the heart (usually ± 1 pixel on several frames). Heart shift also occurred in patients who were coughing, experiencing deep tidal breathing, shivering, moving a leg because of hip pain or leg cramps, jerking awake from sleep, or talking.

Only 13 out of 1,000 stress studies (1.3%) had possible cardiac creep. A study was considered to have cardiac creep if four or more of the final frames in the SPECT study had to be shifted down. Only 11 stress studies with cardiac creep had to be shifted down one pixel. The other two cases had to be shifted down two pixels. There were only 11 studies (1.1%) that had to be shifted ± 2 pixels. One reinjection study had 1 frame shift 2 pixels, and 10 other stress studies (including the two cardiac creep studies mentioned above) were moved ± 2 pixels. One stress study had a frame that was shifted +3 pixels because of intense coughing. No patient studies had to be shifted more than 3 pixels.

DISCUSSION

The percentage of upward creep studies detected in our lab (1.3%) was noticeably lower than that reported by Mester et al. (23%) (3) and Friedman et al. (14%) (4). Our methods are similar to Friedman's, since we acquired the two planar images first. The differences in study results may be because we watched the patients more closely for possible arm movement. Arm movement that occurs during the final frames of SPECT can mimic upward creep. This was detected on a few patients who moved their arms downward and back behind their heads causing the shoulder and chest to shift upward. We were able to minimize heart shift during SPECT by asking patients to stop moving their arms (or legs) if motion was observed. Our data show that by continuously observing the patient, most major pixel shifts (± 2 pixels or greater) can be avoided. Since we are in a clinic setting, our patients were probably more cooperative when asked to hold still, but this shows that movement is the major source of pixel shift versus upward creep.

SPECT examinations that involve imaging the trunk of the body require that patients raise their arms over or behind their heads while lying supine for prolonged periods of time. Most patients have trouble with this position, because their shoulders and back get sore or stiff. Arm movement during SPECT is a major source of patient motion because patients get tired of holding their arms up without support. The challenge for the technologist is to keep patients comfortable and motionless in this position.

There are a variety of devices on the market to assist in keeping patients still with their arms in the appropriate position. Most of the devices are attached to the head of the imaging table. One of these devices has bars that the patient grasps with one or both hands (Fig. 1). This device puts strain on the shoulders since arm support is lacking. Alternatively, a set of mechanical wings called an elbow rest, allows patients to simply rest their arms against the supporting buttress (Fig. 2). This device is usually made out of impact-resistant acrylic material, while other wing devices are made of plexiglass. It is important to be very careful with the plexiglass devices as they are easily cracked if struck by the rotating camera. Some arm devices have Velcro straps used to anchor the arms of the patient (Fig. 3). The patient must have fairly flexible upper extremities in order to use this type of device.

An economical, yet comfortable alternative to these rigid arm restraint devices involves the use of hospital tape (Fig. 4). Patients are asked to cup their hands behind their heads and position their elbows at approximately a 45° angle to the body. Then, a band of tape is wrapped around both elbows. This allows patients to rest their arms against the tape and takes pressure off their shoulders, stabilizing both arms and shoulders. The tape also helps to prevent arm movement. (This taping technique works well when imaging with computed tomography or magnetic resonance imaging. The other devices mentioned above, may not work due to the space limitations inside the small doughnut-shaped imaging equipment.) Also, patients should cup their hands behind their heads instead of crossing their fingers to alleviate finger numbness.

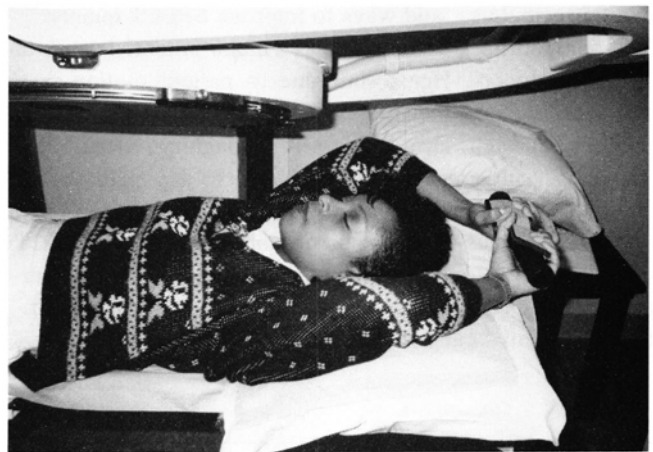


FIG. 1. SPECT handgrips.

Most ^{201}Tl cardiac SPECT examinations start at the 45° RAO position and end at an LPO position (180° clockwise acquisition). The camera rotates around the left side of the body, so the left arm is the only arm in the way. Some technologists have patients keep their right arms down by their sides, with the left arms up. This positioning technique works well with patients who have arthritis or pain in their right shoulders, but it is a difficult position for many patients to maintain. The symmetrical approach (both arms up) is usually more comfortable.

If the technologist does not understand the patients' complaints, the technologist might try lying on the imaging table to determine how to improve patient comfort. Maybe the pad on the exam table is too thin and uncomfortable. A sponge device or pillows placed under the knees will take pressure off the patient's back. The technologist should also consider positioning the patient in the prone position if the patient is more comfortable being prone than supine. The technologist should determine the extent of table or pallet attenuation before imaging the heart when the patient is in the prone position (5). For example, our department imaged a patient in the prone position because an enlarged thyroid (goiter) had caused respiratory distress in the supine position. When positioned supine, the patient had coughing episodes that caused patient motion and would have created potential misleading artifacts. Sometimes a drink of water or a cough drop will alleviate patient coughing that is related to throat dryness created during exercise. In addition, we have found that playing soft music in the background may help alleviate patient anxiety and reduce patient movement.

Once the patient is comfortable, he or she may want to take a nap. Nevertheless, the patient should not be allowed to fall asleep during SPECT imaging of the heart. Some patients move with a jerking motion when they awake and some patients may move their arms down by their sides during sleep. Also, sleeping leads to deeper tidal breathing, which causes the heart to shift during the acquisition (6). This is especially true when doing SPECT of the heart on male patients, because they tend to breathe more deeply during sleep. This heart shift can be verified on the cine loop replay of the raw planar data acquired during SPECT.

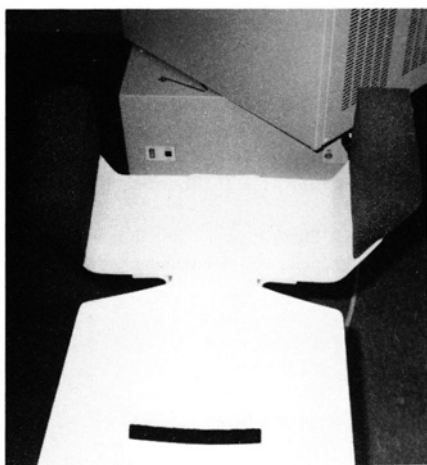


FIG. 2. Elbow rest. Foam was glued to wings for added comfort.

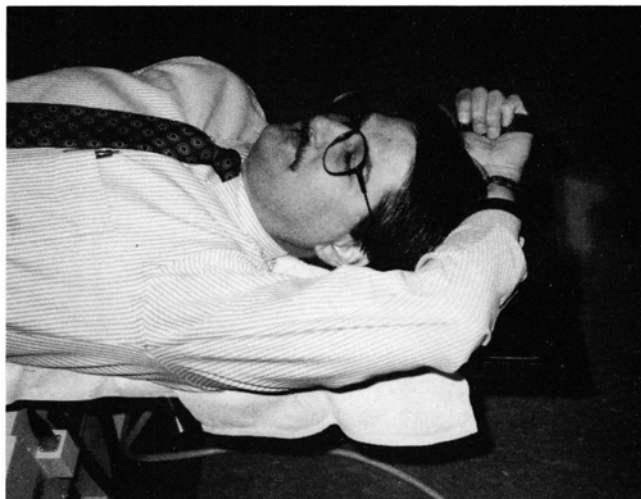


FIG. 3. Velcro strip arm rest.

Many nuclear medicine departments have incorporated a reinjected dose of thallium into their cardiac protocols (7-11). An intravenous (IV) catheter is placed in a hand or arm vein to allow the technologist to inject thallium during exercise and just prior to the resting images (reinjected dose). Sometimes the right arm may have the only accessible veins. Therefore, residual IV activity may be detected when the right arm is down. This residual IV activity may interfere with processing when the activity is directly lateral and in line with the heart and imaging crystal. Other external sources of radioactivity may inadvertently be carried into the imaging room, or a previously injected patient may walk past the room. Proper shielding is very important since sometimes these external sources cannot be avoided.

Most technologists are asked to do too many things at one time. The technologists may be processing the previous study or doing paperwork while imaging is in progress. Nevertheless, it is imperative to watch the patient at all times to make sure he or she holds still during the long acquisition period. In a busy department, it may not always be possible to keep an eye on the patient, but the technologist can use the sense of hearing to detect movement. Using examination paper instead of cloth sheets can help in this regard. The technologist can hear the patient moving on exam paper, because it makes a scraping or crinkling sound. A gentle reminder to the patient not to move is sometimes met with surprise, because they may not realize you are paying attention. Also, examination paper minimizes the amount of lint in the area, as opposed to cotton sheets. The excess lint in the examination room created by cotton sheets is attracted to the filters covering the intake fans on the imaging equipment and computers. If these filters are not cleaned frequently, this can cause overheating of the equipment.

Breast tissue can attenuate the low energy photons of ^{201}Tl , causing attenuation artifacts during cardiac imaging (12). Some nuclear medicine departments attempt to decrease this attenuation by taping the left breast back, which may actually increase attenuation artifacts in certain areas

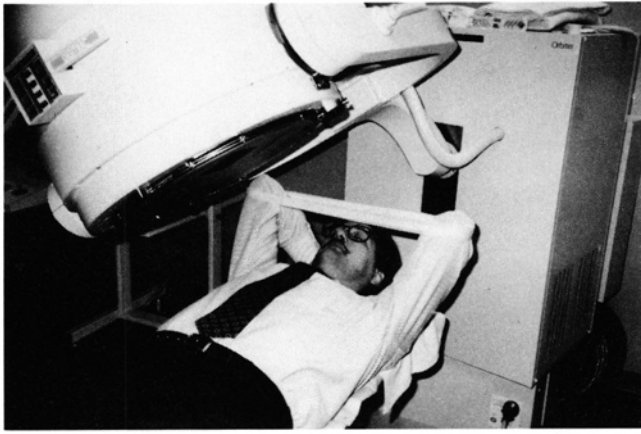


FIG. 4. Shoulder strain is reduced by relaxing against tape wrapped around elbows.

over the heart. As the breast is lifted upward toward the camera, more breast tissue is over a smaller area of the heart. This increases nonuniform attenuation over a localized area of the heart, as opposed to the more uniform attenuation over the entire heart that occurs without such taping. Conducting cardiac imaging on prone women may be a better way to reduce breast attenuation in a localized area.

Pallets are designed with various lightweight materials. This is done in order to minimize the attenuation created by the table. However, because of this lightweight material, some pallets tend to bounce slightly when the patient moves or talks. Technologists should watch carefully for this type of motion and make corrections for it if it occurs.

Some patients will get leg cramps on the imaging table. Leg cramps can usually be alleviated by allowing the patient to cool down at a slow pace on the treadmill. If the patient still has leg cramps after the imaging protocol has already started, slowly raise the leg slightly off the table a few inches and ask the patient to press his or her leg downward as upward resistance is supplied. This maneuver stretches the muscles.

Other helpful hints for SPECT imaging include being sure that the inserted collimators are secured in position at both the 0° and 90° positions. Certain insert collimators have a tendency to shift during SPECT, even though they may seem to be locked tightly in place at the 0° collimator position. Be careful when rotating the collimator in order to remove it for intrinsic studies. If the locks aren't released, the collimator can be forced out; this will jam the collimator. Repeated jarring may cause defects in the collimator septa.

For gated SPECT acquisition, make sure the gel on the electrocardiogram (ECG) pad has not dried out. This can lead to missed or inappropriate ECG signals and create serious artifacts. Every once in a while, you may open a new

package and find dried ECG gel, but generally the gel dries out because the package has been left opened overnight or for more extended periods.

More departments are utilizing adenosine, dobutamine, and persantine for pharmacologic stress testing (13). These patients are usually supine when the pharmaceutical stress agent and the ²⁰¹Tl or other radiopharmaceutical are injected. This allows more of the radiopharmaceutical to enter the liver. The liver uptake can be decreased by injecting the patient in the upright position.

In summary, big improvements in imaging quality can be obtained by adherence to a few meaningful technical points and maneuvers.

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