Commentary

Aspects of Patient Imaging with SPECT

Much has been written about the technical aspects of data acquisition and processing of single photon emission computed tomography (SPECT) studies; however, less has been discussed about the more practical aspects of patient comfort during a SPECT study. This article reviews, in a subjective way, these important aspects of SPECT imaging. The following discussion points out examples that the technologist should consider when imaging a patient tomographically. This should make SPECT imaging easier on the patient and therefore improve the quality of SPECT imaging.

QUALITY CONTROL

Before discussing SPECT patient imaging it is important to consider several details of quality control. When compared to planar imaging, SPECT imaging requires additional quality control procedures and closer attention to camera performance. These procedures include: 1) center of rotation (COR) measurement and correction; 2) uniformity testing and correction of the flood field; and 3) phantom studies to determine overall SPECT performance and to establish proper processing filters on the acquired data.

Incorrectly applied COR values can degrade image quality. It is recommended that the COR measurement be done once a day initially and then perhaps at less frequent intervals depending on the stability of the system. Also, depending on the stability of the camera system, uniformity correction should be done by acquiring at least a 30 million count flood image at frequent intervals. Artifacts can be created by applying an inaccurate or statistically poor flood correction to data reconstruction (*1*). We have found the frequency of acquiring a correction flood on our equipment is less than that of acquiring a COR value, since a 30 million count flood accumulation takes much more time than a COR acquisition. One convenient way to acquire the uniformity correction is to do it at the end of the day so that the correction is ready the following morning.

Phantom studies are helpful since every type of study and every camera system has its own characteristics. Optimal reconstruction parameters are determined by acquiring phantom data and experimenting with different reconstruction variables to achieve the best image quality. The technologist should have an understanding of the basics of SPECT data processing and thus be able to optimize SPECT image quality. Different acquisition schemes such as 180° acquisition and elliptical orbits should be tested with phantoms. Image reconstruction variables such as collimator, filter selection, acquisition time, etc., are factors that the technologist must test when generating the SPECT phantom images (*2*). It is not necessarily important to know how these programs work, but rather to know what happens to SPECT images when a variable is changed in the data reconstruction. For example, if one were to change the cut-off frequency from 0.4 to 0.8 pixels^{-1} what whould happen to the image quality? Figure 1 illustrates what happens to a transaxial slice through a set of blood pool transaxial images when the cut-off frequency in the data reconstruction is changed. By acquiring phantom studies and reconstructing the data, the technologist can get an idea of how the images change with variations in reconstruction parameters.

It is important to note that these quality control procedures should be done on each collimator that is used in SPECT studies. For example, a general purpose collimator used for thallium imaging may give a different COR value than a high resolution collimator used for bone imaging because of different collimating characteristics. The technologist should also periodically check the mechanical performance of a rotating gamma camera. The camera should move in the prescribed fashion and not deviate from that course while at the same time maintain field uniformity with rotation. Several articles have been written about quality control of a SPECT system that address these issues in more detail and should be reviewed by those who are responsible for SPECT quality control (*1–5*).

PATIENT IMAGING

General Imaging Considerations

Before positioning the patient on the tomographic bed, ask the patient specific questions about any possible limitation he or she might have in completing the exam. By knowing potential positioning difficulties in advance, adjustments can be made to make the patient more comfortable before scanning begins and not during the scan. An uncomfortable patient is more likely to move during imaging and thus decrease the chance of successful imaging. One aspect of SPECT imaging that differs from planar imaging is that during planar imaging the patient is allowed to move between images. If a long

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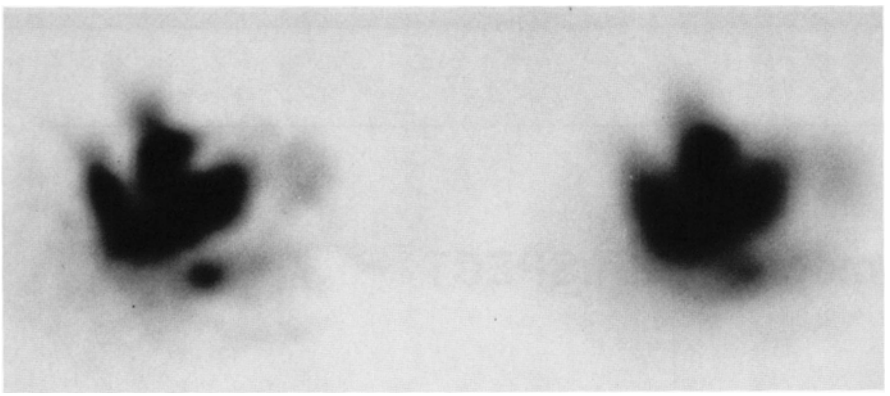

FIG. 1. These transaxial images of a blood pool study represent the effect of different cut-off frequencies on reconstructed data. The image on the left is much noisier and has sharper borders. It was processed with a cut-off frequency of 0.8 pixel^{-1}. The image on the right was processed with a cut-off frequency of 0.4 pixel^{-1}, and is much smoother, and has less definition of the ventricular cavity.

dynamic planar study is acquired, at least the patient is on a relatively comfortable wide bed. With SPECT imaging, the patient is asked not to move for a long period of time while laying on a narrow platform usually with the arms placed above the head in an unnatural position. Given these problems, it is important to recognize that the positioning of the patient is a critical step in maximizing patient comfort. Proper leg, back, and arm support help the patient remain comfortable and therefore not move during the study.

Once patient imaging has begun it is important that the technologist remain in the room with the patient. By remaining in the room, reminding and encouraging the patient to lie still, the technologist can also observe the motion of the camera and be sure that the camera clears potential obstacles such as IV lines and oxygen tanks.

Efficiency in setting up SPECT studies can also help the patient complete the exam. If the patient can remain still for only a limited time, it is important to minimize the positioning time and maximize the imaging time. One way to improve the efficiency of SPECT setup is to position the patient in a systematic fashion. For example, before the patient is on the bed the camera should be positioned in the lateral projection. Once the patient is on the table, adjust the bed height so that the area being imaged is in the center of the field of view. Next, move the camera to the anterior projection and recenter the patient. Then adjust the camera to clear the posterior oblique portions of the bed. The final check in this setup routine should be to make sure the camera head is level. By doing this type of systematic setup each time, positioning time can be reduced. Additionally, when procedures are consistantly done in the same manner the chances of making mistakes are decreased.

The remainder of this article addresses problems associated with imaging various parts of the body. Generally speaking, SPECT imaging can be broken up into four areas of imaging: head, chest, abdomen, and pelvis and legs. Each area has its own set of problems with respect to patient imaging.

Imaging the Head

SPECT imaging of the brain and skull has been shown to be helpful in studying cerebral blood flow and certain skeletal disorders. For example, the most useful images of ^{123}I iodoamphetamine, an agent that distributes in proportion to cerebral blood flow, are obtained by SPECT imaging. Bone scanning of temporal mandibular joints is enhanced by SPECT imaging (*6*). One problem inherent in imaging the head is the difficulty in getting the camera close to the head because of the interfering shoulders. Various techniques are available to decrease the camera's distance from the head. Cut away camera heads, slant hole collimation, and elliptical orbiting are a few of the modifications that are used to improve the resolution of SPECT scanning. Another approach that we have used is to acquire the data over 180° from anterior to posterior over the vertex. This technique works reasonably well for bone scanning but does not work well with the brain blood flow imaging agents because of the high lung activity seen when the camera is in the vertex position.

The key to successful head imaging is stabilization of the patient's head. One of the easiest ways to insure that the head will not move is to simply tape the head with adhesive tape to the table. Commercial head holders are also available and have several advantages because they not only support the head, but they also use velcro straps instead of adhesive tape. However, one must be aware of potential artifacts that can be created by the metal present in the commercial head holders (Fig. 2). Aside from stabilizing the head, it is also important to make the patient feel comfortable psychologically. Some patients who undergo SPECT head imaging find the camera intimidating, especially when placed directly over the face.

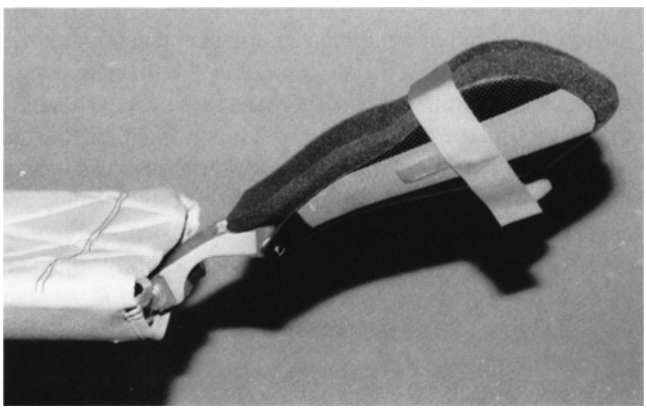

FIG. 2. A commercially available head holder that provides excellent support and head stability.

There are several techniques that can be used to decrease the patient's anxiety. By imaging in the lateral projection first, and then moving the camera posteriorly the patient will realize that the camera is safe and nonthreatening. Additionally, the lights in the room can be dimmed to help the patient relax. Music is also recognized as having a relaxing effect on patients (*7*). As discussed earlier, taking the time to explain the test being performed and helping the patient become as comfortable as possible will decrease the patient's urge to talk or move during the exam.

Imaging the Chest

The most extensive application of SPECT imaging of the chest is in studying myocardial perfusion with thallium-201. Other uses in studying the heart and chest include detecting myocardial infarction with technetium-99m (^{99m}Tc) pyrophosphate, evaluating regional wall motion and chamber volume of the heart with ^{99m}Tc-labeled red blood cells (*8*), and lymphoma staging with gallium-67 (*9*). This section, however, will focus primarily on imaging the heart. The aspects of patient positioning discussed here are basically the same with all types of chest imaging.

The main advantages SPECT imaging of the heart has over planar imaging are its ability to separate overlapping myocardial regions and the increased contrast resolution that it provides. SPECT cardiac imaging should be done with the arm(s) extended above the head so that arm attenuation will not cause an image artifact. Unfortunately, this can be quite uncomfortable for patients who suffer from arthritis or any other disease that limits the range of motion of the arms. This is the major complaint most patients give concerning this exam. Several things can be done to make such patients more comfortable during an exam. Consider the angle that the arm makes with the chest when in the resting position. When placed above the head during data acquisition, as in figure 3, the angle is at a maximum. Simply moving the forearm over the forehead makes a significant improvement by decreasing the angle and strain on the shoulder. By decreasing the angle even more and using an arm strap for support, the strain on the shoulders can be further reduced.

When imaging 180° it is not necessary to place both arms above the head. Some patients prefer to leave the right arm down by the side. Two straps can be used that help the patient do this: one placed around the abdomen to support the right arm, and one placed above to support the left arm.

Another consideration when imaging the thorax is to image in the prone position. Some patients actually prefer to lay on their stomachs, especially if they suffer from low back pain. To decrease the angle that the arms make with the chest, place a small pillow under the chest (Fig. 4). Imaging in the prone position does not seem to cause perceptible artifacts.

After the acquisition is completed it is important to check if patient motion occurred during the exam. When the acquired data is displayed in a cinematic format motion will usually become evident. Another method to check for patient motion is to place two point sources above and below the heart and sum up all images into one image. If the patient remained still during the acquisition then the point sources will appear as two straight lines. These steps should be done after the acquisition and before the patient is allowed to leave. If significant motion occurred data should be reacquired.

Even when the patient does not move during an acquisition, motion artifacts can still occur. If the patient occasionally takes in a deep inspiration, the heart will drop down in those frames

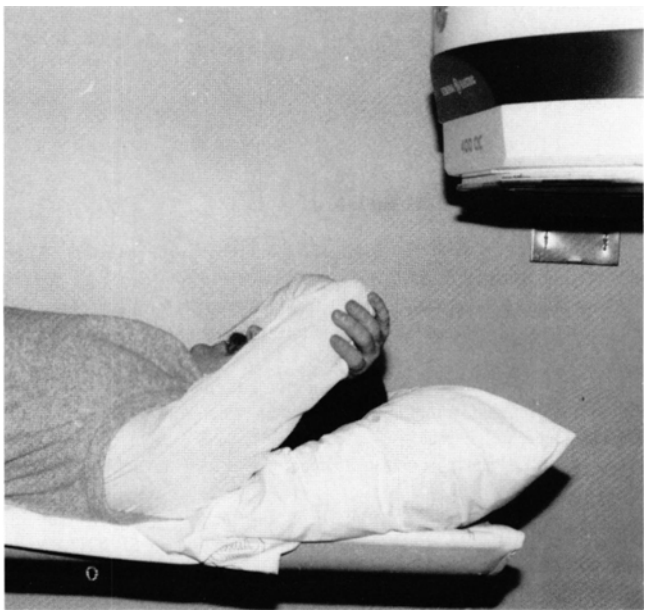

FIG. 3. The angle that the arm makes with the chest should be minimized to increase the level of comfort of the patient when being imaged. Patients comment most often that the shoulder strain was the worst part of the tomographic study.

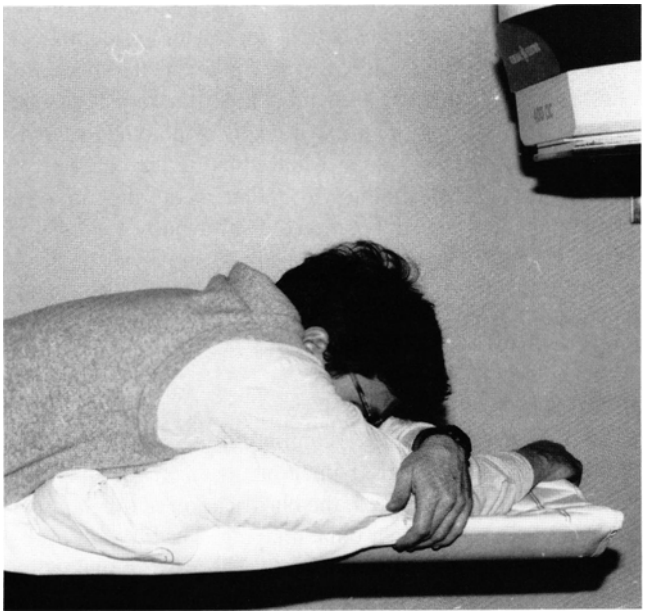

FIG. 4. The "Superman position." Some patients prefer to be in this position when being imaged.

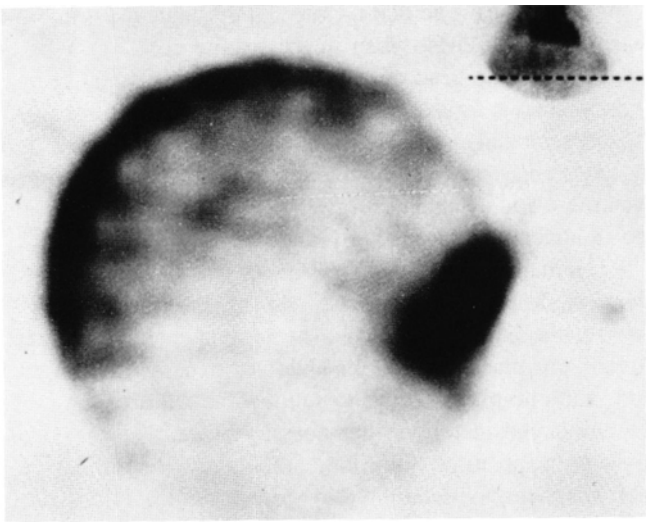

FIG. 5. Image artifact on a blood pool tomogram created by dose infiltration. The artifact streaks are radiating from the injection site.

and potentially cause an artifact. It is therefore important to explain to the patient to breath regularly throughout the exam. Another phenomenon that can cause an artifact, usually a perfusion defect in the inferior or septal wall, is a phenomenon called "upward creep" (*10*). This type of artifact seen in the post-exercise images usually occurs in patients who exercised to high levels and achieved a high heart rate. It is recommended that imaging be started 15 min after injection with such patients, to decrease the chances of this occurring.

Imaging the Abdomen

It is widely accepted that SPECT imaging of the liver and spleen is helpful in adding information to planar imaging (*11*). In bone scanning of the lumbar spine, SPECT can add information about the distribution of radioisotope in the vertebral bodies (*12*). Unlike imaging the chest, the placement of the arms is not as critical. It is recommended that the arms be placed out of the field of view. This can be done by placing the arms up above the head as is done when imaging the chest or, if the patient is uncomfortable with the arms up, they may be left down in their normal position along the body. One major source of artifact is caused by dose infiltration in the arm. Figure 5 shows the effect an infiltrated dose has on a transaxial slice through the liver/spleen region from a gated blood pool study.

Imaging the Pelvis and Legs

The main use for SPECT scanning of the pelvis and legs is for bone scanning. SPECT imaging offers the same advantage as previously discussed, the clarification of overlapping structures seen with planar bone imaging. The types of problems associated with scanning these areas are minimal when compared to the other areas. Placement of the patient on the bed, however, is critical when comparing the relative right-to-left activity in hips or knees.

To help ensure that the patient remains motionless during the exam, taping of the feet and proper back support are necessary. Additionally, strain on the lower back can be reduced by placing a small pad under the knees.

One artifact commonly seen when imaging the pelvis is that from bladder filling. If imaging is begun with the camera either anterior or posterior to the patient the streak artifact will usually be seen to extend both anteriorly and posteriorly. Similarly, if imaging is begun from the lateral position, the artifacts will extend laterally. Accordingly SPECT imaging of the hips should be done starting from either the anterior or posterior position. If possible, SPECT imaging of the sacrum, coccyx, or pubic ramus should be started in the lateral position. Having the patient empty the bladder just before imaging may minimize the effect of bladder filling on the reconstructed images.

SUMMARY

SPECT imaging has been shown to complement planar imaging and often gives additional information about specific disease processes. Major advantages are the ability to sort out overlapping structures and increased contrast resolution. Before patient imaging can take place additional quality control procedures must be performed that ensure the system will not introduce artifacts into the image reconstruction.

Successful imaging depends on patient immobility during the acquisition. Cooperation from the patient in remaining still is made easier when the technologist takes the time to make the patient as comfortable as possible before the scan begins. Depending on the area being imaged, specific steps can be done that help to ensure patient comfort during the study. Remember: A comfortable patient is more apt to remain still.

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