Effects of Tomographic Table Attenuation on Prone and Supine Cardiac Imaging

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The purpose of this study was to determine the attenuation characteristics of tomographic imaging tables and to evaluate these effects on prone and supine imaging of the heart, using a cardiac phantom. Methods: Table attenuation as a function of imaging angle was measured in seven different types of tomographic imaging tables, by imaging $^{99m}$Tc and $^{201}$Tl line sources placed at various distances above the center-line of the table. Three imaging tables exhibiting low, medium and high attenuation were further studied using a cardiac phantom filled with $^{201}$Tl to see the effects of attenuation on myocardial image quality. Studies were performed under three conditions: no table, table above phantom (prone imaging) and table beneath phantom (supine imaging). Circumferential count profiles were generated from short-axis slices of the myocardium. Results: Most SPECT tables attenuated only 5%–10% ($^{99m}$Tc) and 8%–12% ($^{201}$Tl) at an angle of 180° (face of detector parallel to table). At angles of 90° and 270°, however, table attenuation was highly dependent on the tables' design and material content. From the cardiac phantom studies, short-axis circumferential count profiles showed no significant difference for low-attenuation tables and a slight difference (<5%) in the septal region for medium-attenuation tables. In prone imaging, high-attenuation tables caused a reduction in counts in the antero-lateral wall (>10%) and in the septum (>5%). Conclusion: Table attenuation characteristics should be considered when comparing studies from different systems and in establishing a normal database for $^{201}$Tl polar maps. High-attenuation tables should be used with caution in cardiac studies.

Key Words: single-photon emission computed tomography; tomographic table; attenuation; myocardium


Planar and tomographic imaging of the heart with $^{201}$Tl and $^{99m}$Tc-sestamibi is usually performed with the patient in a supine position. This often results in diaphragmatic attenuation of photons arising from the inferior wall of the left ventricle. Several studies have advocated placing the patient in a prone or semidubical position on the imaging table in order to overcome this problem (1–3). These alternative imaging positions have been shown to improve visualization of the inferior wall (4), improve overall specificity for patients with coronary disease (1) and reduce the incidence and severity of patient motion artifacts (4).

A possible drawback of prone imaging is the fact that most of the projections are acquired through the tomographic imaging table. This can lead to three potential problems: (1) increased patient-to-collimator distance due to the presence of the imaging table, resulting in increased scatter and poorer resolution (4); (2) reduced myocardial counts; and (3) increased attenuation at certain angles during SPECT acquisition, leading to the possible generation of artifacts in the image data. Except when the gamma camera is directly underneath the SPECT table, the heart is imaged at an oblique angle through the imaging table. This could lead to significant attenuation at certain angles during the SPECT acquisition. Several studies have suggested the need for specialized tables to ensure that image quality is not compromised by the increased patient-to-collimator distance and variable table attenuation (4,5).

The purpose of this study was to determine the physical and attenuation characteristics of a variety of specialized and conventional SPECT tables and to determine what effects if any, these characteristics had on the quality of $^{201}$Tl tomographic studies of the heart in a phantom model.

MATERIALS AND METHODS

A total of seven tomographic tables were evaluated. Table 1 lists the dimensions and composition of the seven tables. Data are also presented in Table 1 on the year of manufacture since many companies have modified the design and construction of their imaging tables over time. Table attenuation as a function of imaging angle was measured by imaging a 40-cm long line source placed at heights of 1, 3 and 5 cm above the center-line of the table (Fig. 1). The table height was adjusted so that the line source lay close to the center of rotation and along the axis of rotation. The line source was filled with either 1 mCi of $^{201}$Tl or $^{99m}$Tc. For all imaging tables, images of the line source were acquired over 360° using the following acquisition parameters: 60–64 images; 360° circular orbit; 128 × 128 matrix; 20-cm radius of rotation; 40–60 sec per projection. This gave approximately 100–150 kcts/view. Following decay correction, the projection data were analyzed by placing a region of interest (ROI) over the image of the line source and generating a curve of counts versus angle of rotation. From these curves, the angular dependence of table attenuation was...
determined for $^{201}$Tl and $^{99m}$Tc. The attenuation at 180° and the maximum attenuation (at 90° and 270°) were noted.

Phantom Studies

The effects of table attenuation on image counts in the myocardium during $^{201}$Tl SPECT acquisition were studied using a cardiac phantom (Model RH-2, Capintec, Ramsey, NJ). This phantom consists of a Lucite body (30 × 20 cm) with two side compartments containing wood powder to simulate the lungs and a rod of Teflon to simulate the spine and a central compartment in which a heart model could be positioned. The heart consisted of right and left ventricles with separate compartments for the blood pool and myocardium. Two millicuries of $^{201}$Tl were placed as background activity in the central compartment and 1.5 mCi $^{201}$Tl were placed in the myocardial compartment of the heart phantom. These activities were found to give a myocardial-to-background ratio comparable to that seen in clinical studies. No activity was placed in the blood-pool compartment, which was filled with water. The base of the cardiac phantom was then bolted to a special frame that permitted it to be imaged without the need for a supporting table (Fig. 2).

Table Attenuation

Based on the measurements of table attenuation (Fig. 3), three tables (#2, #5, #7) were selected to further evaluate their effects on myocardial image quality. These tables were selected to demonstrate the effects of low (#2), medium (#5) and high table attenuation (#7) on SPECT images of the heart. In order to eliminate the variability of different gamma cameras, collimators, reconstruction algorithms, etc., on image quality, all cardiac phantom studies were performed on an Orbiter system (Siemens Medical Systems, Des Plaines, IL) equipped with a low-energy, high-resolution collimator. Where necessary, tables were removed from their original gantry and remounted for use on this system.

Three acquisitions were performed with each table: (1) no table present; (2) table underneath the phantom (supine imaging); and (3) table face down, on top of the phantom (simulating prone imaging). To accommodate the interposition of the table between the collimator and phantom, we used a slightly larger detector radius of rotation (22 cm) than would normally be required for the supine and “no table” studies. For all acquisitions, the detector radius of rotation and the phantom position remained unchanged. For each study, 32 views were acquired over 180° using a circular orbit starting at -45° RAO and ending at 135° LPO. Images were acquired into 64 × 64-word mode matrix on a Pinnacle computer (Medasys, Ann Arbor, MI). The raw projection data was pre-filtered with a two-dimensional Hann filter (cut-off 0.5 Nyquist) followed by backprojection with a simple Ramp filter.

As the position of the myocardium and detector orbit remained unchanged for all acquisitions, identical reconstruction slices and angles were used to generate oblique long- and short-axis slices of the heart. From the short-axis slices, circumferential profiles were generated using the maximum pixel count along ray lines every 6° over 360°. For each acquisition, the short-axis slices were summed to give a composite image of the myocardium. Total counts in the myocardium were determined from a circular ROI positioned to include the myocardium. For the prone and supine ROI studies, counts in the myocardium were expressed as a percentage of counts in the “no table” study.

![FIGURE 1](image1.png)

FIGURE 1. Forty-centimeter line source positioned in the center of the SPECT table for measurement of table attenuation as a function of the angle of rotation.

![FIGURE 2](image2.png)

FIGURE 2. Cardiac phantom mounted on support frame that permits acquisition without the need for a SPECT table. SPECT tables could be positioned above or below the phantom to simulate prone or supine imaging.
RESULTS

Figure 3 shows the angular effects of different table designs on $^{201}$Tl and $^{99m}$Tc counts, for a line source at 1 cm above the table top. All tables showed a similar angular attenuation pattern, however, the degree of attenuation varied significantly between the various tables and was more dependent on construction material than on table shape. The greatest attenuation was seen with an aluminum table (56% with $^{201}$Tl), and the least attenuation was seen with the two specialized cardiac SPECT tables (#1, #2). At an angle of 180°, most SPECT tables attenuated less than 10% for both $^{201}$Tl and $^{99m}$Tc (Fig. 4). At angles of approximately 90° and 270°, however, table attenuation was highly dependent on table design, and on the distance of the line source above the table surface (Fig. 4). At both 180° and 90° or 270°, there was a 30%–40% greater loss in counts with $^{201}$Tl compared to $^{99m}$Tc. Figure 5 shows the effects of table attenuation on one planar view of the cardiac phantom taken at an angle of 113° during the SPECT acquisition. A vertical band caused by the table reduces the activity seen in the basal half of the myocardium.

Figure 6 presents circumferential count profiles generated from a midventricular short-axis slice for tables #2, #5 and #7. The curves have been adjusted up or down to permit comparison of the profile shapes. The low-attenuation table (#2) gave similar results for both prone and supine imaging and there were no discernible effects of table attenuation on short-axis circumferential count profiles (Fig. 6A). With supine imaging, the medium-attenuation table (#5) demonstrated a slight drop in counts in the antero-lateral wall (<3%), relative to no table. With prone imaging, however, both the antero-lateral and infero-septal wall showed a 5% decrease in counts while the infero-lateral wall showed a slight increase in counts (Fig. 6B). With the high-attenuation table (#7), these findings were enhanced, with the antero-lateral wall showing >10% drop in circumferential profile counts in the prone position (Fig. 6C). Table 2 shows the loss in myocardial counts with prone and supine imaging for the three tables. As expected, table attenuation has little effect on total counts for supine imaging, but with prone imaging, up to a 15% loss in counts was seen with table #7. This count loss was reduced to 5% with the use of a specialized cardiac imaging table (#2).

DISCUSSION

Considerations of SPECT table attenuation are normally limited to the straight through attenuation of radiation. For the seven tables evaluated in this study, Figure 4 shows that these values are low, ranging from 2% to 12%, depending on table design and radionuclide. Figures 3 and 4 show that a more critical parameter is the effective attenuation at an oblique angle through the table, particularly at angles of 90° or 270° when the detector is looking sideways through the table.

Table Construction

Materials used in table construction, particularly aluminum, may accentuate the angular variations in attenuation. The aluminum table (#7) had the greatest angular variation in attenuation and also showed the largest loss in total myocardial counts with prone imaging (Table 2). The degree of attenuation also depends on the distribution of graphite/foam within the table and the inner and outer radii of curvature. Tables #1 and #2 contain very little material...
over the region of the heart, resulting in low attenuation. Both of these tables are limited in terms of their weightbearing capacity and the length of table that can be cantilevered.

Other tables achieve low attenuation by placing most of the graphite in the center of the table with reduced graphite content at the edges giving a tapered design (e.g., #3, #4). Table attenuation is also dependent on the radius of curvature, as a relatively flat table with a large radius of curvature will demonstrate more severe attenuation at 90° or 270° compared to a curved table.

From these results, it would appear that the ideal design features of a cardiac SPECT table are reduced table thickness in the region of the myocardium, elimination of any metal in the imaging portion of the table, tapered edges and a small radius of curvature. SPECT tables designed for cardiac imaging (#1, #2) demonstrated many of these features, making them ideally suited for dedicated cardiac SPECT systems.

Data Acquisition

In conventional supine imaging of the heart, data are acquired from −45° LAO to +135° RAO, hence approximately 40°−45° of the SPECT acquisition involves imaging through the table with the converse being true for prone imaging. Based on the results in Figure 3, the effects of table attenuation should be most noticeable between approximately 90°−120°. The planar views of the cardiac phantom in Figure 5 clearly show the attenuation band caused by the table. What effect this artifact will have in clinical studies will be highly dependent on the size and shape of the patient since attenuation is also affected by the distance of the radiation source from the surface of the table. Figure 4 shows that at a distance of 5 cm, the attenuation effects are approximately 50% of those seen at 1 cm. In the more obese patient, the heart will be further away from the table surface and hence will be less affected by the angular variations in table attenuation, whereas the converse will be true in the thinner patient. While we cannot address these issues in a phantom study, the experimental arrangement used in this study has allowed us to eliminate many of the system variables that can affect myocardial count distribution (e.g., collimator, patient-to-collimator separation, reconstruction algorithm, filtration, etc.), and thereby provides a measurement of the effects of table attenuation per se.

The cardiac phantom studies show that for many of the conventional SPECT imaging tables, table attenuation has a minimal effect on myocardial count distribution for either prone or supine studies of the heart. High-attenuation imaging tables, however, may cause subtle changes in the apparent activity in the anterior or antero-lateral wall and to a lesser degree in the septum (Fig. 6). These changes could potentially lead to under or over estimation of the severity of a lesion in a clinical study, particularly in prone imaging. This artifact makes it potentially difficult to compare studies acquired on different systems and emphasizes the need to establish a normal database in studies where quantitative analysis of the image data is being performed. Even with a normal database, it should be recognized that the magnitude of the artifact will depend on the size and body shape of the patient. Additional factors such as the change in location of the myocardium with prone and supine positions may further accentuate the apparent differ-

![Figure 6](image)

**Figure 6.** Midventricular circumferential count profiles obtained from the short-axis slices comparing no table versus supine and prone table positions for (A) table #2, (B) table #5 and (C) table #7. Profiles go clockwise from anterior wall (0°).

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**Table 2**

<table>
<thead>
<tr>
<th>Table No.</th>
<th>Supine Imaging</th>
<th>Prone Imaging</th>
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<td>7</td>
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<td>85.7</td>
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*Myocardial counts with no table present.
ences in the normal appearance of the myocardium. While we have evaluated a number of commonly used SPECT tables, manufacturers are constantly upgrading or modifying the design of their tables. Therefore, our results serve only as a guide to the potential problems that may arise with SPECT tables. We would recommend that the table attenuation characteristics of each SPECT system be evaluated, particularly if the system is to be used for prone imaging of the heart.

CONCLUSION

Our results indicate that in general, standard graphite or graphite/foam imaging tables have low-attenuation characteristics that cause <10% change in short-axis count profiles and hence do not significantly affect myocardial image quality during either prone or supine imaging of the heart. Tables constructed of aluminum or exhibiting large inner and outer radii of curvature may have significantly higher attenuation leading to larger variations in count profiles (>10%). The attenuation characteristics of such tables should be checked to determine their suitability for cardiac imaging. It is anticipated that current and future developments in the area of attenuation correction will lead to accurate correction for any errors introduced by the table during tomographic imaging.

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REFERENCES