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Investigations into the Effects of Material Filters (Cu 0.125mm and Al 0.2mm) on Image Linearity in Tc-99m SPECT

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***Abstract*: Performance parameters, e.g., spatial linearity and uniformity of single photon emission computed tomography (SPECT) imaging systems are affected by scattered gamma events. Hence, the quality of the reconstructed image is degraded. In this study, material filter method was employed for reducing the adverse effects of scatter events from the Tc-99m spatial linearity images. Material filters work by absorbing the scattered gamma photons before they can reach the surface of the detector of the gamma camera. The filters used were copper (Cu) 0.125mm and aluminum (Al) 0.2mm thick flat sheets. SPECT data were collected by scanning Carlson's phantom with the linearity insert. The radionuclide, Tc-99m was injected into the phantom. Symmetrical energy window (+/-10% centered at 140keV) was selected. Filters were separately mounted on the outer surface of the gamma camera (GCA-901A/HG) with either low energy general purpose or low energy high resolution collimator. Results of material filtered data images show improvement in the image linearity. It is concluded that material filters have the potential to improve overall image quality in Tc-99m SPECT.**

***Keywords:* Gamma Camera, Performance Parameters, Spatial Linearity, Material Filter, Scattered Gamma Photons.**

I. INTRODUCTION

The aim of single photon emission computed tomography (SPECT) is to provide images of the radionuclide distribution present in the object being scanned [1]. In many clinical situations, visual interpretation and semi-quantitative analysis of SPECT images is performed and the accuracy of diagnosis depends upon image quality. In SPECT, image quality is affected by the characteristics of the imaging system by some physical phenomena, e.g., scatter, attenuation, septal penetration, partial volume effect, tomographic reconstruction and physiological factors such as patient motion. In all these factors, the problem of scatter via the Compton process, has given rise to many investigations due to its blurring affect [2]. Since the main objective of SPECT imaging is to obtain good quality images, it is thus essential to maintain the superior performance of the whole system.

Linearity is a fundamental requirement for a SPECT system. This parameter deals with the ability of the system to portray the true shape in the image of the scanned object/organ. In order to test the linearity of imaging systems, phantoms with a linear arrangement of bars or holes is usually used. The image produced should look exactly like the phantom, that is straight lines should be produced as straight [3]. However, changes in SPECT image linearity as a result of scatter and attenuation are very significant. Most of the gamma cameras use NaI(Tl) scintillators. Due to the poor energy resolution, scintillators are unable to stop the detection of scattered gamma photons. Scatter correction techniques have been developed by various researchers for SPECT data correction [4], [5], [6], [7]. However, none has attained the acceptability for the use in clinical SPECT as a gold standard. Material filters for scatter reduction from the SPECT image data have been applied in Tc-99m SPECT to improve the uniformity, spatial resolution, contrast and overall image quality [8], [9], [10], [11], [12].

In the light of the facts mentioned above, the present study was undertaken to investigate the affects of material filters on image linearity. Flat sheets of copper and aluminum were separately mounted on the surface of the collimator to remove some fraction of scattered gamma photons in order to improve the image linearity in Tc-99m SPECT imaging.

II. MATERIALS AND METHODS

SPECT Data Acquisition and Image Reconstruction:

One of the most essential equipment used in this study was the multi-purpose GCA-901A/HG digital gamma camera system, manufactured by Toshiba Medical System. The aim of this study was to obtain an image with the material filter and without the material filter mounted on the outer surface of the collimator. Two different materials were chosen as the filter, a flat sheet of Copper (Cu) 0.125mm thickness and aluminum (Al) 0.2mm thickness were prepared and both were cut into rectangular pieces of the dimension, 46cm x 56.5cm. A rectangular shaped aluminum (Al) frame was made, on which the filter was fitted as depicted in Fig. 1. The linearity insert is a 5cm thick and 20cm outer diameter block with crossed grid of channels cut out in a 3.75cm deep square pattern as shown in Fig. 2.

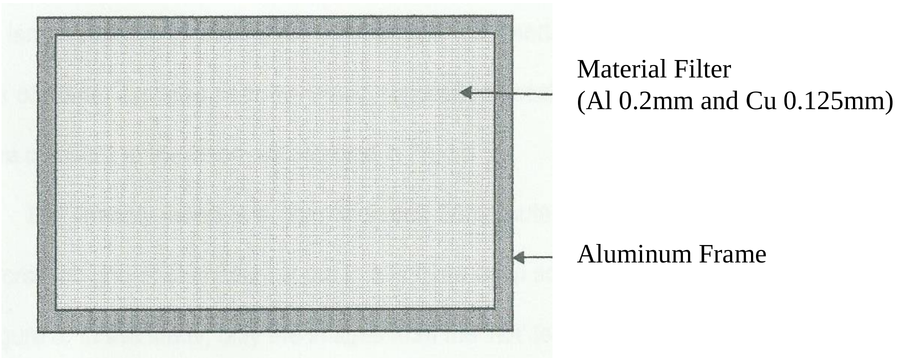


Fig. 1 Show the design of material filter

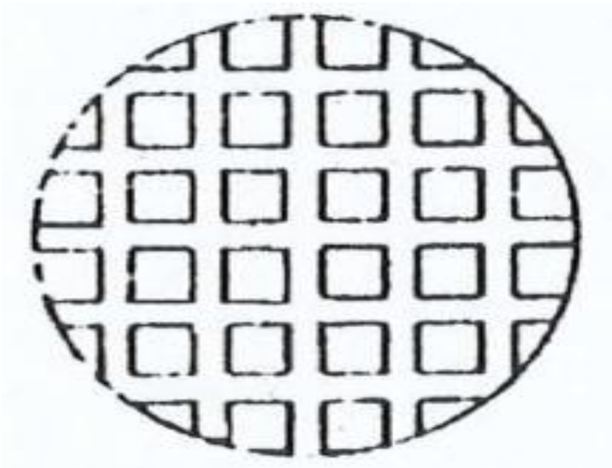


Fig. 2 Cross sectional view of the linearity insert of R. A. Carlson's phantom

Linearity insert was placed into the cylindrical source tank of Carlson's phantom. Plain water was filled into the tank. Tc-99m radioactivity (19.29 mCi) was injected into the tank which was mixed carefully until the phantom was ready. Phantom was placed on the patient examination table, with the axis parallel to the face of the collimator and in the centre of field of view (FOV) of the gamma camera. In order to prevent the movement of phantom it was taped on the patient coach. Image data was acquired by using either LEGP or LEHR collimator mounted on the outer surface of the gamma camera collimator with and without the material filters. A symmetrical energy window +/-10% (at 140 keV) and 128 x 128 matrix size was selected. Sixty views were taken over 360 degrees and the time for each projection/view was 20 seconds. The acquisition parameters were same as those with and without the material filters.

Transverse images of linearity insert were reconstructed. Filtered back projection method was used with an 8^{th} order Butterworth filter having 0.15 cycles/cm cut-off frequency. Chang's method was applied for attenuation correction. Linear attenuation coefficient value of 0.141/cm for Tc-99m was applied to the data in the case where the material filter was mounted, and an effective attenuation coefficient value of 0.131/cm was chosen where no material filter was employed. All the raw data were corrected for the decay, uniformity and center of rotation (COR).

Image Analysis:

The 32nd transverse image slice of the linearity insert (with and without material filter) was analyzed visually and plotting the count profiles which were obtained by drawing horizontal/vertical lines through the centre of the image selecting area over the cross grid of the linearity insert as shown in Fig. 3. For plotting count profiles, image analysis package (GMS-5500) was used which was installed in the computer system of the gamma camera.

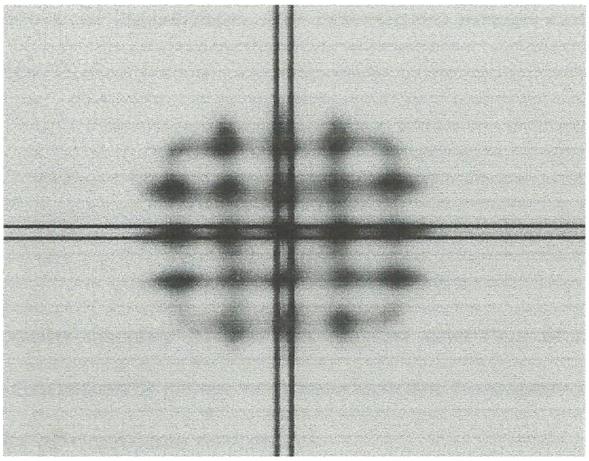


Fig. 3 Show the selection of horizontal/vertical lines through the centre of the cross grid of the linearity insert image.

III. RESULTS AND DISCUSSION

Visual Analysis of Transverse Images of Linearity Insert:

Fig. 4 (a), (b) and (c) shows a transverse image slices of the linearity insert of the Carlson cylindrical phantom with and without material filter using LEGP collimator. In Fig. 4(a), the shape and alignment of each line is not very straight because the gap of the lines between hot and background of cold region is not clearly seen. Furthermore, there is blurring and fog. This is caused by the scattered gamma photons which are not filtered when the material filter was not employed. Fig. 4(b) indicates a transverse image slice of the linearity insert with Cu 0.125mm filter. As the image shows, lines between hot region and background of cold region are fairly straight and well aligned. The gap between the lines is clearly seen. Accordingly, the linearity is considered good when using Cu 0.125mm. Fig. 4(c) shows a transverse image slice with Al 0.2mm filter sheet. The shape and alignment are considered straight although some of the gap of lines between hot region and background of cold region in the middle area of the image is not clearly seen.

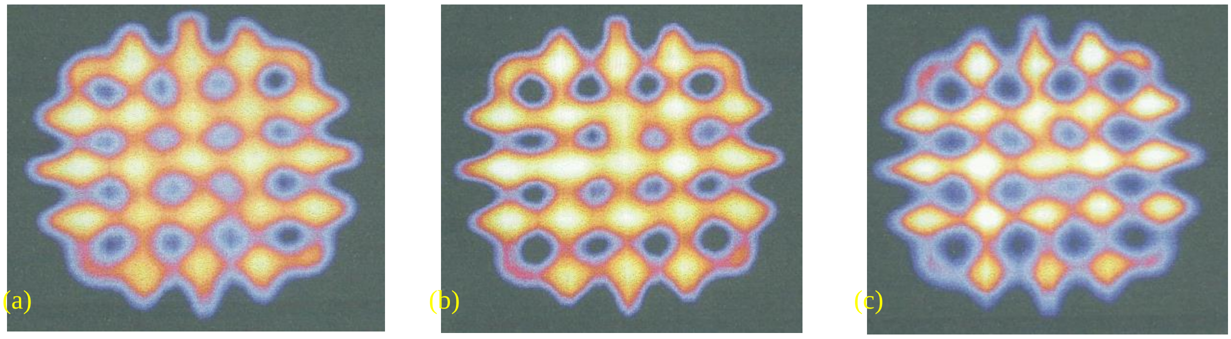


Fig. 4 (a), (b) and (c) Show the transverse images of linearity insert (a) without, (b) with Cu 0.125 mm and (c) with Al 0.2 mm material filter, gamma camera installed with LEGP collimator.

Fig. 5 (a), (b) and (c) shows transverse image slices of the linearity insert with and without material filter using LEHR collimator. The linearity of the image in Fig. 5(a) is considered not satisfactory because the shape and alignment of each line are not very straight. Moreover, the gap of lines between hot region and background of cold region is also not clearly seen. Fig. 5(b) is a representative image of a transverse slice of the linearity insert with Cu 0.125mm filter sheet, which shows a linear image. The shape and alignment of each line are straight and the gap of lines between hot region and background of cold region is visible. Fig. 5(c) is a transverse image slice of the linearity insert with Al 0.2mm material filter. The shape and alignment of each line can be clearly resolved because they are straight and aligned. In addition, the gap of lines between hot region and background of cold region is also easily determined with a visual judgment. The blurring and fog of this image is considered not significant. The linearity of this image is satisfactory.

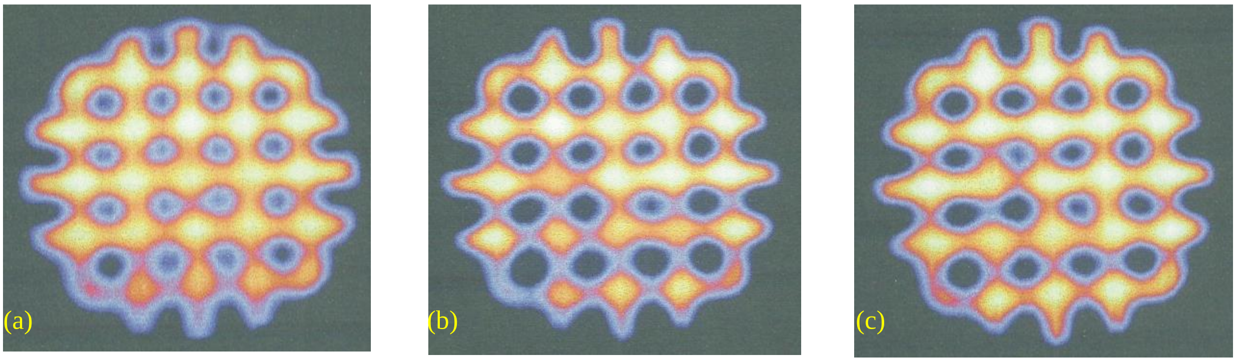


Fig. 5 (a), (b) and (c) Show the transverse images of linearity insert (a) without, (b) with Cu 0.125 mm and (c) with Al 0.2 mm material filter, gamma camera installed with LEHR collimator.

Count Profile Analysis of Transverse Images of Linearity Insert:

Fig. 6 show the count profiles of a horizontal/vertical lines through the centre of the cross grid of the linearity insert with and without material filter using LEGP and LEHR collimator. When material filter was not employed using both the collimators, it is noticed that both the count profile curves are not fairly linear. The count profile curve with Al 0.2mm when using LEGP collimator is also considered linear. However, the count profile curve with Al 0.2mm when employing LEHR collimator is not that linear.

Visual inspection of the shape and alignment of each cross grid lines of the linearity insert were adopted as a means for judging the goodness of linearity performance in SPECT. Lines are fairly straight and well aligned, especially in the transverse image slices obtained with Cu 0.125mm and Al 0.2mm material filter using either LEGP or LEHR collimator. The linearity of the image reconstructed from unfiltered (material) data is not considered satisfactory because the shape and alignment of each cross grid line are not very straight and the blurring and fog is also significant.

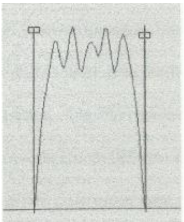
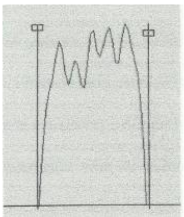
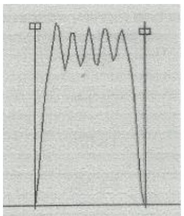
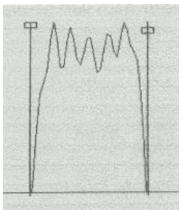
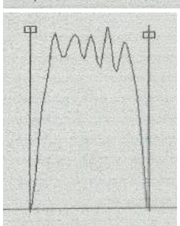
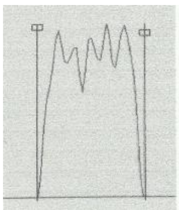
Method	**LEGP Collimator**	**LEHR Collimator**
Without Material Filter		
Cu 0.125mm Filter		
Al 0.2mm Filter		

Fig. 6 Shows the count profiles of a horizontal/vertical area in the middle of the cross grid of the linearity insert with and without material filter Cu 0.125mm and Al 0.2mm using LEGP and LEHR collimators.

IV. CONCLUSION

Visual inspection and count profile analysis of transverse images of linearity insert showed an improvement in image quality with both material filters as compared to without material filtered data images. It is therefore undeniable that the material filter technique reduces the influence of scattered gamma photons in the projection data. In conclusion, material filters may be used for more phantom studies to confirm their utility in Tc-99m clinical SPECT.

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