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IMPROVEMENT OF IMAGE QUALITY BY USING PHYSICAL FILTERS IN NUCLEAR MEDICINE IMAGING

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Abstract

Single Photon Emission Computed Tomography (SPECT) is one of the diagnostic modality of Nuclear Medicine technology, which is used as an important tool for diagnosis of diseases in human. The limits of this modality among the others are due to equipment and the gamma photon physics viz., scattering and absorption of gamma photons in the patient's body. Due to the scatter effect image quality is degraded and the non-linearity in the quantitation of radioactivity uptake is resulted.

The work presented here attempts to explore the use of unconventional (material) filters in the Tc-99m SPECT for enhancement of image quality by reducing the effects of scattered gamma photons.

Carlson phantom is scanned by mounting the filter(s) on the collimator face with cold and hot region inserts filled with water and Tc-99m radionuclide was uniformly distributed within the phantom. Images of the same phantom are also acquired without material filter(s). Individual studies have been carried out for each material filter by using either LEGP or LEHR collimator. The standard energy window (126 – 154 keV centered at 140 keV) is chosen for the data acquisition.

Results show that the perceived image quality of hot and cold region and also their detectability has been improved when unconventional filters are used. It is concluded that this approach may have important clinical applications.

Introduction

Nuclear Medicine Imaging is considered as an important modality amongst the other medical imaging techniques (1). It has two main categories – conventional imaging and tomographic imaging. The later can be subdivided into Single Photon Emission Computed Tomography (SPECT) and Positron Emission Tomography (PET).

SPECT is widely used in the developed countries as an important tool for diagnosing abnormalities in humans, and is rapidly growing and developing in the rest of the world. It has the main problems of scatter and attenuation of gamma photons in the patient to be scanned, which compromise its utility e.g., poor quality images and non-linearity in the quantitation of radioactivity distribution. Scanning systems use NaI(Tl) scintillation detectors (2,3). These have relatively poor energy resolution as compared to other radiation detectors. The standard method of data acquisition is to set energy window over the primary photopeak of the energy spectrum of the radionuclide in use. Due to poor energy resolution, a significant fraction of scattered photons is still detected (4). The presence of scattered photons, degrade the spatial resolution in the image, decrease the image contrast, and reduce the signal to noise ratio (SNR) in the image and lead to an overall degradation in the quality of the image (5).

A method for the reduction of the influence of low energy (scattered) gamma photons on SPECT projection data by means of unconventional (material) filters is proposed. Such filters will decrease the relative concentration of low energy scattered gamma photons by preferentially removing them before they can reach the surface of the detector of gamma camera (6,7,8).

Materials and Methods

a). GCA-901A/HG Gamma Camera

b). Collimators - LEGP and LEHR

c). Radionuclide - Tc-99m

d). Copper (Cu) 0.125mm, Aluminum (Al) 0.2 and 0.3 mm thick sheets (Figure 1)

e). Ray A. Carlson Cylindrical Phantom (Figure 2)

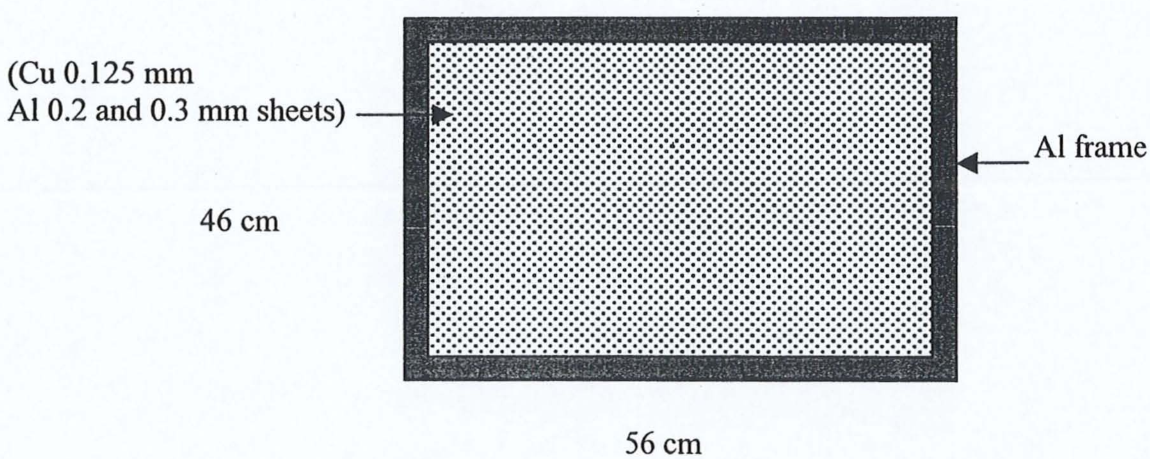

Figure 1. Construction of unconventional (material) filter(s)

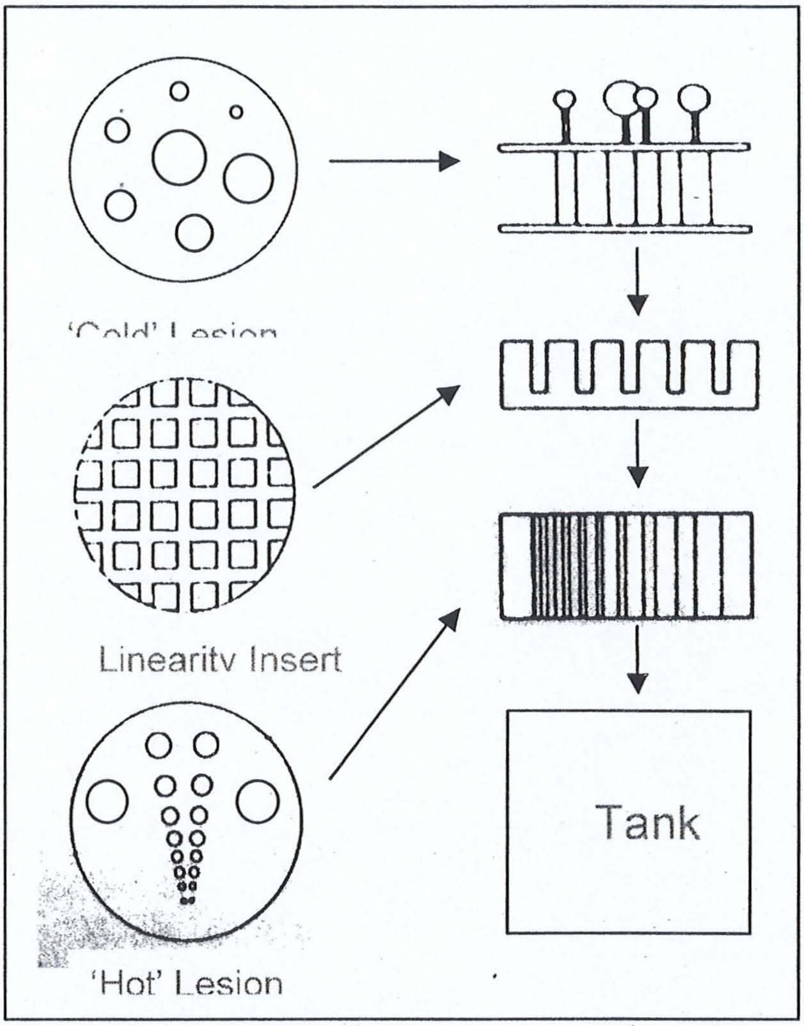

Figure 2. Cross sectional view of the R. A. Carlson phantom.

The Carlson phantom was prepared by filling the water into the tank and the hot and cold regions inserts were placed in the phantom tank. The phantom was put aside overnight to allow dissolve air bubbles if any to dissipate from the water. The solution of Tc-99m (19.29mCi) was added into the tank. The solution in the tank was mixed thoroughly. The phantom was placed on the patient couch (Figure 3).

The image data were acquired by mounting LEGP collimator on the gamma camera without using any material filter. The data were acquired within a 20% symmetrical energy window (126 to 154 keV) centered at 140 keV and 128 x 128 imaging matrix was chosen. Sixty views were taken over 360° anti clockwise rotation and the time for each projection/view was 20 seconds. The procedure was repeated by mounting a filter Cu 0.125mm thick on the outer surface of the collimator, and followed by using 0.2 and 0.3 mm thick aluminum (Al) sheets separately. Also the whole procedure was repeated by using the LEHR collimator.

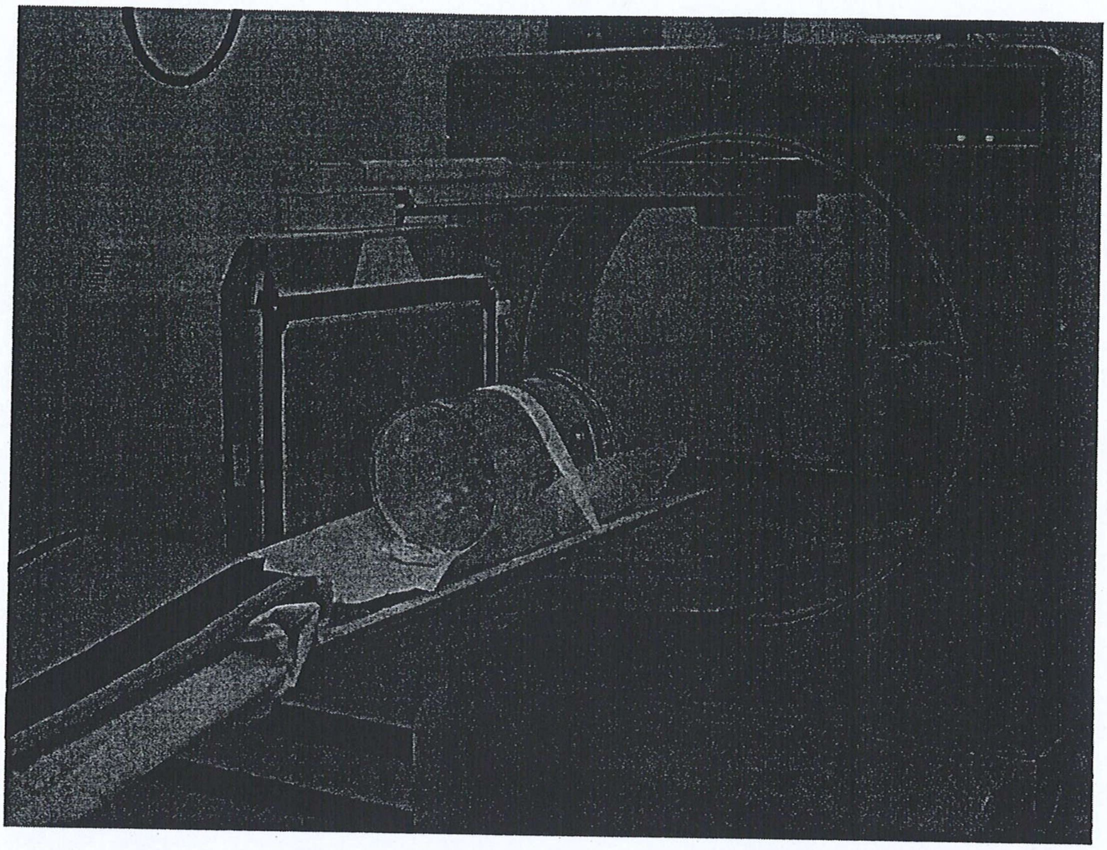

Figure 3. Scanning of phantom for SPECT image data acquisition with gamma camera GCA-901A/HG

Images were reconstructed by the filtered back projection method. Chang's technique was used for the attenuation correction (9). All data were corrected for the decay of Tc99m, uniformity and center of rotation (COR).

Results and Discussion

Hot region image analysis

Figures (4a-d and 5a-d) for LEGP and LEHR collimators respectively by visual inspection indicate that with material filter, the influence of scattered gamma photons in the transverse images is reduced and the detectibility of small hot regions is improved. The images reconstructed from material filtered data are smoother than those from unfiltered data. Further, there is less blurring and fog when material filter is employed. The visual analysis of the images also shows that the scattering field between the first two pairs (top four of a V shape arrangement of pairs) of hot regions as well as the hot regions with 30 mm diameter is decreased with a material filter when either LEGP or LEHR collimator was mounted.

Figure 4a. Without material filter

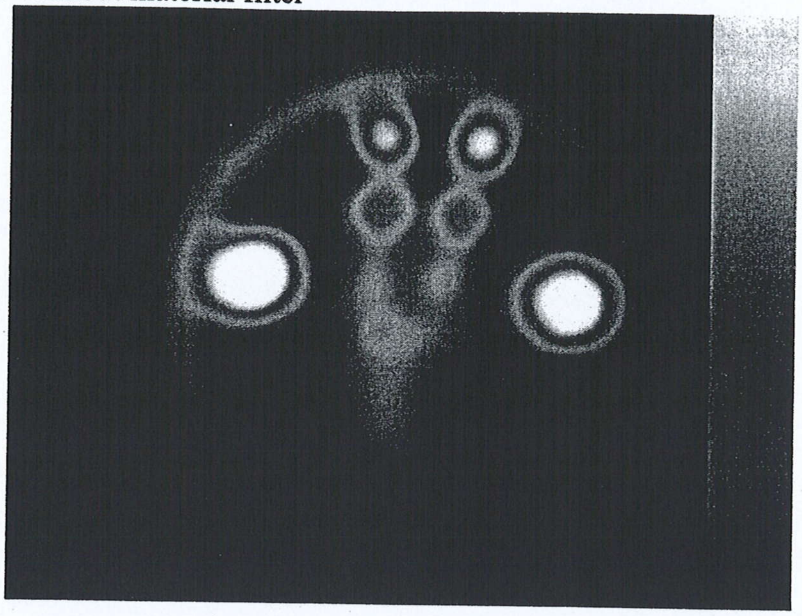

Figure 4b. With material filter Cu 0.125 mm

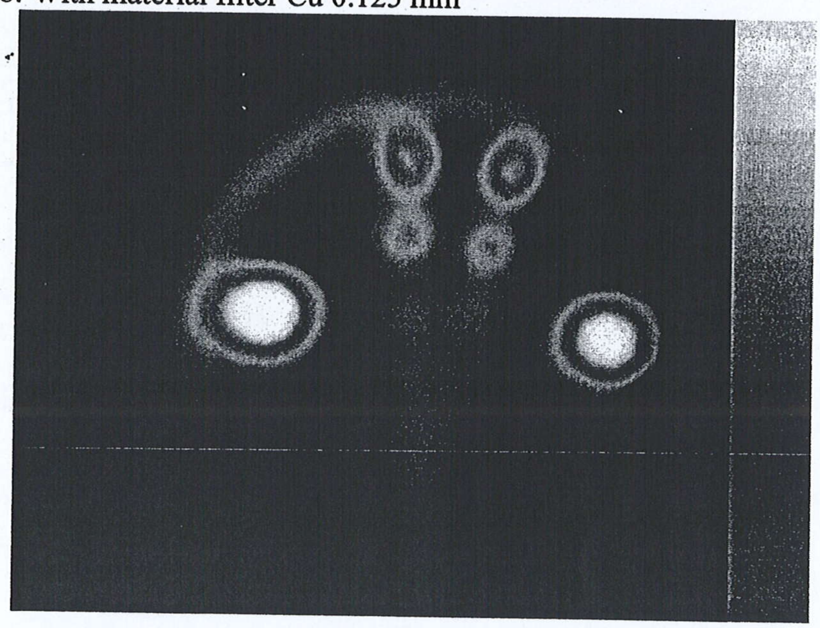

Figure 4c. With material filter Al 0.2 mm

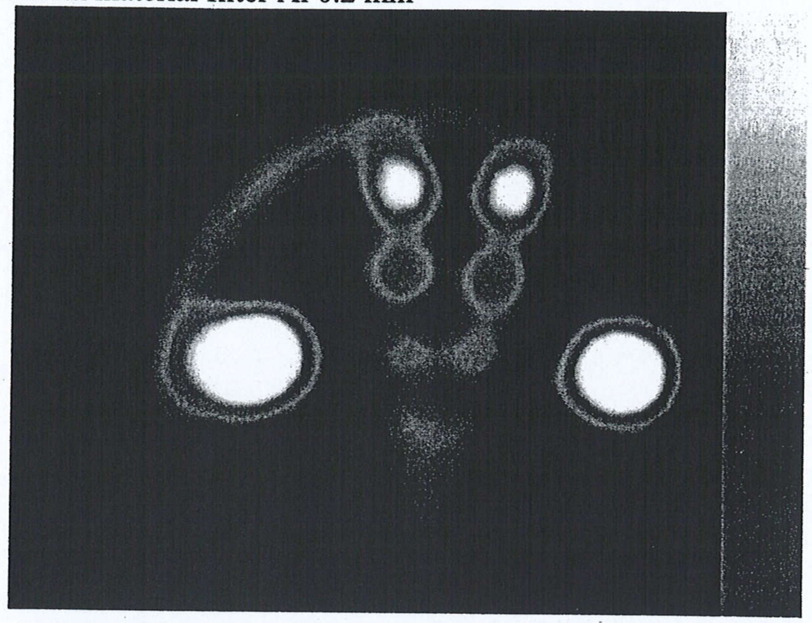

Figure 4d. With material filter Al 0.3 mm

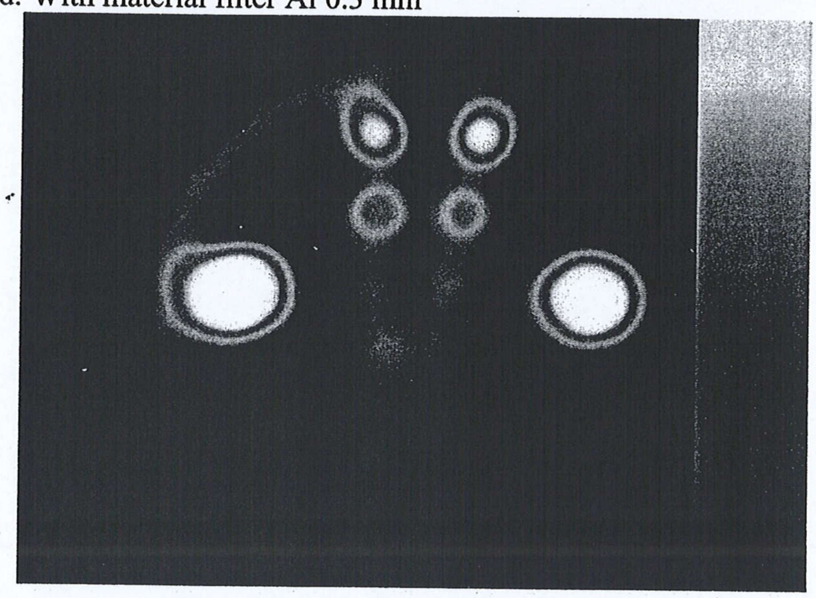

Figure 4a-d. Transverse image slice of a hot region insert (a) without material filter (b) Cu 0.125 mm (c) Al 0.2 mm and (d) Al 0.3 mm, respectively, with LEGP collimator.

Figure 5a. Without material filter

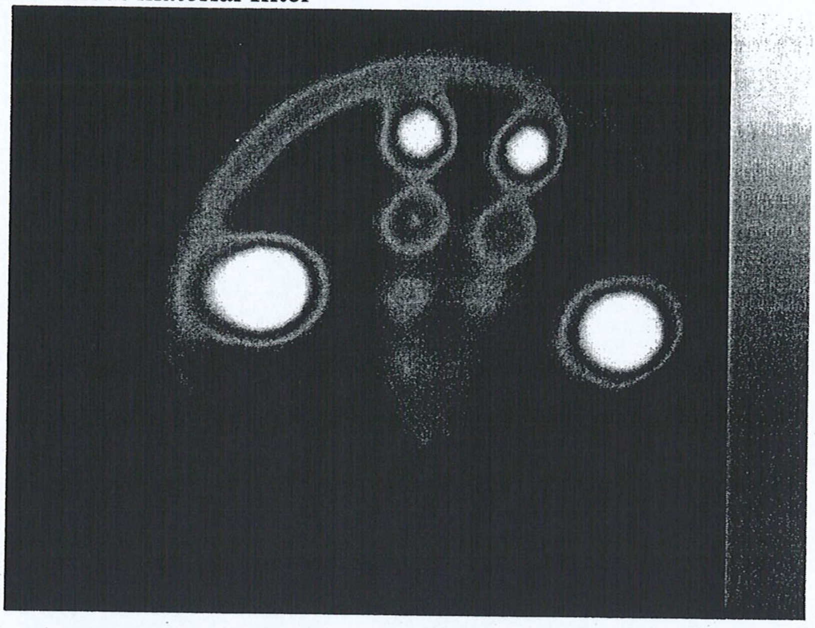

Figure 5b. With material filter Cu 0.125 mm

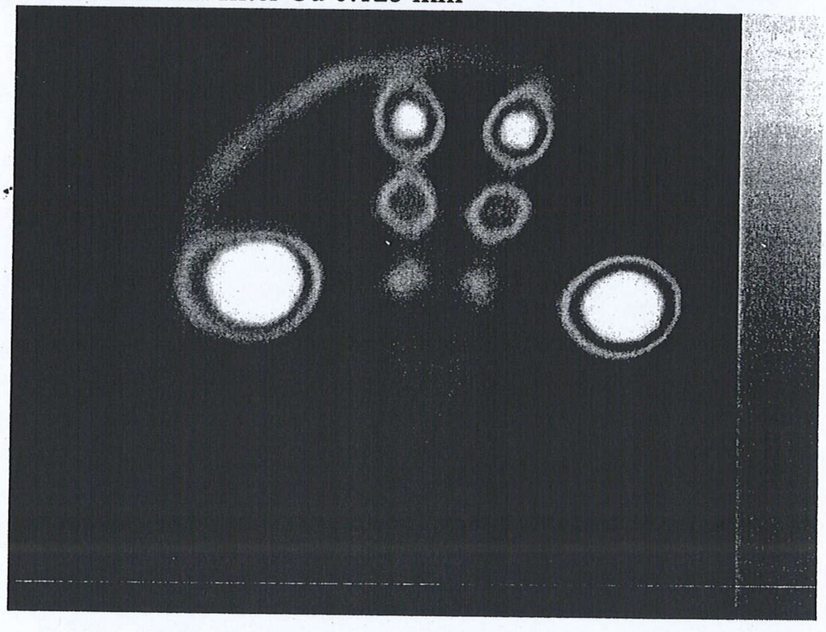

Figure 5c. With material filter Al 0.2 mm

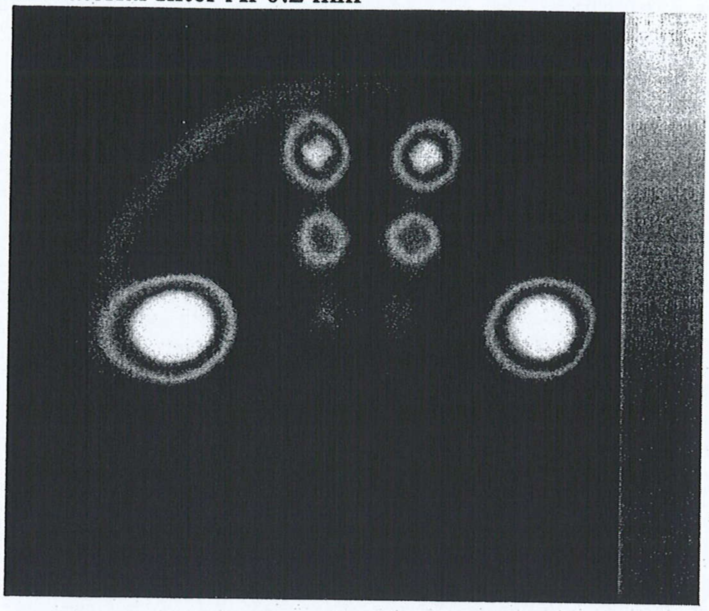

Figure 5d. With material filter Al 0.3 mm

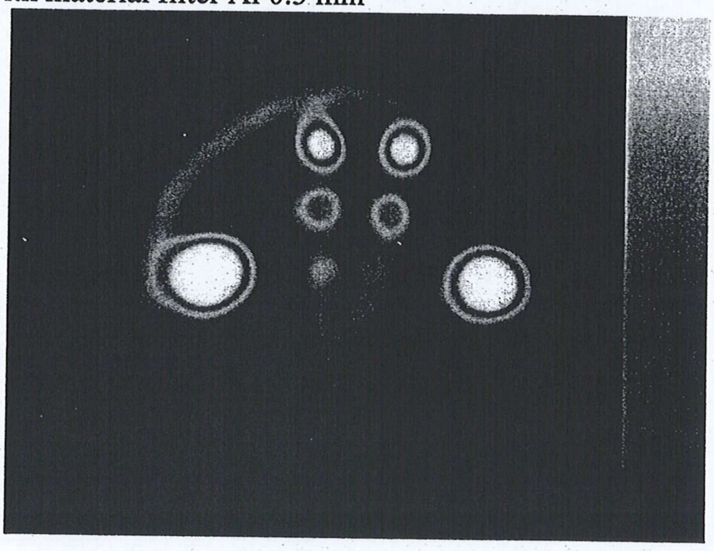

Figure 5a-d. Transverse image slice of a hot region insert (a) without material filter (b) Cu 0.125 mm (c) Al 0.2 mm and (d) Al 0.3 mm, respectively, with LEHR collimator.

Slight improvement in contrast with the material filters Cu and Al relative to without material filter when LEGP collimator was used (Figure 6). With LEHR collimator the hot region contrast is significantly improved with the material filter as compared to without material filtered data (Figure 7). Better hot region contrast values for larger regions relative to smaller regions are obtained. The improvement of contrast is achieved by reducing the scatter component from the projection data via unconventional filter technique.

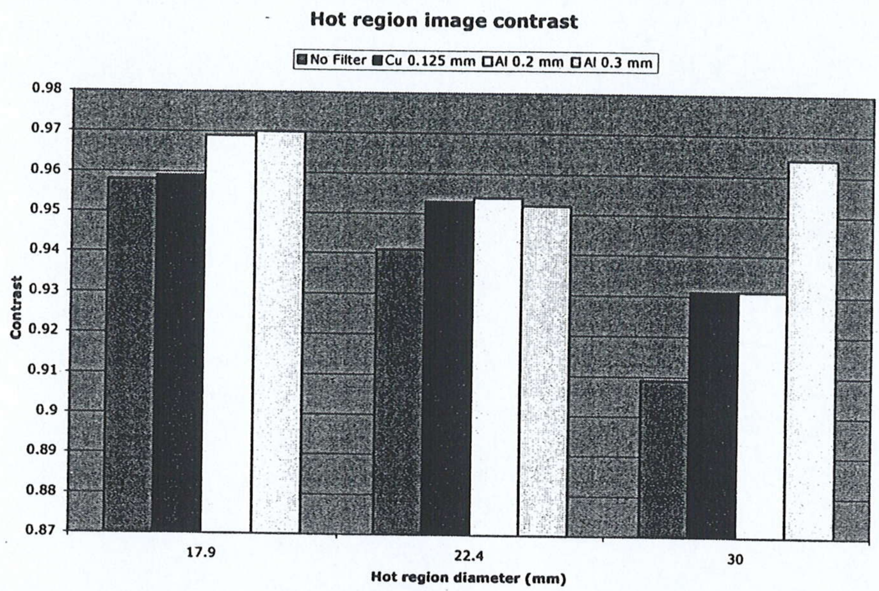

Figure 6. Hot region image contrast without and with material filters, with LEGP collimator.

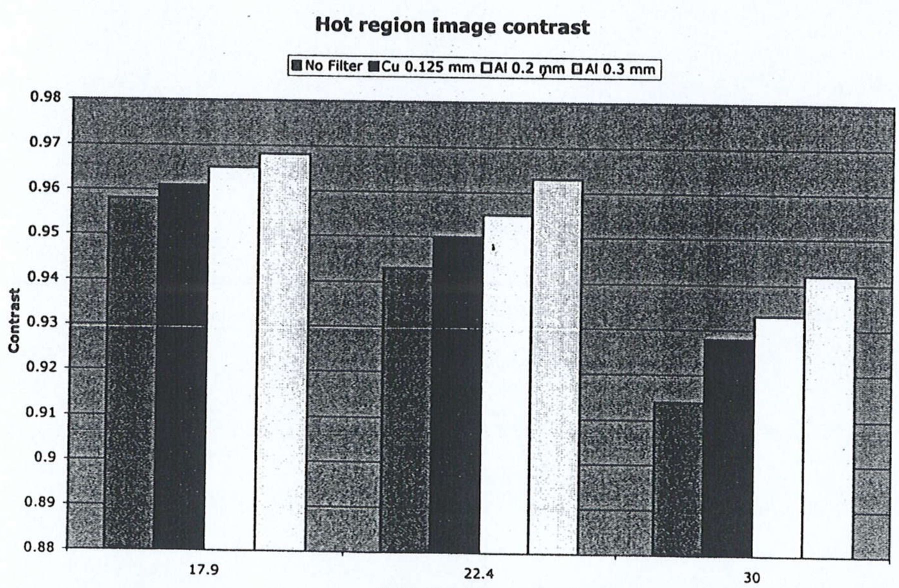

Figure 7. Hot region image contrast without and with material filters, with LEHR collimator.

Coldregion image analysis

Figures (8a-d and 9a-d) show the images of a Carlson phantom with cold region insert without and with material filters. Images with LEGP collimator obtained with material filtered data are more uniform and more cold regions can be seen as compared to without material filtered data. Further images with LEHR collimator are clearer as compared to LEGP collimator.

Figure 8a. Without material filter

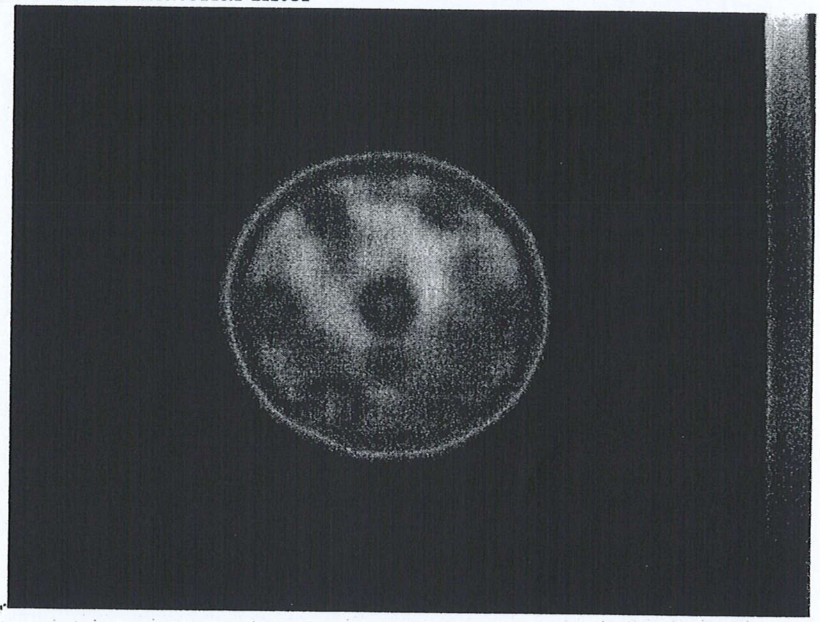

Figure 8b. With material filter Cu 0.125 mm

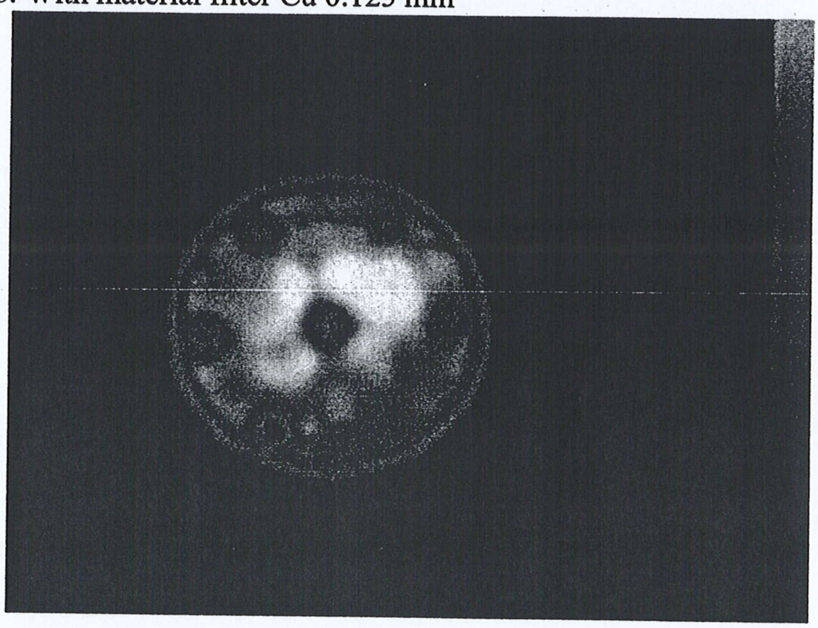

Figure 8c. With material filter Al 0.2 mm

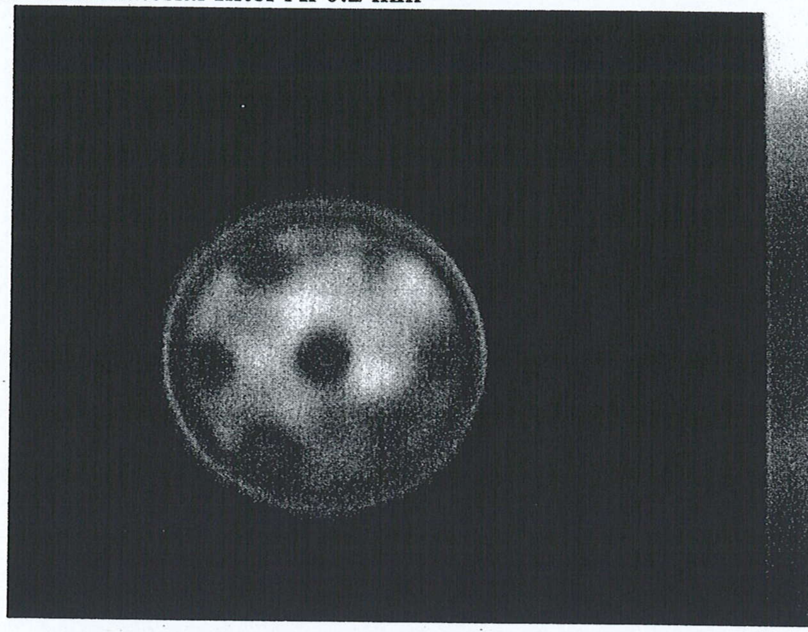

Figure 8d. With material filter Al 0.3 mm

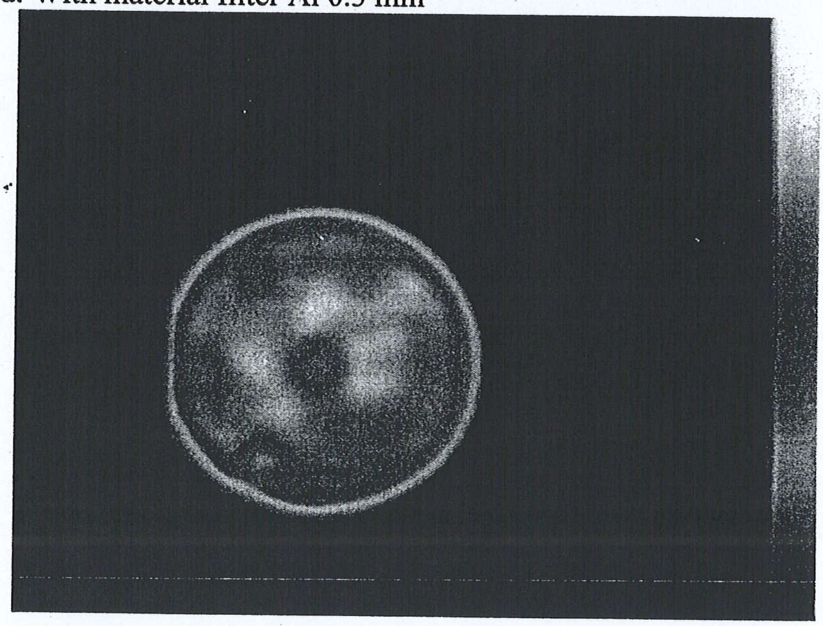

Figure 8a-d. Transverse image slice of a cold region insert (a) without material filter (b) Cu 0.125 mm (c) Al 0.2 mm and (d) Al 0.3 mm, respectively, with LEGP collimator.

Figure 9a. Without filter

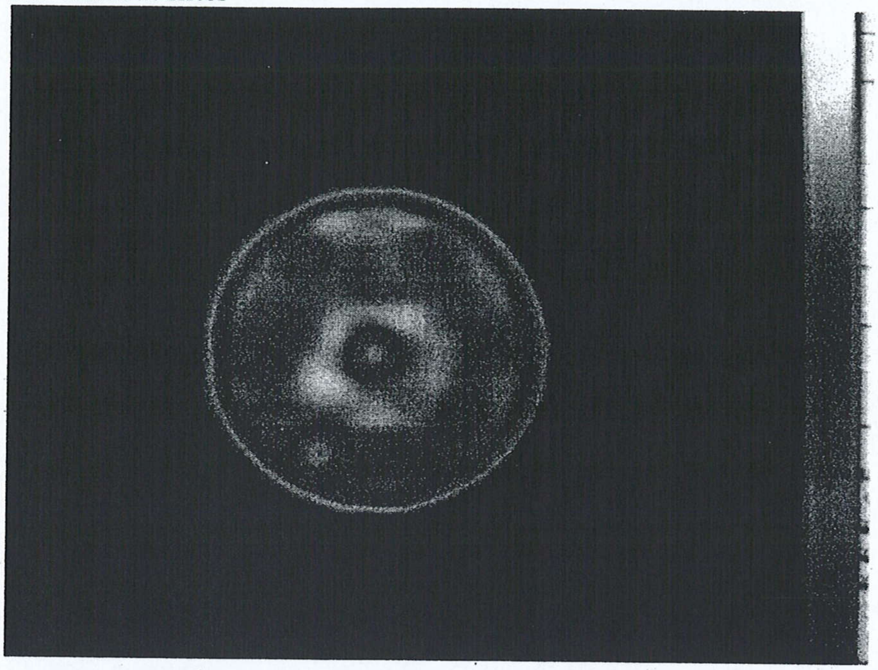

Figure 9b. With material filter Cu 0.125 mm

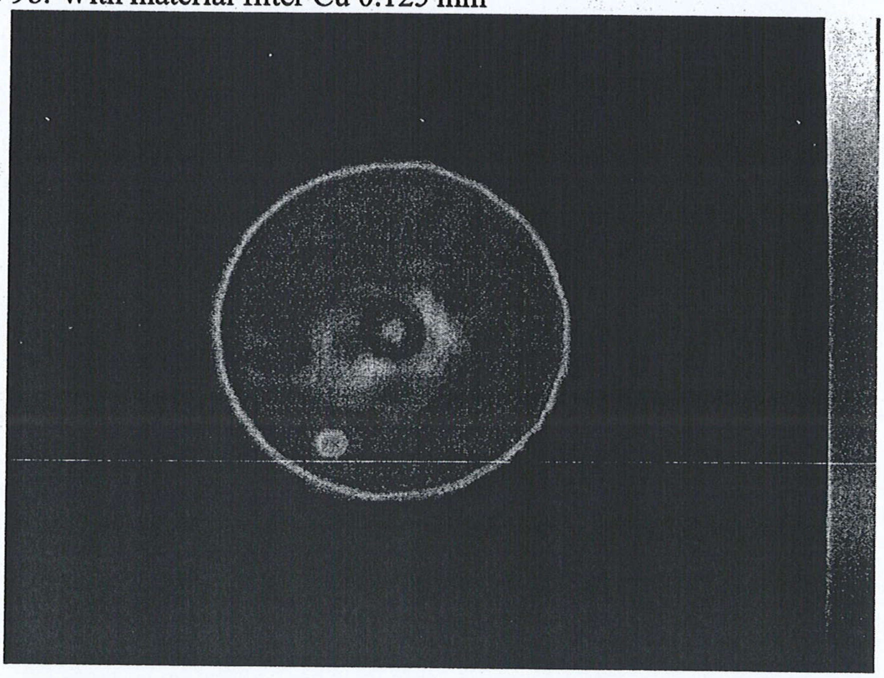

Figure 9c. With material filter Al 0.2 mm

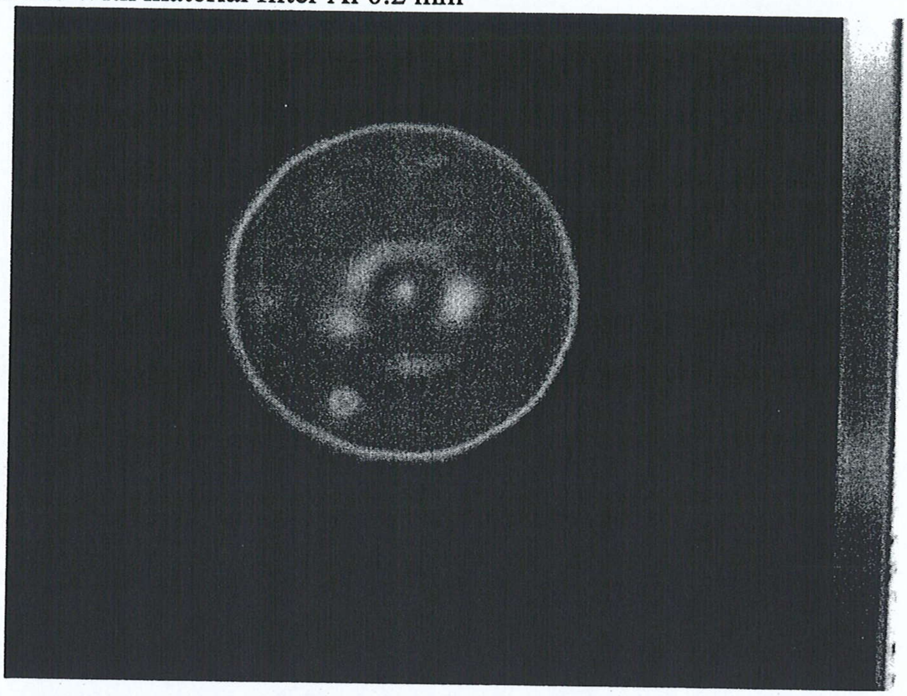

Figure 9d. With material filter Al 0.3 mm

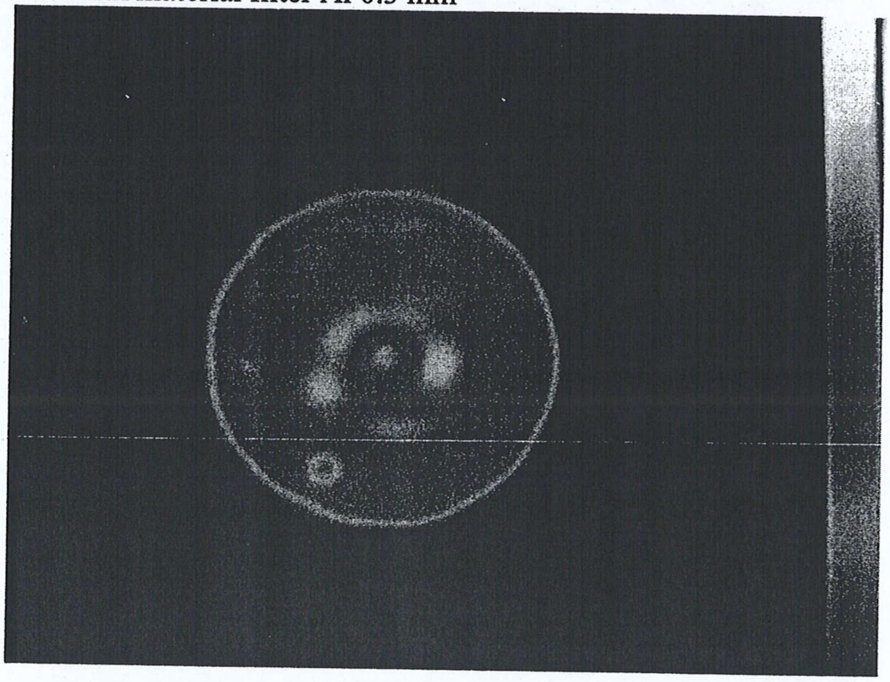

Figure 9a-d. Transverse image slice of a cold region insert (a) without material filter (b) Cu 0.125 mm (c) Al 0.2 mm and (d) Al 0.3 mm, respectively, with LEHR collimator.

Contrast values measured from images obtained without material filter were compared to with those measured in the images obtained by using material filter shows improvement in contrast with both the collimators (LEGP/LEHR) Figure 10 and 11.

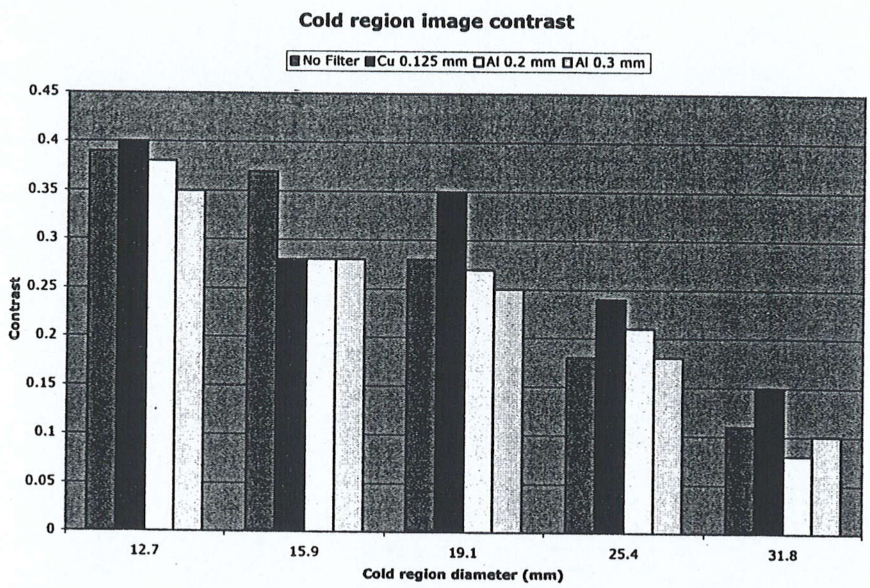

Figure 9. Hot region image contrast without and with material filters, with LEGP collimator.

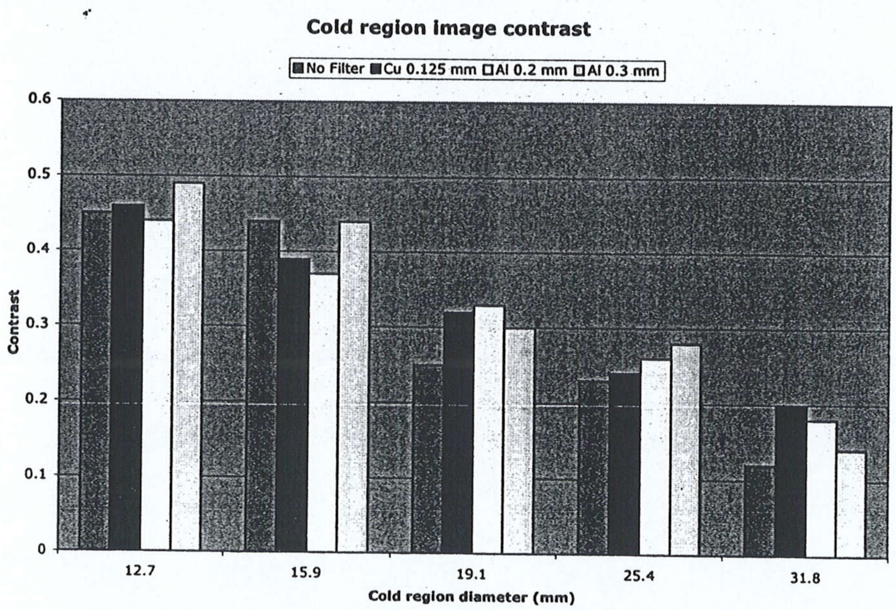

Figure 10. Hot region image contrast without and with material filters, with LEGP collimator.

Conclusion

All the findings, visual investigations and quantitative analysis of the transaxial images of hot and cold regions of the Carlson phantom showed an improvement in the image quality with material filter as compared to without material filtered data images with both the collimators. The technique reduces the influence of the scattered gamma photons in the projection data and may be named as on line scattered reduction technique. Moreover, this technique does not require any additional labour once the filter is mounted on the face of collimator. The material filters used in this study are not expensive and are easily available.

Material filtering technique has proven its potentiality in improving of the image quality in SPECT. This technique may have important clinical applications.

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