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TOPIC

THE EFFECT OF COLLIMATOR SELECTION ON IMAGE RESOLUTION IN SPECT WITH VARYING ACQUISITION PARAMETERS

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ABSTRACT

The study is to evaluate the effect of collimator selection on image resolution with varied acquisition parameters. Images were acquired by placing a quadrant-bar phantom on flood field uniformity Phantom filled with a 99m-Tc solution. The method involved varying the Acquisition parameter by using LEAP collimator after which the LEAP is replaced with the LEHR collimator. The experimental results demonstrate that as the matrix size increases from 64x64 to 1024 x 1024 the image quality improved by 26.4% in image resolution for LEHR collimator and 28% in image resolution for LEAP collimator. Image resolution degrade by 46.4% when the object-collimator distance increase from 0.00mm to 80mm with LEHR and degrade by 30.5% with the same increase in distance for LEAP collimator. However, count density has a little influence on image resolution, but may introduce artifacts with patient stability due to longer acquisition time; hence a range of 15Mcts to 20Mcts is recommended. Low energy high-resolution collimators (LEHR) produce better image resolution than Low energy all-purpose collimators (LEAP).

KEYWORDS: Collimator, LEHR, LEAP, Resolution, SPECT/PET/CT, resolution, image quality, count density, object-collimator distance, matrix size

INTRODUCTION

In Ghana, Nuclear medicine is mainly used for diagnostic purposes using SPECT imaging system. This is performed as complementary study to other imaging modalities in radiology mostly CT in other to give a better diagnosis of the extent of a disease-process in the body.

In nuclear medicine, the imaging procedure is a combination of radiopharmaceutical selection, injected dosage of radioactivity, collimator selection and imaging time, the goal is to optimize each of the parameters to obtain an image quality that allows the nuclear medicine physician to answer all the clinical questions [1]. The difficulty is that these parameters are not independent. Changing one parameter will affect the others. The simplest form of Nuclear Medicine imaging system is the Planar Scintigraphy ("scint"). This is a form of diagnostic test whereby detector captures and forms two-dimensional images from the radiation emitted by the radiopharmaceuticals.

A relatively advanced form of imaging to planar Scintigraphy is the SPECT in which Tomographic images are acquired with the gamma camera system. It is a three dimensional tomographic technique that uses gamma camera data from many projections and can be reconstructed in different planes [2].

A gamma camera combined with a computed tomography (CT) scanner, which provides localization of functional SPECT data, is termed a SPECT/CT camera, and has shown utility in advancing the field of molecular imaging [3].

The latest and more advance imaging device in Nuclear Medicine is the Positron Emission Tomography (PET) which uses coincidence detection to image functional processes. Short-lived positron emitting isotopes, such as F-18, is incorporated with an organic substance such as glucose, creating F18-fluorodeoxyglucose, which can be used as a marker of metabolic utilization. Images of radioactivity distribution throughout the body can show rapidly growing tissue, like tumor metastasis, or infection. PET images can be viewed in comparison to computed tomography (CT) scans to determine an anatomic correlation with physiological functioning. Modern scanners combine PET with a CT, or even with Magnetic Resonance Imaging (MRI), to optimize the image reconstruction involved with positron imaging. This is performed on the same equipment without physically moving the patient off the gantry (patient bed). The resultant hybrid of functional and anatomic imaging information is a useful tool in non-invasive diagnosis and patient management [4].

However, most nuclear medicine centers still use the less costly but efficient imaging devices like SPECT for imaging [5]. In Ghana SPECT is the available nuclear medicine imaging device used for imaging and hence, the reason for the use of SPECT for this study. The SPECT system in Ghana has three types of collimators namely, Low energy all purpose (LEAP), Low energy High resolution and High energy collimators. They have different spatial resolution and geometric efficiency. By selecting the appropriate collimator for SPECT use, there is a trade-off between spatial resolution, which can limit the contrast of the image resolution, and detection efficiency, which determines the noise in the image [6]. In this study, two types of collimators were used to study the effect of collimator selection on image resolution using quadrant bar phantom on flood field uniformity phantom.

A number of choices of collimators are available with which to acquire Nuclear Medicine data. However, user and clinical practitioners of imaging equipment always have to decide what type of collimator to use with specific procedure. The choice of collimators in nuclear medicine is a tradeoff between sensitivity and resolution. Collimators with better resolution typically will have smaller holes and because of this will have lower sensitivity. The converse is true for collimators that are higher in sensitivity; they will have larger holes and thus poorer resolution. In addition, thicker collimators will maintain their resolution as the distance from the collimator increases than will a thinner collimator. The goal is to match the collimator to the imaging task. In general, dynamic images do not require high resolution and can be acquired using a low-energy general purpose (LEAP) or a high sensitivity collimator. Some static images such as lung ventilation and perfusion scans are also lower resolution and could also be acquired using a LEAP collimator [7].

SPECT SYSTEM IMAGING

SPECT deals with single photon emission. Gamma ray emissions are the source of information, rather than X-ray transmissions as used in conventional computed tomography similar to Magnetic Resonance Imaging (MRI), SPECT allows us to visualize functional information about a patient's specific organ or body system [3].

The basic principle of a SPECT system is dependent on the rotating camera concept, where a series of planar images are collected, while the camera is rotated through either 180^o or 360^o around the patient. These planar images are called projection images and are used to create transaxial slice images by filtered back projection of the data into the transaxial plane. SPECT system principle is applied in both whole-body and phantom scanning [3].
Most SPECT systems use one or more scintillation camera heads that revolve around the patient. If the camera revolves around the patient, the camera acquire views of the tracer distribution at a variety of angles. After all these angles have been acquired, it is possible to reconstruct a three dimensional view of the radiotracer distribution within the body. Internal radiation is administered by means of a pharmaceutical which is labeled with a radioactive isotope. This radiopharmaceutical, or tracer, is injected, ingested, or inhaled. The radioactive isotope decays, resulting in the emission of gamma rays.

These gamma rays give us a picture of all functional processes in patient's body after a series of transformation by gamma camera imaging system. SPECT imaging is extensively used in nuclear medicine imaging.

COLLIMATORS

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There are 5 basic collimator designs to channel photons of different energies, to magnify or minify images, and to select between imaging quality and imaging speed. Types of collimators available in SPECT imaging include pinhole, fan beam, converging and diverging, slant hole, and parallel hole collimators. The parallel hole collimator has all holes parallel to each other, and most common designs of it include Low Energy All Purpose (LEAP), Low Energy High Resolution (LEHR), Medium Energy (ME), and High Energy (HE) collimators. The LEAP, LEHR and HE collimators are available at the Korle-Bu Teaching Hospital. LEAP collimators have holes with a large diameter as compared to the others. The sensitivity is relatively high and the resolution is moderate. LEHR collimators have more holes that are both smaller and deeper, giving them the ability to produce higher resolution images than the LEAP, but with moderate sensitivity [8].

The first object that an emitted gamma photon encounters after exiting the body is the collimator. The collimator is a pattern of holes through gamma ray absorbing material, usually lead or tungsten, that allows the projection of the gamma ray image onto the detector crystal. The collimator achieves this by only allowing those gamma rays traveling along certain directions to reach the detector; this ensures that the position on the detector accurately depicts the originating location of the gamma ray [8].

MATERIALS/EQUIPMENT

Materials used included; flood-field uniformity phantom, Quadrant bar phantom, SPECT System, Radioactive source (Tc-99m), Mo/Tc Generator, LEAP and LEHR Collimators.

METHOD

In order to image a Quadrant Bar-Phantom on flood-field uniformity phantom, to ascertain the effect of collimator selection on image quality, the flood field uniformity phantom was filled with water and 925 MBq (25 mCi) of Tc-99m, the quadrant bar phantom was then placed on the flood field uniformity phantom for imaging. The LEAP collimator was first mounted and the camera system position and ready for imaging. Series of images were acquired and the LEAP collimator was replaced with the LEHR collimator and the process repeated. The following parameters were varied during the acquisition.

The matrix size was varied, while keeping the count density and the object-collimator constant and the results tabulated using LEAP and LEHR.

The count density was then varied, while, keeping the object-collimator distance and the matrix size constant and the results tabulated using LEHR and LEAP collimators.

Finally, the object-collimator distance was also varied, while keeping count density and matrix size constant and the results tabulated using LEHR and LEAP.

RESULTS

The result obtained are Tabulated below

Table 1: FWHM for LEAP and LEHR collimators with varied matrix size.

Matrix Size (pixel)	FWHM LEHR (mm)	FWHM LEAP (mm)
64X64	6.7	6.8
128X128	6.2	6.3
256X256	5.6	5.8
512X512	5.5	5.4
1024X1024	5.3	5.3

Figure 1 shows a graphical view of the variation between matrix size and the FWHM for low energy all-purpose collimator (LEAP) and low energy high resolution (LEHR) collimator. The matrix size was varied from 64x64 to 1024x1024 matrices, while keeping object-collimator distance and count density constant.

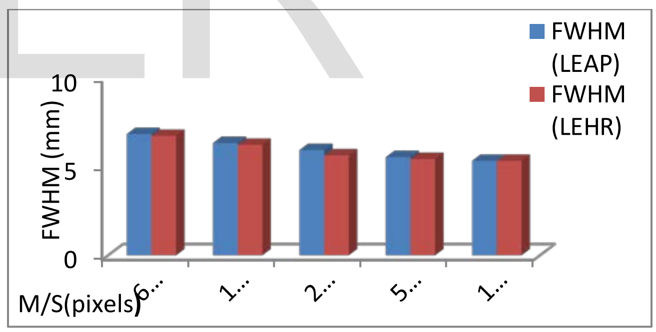

Figure1: Variation between acquisition matrix size and FWHM.

Table 2: FWHM for LEAP and LEHR collimators with varied count density

Count Density (Mcts)	FWHM LEHR (mm)	FWHM LEAP (mm)
5	5.9	5.9
20	5.8	5.8
25	5.8	5.8
30	5.7	5.8
35	5.7	5.8

Figure 2 shows a graphical relationship between the variation of count density and FWHM for the two collimators, low energy all purpose and low energy high resolution. The acquisition count densities (C/D) were varied from 15 Mcts to 35 Mcts while keeping the matrix size and the object-collimator distance constant.

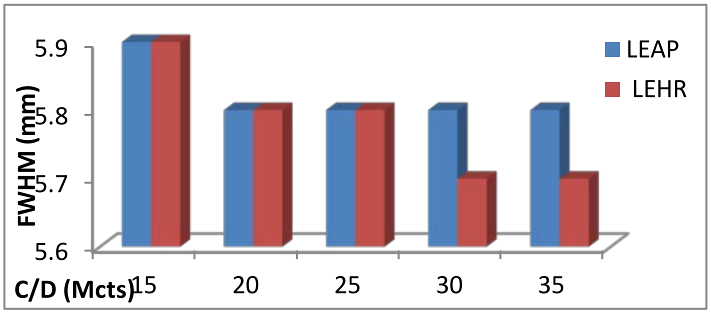

Figure2: Variation between acquisition count density and FWHM

Table 3: FWHM for LEAP and LEHR collimators with varied object-collimator (O-C) distance

O-C Distance (mm)	FWHM LEHR (mm)	FWHM LEAP (mm)
0.00	3.70	5.00
20.00	5.80	6.00
40.00	6.40	7.00
60.00	6.80	7.10
80.00	6.90	7.20

Figure3 shows a pictorial view of a variation between object-collimator distance (O/C) and FWHM for the LEAP and LEHR collimators. The acquisition object-collimator distances varied from 0mm to 8mm while keeping the matrix size and count density constant.

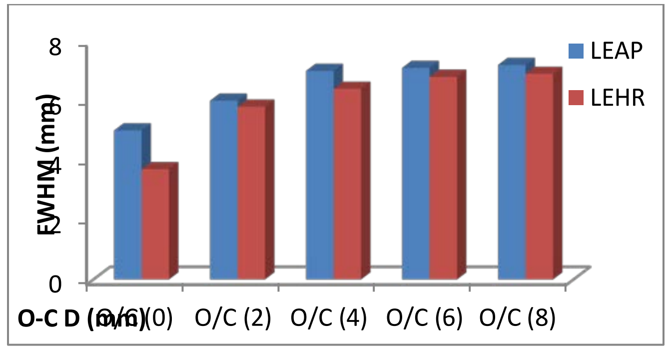

Figure3: Variation between acquisition object collimator (O-C) Distance and FWHM

DISCUSSION

Figure1 shows 26.4% improvement in resolution for LEHR collimator from 64x64 to 1024x1024 pixels and 28.3% improvement in resolution for LEAP collimator. Between the default matrix of 256x256 and the highest matrix size of 1024x1204, there were improvements in resolution of 9.4% for LEHR collimator as against 11.3% for LEAP.

The graphical relationship in figure 2 shows the behaviour of FWHM with varied count density, the effect of the change shows 1.7% change in image resolution in the case of LEHR collimator and 3.4% change in LEAP collimator, both collimators show slight improvements in resolution, even though LEHR collimator shows better improvement comparatively.

The graphical presentation of the variation of object-collimator distance on image quality is shown on Figure 3 in which the object-collimator distances increases from 0 to 80mm. The experimental result show 30.5% reduction in image quality for LEAP and 46.4% reduction for LEHR.

The design of the collimator determined the number of photons that were received by the detector. The energy and the availability of the radionuclide in a specified volume determine the count density. The flood-field uniformity or the response to uniform irradiation describes the degree of uniformity of count density in the image when the detector is “flooded” with a spatially uniform flux of incident gamma radiation. This explains why a uniform flood field on the quadrant-bar phantom was used. The study shows that count density has little effect on the quality of image produced. However, count density depends largely on the design of the collimator as shown.

The object-collimator distance is the distance between the surface of the object to be imaged and the detector which has the collimator on its surface. Theoretically, resolution of the gamma camera degrades as the distance between the camera and object being imaged increases [17]. This is because certain fraction of gamma rays from an object is absorbed when they are emitted in an attenuating medium, such as a phantom or a patient. This phenomenon varies according to the depth of attenuating medium between the object and the gamma camera.

CONCLUSION

The low energy high resolution collimator (LEHR) was found to provide better spatial resolution than low energy all-purpose collimator (LEAP)

From the above results and discussions it is clear that collimator selection have substantial effect on image quality or resolution and the results agree with international accepted standard.

This is an extended study to compare the LEAP and LEHR collimators as published in IJST with the title "evaluating the effect of acquisition parameters on image quality in SPECT with LEAP using quadrant-bar phantom at Korle-Bu Teaching Hospital" by the same Authors.

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