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The Effect of Collimator Selection on Acquisition Time with varying Acquisition Parameters using Quadrant Bar Phantom at Korle-Bu Teaching Hospital

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ABSTRACT

The study was undertaken to evaluate the effect of collimator selection on acquisition time while varying the matrix size, the count density and the object-collimator distance. Images were acquired by placing the quadrant-bar phantom on flood field uniformity Phantom filled with a 99m-Tc solution. The method involves imaging the combined Phantom with the SPECT system by using Low energy all-purpose (LEAP) collimator after which the LEAP collimator was replaced with the LEHR collimator and the process repeated. The experimental results demonstrate an increase from 11.89% to 170.29% in acquisition time when the acquisition parameters were varied using LEAP collimator and 9.63% to 164.82% in acquisition time when the acquisition parameters were varied the same way using LEHR collimator. Hence, the LEHR collimator has better acquisition time efficiency than the LEAP collimator. Also, LEHR collimator is better suitable for patient stability and appropriate in obtaining patients images. In patient study, patient motion occurring during data acquisition in SPECT could cause serious artifacts. This is likely to happen when images are acquired at much longer time. Hence the acquisition time should be suitable for patient stability.

Keywords: *LEAP and LEHR Collimators, Acquisition Time, flood field uniformity Phantom, Artifacts and SPECT*

I. INTRODUCTION

The choice of collimators in nuclear medicine is a tradeoff between sensitivity and resolution [1]. 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 all 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. The use of the lower resolution collimator would allow for a shorter imaging time or a reduction in the injected dosage [2]. In general, high resolution studies, such as bone scans, are best done with a higher resolution collimator such as the low-energy high-resolution (LEHR) [3]. One would have to image longer if less radioactivity were injected to reduce the absorbed dose.

Finally, the fabrication of collimators varies depending on the manufacturer. One should have a good understanding of the collimators you are using. One manufacturer's low energy all-purpose (LEAP) collimator may have a very similar resolution at 10 cm to another manufacturer's LEHR collimator at the same distance. If the sensitivity of the LEAP were better than the LEHR, it may be the better choice for studies such as the bone scan.

II. OBJECTIVES

This study would help in detecting the performance level of the e-cam® SPECT system at Korle-Bu Teaching Hospital and advice on what should be done during collimator selection and to examine the effects of collimator type on acquisition time.

Relevance and Justification

Nuclear medicine professionals deal with various medical images almost daily. Often, however, due to limited information available to these professionals or lack of experience in collimator selection and also in other to provide nuclear medicine professionals with appropriate acquisition time for exact scanning process in other to save time and artifacts during imaging, it is essential for a study of this nature to be able to advice practitioners on how to solve such imaging problem.

Mostly collimators are used at random and as such a comparative study was done on the two mostly used collimators (LEHR and LEAP) at Nuclear medicine center of Korle-Bu Teaching Hospital to help to advice the users of the SPECT system on the best choice of collimators.

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III. LITERATURE REVIEW

Collimator Type

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 [4]. 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.

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. [5]

Acquisition Time

An acquisition time that allows adequate image statistics is mandatory for the production of diagnostic images. This is in large part determined by count rate, matrix size, and number of projections per orbit. Obviously, the longer the acquisition, the more counts collected and the better the image resolution. However, typical patient tolerances for acquisition times make 30 to 45 minutes a realistic maximum. Thus times per projection (stop) must be predicted on an appraisal of the patient's ability to remain still. Any significant motion of the patient during acquisition may render the results unusable.

IV. METHODOLOGY

Equipments and Materials

The materials used included;

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

Method

The flood field uniformity phantom was half filled with water and then an approximately 925 MBq (25 mCi) of Tc-99 m was added and then the quadrant bar phantom placed on the flood field uniformity phantom for imaging. The LEAP collimator was first mounted and 'Homing' is performed to position the camera system ready for imaging.

The combined phantom (quadrant bar phantom on flood field uniformity phantom) was positioned on the SPECT gamma camera patient bed, by ensuring that the flat axis of the phantom was positioned parallel to the axis of the gamma camera detector, within the field of view (FOV) of the detector. Quadrant Bar phantom on the flood field phantom together were placed under the detector. The acquisition protocol on the computer system software was selected and imaged. The LEAP collimator was replaced with the LEHR collimator and the process repeated. In each case the acquisition parameters were varied.

The image quality was assessed using the calculated FWHM values to estimate the resolution. The acquired data were evaluated and interpreted based on the effect of the three acquisition parameters on the Acquisition time**,** which is the time require to acquire an image.

V. RESULTS AND DISCUSSION

Table 1: Matrix size variation with Acquisition time for LEAP and LEHR collimators

Matrix Size (pixel)	**Acquisition Time for LEAP (mins)**	**Acquisition Time for LEHR (mins)**
64X64	10.09	9.50
128X128	10.29	10.10
256X256	10.47	10.20
512X512	11.09	11.04
1024X1024	11.29	11.27

Table 2: Acquisition count density variation with Acquisition time for LEAP and LEHR collimators

Count Density (Mcts)	**Acquisition Time for LEAP (mins)**	**Acquisition Time for LEHR (mins)**
15	7.27	8.42
20	10.12	11.51
25	13.27	15.16

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30	16.37	19.03
35	19.65	22.43

Table 3: Object-Collimator distance variation with Acquisition time for LEAP and LEHR Collimators

Object-Collimator Distance (mm)	Acquisition Time for LEAP (mins)	Acquisition Time for LEHR (mins)
0.00	12.36	13.29
20.00	13.17	14.20
40.00	15.45	14.27
60.00	16.11	14.39
80.00	18.57	14.57

Relationship between Collimator selection and acquisition time with varying acquisition parameters.

The variation between the three acquisition parameters (matrix size, count density and object-collimator distance) and Acquisition time are presented graphically in figure 1 to 3.

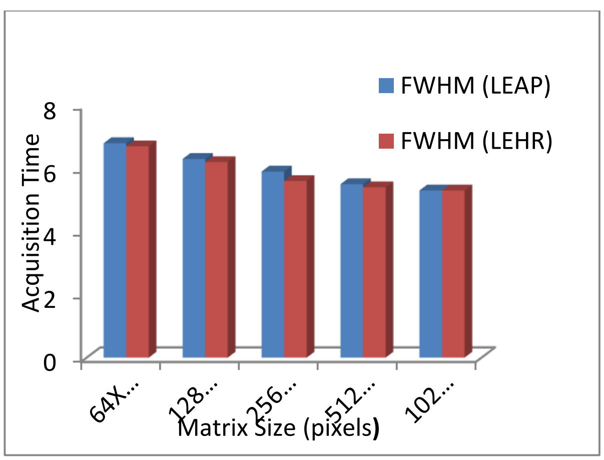

Figure 1: a graphical relationship between LEAP and LEHR collimators and Acquisition Time with varied matrix size.

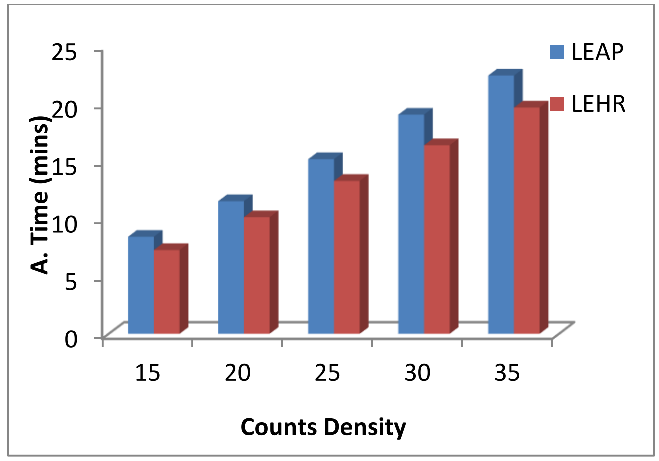

Figure 2: a graphical relationship between LEAP and LEHR collimators and Acquisition Time with varied count density.

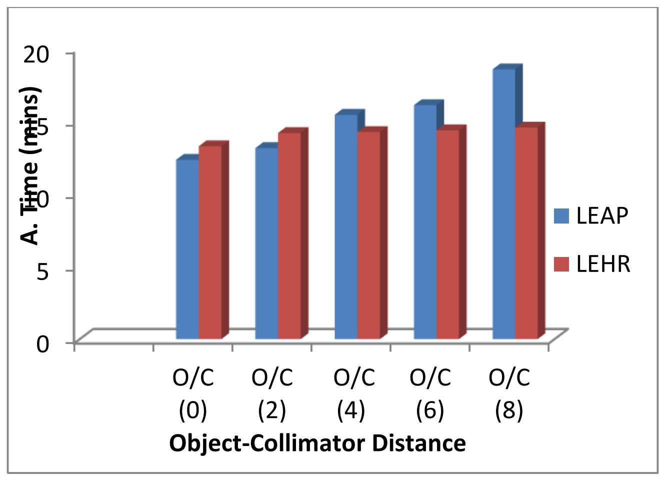

Figure 3: a graphical relationship between LEAP and LEHR collimators and Acquisition Time with varied object-collimator distance and Acquisition Time (A. Time).

VI. DISCUSSIONS

In SPECT studies, collimators of different spatial resolution and geometric efficiency are available for imaging [6]. By selecting the appropriate collimator for SPECT use, there is a trade-off between acquisition time, which can limit the contrast of the image resolution by introducing artifacts, and detection efficiency, which determines the noise in the image. In this study, two types of collimators were used to study the effect of collimator selection on acquisition time with varied acquisition parameters using quadrant bar phantom on flood field uniformity phantom.

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From Table 1 through to Table 3 established clearly a positive correlation in the values of the acquisition time of the LEAP and LEHR collimators. In the three Tables for instance as the matrix size increases from 64x64 to 1024x1024, the acquisition time increase from 10.09 to 11.29 minutes for LEAP collimator and 9.50 to 11.27 minutes for LEHR collimator. The reduction is shown graphically in Figure 1 to Figure 3. The acquisition time shows different variations for different collimators. With variation of matrix size from 64x64 to 1024x1024 acquisition time increases by 11.89% for LEAP and 18.63% for LEHR collimators. Also, when count density changes from 15Mcts to 35Mcts acquisition time increases by 170.29% for LEAP and 164.82% for LEHR collimators. This is because the number of photon received by the detector within a specified volume depends to the larger extends the design of the collimator and not the count density and or count-rate performance of a scintillation camera which describes the non-linearity in the relationship between the count rate and the intensity of incident (received) gamma radiation by the detector [6].

In other words the design of the collimator determined the number of photons that were received by the detector and also 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

Finally, when the Object-collimator increases from 0.00 mm to 80.00 mm the acquisition time increases by 50.24% for LEAP and 9.63% for LEHR collimators.

LEHR collimator produces much better time efficiency as compared to LEAP collimator. In other words LEHR collimator show more sensitivity to photon passage than LEAP collimator as shown in the acquisition time on various Table and Figure above.

VII. CONCLUSION

The low energy high resolution collimator (LEHR) was found to provide better time efficiency than Low energy all-purpose collimator (LEAP).

In patient study, patient motion occurring during data acquisition in SPECT could cause serious artifacts. This is likely to happen when images are acquired at much longer time. Hence the acquisition time should be suitable for patient stability. About 15 to 25 minutes is recommended to be appropriate in obtaining patient images.

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