Assessment of Gamma Camera SPECT Resolution using Developed Quality Control Phantom

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Abstract: ***The aim of this study; was to developed and designs an indigenous quality control phantom QCP to be used for gamma camera resolution QC test which installed at Royal Care hospital (RCH) and Radiation & Isotopes Center of Khartoum (RICK), as well to compare its performance relative to the standard QC phantom recommended by National Electronic Manufacture Association NEMA. The phantom has been designed based on the parameters and specifications recommended by NEMA with specific indigenous designing in view of utilizing local cheep material such as Perspex and wires lead and geometrical engineering. The comparative QC assessment for RCH and RICK revealed that: for RCH and RICK the resolution was 94.0% and 89.5% respectively which was dependant on the minimum object size resolved in the designed phantom (0.5 mm), while the resolution obtained by NEMA standard phantom showed 95.5% and 91.8% respectively. Quite similar resolution% has been obtained by the designed phantom depending on the object frequency (number of object/cm) i.e. number of lead wires resolved per cm^2, in this view the resolution was resolution was 94% and 90.3% respectively and in comparison with that obtained by NEMA phantom which was 95.5% and 91.8% respectively, the average deviation factor of the designed phantom from the standard was 1.5% - 1.9. Also the general trend of correlation between object size versus resolution showed a linear proportional equation in a form of $y = 6.59x + 47.87$ and $y = 6.64x + 43.1$ for RCH and RICK respectively with significant correlation as $R^2 = 0.98$. And for object frequency versus resolution, the equation trend was inversely according to: $y = -242.68x + 113.01$ for RCH and $y = -258.1x + 110.46$ for RICK, where x refers to object frequency and y refers to resolution%, with significant correlation as $R^2 = 1$.***

Keywords: Gamma, Camera, Phantom, Resolution, Quality control

1. Introduction

Within Nuclear Medicine, image abnormalities and artifacts Within Nuclear Medicine, image abnormalities and artifacts affecting the quality of images are well known phenomena [1]. Therefore, it is of great importance to have Quality Assurance for gamma and SPECT cameras to minimize the occurrence of these abnormalities and artifacts. National Electrical Manufacturers Association NEMA has made recommendations of routine quality control for nuclear medicine instrumentation [2]. After installation and before the camera is put into clinical use, it should undergo National Electrical Manufacturers Association (NEMA) Performance standard measurements to verify that the camera performs according to specification supplied by the manufacturer and to establish baseline conditions for all future measurements. The NEMA (NU 1-2007) Standards Publication [3] describes how to perform process and report of QC tests for gamma and SPECT cameras [2]. Often, with support from the manufacturers, all necessary phantoms can be supplied and acquisitions can be done according to NEMA standards, but Quality Assurance also requires a careful handling of the measured QC data. For optimal diagnostic use of nuclear medicine instruments it is essential that routine performance evaluation must be carried out as part of an ongoing quality assurance program. The NEMA publication (NU 1-2001) [4] is the basic recommended standard for performance evaluation and acceptance tests of scintillation cameras, however, the methodology and guidelines described is more complex than necessary for many nuclear medicine departments to use on a routine basis. The intrinsic flood uniformity test of a gamma camera is a measure of the response of the gamma camera to a uniform flux of radiation from a point source when the collimator is removed or extrinsic flood uniformity test which assess the response of camera and collimator to uniform flux of radiation from ^{99m}Tc liquid flood phantom, which is one of the primary tests performed on the gamma cameras. Also there are two different uniformity parameters, usually measured during this test are: integral uniformity and differential uniformity. These are calculated for both the central field of view (CFOV) and useful field of view (UFOV) of the gamma camera. The integral uniformity has typical values of 2% to 4% [2]. For differential uniformity in most cases, a value of less than 3% is obtained after uniformity correction [5]. When the value for differential uniformity exceeds 3%, maintenance service should be carried out on the gamma camera [6]. Values of differential uniformity in the range 1.0% to 2.5% and values of integral uniformity in the range of 1.5% to 3.5% when the uniformity correction is applied are an indication that the system is working optimum. Generally, between 10 and 30 million count flood images are adequate for verification of non uniformity of the system, for all clinical studies. Spatial linearity is one of the parameters that influence flood field uniformity. In the ideal system, a straight line source of gamma rays should yield a straight line in the image. The NEMA protocol for measuring linearity involves the acquisition along the X and Y directions of an image from a multi-slit phantom, the same one used for the spatial resolution measurement, followed by an analysis of the line spread peak positions [7] (John et al, 2011). A deviation of the peak position from the true location of the center of the slits is a measure of the deviation from linearity. Typically, most departments do not measure linearity separate from either spatial resolution or flood field uniformity [8]. Due to disadvantages of techniques used to measure gamma camera system linearity (removal of the collimator which may implies crystal break or deformity of lead septa of the collimator), the complexity of technique, and due to shortness\little funding for maintenance and the lack of a manufacturer independent QC-software supporting a NEMA performance standard which is considered as a major problem to perform NEMA QC tests; the researchers feel curious to develop a full suite of data handling software based upon the NEMA Standard Publication of NEMA NU-1 2007 [3] using interactive data language (IDL) program together with a developed phantom which is friendly applicable for routine gamma camera (SPECT) tests and low cost in Sudan. The fabricated phantom has been compared with the standard SPECT phantom to determine to what extent it mimics the standard one in view of QC test.

2. Materials and Method

The designed phantom has been excerpted from the phantom parameters stated by International Atomic Energy Agency DOC-602 [9], NEMA-2001[4], Ng et al, [10], Holstensson et al, [11]-[12] and Islamian et al, [13], which consists of four quadrate bars as recommended by Zanzorico et al, [14].

The frontal part of the phantom made of Perspex (42×42×10 cm) shown in Figure (1) that simulates the four quadrant bars phantom each one was 20×20 cm, which have been grooved by laser cutting bed (BCL-B series model BCL1318B china 1991). The first quadrant implies 26 grooves with dimensions of 18×0.35 cm and separated from each other by distance of 3.5mm. The second quadrant contains 30 grooves as 18 cm×3mm and each adjacent grooves was separated by distance of 3 mm, the third quadrant contains 32 grooves with dimension of 18cm × 0.25 cm separated by 2.5 mm distance, and the forth quadrant contains 32 Grooves with 18 cm× 2 mm and separated from each other by factor of 2 mm. The edge of the phantom i.e. the remaining 2 cm; a big grooves was made with dimension of 36 cm length and 5 mm width, which is used to measure the linearity of the gamma camera by measuring Modulation transfer function (MTF) of the Line Spread Function (LSF). The back part simulates the liquid flood phantom made of Perspex (42×42×1 cm) Figure (2) and has orifice 0.5 cm to be fill with a liquid radioactive material, controlling the air bubbles and insuring the homogeneity. Then some lead wires have been fabricated in smooth and fine shapes according the dimension of the grooves (18 × 0.35cm, 18×0.3 cm, 18×0.25 cm, 18× 0.2 cm and 36×0.5 cm) which then have been mounted in the relevant grooves in the front quadrants.

Then a mixture of water (1500ml) and $Na^{99m}TcO_4$ (1.3 mCi) has been flushed into the phantom via the orifice, shacked to maintain the homogeneity and air bubbles free. Then, the phantom has been put on the couch and centered to the gamma camera (Nucline Sprit model, single head SPECT-Hungarian) facing the central Field of View (CFOV) and image was acquired using count mode of 16 million counts last for 2014 seconds at rate of 7749 count/second (cps) using the parameter of 256 × 256 × 16 matrix size, body contour and full field. The method of imaging acquisition, phantom parameters and data collection was performed according to the parameters recommended by NEMA, IAEA, [14] and Ellinor et al, [2].

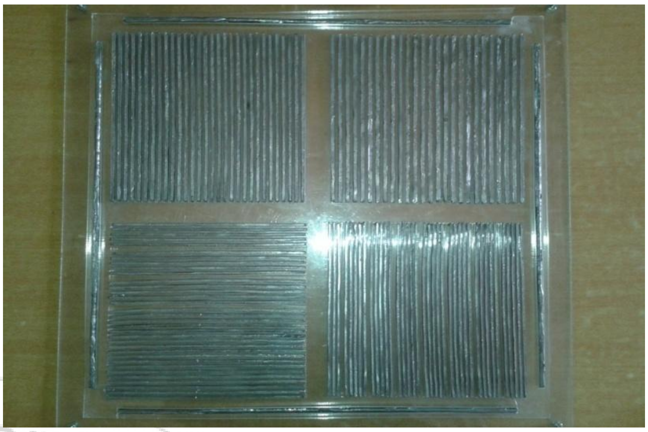

Figure 1: shows the frontal part of the phantom made of Perspex (42×42×10 cm) that simulates the four quadrant bars phantom each one was 20×20 cm

Figure 2: shows the back part simulates the liquid flood phantom made of Perspex (42×42×1 cm) and has orifice 0.5 cm to be fill with a liquid radioactive material

Then for all obtained images, the researcher applied their own developed mathematical IDL program to measure the resolution in percent versus frequency of object (numbers of wires/cm) and size of wires. The QC test of resolution has been carried out for two nuclear medicine departments specifically at Royal care and Radiation & Isotopes Center in Khartoum using the fabricated phantom and the reference standard one.

3. Results

The highlighted results show the obtained resolution percent versus object size in mm and the frequency (number of wires/cm) for Royal Care and Radiation & Isotopes Center hospitals Figure 1 and 2 as well these results have been compared with the reference result of QA done by the standard quadrant bars phantom Figure 3 and 4 respectively.

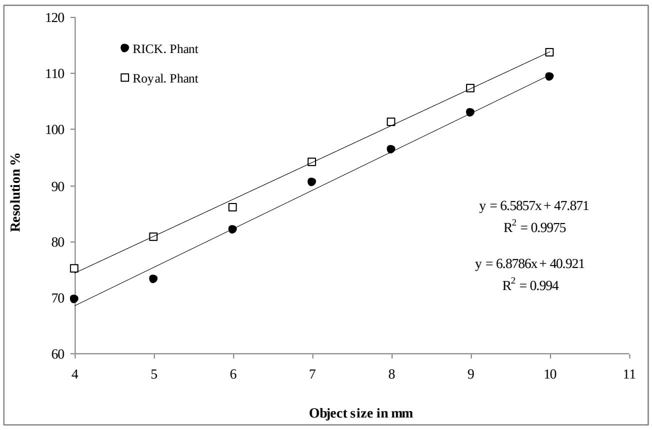

Figure 1: shows the resolution % vs. objects size for SPECT in RICK and Royal care hospitals-Khartoum Sudan using developed phantom.

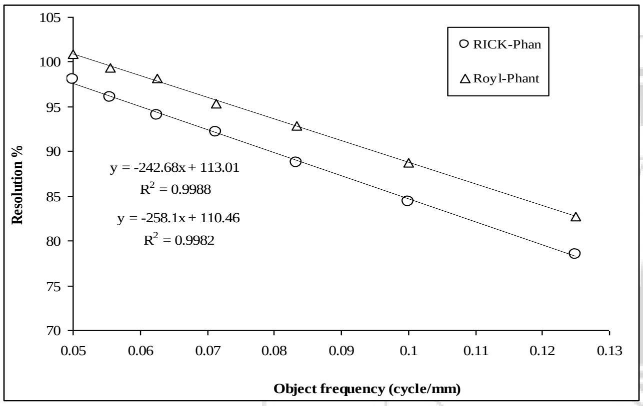

Figure 2: shows the resolution % vs. objects frequency for SPECT in RICK and Royal care hospitals-Khartoum Sudan using developed phantom.

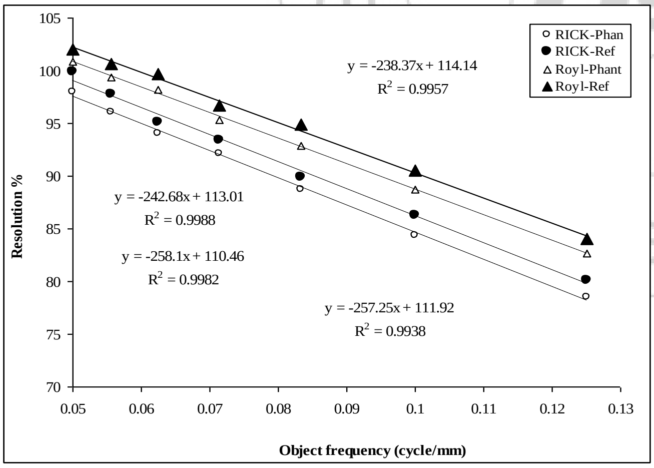

Figure 3: shows the comparison resolution% measured by phantom and the QA base line for Royal Care and RICK hospitals.

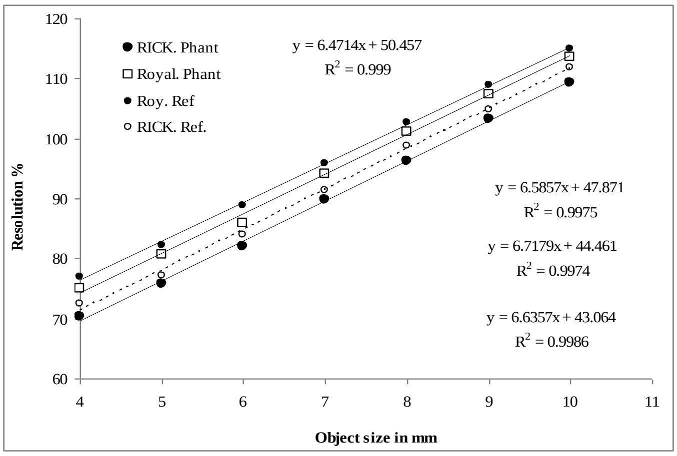

Figure 4: shows the comparison resolution% measured by phantom and the QA base line for Royal Care and RICK.

4. Discussion

Figure (1) shows the resolution % vs. objects size for SPECT at RICK and RCH-Khartoum Sudan. The analysis reveals that: the resolution percent increases following the objects size increment for both hospitals i.e. RCH and RICK, however RCH and RICK showed the average resolution of 94.0% and 89.5% respectively as measured by the designed phantom relative to the standard resolution measured by the NEMA phantom which was 95.5% and 90.8%, while the correlation between the resolution% and the objects size in mm could be fitted to the following equation y = 6.59x + 47.87 and y = 6.64x + 43.1 for Royal Care and RICK respectively with significant correlation as R2 = 0.98. The system resolution at RCH has been within the tolerance level i.e. 3-5% from the optimum resolution (100%), however the system at RICK showed an action level which is > 5% relative to the optimum resolution (100%) as has been mention by IAEA, [15] and Ellinor et al, [2]. Therefore the system installed at RICK should be subjected to serious QC process to reassure the optimum or at least tolerance level of resolution.

Figure 2 shows the comparative resolution % vs. objects frequency for SPECT at RICK and RCH. The analysis showed that: there is inverse linear relationship between the resolution% and the objects frequency (number of wires/cm) i.e. as the frequency increases the resolution% decreases for both hospitals and the average resolution% was 94% and 90.3% respectively as measured by the designed phantom and in comparison with that obtained by NEMA phantom which was 95.5% and 91.8% respectively, the average deviation factor of the designed phantom from the standard was -1.5%. in contrast with the standard ranged of resolution stated by Ellinor et al, [2], both systems installed at RCH and RICK have been shifted from the standard range but the system at RICK was at action level. The correlation between resolution % and the objects frequency could be fitted in equations: $y = -242.68x + 113.01$ for RCH and $y = -258.1x + 110.46$ for RICK, where x refers to objects frequency and y refers to resolution%, such correlation was significant as R2 = 1. The average resolution% measured by the phantom was 94% and 90.3% respectively.

Figure 3 shows the comparison resolution% versus object frequency measured by developed phantom and the QA base line for RCH and RICK. The general trend of the analyzed data showed that: there were inversely linear relationships between object frequency and resolution with significant point at $R^2 = 0.9$ % i.e. as the object frequency increases the resolution% decreases. The average resolution measured by the developed phantom was 94.0% and 90.3% for RCH and RICK respectively, these results relative to the standard NEMA QA phantom which was 95.5% and 91.8% respectively. Same resolution as 94.0% and 89.5% have been obtained for RCH and RICK respectively depending on the resolved object size as shown in Figure (4) which is compared with standard results obtained by NEMA phantom as 95.8% and 91.5% to deduce that: the average shift of the designed phantom relative to standard one was also 1.9%. Hence the developed designed phantom could be use successfully to carry out the QC tests for SPECT in Sudan with an average deviation factor of -1.3% from the optimum resolution measured by NEMA phantom.

5. Conclusion

In case of low budgets or lack of funding to purchasing SPECT system with full option of QC tools, the designed phantom could serves the NM specialist to carry out the resolution QC test successfully and the other tests could be contemplated and verified also with figuring out the deviation factor.

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