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Design of gamma camera quality control phantoms using inkjet printer

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Abstract:
developing a gamma camera quality control phantom using inject printer with algorisms to represent the gamma camera quality control tests in a numerical platform and develop of independent algorism to evaluate the gamma camera performance, the study conducted at royal care international hospital in period from May 2019 till October 2020.

The result of this study shows that the integral and differential uniformity for central field of view and useful field of view, all images were measured with integral and differential uniformity, for center field of view the measurements from images 1 till 9 was almost same 4.09 – 4.95 for IU and 2.06 – 2.56 for DU, but the images number 10 and 11 was shown a different measurement for IU and DU was 8.28 and 6.76 respectively. The measurements of UFOV for images 1-9 was almost similar for IU and DU were the measurements ranges from 4.45 to 5.12 and 2.54 to 3.54 while in images 10 and 11 was 7.87 and 6.45 for IU and 4.98 and 4.42 for DU respectively.

The scatter plot shows a direct linear relationship of IU of UFOV with CFOV were the rate of change for IU for UFOV increase by rate 0.7539 for each unit of IU for CFOV. the scatter plot shows a direct linear relationship of DU of UFOV with CFOV were the rate of change for DU of UFOV increase with rate 1.0261 for each unit of DU of CFOV. The shade Surface 3-D histogram is a representation of three-dimensional dataset TO describes a functional relationship between two independent variables X and Z and a designated dependent variable Y, rather than showing the individual data points.

Keywords: *Design Phantom, Gamma Camera, CFOV, UFOV*

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I. Introduction:

The correct functioning of instruments is essential for a successful nuclear medicine practice. Quality control programs for nuclear medicine equipment guarantee that clinical studies are of the highest quality, combining accuracy, precision, and rigor with practical criteria. Cuba has

10 gamma-cameras and SPECT systems installed in 9 nuclear medicine departments. This equipment has historically been evaluated and monitored according to institutional quality control programs based on international standards (e.g., protocols from organizations such as the National Electrical Manufacturers Association (NEMA), the International Atomic Energy Agency (IAEA), and the American Association of Physicists in Medicine), taking into account the local availability of clinical and standard phantoms, radioactive sources, and other resources. A routine quality assurance program should then be developed and followed where tests are performed on regular intervals. These tests do not include all the acceptance tests performed when commissioning a system and they mostly deviate from the original tests in the manner they are performed as well as in terms of the devices and phantoms employed.

In general, phantoms used for quality assurance can be expensive and not always easily accessible. In addition, due to the fact that there are different camera configurations and detector sizes, such phantoms should, in some cases, be camera specific. It will therefore be of great benefit to nuclear medicine departments to have an alternative and cheaper way to manufacture phantoms according to their own needs. As we know, the intrinsic floods are often being used and preferred than the extrinsic ones due to its lower radiation exposure to the staff, the higher purchasing cost of flood source or phantom as well as less experiment time when acquiring the high-count floods [1,2].

Adaptive Quality Control Phantom AQCP designed to perform a uniform set of procedures that can be used for routine quality control of a scintillation camera-based system. AQCPis an electromechanical device designed to acquire the field uniformity, center of rotation and collimator hole angulation by using some advanced methods of position control [3-5].

Planar system uniformity test: The planar system uniformity was assessed for the camera fitted with the Low Energy High Resolution (LEHR) collimator with an energy range of 60-140 keV and sensitivity 235 (cpm/Ci) as well as using a 10 mCi 99mTc flood phantom placed on the parallel hole collimator. The IAEA protocol for systematic flood field uniformity analyzes Integral Uniformity (IU) over the Useful Field Of View (UFOV) [6]. The IU represents the maximum pixel count difference over the indicated field of view expressed in percentage. Integral Uniformity of uniform images can be measured by using relation 1 given below:

$$IU = (Max-Min) / (Max+Min)*100 \quad (1)$$

Here, Max and Min are Maximum and Minimum pixels count within the UFOV= 0.95*FOV, respectively.

For measuring of the planar system uniformity with AQCP, the line source is moved over the field of view in a precisely defined condition as illustrated below:

Length of the source = 4 cm, Inner diameter of the source 1.6 mm activity 1 mCi, window: 20% and measuring distance source to collimator = 10 cm.

To irradiate all the pixels in a uniformly manner, the timing and speed of the motion as well as the delay time between 2 steps of step motors should be adjusted and to meet this feature, a particular attention should be paid to the path and the velocity of the moving source. Uniformity image taken by AQCP method was evaluated by calculating IU parameter from relation No:1 same as the IAEA-TECDOC-602 method.

In this study we aimed to use of a standard inkjet printer to produce radioactive phantoms that can be used for routine quality control of gamma cameras and to evaluate the printed radioactive phantoms and demonstrate their use by determining the uniformity of the camera.

II. Methodology:

The study were conducted at Royal Care International Hospital, using a gamma camera Model: Nucline Spirit, SN: DH-004167-V and MON.TEK ^{99}Mo/^{99m}Tc generator contains fission Molibdenium-99 (^{99}Mo) adsorbed by aluminum oxide (Al_2O_3) in a glass column. Technetium-99m (^{99m}Tc) formed by the decay of ^{99}Mo, is a radiactive isotope having a half life of 6.007 hours. After eluting by 0.9% NACl solution, ^{99m}Tc Sodium Pertechnetate solution which is isotonic, colourless, clear, sterile, non-pyrogenic and suitable for I.V. injection is obtained. (^{99m}Tc) Sodium Pertechnetate solution can be administrated to the patients directly as a diagnostic agent or for labeling the kits

Inkjet printer: HP DeskJet 2130 All-in-One Inkjet Printer, 63 Setup Black Ink Cartridge (~135 Pages), 63 Setup Tri-Color Ink Cartridge (~100 Pages), Power Cord.

method of data collection: using 50 mCi of the Tc99m was withdrawn and it was in 0.2 ml in volume, the TC-99m was then mixed with 2 ml black ink and then added to the cartridge of an inkjet printer and we used the MS word software to create a black image that will be representative of the radioactive distribution required the black image ,it was printed on a A4 (80 gm/) paper it was placed inside a plastic sheet to prevent any possible contamination and placed on top of the gamma camera table facing the Central Field of View (CFOV) and image was acquired using 512 X 512 matrix size, the image contain on million counts and this image demonstrate the extrinsic uniformity of Nucline Sprit camera (hangarian) fitted with a low energy all purpose (LEAP) collimator.

Uniformity of print flood sources: eleven radioactive flood sources (21 × 29.7 cm) will print. Approximately 740 MBq ^{99m}Tc will deposit onto each paper sheet. Each source inside its plastic sheet will place directly on the camera detector and the image of count of 10 000 counts was obtained. The integral (IU) and differential uniformities (DU) was calculating according to NEMA specifications (NEMA 2001) IU and DU was calculate for the central field of view (CFOV). A collimated with NaI (Tl) crystal scintillation detector which is connected to a multi-channel analyzer (MCA) system was used to obtain a series of counts from the uniform phantom. The crystals shielded with thick lead platform to which the flood source will be placed on . The holes in the centre of the lead allow for gamma rays from the print flood source to be detect. A region of interest (ROI) representing a 15% energy window to include the 140 keV 99mTc photo peak will select on the spectra obtain from the MCA. The MCA was set to acquire 10 000 counts in the select ROI and the acquisition time will note. The count rate will calculate. For each phantom different reading space equally across the area of the phantom will obtain in the central field of view. The count rates will decay correct and an IU value calculate. No filtering will apply to the data before calculating the IU value.

method of data analysis: The developed Q.C software complements cameras specific manufacture software by providing an independent processing platform regardless the type of camera. The software must be based on NEMA recommendation regarding processing and analysis of the data (9), Our independent software for analysis of the gamma camera quality control image was basically designed according to the equations and parameter recommended by The NEMA Standards Publication NU 1-2007 which described how to perform process and report QC tests for gamma and SPECT cameras and run in IDL (Interactive Data Language for windows integrated development environment version 6.1) it is capable for calculating extrinsic integral and differential uniformity. The program is aimed to make the processing of Q.C data simple, easy and independent on manufacture.

III. Results:

Table 1. show the Integral uniformity (IU) and differential uniformity (DU) uniformity values for central field of view (CFOV)

	CFOV		UFOV	
Images	IU	DU	IU	DU
1	4.26316	2.3746700	4.892	3.4567700
2	4.9126	2.5641026	5.10345	3.5456700
3	4.09383	2.4258761	4.45634	2.5467340
4	4.32278	2.061856	4.67847	2.825346
5	4.37634	2.139037	4.89746	3.1285675
6	4.31915	2.188172	5.08754	3.234865
7	4.32821	2.313625	4.67543	2.789345
8	4.95455	2.387268	5.067543	3.276543
9	4.86595	2.247191	5.127654	2.894563
10	8.2842	4.263158	7.87656	4.986543
11	6.7684	3.298013	6.452348	4.427854

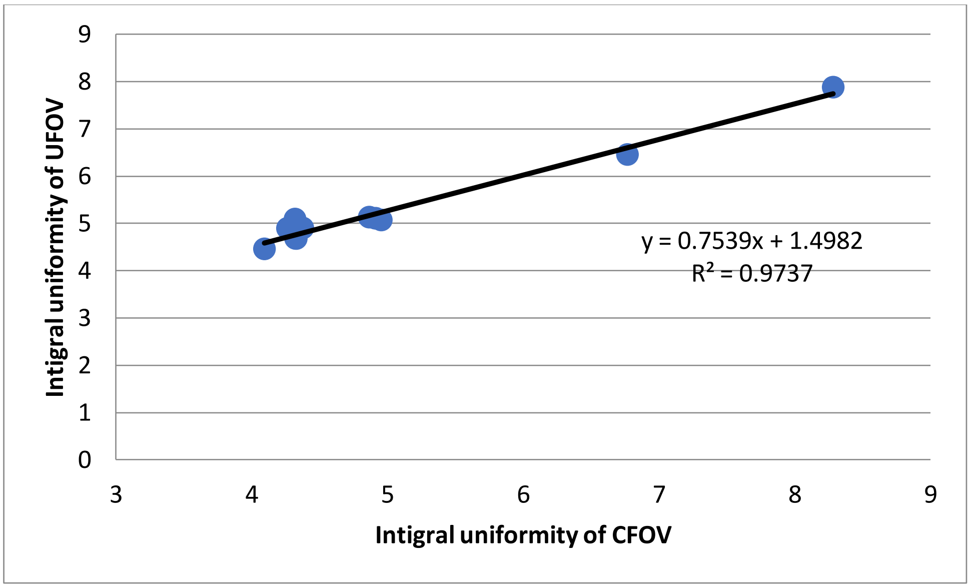

Figure 1. scatter plot shows a direct linear relationship of IU of UFOV with CFOV

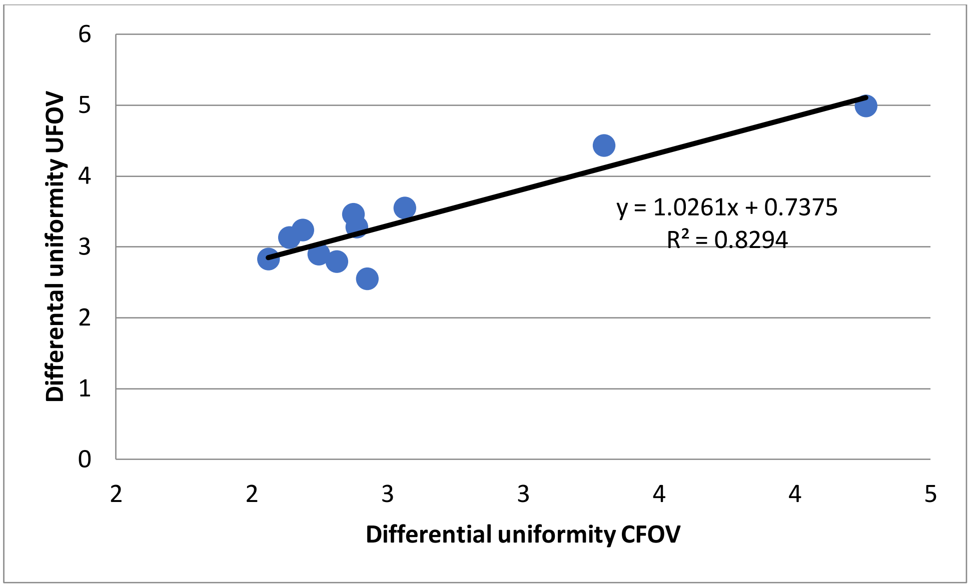

Figure 2. scatter plot shows a direct linear relationship of DU of UFOV with CFOV

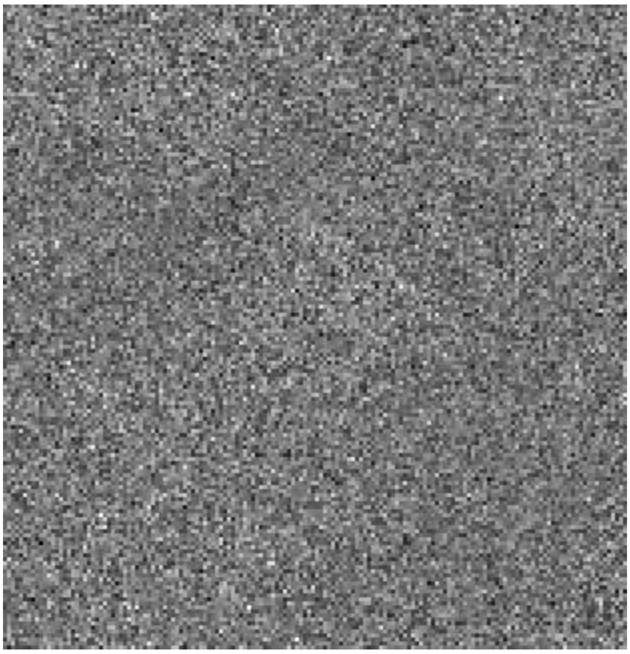

Figure 3. a gamma camera image for phantom that generated by ink jet printer for uniformity test

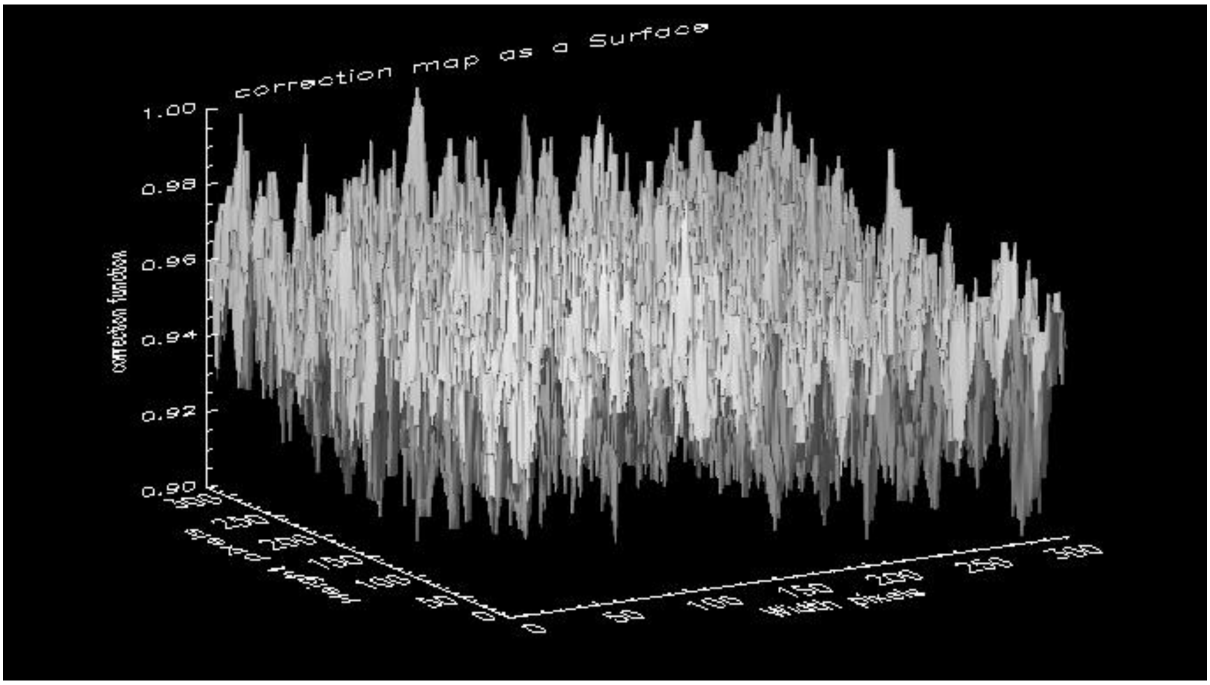

Figure 4. shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits.

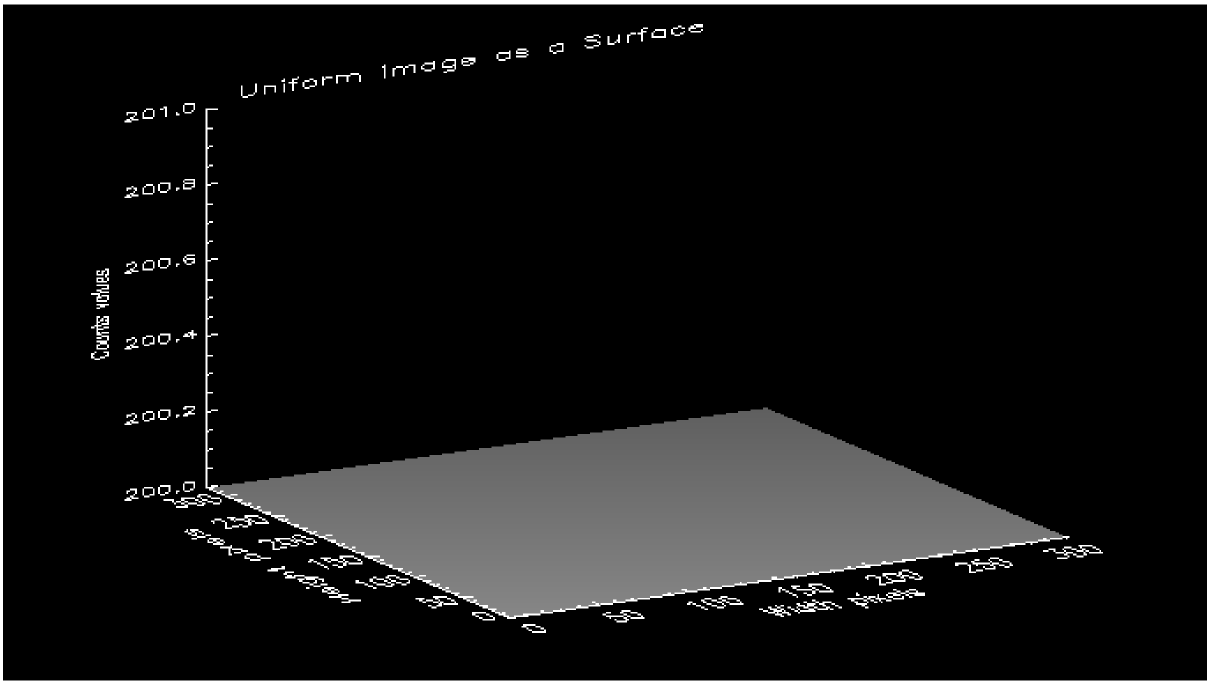

Figure 5. shade Surface for the uniformity image (4-5) that generated by ink jet printer after applying correction map.

IV. Discussions:

Table 1. show integral and differential uniformity for central field of view and useful field of view, all images were measured with integral and differential uniformity, for center field of view the measurements from images 1 till 9 was almost same (4.09 – 4.95) for IU and (2.06 – 2.56) for DU, but the images number 10 and 11 was shown a different measurement for IU and DU was 8.28 and 6.76 respectively. The measurements of UFOV for images 1-9 was almost similar for IU and DU were the measurements ranges from 4.45 to 5.12 and 2.54 to 3.54 while in images 10 and 11 was 7.87 and 6.45 for IU and 4.98 and 4.42 for DU respectively. Figure 1. show scatter plot show a direct linear relationship of IU of UFOV with CFOV were the rate of change for IU for UFOV increase by rate 0.7539 for each unit of IU for CFOV. Fig 2. Show scatter plot show a direct linear

relationship of DU of UFOV with CFOV were the rate of change for DU of UFOV increase with rate 1.0261 for each unit of DU of CFOV. Fig 3. Show gamma camera image for phantom that generated by ink jet printer for uniformity test, were the images show the distribution of solution of the radioactive material TC-99m with ink jet printer. Fig 4. Show shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits. Fig 5. shade Surface for the uniformity image (4-5) that generated by ink jet printer after applying correction map.

The shade Surface 3-D histogram is a representation of three-dimensional dataset. It describes a functional relationship between two independent variables X and Z and a designated dependent variable Y, rather than showing the individual data points. It is a companion plot of the contour plot. It is similar to the wireframe plot, but each face of the wireframe is a filled polygon. This helps to create the topology of the surface which is being visualized.

V. Conclusion:

a gamma camera quality control phantom using inject printer with associated algorisms were the study conducted at royal care international hospital, the linear relationship of IU of UFOV with CFOV were the rate of change for IU for UFOV increase by rate 0.7539 for each unit of IU for CFOV. The scatter plot shows a direct linear relationship of DU of UFOV with CFOV were the rate of change for DU of UFOV increase with rate 1.0261 for each unit of DU of CFOV. The gamma camera image for phantom that generated by ink jet printer for uniformity test, were the images show the distribution of solution of the radioactive material TC-99m with ink jet printer. shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits. And shade Surface for the uniformity image (4-5) that generated by ink jet printer after applying correction map. The shade Surface 3-D histogram is a representation of three-dimensional dataset. It describes a functional relationship between two independent variables X and Z and a designated dependent variable Y, rather than showing the individual data points. It is a companion plot of the contour plot. It is similar to the wireframe plot, but each face of the wireframe is a filled polygon. This helps to create the topology of the surface which is being visualized.

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