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Development of Phantom for Simple Routine Testing of Single Photon Emission Computed Tomography using Inkjet Printer

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Abstract:
the aim of this study to develop a gamma camera quality control phantom using inject printer associated with algorisms to represent the gamma camera quality control tests in a numerical platformto evaluate the gamma camera performance were the study conducted at royal care international hospital in period from May 2019 till October 2020.
The results of this study show that the Integral uniformity (IU) and differential uniformity (DU) uniformity values for upper field of view (UFOV), for IU and DU the measurements for images from 1 to 9 was almost with same ranges from 4.45 to 5.12 and 2.54 to 3.45 for IU and DU. while the images 10 and 11 gives different results for image No.10 found 7.87 and 4.45 and for image No.11 was 4.98 and 4.42 for IU and DU respectively.
scatter plot shows a direct linear relationship of DU of UFOV with IU, were the rate of change of DU increase by rate 0.6974 for each unit of IU. shade-surface image for the matrix that used to calculate the differential uniformity each square represents the value of 5×5 pixels. shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits.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: *Gamma Camera, Quality Control, Integral Uniformity, Differential Uniformity*

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I. Introduction:

Single Photon Emission Computed Tomography (SPECT) has a number of advantages over conventional Nuclear Medicine (NM) imaging: Contrast improvement and Total volume imaging [1-6]. In order to realize these advantages, rigorous QC procedures must be performed on a routine basis. Important considerations for tomography, unlike planar imaging, include flood field uniformity and Center of Rotation (COR) correction/verification and Collimator Hole Angulation (CHA) [1,4,7,8].Foroptimal diagnostic use it is essential that routine performanceevaluation is carried out as part of an ongoing quality assuranceprogramme. The NEMA publication NU 1-2001[9]isthe basic recommended standard for performance evaluation andacceptance testing of scintillation cameras. These guidelines wereoriginally intended for use by manufacturers as a means forspecifying the standards of equipment and were later modified byworkers wishing to assess ongoing equipment performance.However, the methodology described in the NEMA guidelines ismore complex than necessary for many departments to use on aroutine basis. It is therefore of important practical value todevelop a more accessible means for routine testing.

In general, phantoms used for quality assurance can be expensive and not always easilyaccessible. In addition, due to the fact that there are different camera configurations anddetector sizes, such phantoms should, in some cases, be camera specific. It will therefore beof great benefit to nuclear medicine departments to have an alternative and cheaper way tomanufacture phantoms according to their own needs.

It has been demonstrated in the literature that a standard inkjet printer can be used to createphantoms in nuclear medicine. Larssonet al [10] designed a printed brain phantom in orderto enable scatter- and attenuation-free single photon emission tomography imaging, whileEl-Aliet al [11] established a relationship between the voxel grey levels and their equivalentactivity on paper sheets. The use of printed phantoms for quality assurance purposes was,however, not investigated in these articles.

In this study we aimed to use of a standard inkjet printer to produce radioactive phantomsthat can be used for routine quality control of gamma cameras. The purpose of this studywas to evaluate the printed radioactive phantoms and demonstrate their use by determiningthe 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 andMON.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 wasobtained. 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. the Integral uniformity (IU) and differential uniformity (DU) uniformity values for upper field of view (UFOV)

UFOV		
Images	IU	DU
1	4.892	3.4567700
2	5.10345	3.5456700
3	4.45634	2.5467340
4	4.67847	2.825346
5	4.89746	3.1285675

6	5.08754	3.234865
7	4.67543	2.789345
8	5.067543	3.276543
9	5.127654	2.894563
10	7.87656	4.986543
11	6.452348	4.427854

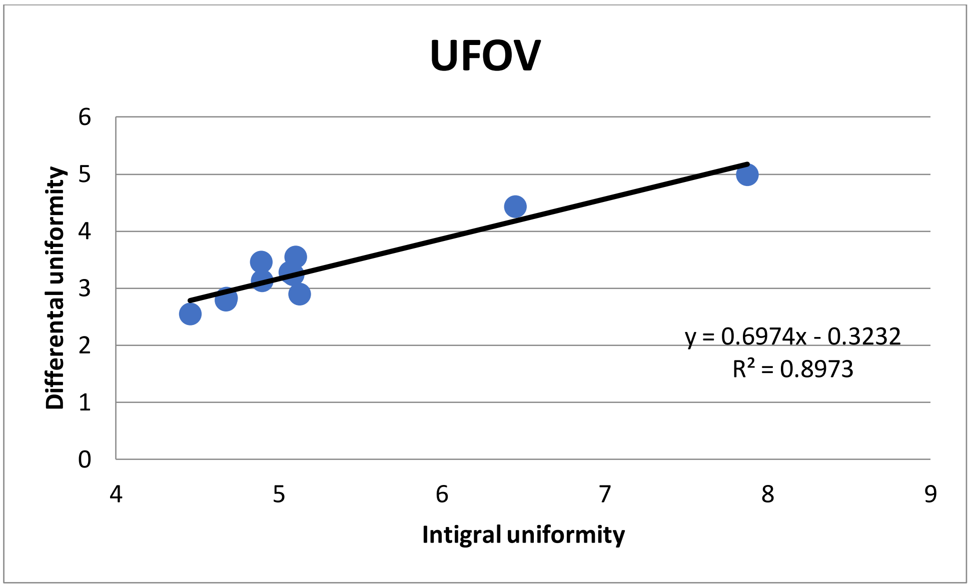

Figure 1. scatter plot show a direct linear relationship of DU of UFOV with IU

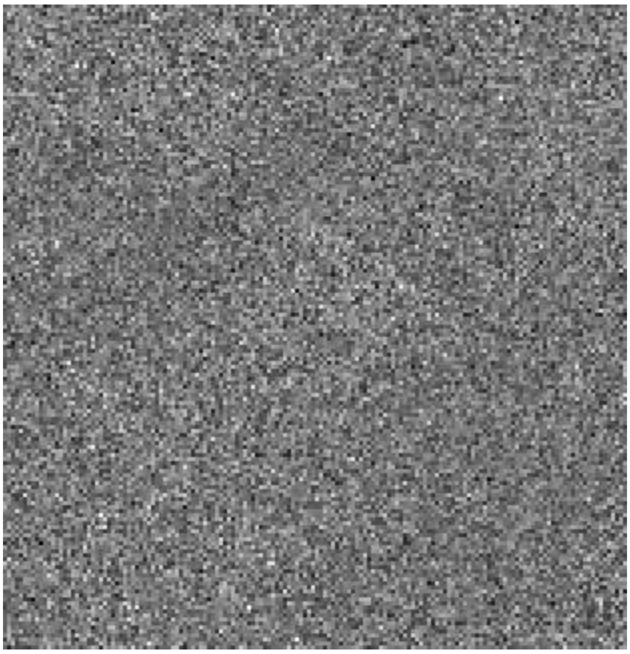

Figure 2. a gamma camera image for phantom that generated by ink jet printer for uniformity test

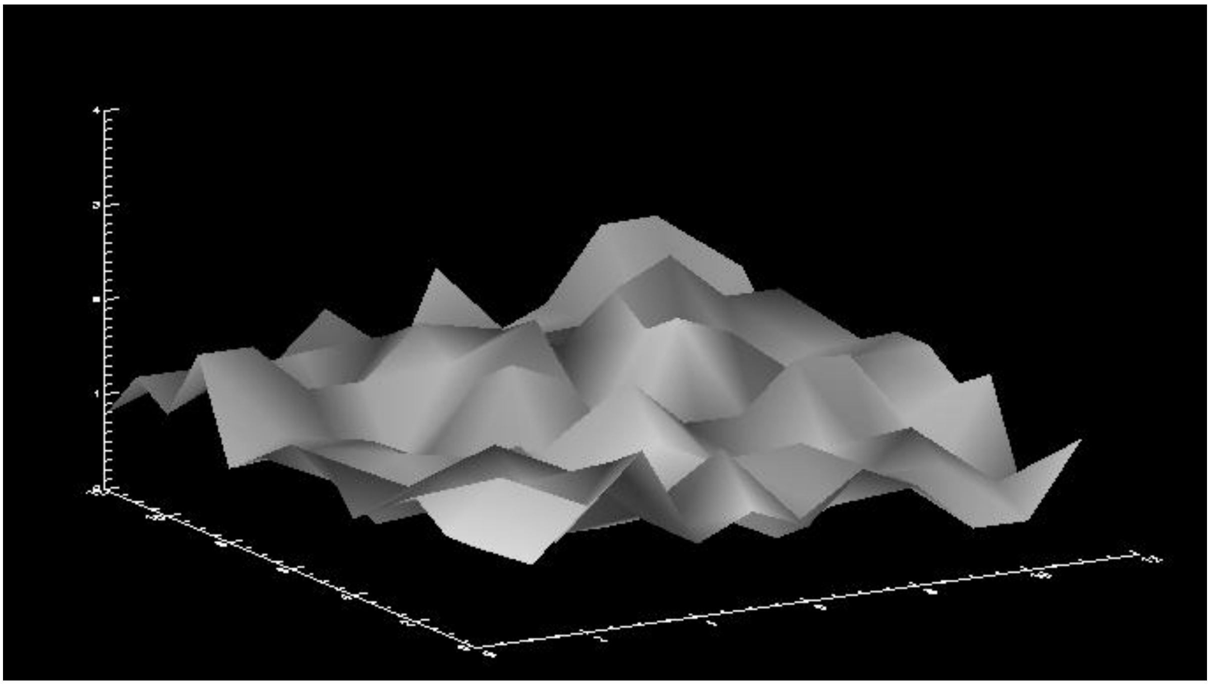

Figure 3. shade-surface image for the matrix that used to calculate the differential uniformity each square represents the value of 5×5 pixels.

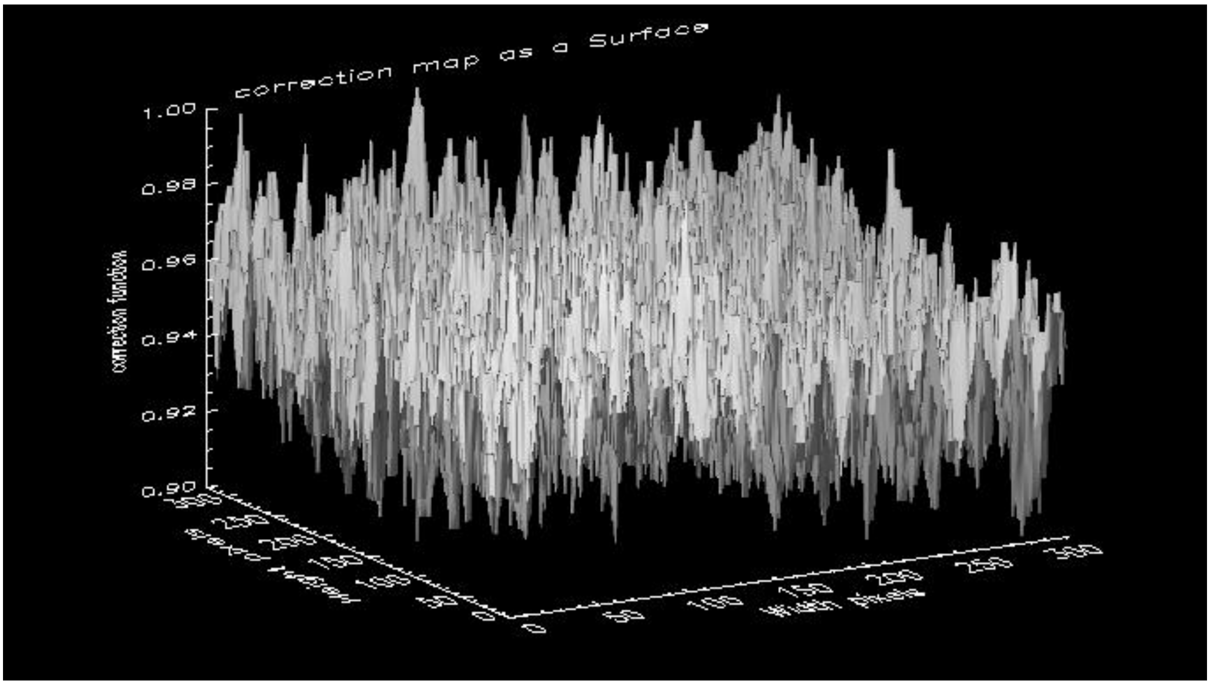

Figure 4. shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits.

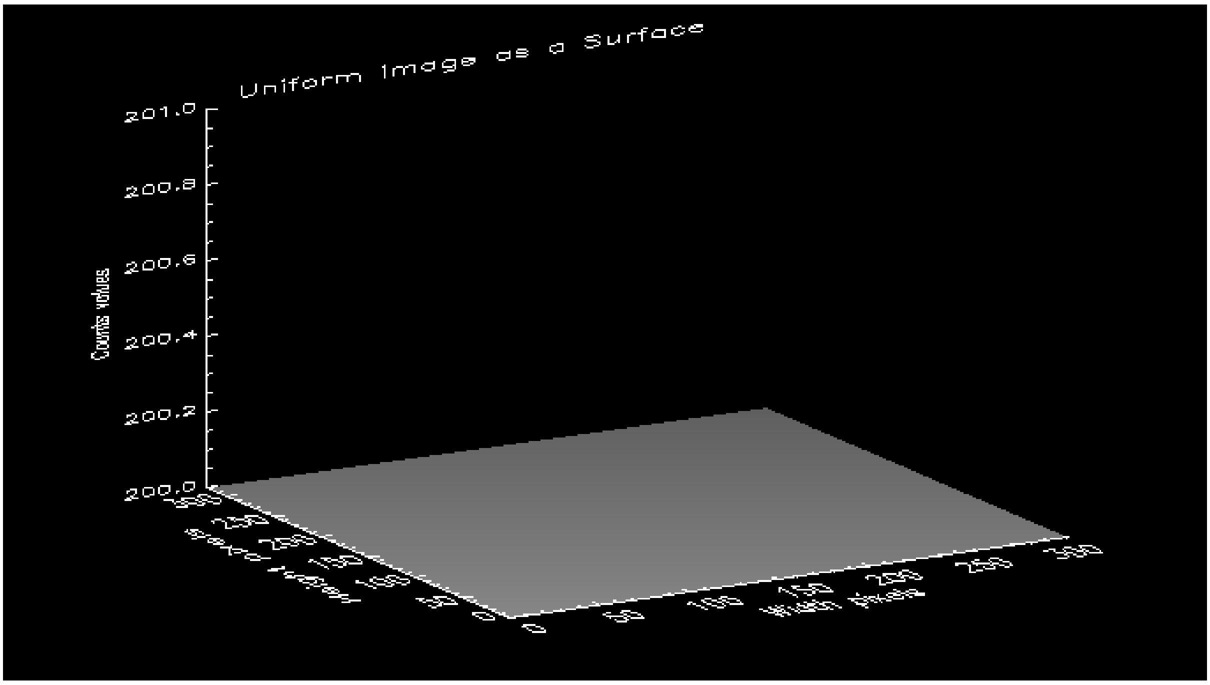

Figure 5. shade **Surface for the uniformity image that generated by** ink jet printer after applying correction map.

IV. Discussions:

A gamma camera quality control phantom using inject printer with associated algorisms and the results presented as tables and figures. Table 1. show the Integral uniformity (IU) and differential uniformity (DU) uniformity values for upper field of view (UFOV), for IU and DU the measurements for images from 1 to 9 was almost same ranges from 4.45 to 5.12 and 2.54 to 3.45 for IU and DU while the images 10 and 11 gives different results for image no 10 7.87 and 4.45 and for image 11 was 4.98 and 4.42 for IU and DU respectively.

scatter plot shows a direct linear relationship of DU of UFOV with IU, were the rate of change of DU increase by rate 0.6974 for each unit of IU. Fig 2. 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. Figure 3. shade-surface image for the matrix that used to calculate the differential uniformity each square represents the value of 5×5 pixels. shade-surface of the correction matrix that used to overcome the problem of uniformity if the value of uniformity exceeds the limits as shown in figure 4. Figure 5. shade Surface for the uniformity image that generatedbyink 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. scatter plot shows a direct linear relationship of DU of UFOV with IU, were the rate of change of DU increase by rate 0.6974 for each unit of IU. 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. And shade-surface image for the matrix that used to calculate the differential uniformity each square represents the value of 5×5 pixels. 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 that generatedbyink jet printer after applying correction map.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

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