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Optimization of Uniform Field of View and Centre Field of View for Intrinsic Uniformity of Hybrid SPECT/CT using Technitium-99m

Shaukat Ali Shahid[1], Maria Yaseen[1], Muhammad Shahbaz[2], Abdul Ghaffar[1]*
Maryam Liaqat[1], Shameela Sadaf[1], Amir Shafeeq[3]

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Abstract

Single Photon Emission Computed Tomography (SPECT) is employed to investigate the radiopharmaceutical distribution in human organs in which a gamma camera detects the distribution of the injected radiopharmaceuticals. The quality control (QC) test for intrinsic uniformity of gamma camera before going to start the device for clinical purpose is an essential requirement for imaging. In old gamma cameras the system itself calculated Integrated Uniformity (IU) and Differential Uniformity (DU) values at the fixed uniform field of View (UFOV) and central field of view (CFOV). However the new GE SPECT / CT Infinia Hawkeye 4 system software allow to change the value of UFOV to get optimum and best suited value of uniformity to record in the system for creating better correction matrix. Studies were carried to optimize the values of UFOV and CFOV using Tc-99m source at photo-peak 140-keV for different acquisition counts (45 to 60 kcts). The investigations revealed that by increasing the gamma radiation counts, although the acquisition time will increase however we can get better values of IU & UFOV at acquisition counts about 55 kcts to 60 kcts and the best suited range of UFOV is 75% to 85%.

Keywords: *SPECT-CT Infinia Hawkeye 4; Technetium-99m; Intrinsic Uniformity; UFOV; CFOV.*

Introduction

Nuclear medicine has become an integral part of medical practice as the scope of imaging has broadened from anatomy to metabolism. In diagnostic nuclear medicine, radioactive materials in the form of compounds labeled with radionuclide are injected or inhaled by the patient. The radiation from the patient is detected with NaI (TI) detector and tomographic images are recorded on a computer screen to locate and measure the radioactive material in the patient [1].

Single photon emission computed tomography (SPECT) is a valuable maneuver to acquire images of three dimensional distributions of internally disseminated radiopharmaceuticals [2-7]. However, the high quality SPECT images free of artifacts can only be acquired after routine quality control procedures. [8-9]. Although QC measures have been published comprehensively for acceptance testing of SPECT systems in NEMA standards and AAPM report # 22 [10,11], however, many of the described tests involve unique equipment alongwith software and cannot be

[1] *Department of Physics, University of Agriculture, Faisalabad-38040, Pakistan.*
[2] *Punjab Institute of Nuclear Medicine, Faisalabad-38000, Punjab, Pakistan.*
[3] *Institute of Chemical Engineering & Technology University of the Punjab, Lahore-54590, Pakistan.*
Corresponding Author: Shaukat Ali Shahid (shaukatuafpy@uaf.edu.pk)

accomplished within a reasonable time frame. Moreover, there is no range of acceptable values given for the tests [11-13]. Hence, American Association of Physicists in Medicine (AAPM) provided protocols for SPECT to evaluate gamma cameras practically and efficiently [13].

Although, the change in several measured parameters such as intrinsic uniformity, linearity and energy resolution etc., are linked to each other, however, in a situation when an electrical/ mechanical alteration in the system results in the change in several measured parameters, it is persuasive to depend or rely on the measurement of only one or two parameters, such as Uniformity for routine quality control (QC) [13-16].

Different acquisition counts are used for performing quality control test for intrinsic uniformity of gamma camera before going to start the device for clinical purpose. In old gamma cameras there were fixed values (75%) of Central Field of View (CFOV) and Uniform field of View (UFOV). The system could itself calculate integrated uniformity (IU) and differential uniformity (DU) values at these fixed UFOV and CFOV. In the new SPECT- CT Infinia Hawkeye 4 System, there is a privilege of adjusting UFOV and CFOV at one's own choice.

The objective of the present study was to optimize the values of best suited range of uniform field of view (UFOV) and central field (CFOV) to get best correction matrix for the enhancement of quality of patient's images. These values are used by system to create correction matrix and stored in it till next values are obtained.

Materials and Methods

The gamma camera, Infinia Hawkeye 4 which is all-purpose dual detector hybrid SPECT-CT imaging system, installed at PINUM (Punjab Institute of Nuclear Medicine) was used in this study. The system was prepared to study the response of intrinsic flood uniformity to a uniform flux of radiation from a point source when the collimators are removed (Figure 1).

Fig. 1. *The setup for flood uniformity test of gamma camera Infinia Hawkeye 4 (GE Health Care U.K)*

The AAPM # 52 [13] and IAEA Quality Control Procedures Applied to Nuclear Instruments (2007) were adapted to measure the effect of variation in the UFOV and CFOV on Intrinsic Uniformity of SPECT-CT system [16]. The collimator was removed from gamma camera and a decoy sheet made of glass for the protection was adjusted which saves the sodium iodide sheet from damaging.

The room background was measured to ensure that there is no contamination in the specific region and background is low as possible so that it may not affect the performance of device. The criteria defined by protocol are that it should be less than 2.5 kcts. The time of acquisition to measure the room background was 60s and it was measured by using sodium iodide crystal for both detectors (D1, D2) and the test results were acceptable (Figure 2).

For preparing a point source, a small cotton swab was used and concentrated activity of technetium-99m pertechnetate (99mTcO-4) in the form of drop ranging from 0.6 – 0.7 µCi was dropped with the help of a syringe of 1cc. Then the activity of the point source was carefully measured by dose calibrator in Hot Lab. In case of intrinsic uniformity the distance of point source from detector was set at 5×UFOV (5×1.7=8ft) and the detector position was adjusted at L mode. The point source holder was specifically made according to the study requirement which could be moved vertically and horizontally (Figure 1). Its height could be changed from 5 to 80 cm. It was ensured that source holder position was aligned with the center of detector to get good geometry.

The spectrum of Tc-99m source at photo-peak 140-keV was acquired at different counts rate (45, 50, 55 and 60 kcts). The energy window was adjusted at the NEMA standard 10% full width half maximum (FWHM) and the matrix size 256×256 [9,11-13]. The acquired data was processed at XelerisTM 2 Work Station (GE Health Care U.K). The acquisition parameters were evaluated for 45 to 60 kcts and obtained the value of IU at both detectors, adjusting UFOV from 60-99 % at fixed pixel size 2.21 mm for intrinsic uniformity. The values of length 540 mm and width 400 mm of rectangular detectors was put for calculation which was already defined by GE Health Care U.K.

Results and Discussion

The common sources of artifacts that make the images unreadable in gamma camera detectors are non-uniformity. The artifact intensity depends upon the extent of the non-uniformity [13,17]. Two main causes of field non-uniformities in flood field images of scintillation cameras are energy-axis shifts of the photopeak at different points in the field of view and the distortion [17-20].

In old gamma cameras the system itself calculated Integrated Uniformity (IU) and Differential Uniformity (DU) values at the fixed uniform field of View (UFOV) and central field of view (CFOV). However the new GE SPECT-CT Infinia Hawkeye 4 system software allow to change the value of UFOV to get optimum and best suited value of uniformity to record in the system for creating better correction matrix. Therefore, studies were carried out to optimize the values of UFOV and CFOV using Tc-99m source at photo-peak 140-keV. The data was acquired thrice and the average values of IU were taken to construct the graphs and tables. In this case an AAPM guide line in the variation of IU against UFOV has not been mentioned yet. Therefore acquired values are compared with each other.

The studies on total counts ranging from 45 to 60 kct of gamma camera showed linear increase in IU (%) value with increase in UFOV (Table 1). However, the studies of 50, 55 and 60 kct showed minimum deviation in IU value with respect to UFOV (Figure 2-5). This indicates that for intrinsic uniformity, over all suitable range of UFOV is 50 to 60 kct for daily quality control. Previously, Elbeshir et al., [21] suggested that the acquisition count rates should not exceed 20K-30Kcps. to reduce time of acquisition [22]. However, we studied response at both low and high from 45 to 60 kcts and our present investigations revealed that by increasing the gamma radiation counts, although the acquisition time will increase however we can get better values of IU & UFOV at acquisition counts about 55 to 60 kcts.

The slope value of linear curve at different counts (Table 2) show a quite small deviation which shows the response of both the detectors D1 and D2 do not deviate largely from each other and it will not affect the uniformity of the image. From frequency Table 3 it is clear that most suitable region of UFOV for IU value is from 75% to 85%.

Integral uniformity (IU) versus Uniform field of view (UFOV) at 45 kcts

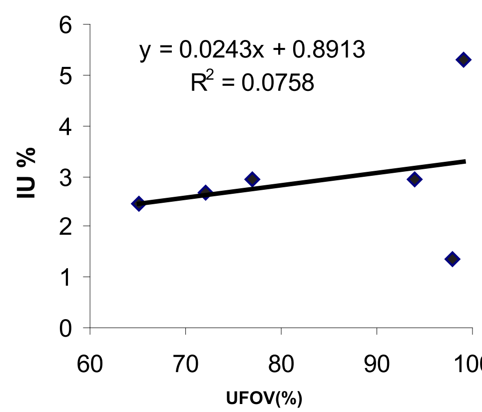

Fig. 2. *Integral uniformity versus Uniform field of view, shows linear behavior of IU values of detector fuse image of both detector D1+D2 at 45 kcts. The slopes of the line are positive which shows that by increasing UFOV the IU increases and for one unit increase in the value of UFOV, IU is increasing by the previous value.*

Integral uniformity (IU) versus Uniform field of view (UFOV) at 50 kcts

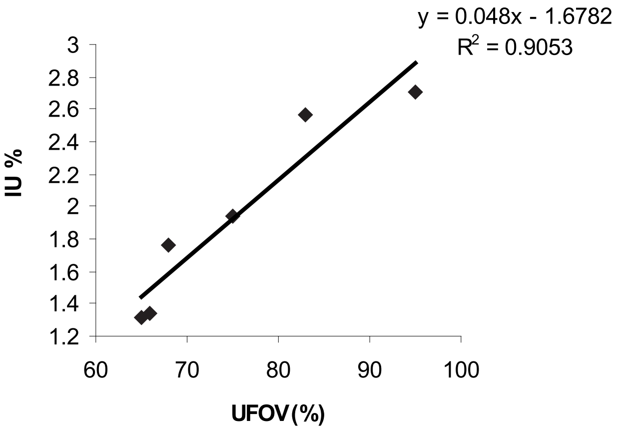

Fig. 3. *Integral uniformity versus Uniform field of view, shows linear behavior of IU values of detector fuse image of both detector D1+D2 at 50 kts. It shows that as counts increases the data points are quite fitted in the linear curves in some way and the scattering of data counts are near the slope of line and also provide the uniform response in imaging .*

Integral uniformity (IU) versus Uniform field of view (UFOV) at 55 kcts

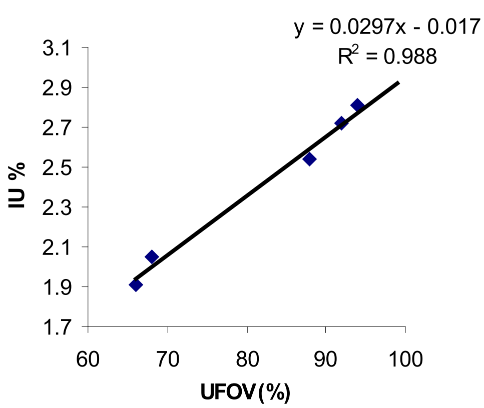

Fig. 4. *Integral uniformity versus Uniform Field of View at 55 kcts. The linear behavior of IU values of detectors D1+D2 at 55 kcts. shows the better response because the slope values are small. The deviation in statistical data decreases and normal behavior is gained in uniform image.*

Integral uniformity (IU) versus Uniform field of view (UFOV) at 60 kcts

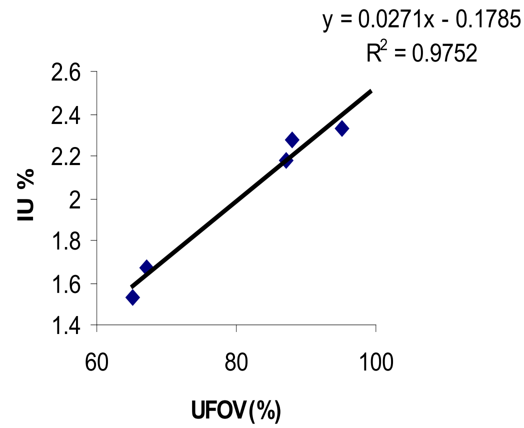

Fig. 5. *Shows linear behavior of IU values of detectors D1+D2 at 60 kcts. The slope values is small, it shows by increasing counts better response of slope values are found. As statistical fluctuations of data decreases, a normal behavior is achieved in uniform image.*

Table 1: IU values against UFOV at different acquired counts.

		Detectors		
	UFOV (%)	Value of IU(%) from Max - Min		
Counts	**Interval**	**D1**	**D2**	**D1+D2**
45KCT	65 - 95	2.00 - 3.14	3.47 - 3.86	2.45 - 2.94
50KCT	65 - 95	1.56 - 2.70	0.87 - 2.52	1.32 - 2.71
55KCT	65 - 95	1.47 - 1.84	2.80 - 3.17	1.91 - 2.81
60KCT	65 - 95	1.44 - 2.38	2.75 - 3.34	1.53 - 2.33

Table 2: Slope values at different counts and Standard deviation

COUNTS	45KCTS	50KCTS	55KCTS	60KCTS	S.D
Slope of D1	0.0415	0.0403	0.0072	0.0334	0.019466
Slope of D2	0.0575	0.0508	0.0203	0.0269	0.019828
Slope of D1+D2	0.0243	0.048	0.0297	0.0271	0.012421

Table 2 shows slope value of linear curve at different counts. It is quite small deviation which shows the response of the detectors do not deviate largely from each other and it will not affect the uniformity of the image.

UFOV %	Frequency at 45 K_cts			Frequency at 50 K_cts			Frequency at 55 K_cts			Frequency at 60 K_cts		
	D1	D2	D1+D2	D1	D2	D1+D2	D1	D2	D1+D2	D1	D2	D1+D2
65-69	1	1	1	3	2	3	1	2	2	1	2	2
70-74	2	2	2	2	1	1	2	2	1	3	1	1
75-79	1	1	2	2	1	2	1	1	1	1	1	1
80-84	2	2	1	2	2	2	1	1	1	1	1	1
85-89	1	1	1	1	1	1	1	1	2	2	1	3
90-94	1	1	2	1	2	1	2	3	3	1	3	1
95-99	1	5	3	3	4	1	4	3	1	1	5	1

Table 3. UFOV versus Frequency of different counts

Table 3 Shows the consistent region at 45 Kcts is from 85-89% at 50 Kcts is from 85-89%, at 55 Kcts is from 75-84% and at 60 Kcts is 75-84%. The frequency of D1, D2 and D1+D2 has more consistent Region of UFOV from 75 to 85% and at 55 to 60 kcts suitable value of UFOV does not change which is suitable value of IU.

Conclusions

The new GE SPECT-CT Infinia Hawkeye 4 system software allow to change the value of uniform field of view (UFOV) to get optimum and best suited value of uniformity to record in the system for creating better correction matrix. This study gave us the range of UFOV for different gamma radiation counts to get best correction matrix which will enhance quality of patient's images. The results indicate that by increasing the gamma radiation counts, although the acquisition time will increase however we can get better values of integrated uniformity (IU) and better uniform field of view (UFOV) at acquisition counts about 55kcts to 60kcts for intrinsic uniformity is 75% to 85%.

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