Effect of Source Activity and Source Volume on Intrinsic Uniformity of SPECT Gamma Camera

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Abstract: *Purpose:* The quality control of the gamma camera is obligatory for the proper diagnosis of the patients. The most intensive and sensitive routine quality control of gamma camera is intrinsic uniformity. The main objective of this research work is to determine the best parameters for daily quality control testing of intrinsic uniformity for dual head Single Photon Emission Computed Tomography (SPECT) gamma camera.

Method: The integral and differential intrinsic uniformity test for both Useful Field Of View (UFOV) and Central Field Of View (CFOV) was done by placing a point source of ^{99m}Tc in front of the detectors with removed collimators to measure the effect of source activity and source volume on intrinsic uniformity.

Result: The result shows that the best intrinsic uniformity image is obtained at activity volume in the range of 0.2 – 0.7 ml in 3 ml syringe with source activity between 70 – 200 MBq since place of point source on the central axis of the detector at a distance from its face equal to five times the diameter of the useful field of view as defined by the lead mask.

Conclusion: Finally we can conclude that, the lower the intrinsic uniformity the better the imaging and diagnosis.

Keywords: Quality Control (QC), Intrinsic uniformity, Useful field of view (UFOV), Central field of view (CFOV), Source activity, Source volume.

1. INTRODUCTION

The Gamma Camera is a diagnostic machine, which introduces an exquisite genre of imaging. It has progressed out of the necessity in nuclear medical imaging to view and investigate images of the humanoid body or the distribution of pathologically inhaled, injected or ingested radionuclides radiating gamma rays [1]. In the arrangement for measuring the value of Intrinsic Uniformity of a gamma camera, the gamma ray spectrometry system is very essential.

Camera approval and the quality control test for a SPECT gamma camera system do not have any general agreement [2, 3]. Many authors have suggested various conventions for resounding out QC tests for intrinsic uniformity [4-9]. According to National Electrical Manufacture Association (NEMA) [4] and International Atomic Energy Agency (IAEA) [5], the evaluation of detector non-uniformity is the most prevalent practice in present day quality control procedures of gamma camera. Before using gamma camera, daily evaluation and comparison of flood-field uniformity is required for patient testing [10, 11]. Any non-uniformity must be eradicated and resolved before patient testing to remove artifacts and false-positive or false-negative patient effects. We prefer intrinsic uniformity testing because a ^{99m}Tc point source is freely available.

The majority of imaging in general nuclear medicine is performed with the gamma camera. Scintillation occurs when γ photons emitted from the source or patient interacts with the sodium iodide crystal to produce light. The primary components of the scintillation camera include the collimator, scintillation crystal, photomultiplier tube, positioning logic network, pulse height analyzer, and display [12].

Two types of uniformity parameters are considered in SPECT imaging. Among them, the Integral Uniformity (IU) is calculated as [13, 14],

$$\text{IU (\%)} = \pm 100\% \times \frac{Max - Min}{Max + Min} \quad (1)$$

The maximum and the minimum pixel counts are found from the smoothed data. On the other hand, the Differential Uniformity (DU) is calculated as [15],

$$\text{DU}(\%) = \pm 100\% \times \frac{High - Low}{High + Low} \quad (2)$$

We executed quality test in accordance to intrinsic uniformity for SPECT gamma camera [11]. The main objective of this present research work is to determine the best parameters for daily quality control testing of intrinsic uniformity for dual head SPECT gamma camera from Siemens *E. Cam* signature series,

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E-ISSN: 2408-9788/15

Germany, installed at Institute of Nuclear Medicine and Allied Sciences (INMAS), Dhaka Medical College Hospital (DMCH), Dhaka. The integral and differential intrinsic uniformity test for both useful field of view (UFOV) and central field of view (CFOV) was done by placing a point source of ^{99m}Tc in front of the detectors with removed collimators to measure the effect of source activity and source volume on intrinsic uniformity. The intrinsic uniformity of the system is measured for the CFOV and UFOV [13]. The measured values are compared with the specification. The effects of source activity and source volume have been investigated using intrinsic uniformity to assure quality control of SPECT gamma camera.

2. METHODOLOGY

2.1. Source Materials

^{99m}Tc radionuclide was used to measure intrinsic uniformity in this research. The gamma camera used in this current study was a dual head variable angle system, *model E. Cam* series, manufactured by *Siemens (Model No.7823946)*. The manufacturer of Mo-99/Tc-99m generator from which Tc-99m was eluted, is Radioisotope Production Division, Bangladesh Atomic Energy Commission (www.baec.org.bd). The impurity of 0.01microcuri Mo-99 per 1 milicuri Tc-99m was present.

2.2. Experimental Procedure and Data Acquisition

The collimator has been detached from the camera. The camera has been set with its face at right angles to the floor. Source holder has been seated on the gantry arm facing the centre of detectors with varied distance. Camera surface and the room have been cleaned to ensure that there is no contagion. Then, after confiscating all available sources from the room, the background radiation of the room has been cautiously measured using the NaI (TI) crystal of the gamma camera, which was 140 cps. The activity of a ^{99m}Tc point source in a syringe has been measured in the dose calibrator after interchanging the needle. The linearity of the dose calibrator in the range of 3.7 – 1800 MBq was < 5%. We varied the source activity between 10 MBq and 240 MBq to determine the effect of source activity on intrinsic uniformity. The volume of 95 MBq point sources has been varied (increased) by adding 0.9% sodium chloride to the syringe to determine the effect of point source volume on intrinsic uniformity. The point source has been carefully aligned with the center of the camera. The ^{99m}Tc gamma spectrum has been acquired and a 15% window width around the 140-keV photo-peak has been set. It is to be noted that place of point source on the central axis of the detector at a distance from its face equal to five times the diameter for better imaging. NEMA (2001) and IAEA (1991) approach for the measurement of intrinsic uniformity has been followed. The intrinsic flood-field image was obtained. The intrinsic uniformity of the camera (Differential Uniformity (DU) & Integral Uniformity (IU)) has been determined using *Inter View* and *DIAG* software where the maximum and minimum pixel values were determined.

2.3. Test Conditions

Prior to performing the uniformity calculations, the pixels for inclusion are determined through the following steps:

First, any pixels at the edge of UFOV containing less than 75% of the mean counts per pixel in the CFOV is set to zero.

Second, those pixels which now have at least one of their four directly abutted neighbors containing zero counts is also set to zero. The remaining non-zero pixels are the pixels to be included in the analysis for the UFOV. This step shall be performed only once. Any pixel that has at least 50% of its area inside the CFOV shall be included within the CFOV analysis.

3. RESULTS AND ANALYSIS

The Tables **1** and **2** show how the intrinsic uniformity varies with source activity and source volume for detectors 1 and 2 with respect to both UFOV and CFOV.

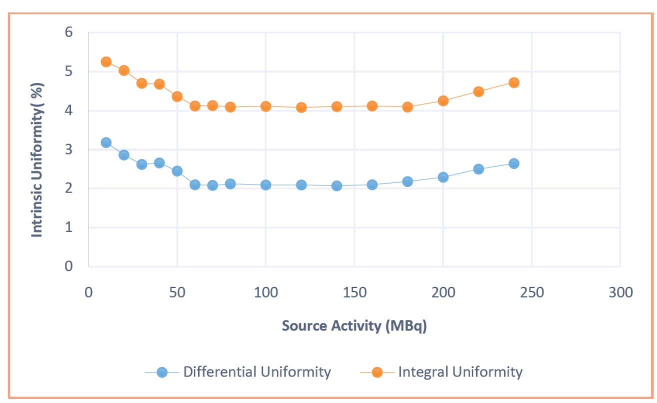

Figure 1: Intrinsic Uniformity versus Source Activity in UFOV (Detector-1).

Table 1: Intrinsic Uniformity vs. Source Activity

Source Activity (MBq)	Detector - 1				Detector - 2			
	UFOV (%)		CFOV (%)		UFOV (%)		CFOV (%)	
	DU	IU	DU	IU	DU	IU	DU	IU
10	3.18	5.25	3	5.14	3.5	5.62	3.35	5.55
20	2.86	5.03	2.92	4.98	3.17	5.39	3.14	5.4
30	2.62	4.7	2.76	4.77	2.95	5.01	2.93	5.17
40	2.66	4.68	2.58	4.8	2.85	4.89	2.96	5.25
50	2.45	4.36	2.43	4.52	2.62	4.72	2.58	4.8
60	2.1	4.12	2.12	4.28	2.51	4.49	2.46	4.49
70	2.08	4.13	2.1	4.16	2.33	4.31	2.38	4.45
80	2.12	4.09	2.07	4.12	2.15	4.19	2.19	4.18
100	2.09	4.11	2.14	4.17	2.07	4.12	2.06	4.06
120	2.09	4.08	2.07	4.11	2.08	4	2.12	4.13
140	2.07	4.1	2.17	4.15	2.13	4.09	2.1	4.07
160	2.1	4.12	2.09	4.06	2.06	4.03	2.06	4.05
180	2.18	4.09	2.13	4.09	2.11	4.07	2.11	4.1
200	2.29	4.25	2.3	4.2	2.07	4.04	2.09	4.11
220	2.5	4.49	2.38	4.42	2.22	4.29	2.2	4.23
240	2.64	4.72	2.59	4.65	2.53	4.46	2.47	4.44

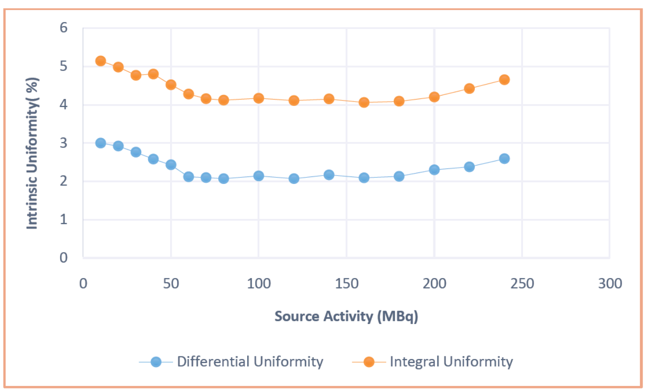

Figure 2: Intrinsic Uniformity versus Source Activity in CFOV (Detector-1).

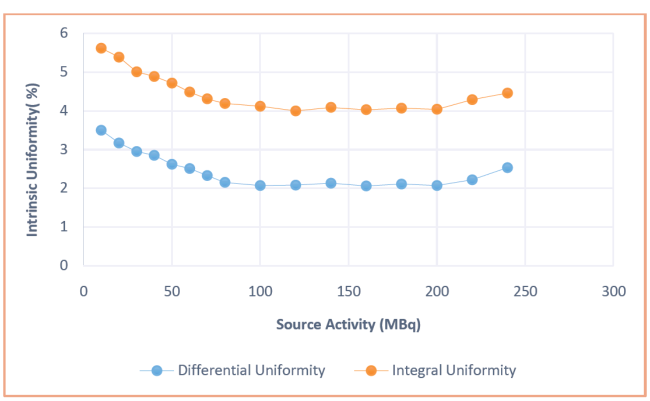

Figure 3: Intrinsic Uniformity versus Source Activity in UFOV (Detector-2).

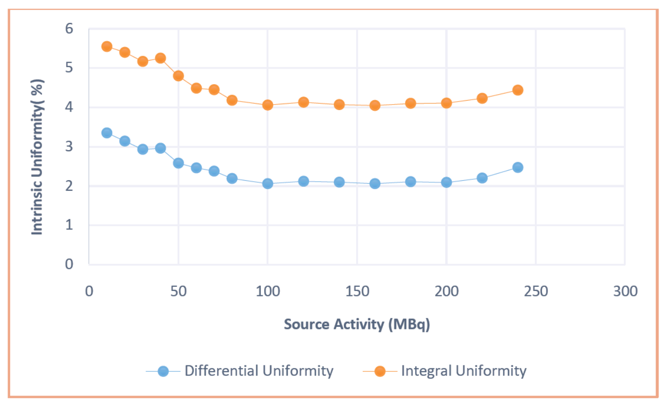

Figure 4: Intrinsic Uniformity versus Source Activity in CFOV (Detector-2).

Figures **1** and **2** show the measured UFOV and CFOV intrinsic uniformity of detector-1 of the system versus source activity and Figures **3** and **4** show the measured UFOV and CFOV intrinsic uniformity of detector-2 of the system versus source activity, when 16×10^6 (16 M) count flood-field images were acquired. From the figures, we found that, at source activities <70 MBq, the IU improves as source activity increases. This was due to the decreased role of room background in determining the IU as source activity increases. At source activities between 70 – 200 MBq, the system IU was almost constant about 4% and DU

Table 2: Intrinsic Uniformity vs. Source Volume

Source Volume (ml)	Detector - 1				Detector - 2			
	UFOV (%)		CFOV (%)		UFOV (%)		CFOV (%)	
	DU	IU	DU	IU	DU	IU	DU	IU
0.2	1.81	3.74	1.78	3.7	1.82	3.75	1.81	3.72
0.3	1.85	3.75	1.8	3.72	1.83	3.77	1.83	3.75
0.4	1.87	3.79	1.81	3.75	1.85	3.78	1.84	3.75
0.5	1.85	3.74	1.83	3.77	1.83	3.76	1.86	3.78
0.6	1.9	3.79	1.88	3.81	1.91	3.9	1.92	3.89
0.7	1.92	3.83	1.95	3.87	1.98	3.92	1.97	3.99
0.8	2.17	4.15	2.16	4.13	2.17	4.21	2.19	4.22
0.9	2.25	4.29	2.22	4.33	2.24	4.33	2.3	4.36
1.0	2.31	4.47	2.3	4.43	2.27	4.42	2.33	4.4
1.1	2.36	4.46	2.46	4.64	2.34	4.54	2.43	4.49
1.2	2.36	4.59	2.53	4.81	2.41	4.62	2.51	4.57
1.3	2.52	4.8	2.67	4.96	2.5	5.0	2.64	4.8
1.4	2.57	4.85	2.66	5.0	2.59	4.91	2.71	4.73
1.5	2.78	4.96	2.8	5.23	2.6	4.99	2.8	4.87
1.6	2.91	4.97	2.89	5.36	2.75	5.0	2.83	4.95
1.7	2.96	5.01	2.99	5.42	2.8	5.02	2.92	5.02

was about 2%. At source activities >200 MBq, the IU slowly degraded in both cases. This was probably due to the increased effect of counting rate losses caused by system dead time as source activity increases. It is must be prominent that place of point source on the central axis of the detector at a distance from its face equal to five times the diameter of the useful field of view as defined by the lead mask. And as a result better imaging is found at activity 70-200MBq for this SPECT machine.

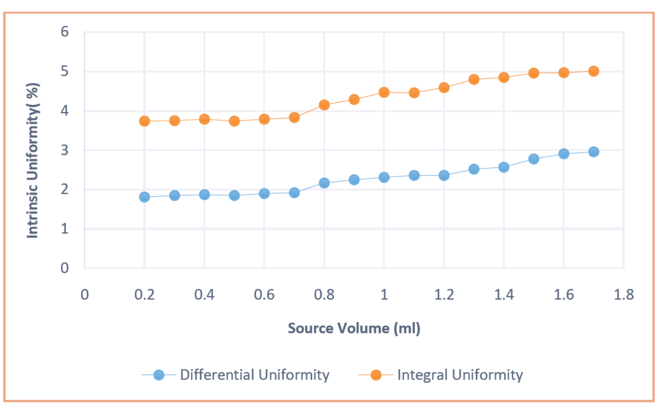

Figure 5: Intrinsic Uniformity versus Source Volume in UFOV (Detector-1).

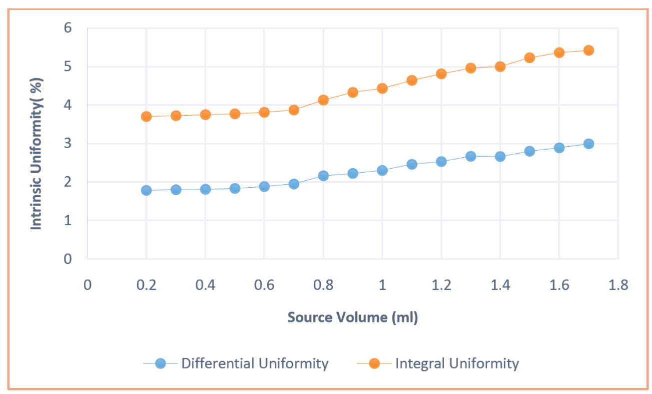

Figure 6: Intrinsic Uniformity versus Source Volume in CFOV (Detector-1).

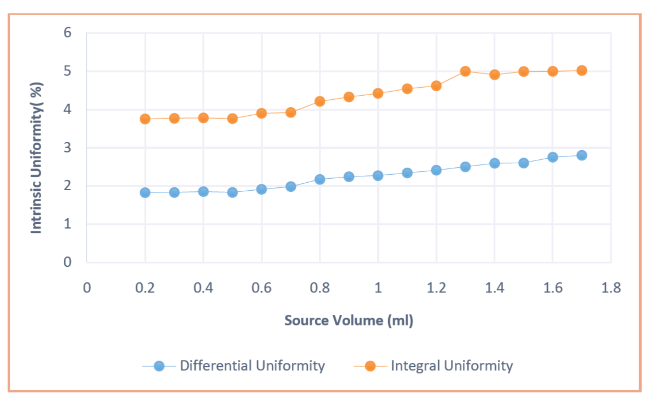

Figure 7: Intrinsic Uniformity versus Source Volume in UFOV (Detector-2).

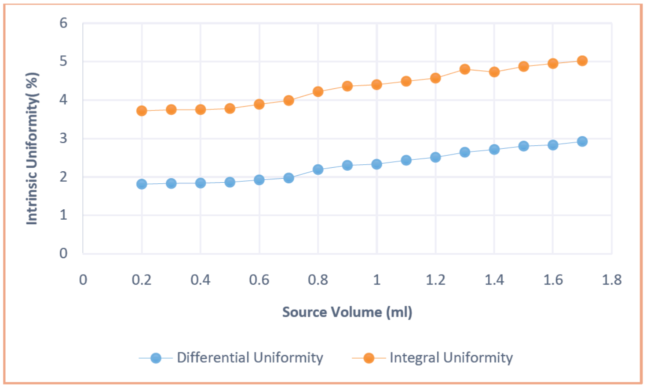

Figure 8: Intrinsic Uniformity versus Source Volume in CFOV (Detector-2).

Figures **5** and **6** shows the experimental results IU of detector-1 and Figures **7** and **8** show the experimental results IU of detector-2 of the system for the CFOV and the UFOV respectively at different source volumes. The ^{99m}Tc activity was 95 MBq and the number of acquired counts was 30 M for each flood-field image. The above figures show that both the integral and differential IU of the system slightly degraded as the source volume increased. For source volumes from 0.2 ml to 0.7 ml, the integral and differential IU was almost constant.

4. CONCLUSION

Camera approval test and the quality control program for a gamma camera system do not have any common agreement. The results ensemble the fact that the intrinsic uniformity is apt as long as it is maintained to the minimum level *i.e.* the lower the intrinsic uniformity the better the imaging and diagnosis. The result shows that the best intrinsic uniformity image obtained with source volume in range of 0.2 - 0.7 ml in 3 ml syringe and a source activity in between 70 – 200 MBq since place of point source on the central axis of the detector at a distance from its face equal to five times the diameter of the useful field of view as defined by the lead mask.

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Received on 11-05-2015 Accepted on 13-06-2015 Published on 21-09-2015

http://dx.doi.org/10.15379/2408-9788.2015.02.02.02