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STUDY OF PARAMETERS OF INTRINSIC UNIFORMITY QUALITY CONTROL TEST FOR SINGLE HEAD GAMMA CAMERA

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ABSTRACT

The aim of the study was to determine the best parameters for rapid performance of daily quality control testing of intrinsic uniformity for the single-head gamma- camera, by changing one parameter while keeping all other parameter constant. A set of parameters for rapid performance of daily gamma-camera intrinsic uniformity was determined. The intrinsic uniformity improved as the number of counts increased, source strength increased, distance decreased and degrades as volume increased. The best optimized set of values were found to be the collection of 50 millions counts from a source of 50μCi per 50μl placed at a distance of 4.5 feet from the camera head. With our recommended parameters, the intrinsic uniformity quality control testing can be performed in 30-40 min with quite good results.

Key Words: Intrinsic flood-field uniformity; quality control; gamma camera, bio-physics

INTRODUCTION

The intrinsic uniformity is the response of the system without a collimator to a uniform flux of radiation from a point source. The daily evaluation and comparison of intrinsic flood-field uniformity (IU) makes it possible to correct many gamma-camera problems as soon as they appear. The quality control (QC) tests for IU, performed with the collimator removed, usually performed by exposing the gamma camera's crystal to a uniform flux of gamma radiation from a technetium-99m (^{99m}Tc) point source. Daily evaluation and comparison of flood-field uniformity is required before using the gamma camera for patient testing. Any nonuniformity must be eliminated before patient testing to eliminate artifacts and false-positive or false-negative patient results. Different authors/researchers adopted different parameters of intrinsic uniformity testing Elkamhawy *et* al. (2000) studied the effect of gamma source activity, number of acquired counts for the flood image, source-to-camera distance, image matrix size, and source volume for intrinsic uniformity measurements and relative sensitivity. Graham *et al*. (1986) studied the improvement in spatial resolution and loss of field uniformity for 99mTc, 201Tl, and 131I were measured as a function of window asymmetry (up to 30%, defined relative to the loss of counts as compared to a symmetric window under intrinsic conditions). Flood field uniformity was inversely related to the degree of window asymmetry. A report of NEMA showed that an acquisition of a minimum 4000 counts/pixel, a minimum distance of 5 UFOV diameter of source from the detector, source strength of 100 to 200μCi and of 10ml is used for the flood field image at a window width of 20% window (Anonymous, 1986). AAPM recommended that flood field image should be acquired at a total counts of 45000 counts/cm^2, distance of 5 crystal diameter from the detector center, a source strength of 150 to 200 μCi and a volume of 1cc or less (Anonymoys, 1987). Robert in his book nuclear medicine recommended that flood field image should be acquired at 1.25 million counts at a distance of 5 times the largest dimension of the detector and on the central axis, a ^{57}Co source or a point source of Tc-99m is used. (Robert *et al*., 1996). Vender (Siemens) suggests a total counts of 5 million, source activity should be 15-20μCi and the use of liquid is as little as possible, for daily intrinsic uniformity test (Vender, 1998). We prefer intrinsic uniformity testing because a ^{99m}Tc point source is readily available. Two different uniformity parameters should be determined i.e. Integral uniformity in CFOV and UFOV and Differential uniformity in CFOV and UFOV.The 90% of total field of view form the center of gamma camera head is called its useful field of view (UFOV) and 75% of useful field of view form the center of gamma camera head is called its central field of view (CFOV). The purpose of this study was to accomplish the two main objectives.
1) To study the effects of various acquisition parameters i.e., Number of Count acquired, Source to Camera Distance, Source Strength, and Volume on the intrinsic uniformity values of a single headed gamma camera and
2) To define a set of optimum parameters for routine Quality Control.

MATERIALS AND METHODS

The following procedure was used to measure the system IU. Gamma source activity, the number of acquired counts for the flood image, source-to-camera distance, and source volume, each was evaluated to determine the ideal procedure for gamma camera.

1) The Tc-99m radioisotope was eluted in solution form from generator in the form of sodium pertechnetate ($Na^{99m}TcO_4$).
2) The point source was prepared in the hot lab.
3) The collimator was removed from the camera
4) The room background was carefully measured using the sodium iodide thallium activated (NaI) crystal of the gamma camera. We made every attempt to keep the background as low as possible (< 400 cps) by removing all the radioactive sources from the room. Any radioactive source or minor contamination would increase the background and could degrade the uniformity of the flood image.
5) We varied the source activity between 10µCi and 80µCi to determine the effect of source activity on IU. The volume of 50 µCi point source was varied 50µl to 500 µl (increased) by adding 0.9% sodium chloride to determine the effect of point source volume on IU.
6) The point source was carefully aligned with the center of the camera. The distance between the point source and the crystal face was varied between 93cm to137cm to determine the effect of source distance on IU.
7) The ^{99m}Tc gamma spectrum was acquired and a 20% window around the 140-keV photo peak was set.
8) We acquired data between 5 M and 60 M counts to determine the effect of counts acquired on IU.
9) IU = $\frac{Max - Min}{Max + Min}$x 100.
10) Data was collected as four sets of percentage uniformity values i.e., CFOV, UFOV for integral uniformity and CFOV and UFOV for differential uniformity
11) Different regression models were fitted to each data set and their trend and relationship among variables will be measured along with its reliability. Also optimum parameters will be sorted out and assessed.

RESULTS AND DISCUSSION

We studied the extent of effect of the following parameters on intrinsic uniformity and obtained optimized values.

Intrinsic Uniformity Versus Number of Acquired Counts

First of all, we varied total number of counts acquired from 5 million to 60 million with a step of 5 million counts and observed their effect on intrinsic uniformity (Fig. **1**). We used 1024×1024 matrix size to acquire the data. All other parameters (source strength, distance of source from camera head etc.) were kept constant during rest of the measurements. The IU improved as the number of counts increases. This is due to the fact that as number of counts increases, the difference between maximum and minimum counts in the pixels decreases resulting in improved IU values. However, the incremental gain in IU on the left side of the graph was greater as compared to on right side.

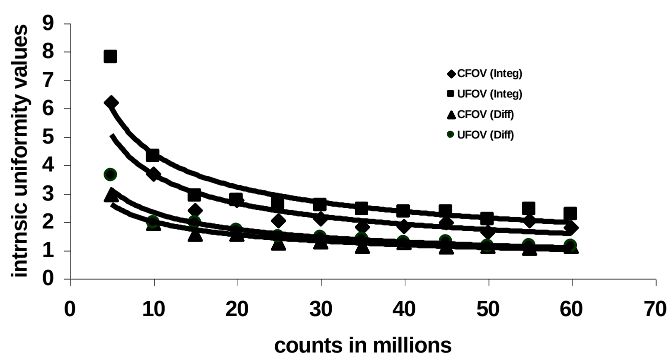

Fig.1. Effect of number of acquired counts on intrinsic uniformity.

Intrinsic Uniformity Verses Source Strength

Source Strength is the second parameter whose influence was observed on the intrinsic uniformity (Fig. **2**). We varied the source strength from 10µCi to 80µCi with a step of 10µCi. We acquired 50-million count flood to get reasonable Intrinsic Uniformity values. The graph shows that as source strength increases from 10µCi to 30µCi, the

Intrinsic Uniformity improved and stays constant from 30 µCi to 50µCi and then degrades as Source Strength increases. The decrease in intrinsic uniformity may be because of high dead time losses since it increases with source strength (count rate).

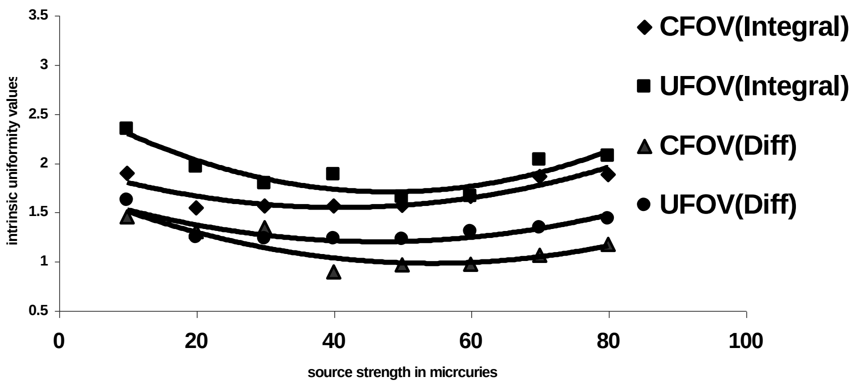

Fig. 2. :Effect of source strength on intrinsic uniformity.

Intrinsic Uniformity Versus Source Volume

To see the effect of source volume (specificity of source) on IU (Fig .**3**). The volume of the source was varied from 50µl to 500µl with a step of 50µl and collected 50 million flood images. We kept the source strength as in the last parameter i.e., 50µCi.The graph shows that as the specificity in source volume decreases (volume increases), the intrinsic uniformity increases, i.e., degrades. The volume of the source was precisely measured with a variable micropipette.

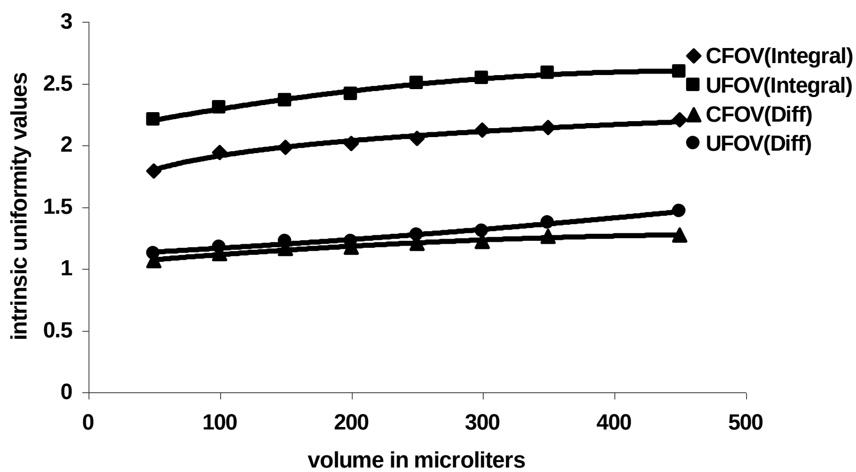

Fig. 3. Effect of volume on intrinsic uniformity.

Intrinsic Uniformity Versus Distance

The last parameter checked was distance of point source from the detector (Fig. **4**). A 50µCi point source was prepared and a flood image for a total count of 50 million was acquired. The distance of point source was varied from 137 cm to 48 cm. Intrinsic uniformity values degrade as the distance of point source from the camera decreases. At large distance, Intrinsic Uniformity improves since whole crystal face was exposed uniformity to gamma radiation flux, and there is less difference between maximum and minimum counts. At small distances only a small portion of the crystal was exposed to gamma flux so Intrinsic uniformity values worse at smaller distances.

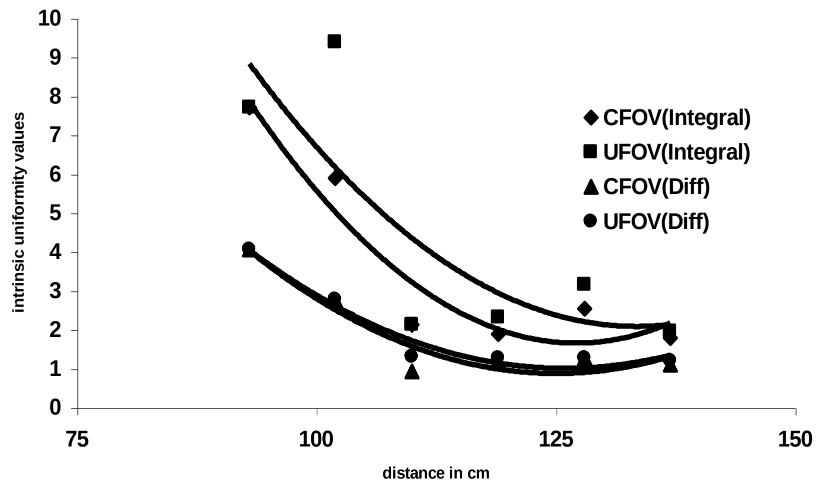

Fig. 4. Effect of distance on intrinsic uniformity.

STATISTICAL ANALYSIS

To find out a relation between these variables the scatter plot of the data was obtained. The scatter plot was to see if the relationship between the variables is linear or non-linear. To find out the exact nature of relationship different regression models were applied. The fitness of the model and the magnitude or strength of the relationship was evaluated from calculated R^2 value. The sample R squared tends to optimistically estimate how well the models fit the population. It is the proportion of variation in the dependent variable explained by the regression model. The values of R squared ranges from 0 to 1. Small values indicate that the model does not fit the data well. It is used to determine which model is best. R^2 values close to 1 indicate more strong relationship between the variables.

We had four sets of data for which different regression models were fitted

Total counts acquired and uniformity values: Five different regression models were applied to each set of data namely; linear, exponential, logarithmic, power, and polynomial. Power regression model is found to be best fitted in this set of data, as calculated R^2 value is closer to 1 as compared to that obtained from other models. This indicates that there is strong relationship between the two variables.

Source-camera distance and uniformity values: Same five different regression models as in case of total counts were applied to each set of data. Polynomial regression model is found to be best fitted in this set of data, as calculated R^2 values are closer to 1 as compared to that obtained from other models. This indicates that there is a strong relationship between the two variables except in the case of UFOV (integral) for which the R^2 value is 0.66 indicative of relatively weaker relationship between the variables.

Source strength and uniformity values: Here also five different regression models were applied to each set of data. Polynomial regression model is found to be best fitted in this set of data, as calculated R^2 values are closer to 1 as compared to that obtained from other models. This indicates that there is strong relationship between the two variables.

Volume and uniformity values: Five different regression models were applied to each set of data namely; linear, exponential, logarithmic, power, and polynomial. Polynomial regression model is found to be best fitted in integral and differential uniformity CFOV, as calculated R^2 values are closer to 1 as compared to that obtained from other models. Power regression model is found to be best fitted in integral and differential uniformity UFOV as calculated R^2 values are closer to 1 as compared to that obtained from other models. This indicates that there is a strong relationship between the two variables.

The Independent-Samples T Test procedure compares means for two groups of cases. The mean values for the two groups are displayed in the Group Statistics table. If the significance value for the Levene test is high (typically greater that 0.05)...Use the results that assume equal variances for both groups. If the significance value for the Levene test is low... Use the results that do no assume equal variances for both groups. A low significance value for the t test (typically less than 0.05) indicates that there is a significant difference between the two group means (Table 1).

Table 1. Reliability of the fitness (Comparison between observed and calculated values).

Independent variable		**Integral Uniformity**		**Differential Uniformity**	
		CFOV	**UFOV**	**CFOV**	**UFOV**
Total counts	**t-value**	-0.216	-0.334	-0.181	-0.223
	p-value	**0.831**	**0.742**	**0.858**	**0.826**
Distance	**t-value**	-0.12	0.77	0.24	-0.45
	p-value	**0.90**	**0.45**	**0.81**	**0.65**
Source strength	**t-value**	9.23	-8.11	-1.63	-7.43
	p-value	**0.09**	**0.15**	**0.12**	**0.08**
Volume	**t-value**	0.004	1.793	-0.639	0.773
	p-value	0.997	0.095	0.533	0.452

Reliability of the optimum parameters (Comparison between observed and cut-off values given by vendor)

All the observed values are less than the values given by vendor. The One-Sample t-test procedure was applied to test whether the mean of the observed uniformity values differs from a specified constant i.e., values given by vendor. The table shows the t-value and p-value for each data set (Table 2).

The p-value in all the cases is significantly low ($p<0.001$) indicating that there is significant difference between the observed uniformity values and the values given by vendor. As it is clearly shown the values are significantly less than the limits provided by the vendor, which is indicative of good uniformity.

Different authors suggested different protocols to obtain optimum intrinsic uniformity value. American Association of Physicist in Medicine (AAPM) suggests a total count of 4500-counts/ cm^2 of exposed crystal exceed 10 kcps (Anonymous, 1987). National electrical manufacturing association (NEMA) has suggested an acquisition of a minimum 4000 counts/pixel in the central pixel of 64x64 matrix, a minimum distance of 5 UFOV diameter of the source from the detector, a point source of Tc-99m of 100 to 200µCi is used for the flood field image at a window width of 20% window and activity will be in a volume of 10ml (Anonymous 1986). Vender (Siemens) suggests that the source activity should be 15-20µCi for the intrinsic flood (Vender, 1998). AAPM report suggests that the activity is in a volume of 1cc or less (Anonymous, 1987). Siemens suggest that use of liquid as little as possible should be used and ensure that the point source's activity is correct. According to AAPM report the distance of point source and detector is 5-crystal diameter from the detector center (Anonymous, 1987).

Table 2. Reliability of optimum parameters (Comparison between observed and cut-off values given by vendor).

	Integral Uniformity		**Differential Uniformity**	
	CFOV	**UFOV**	**CFOV**	**UFOV**
t-value	-74.46	-51.77	-63.70	-65.33
p-value	<0.001	<0.001	<0.001	<0.001

Looking at these different protocols, we were faced with the problem of deciding which set of parameters was to be used for rapidly performing our daily gamma camera QC testing. Our results indicated that the best set of image acquisition parameter and geometry for rapid performance of the daily gamma camera QC testing.

- Room back ground <400cps
- Point source of 50μCi
- Source volume of <50μl
- Source to camera distance 4.5ft.

Other factors effecting uniformity values

A symmetrical analyzer window should be set to the width normally used in clinical studies for Tc-99m (even if ^{56}Co is used) (Robert *et al.*, 1996). NEMA suggests a window width of 20% window got the flood field image [4]. Vender (Siemens) suggest a 20% window for Tc-99m And 15% window for ^{57}Co (Vender, 1998). AAPM report suggests that center the photopeak 15% or 20% window, which ever is to be used clinically (Most manufacture's specifications are measured with a 20% window (Anonymous, 1987). Vender (Siemens) suggested that SPECT studies were acquired in 64x64 matrices; floods of 50 million counts are sufficient to correct images. However SPECT studies were acquired in 128x128 matrices it is recommended you acquired intrinsic flood with 200 million counts per detector (Vender, 1998). NEMA suggests a matrices size of 64x64 for intrinsic flood (Anonymous, 1986). These factors are not taken into account in this particular study and we contained our self to the four describe earlier.

Optimum acquisition parameters

The best optimized set of values obtained for daily gamma camera Quality Control testing of Intrinsic Uniformity were found to be the collection of 50 millions counts from a source of 50μCi per 50μl placed at a distance of 4.5 feet from the camera head. By implementing all the above parameters, we obtained a set of best values for intrinsic uniformity. The performance reliability of the optimum parameters was assessed by applying one sample t-test. All the calculated values were significantly less ($p<0.001$) than the maximum limit defined by the vendor.

CONCLUSION

Intrinsic Uniformity improves as number of counts increases; distance increased to certain extent beyond which it degrades, source strength in micro curies and volume is smaller. The best set of values obtained for daily gamma camera Quality Control testing of Intrinsic Uniformity are found to be the collection of 50 millions counts from a source of 50μCi per 50μl placed at a distance of 4.5 feet from the camera head.

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