PHYSICS, ORIGINAL ARTICLE

A Comparison between Two Methods of Performing the Daily Intrinsic Uniformity Quality Control Test for Gamma Camera

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ABSTRACT

Field flood uniformity is a fundamental pre-requisite for using the gamma camera in clinical routine. Different techniques are available for evaluating the intrinsic flood uniformity of dual head gamma camera during the daily quality control. Some manufacturers recommend a simultaneous acquisition (manufacturer method) using the two detectors and others use a single detector method (conventional method). A comparison of the two methods is questioned to determine how much difference might be seen if one of the two methods is applied routinely.

Two methods were used to evaluate the intrinsic uniformity of a commercially available gamma camera (Siemens ECAM, Dual head) applying the following acquisition parameters: number of acquired counts, count rates, source volume, offset center x-axis, offset center y-axis and source-to-camera distance. One method uses the two detectors simultaneously (denoted by A) while the other method uses a one detector at a time (denoted by B). The integral and differential uniformity for the central and useful field of view were calculated and recorded for comparison.

The acquisition parameters that achieved the optimal uniformity values are tabulated below. Method A demonstrated better uniformity values over that yielded by the conventional method B with respect to all acquisition parameters considered ($p<0.05$). Using the tabulated results, a daily routine of flood uniformity will take approximately a time of 7-10 min if method A is used while a time of 10-12 min is taken if the conventional single detector method is used.

Protocol	Acquired counts	Count rate	Source volume	Offset center		Source-to camera distance
				X-axis	Y-axis	
Protocol–A	30 M	50-70 kcps	<0.1ml	<25 cm	<5 cm	37.5 cm.
Protocol-B	30 M	≈ 40 kcps	<0.1ml	≤25 cm	≤25 cm	> 5 times UFOV

Conclusion: The method recommended by the manufacturer provides fast, reliable, and even better results than that demonstrated by the conventional method. Moreover, it helps to perform the daily quality control in a convenient and short time. However, source preparation and positioning particularly in Y-axis were found to need some precautions and handling more than that needed by the conventional method.

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Introduction: Gamma camera uniformity is often monitored for quality control of performance. The uniformity or flood QC procedure checks the response of the detector to a uniform irradiation within defined limits[1]. Uniformity can be checked either without collimator **(intrinsic)** or with collimator **(extrinsic).** Intrinsic uniformity is simpler to perform and does not require a flood tank or sheet source. It is preferable to do daily intrinsic uniformity QC test because ^{99m}Tc-point source is readily available and also relative sensitivity of the gamma camera (count rate per unit source activity cpm/µci) can be checked simultaneously. Uniformity can be quantified in terms of the maximum variation in count density over the entire field-of-view [Integral uniformity (IU)] or in terms of the maximum rate of change in count density over a specified distance [differential uniformity (DU)].

To detect gradual deterioration in uniformity it is important that uniformity measurements are carried out in a consistent manner (i.e. using same method of performance with same orientation, same number of counts, same count rate, same source to camera distance, same matrix size, etc) and records are kept to allow comparisons over period of weeks or even months. Regular analysis of uniformity by a computer can facilitate detection of gradual deterioration prior to any visible change. Many quantitative measurements can be derived from computer analysis of uniformity image. So, comparing methods of performing daily intrinsic uniformity is questioned to determine how much difference might be seen in quantitative measurements of uniformity if one method is applied routinely. The intrinsic uniformity measured herein was undertaken for same detector of the gamma camera, once by applying method-A (manufacturer method) and once by applying method-B (conventional method). Same acquisition parameters were used for both methods so as to undertake a one to one comparison between the two methods.

MATERIALS AND METHODS

1. Gamma camera system: The scintillation camera used in this study was E.CAM (Dual-Head Variable-Angle System) associated with e-soft computer for acquisition and processing of flood images.
2. Point sources: special shape of vials made by the manufacturer for containing the ^{99m}Tc-point source. It was used to study all parameters except for source volume parameter; it was replaced by syringe point source (because vial point source has a limited volume ≤1ml).
3. Dose calibrator: Veenstra PC dose calibrator (VDC405 version 3.24) for accurate measurements of ^{99m}Tc-point sources.

METHODS

Two methods were used to measure the intrinsic uniformity including integral and differential values in the central and useful field of views (CFOV&UFOV). The first one was the manufacturer method (method-A) and the second was the conventional method (method-B). The base lines of method-A are: Using a nearby ^{99m}**Tc** point source of activity ≈ (20-30 µci), placing it in a source holder of the rear bed of the gamma camera facing the detector centre at a distance ≤ the radius of the camera orbit (=37.5cm) then a flood field image is acquired with a set of parameters. The base lines of method-B are: Using a relatively far ^{99m}**Tc** point source of activity ≥100 µci, placing it at a distance ≥ five times the useful field of view (UFOV) of the camera and facing the detector centre, then a flood field image is acquired with a set of parameters. The set of parameters that were used to study the present comparison between the two methods (A&B) are: number of acquired counts, count rates, source volume, offset center (x-axis), offset center (y-axis), and source-to-camera distance. The following steps were done to perform the present study:

- The collimators were removed from the gamma camera by using the semiautomatic method of removing.
- The camera was set such that its two detectors were: facing each others with point source between them (method-A) and in perpendicular position with point source facing one detector only (method-B).
- The room background was carefully measured using the NaI crystals of the gamma camera. Every attempt was made

to keep the background as low as possible (<200cps).

- The number of acquired counts was varied between 10-60 million by changing the stop conditions of acquisition to compare the effect of acquired counts on intrinsic uniformity for the two methods.
- The source activity was varied to obtain variable count rates in the range of 10-140 kcps to compare the effect of count rate on intrinsic uniformity for the two methods.
- The source volume was varied between 0.1-2.5ml (by adding normal saline) to compare the effect of source volume on intrinsic uniformity for the two methods.
- The ^{99m}***Tc***-point source was carefully clamped into the source holder of the rear bed of the gamma camera. The distance between the detector and point source was varied: in the range of 15-35cm (for method-A) by moving the detectors in and out using the hand switch of the camera, and in the range of 80-250cm (for method-B) by moving a movable stand closer to or further from the detector to compare the effect of source to-camera distance on intrinsic uniformity for the two methods.
- The offset centers (x-axis) and (y-axis) were varied between 0-25cm by moving the source holder horizontally and vertically to compare the effect of changing offset center (x-axis) and (y-axis) on intrinsic uniformity for the two methods.
- Peaking test was done before starting each test, ^{99m}***Tc*** gamma spectrum was acquired and a 20% window around the 140kev photo peak was automatically set.
- In all flood uniformity acquisitions of this study, there were some default settings (instructed by the manufacturer), these default settings were: matrix size = 1024x1024, zoom factor = 1 and isotope = one
- T-test was used to determine the statistical significance (P value) of difference between two samples.
- The quantitative measurements of intrinsic uniformity of the system (both UFOV&CFOV) were done using the software provided by the manufacturer.
- The intrinsic uniformity is expressed by the equation given by the National Electrical Manufactures Association standard (NEMA). NEMA (1994) which defined the uniformity as:

$$\textbf{Uniformity, (U)} = \frac{N_{\max} - N_{\min}}{N_{\max} + N_{\min}} X100\%.$$

Where; in case of calculating **integral uniformity**; N_{max} and N_{min} are the maximum counts at one pixel and the minimum at another pixel in the Central field of view (Integral uniformity of CFOV) or in the useful field of view (Integral uniformity of UFOV).While, in case of calculating **differential uniformity**; N_{max} and N_{min} are the maximum and minimum counts in a region of interest (ROI) chosen automatically in a region of 1x5 pixels in the Central field of view (Differential uniformity of CFOV), or in the useful field of view (Differential uniformity of UFOV).

RESULTS

Since method-A (Manufacturer method) can be utilized to perform the intrinsic uniformity test for both detectors simultaneously while method-B (conventional method) can only be used to check one detector for uniformity at a time so, for comparison purposes between the two methods, one detector only (detector-2 of the dual head camera) was selected to be checked for uniformity once by method-A, and once by method-B. The effect of acquisition parameters on the measurements of intrinsic uniformity including integral and differential values in the central and useful field of view were plotted through a comparison pattern between the two methods (A&B) in order to simplify the interpretation of the results for the following parameters:

1- Number of acquired counts

Variable acquired counts (10-60 million) were used in both methods. **Figures (1-a, 1-b, 1-c, and 1-d)** show a comparative analysis for uniformity measurements obtained as a result of varying the number of acquired counts using the two methods.

The effect of total counts on image uniformity was in favor of increasing the total counts in the acquired images. This finding was consistent in both methods since it provides better statistical certainty by reducing the random noise associated with random nature of radioactive decay. As a result, the optimal measurements obtained for the intrinsic uniformity in the CFOV and UFOV was at the highest total counts applied namely 60 million. Camera uniformity obtained by method-A was generally better than that achieved by method-B.

The following table **(Table-1)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the acquired counts was incrementally increased by a step of 10M starting from 10M until 60M.

A statistical significance was obtained when both data sets were compared **($p<0.05$)**.

Table (1): The effect of total counts on intrinsic uniformity using methods (A&B).

Uniformity / Field	Results of Method-A	Results of Method-B
IU/CFOV figure (1-a)	Improved from 3.5% to 1.5% (Improvement = 2%)	Improved from 3.6% to 2.3% (Improvement = 1.3%)
IU/UFOV figure (1-b)	Improved from 4.5% to 1.8% (Improvement = 2.7%)	Improved from 4.0% to 2.8% (Improvement = 1.2%)
DU/CFOV figure (1-c)	Improved from 2.0% to 1.0% (Improvement = 1%)	Improved from 2.4% to 1.3% (Improvement = 1.1%)
DU/UFOV figure (1-d)	Improved from 2.5%to1.25% (Improvement = 1.25%)	Improved from 2.4% to 1.4% (Improvement = 1%)

2-Count rates A range of count rates (10-140 kcps) was applied in both methods. **Figures (2-a, 2-b, 2-c, and 2-d)** show a comparative analysis for uniformity measurements obtained as a result of varying the count rate using the two methods.

According to comparison of count rates, camera uniformity obtained by method-A was generally better than that achieved by method-B.

The following table **(Table-2)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the count rate was incrementally increased by a step of 30kcps starting from 10kcps until 140kcps.

A statistical significance was obtained when both data sets were compared **($p<0.05$)**.

Table (2). The effect of count rates on intrinsic uniformity using methods (A&B).

Uniformity / Field	Results of Method-A	Results of Method-B
IU/CFOV figure (2-a)	Improved from 2.25% to 1.75% (improvement=0.5%). Critical value at 110 kcps, then it was degraded from 1.75% to 2.25% (degradation = 0.5%)	Improved from 3.2% to 2.5% (improvement = 0.7%). Critical value at 40 kcps, then it was degraded from 2.5% to 3.6% (degradation = 1.1%)
IU/UFOV figure (2-b)	Improved from 3.25% to 2.75% (improvement = 0.5%). Critical value at 110 kcps, then it was degraded from 2.75% to 3.0% (degradation = 0.25%)	Improved from 3.3% to 3.2% (improvement = 0.1%). Critical value at 40 kcps, then it was degraded from 3.2% to 4.2% (degradation = 1%)
DU/CFOV figure (2-c)	Improved from 1.35% to 1.1% (improvement = 0.25%). Critical value at 110 kcps, then it was degraded from 1.1% to 1.5% (degradation = 0.4%)	Improved from 1.75% to 1.6% (improvement = 0.15%). Critical value at 40 kcps, then it was degraded from 1.6% to 2.0% (degradation = 0.4%)
DU/UFOV figure (2-d)	Improved from 1.6% to 1.2% improvement = 0.4%. Critical value at 110 kcps, then it was degraded from 1.2% to 1.7% (degradation = 0.5%)	Improved from 1.75% to 1.6% (improvement = 0.15%) Critical value at 40 kcps, then it was degraded from 1.6% to 2.1% (degradation = 0.5%)

3-Source volumes: Variable source volumes (0.1 – 2.5 ml) in syringe-point sources were used in both methods. **Figures (3-a, 3-b, 3-c, and 3-d)** show a comparative analysis for uniformity measurements obtained as a result of varying the source volume using the two methods.

According to comparison of source volume, camera uniformity obtained by method-A was generally better than that achieved by method-B.

The following table **(Table-3)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the source volume was gradually increased starting from 0.1ml until 2.5ml.

A statistical significance was obtained when both data sets were compared **($p<0.05$)**.

Table-3; the effect of source volume on intrinsic uniformity using methods (A&B).

Uniformity / Field	Results of Method-A	Results of Method-B
IU/CFOV figure (3-a)	Degraded from 1.6% to 2.6 % (Degradation = 1%)	Degraded from 2.5% to 3.0% (Degradation = 0.5%)
IU/UFOV figure (3-b)	Degraded from 2.25% to 2.75% (Degradation = 0.5%)	Degraded from 2.7% to 3.1% (Degradation = 0.4%)
DU/CFOV figure (3-c)	Degraded from 1.4% to 1.6% (Degradation = 0.2%)	Degraded from 1.5% to 1.8% (Degradation = 0.3%)
DU/UFOV figure (3-d)	Degraded from 1.4% to 1.7% (Degradation = 0.3%)	Degraded from 1.7% to 2.2% (Degradation = 0.5%)

4-Source offsets (x-axis): The point source was shifted along x-axis (0-25 cm) in both methods. **Figures (4-a, 4-b, 4-c, and 4-d)** show a comparative analysis for uniformity measurements obtained as a result of varying the source offset (x-axis) using the two methods.

According to comparison of source offsets (X-axis), camera uniformity obtained by method-B was better than that achieved by method-A (Obvious difference was clearly noted).

The following table **(Table-4)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the source offset (x-axis) was incrementally increased by a step of 5cm starting from zero-offset (center) until 25cm.

A statistical significance was obtained when both data sets were compared **($p<0.05$)**.

Table-4: Effect of source offsets (x-axis) on intrinsic uniformity using methods A&B

Results of Method-B	Results of Method-A	Uniformity / Field
No Critical value. IU degraded from 2.7% to 3.8% (degradation = 1.1%)	Constant IU=2% at Offset x-axis (0-20cm). Critical value at 20 cm then IU degraded from 2% to 50% (Degradation = 48%)	**IU/CFOV** Figure (4-a)
No Critical value. IU degraded from 3.8% to 4.1% (Degradation = 1.3%)	Constant uniformity =2% at Offset x-axis (0-20cm). Critical value at 20 cm, then IU degraded from 2% to 50% (Degradation = 48%)	**IU/UFOV** Figure (4-b)
No Critical value. DU degraded from 1.7% to 1.9% (Degradation = 0.2%)	DU degraded from 1.2% to 1.9% at Offset X-axis (0-20cm) (Degradation = 0.7%). Critical value at 20 cm then it degraded again from 1.9% to 6% (Degradation = 4.1%)	**DU/CFOV** Figure (4-c)
No Critical value. DU Degraded from 1.7% to 1.9% (Degradation = 0.2%)	DU degraded from 1.5% to 1.9% at Offset X-axis (0-20cm) Degradation = 0.4%. Critical value at 20cm then it degraded again from 1.9% to 5.5%. Degradation = 3.6%	**DU/UFOV** Figure (4-d)

5-Source offsets (y-axis): The point source was shifted along y-axis (0-25 cm) in both methods. **Figures (5-a, 5-b, 5-c, and 5-d)** show a comparative analysis for uniformity measurements obtained as a result of varying the source offset along (y-axis) using the two methods.

According to comparison of source offsets along (y-axis), camera uniformity obtained by method-B was better than that achieved by method-A (Obvious difference was clearly noted).

The following table **(Table-5)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the source offset along (y-axis) was incrementally increased by steps of 5cm starting from zero-offset (center) until 25cm.

A statistical significance was obtained when both data sets were compared **(p<0.05)**.

Table (5): The effect of source offsets (Y-axis) on intrinsic uniformity using methods A&B

Results of Method-B	Results of Method-A	Uniformity / Field
No Critical value. IU degraded from 2.7% to 3.75% (Degradation = 1.05%)	Constant Uniformity = 2% at Offset x-axis (0-5cm) Critical value at 5cm, then IU degraded from 2% to 53% (Degradation = 51%)	**IU/CFOV** figure (5-a)
No Critical value. IU degraded from 3.4% to 4.1% (Degradation = 0.7%)	Constant Uniformity =2% at Offset x-axis (0-5cm) Critical value at 5 cm, then IU degraded from 2% to 60% (Degradation = 58%)	**IU/UFOV** figure (5-b)
No Critical value. DU degraded from 1.66% to 1.95% (Degradation = 0.29%)	Constant Uniformity =1.3% at Offset x-axis (0-5cm) Critical value at 5 cm, then DU degraded from 1.3% to 6.5% (Degradation = 5.2%)	**DU/CFOV** figure (5-c)
No Critical value. DU degraded from 1.63% to 1.98% (Degradation = 0.35%)	Constant Uniformity =1.3% at Offset x-axis (0-5cm) Critical value at 5 cm, then DU degraded from 1.3% to 6.5% (Degradation = 5.2%)	**DU/UFOV** figure (5-d)

6- Source-to camera distances (cm): The source distance considered in both methods was different in the sense that in method-A, the two detectors were measured simultaneously and therefore the available space for the source was confined by the maximum separation of the two detectors = 75 cm. In method-B, the available space was greater since one detector was used. Hence, comparing the two methods was carried out by computing the percentage change in uniformity values, taking the source distances at 37.5 cm and 5 x UFOV=190 cm as references. Analysis of the comparison was recorded in table-6 and displayed in **Figures (6-a, 6-b, 6-c, and 6-d)**.

According to comparison of source-to camera distances, camera uniformity obtained by method-A was generally better than that achieved by the single detector method-B.

The following table **(Table-6)** shows the intrinsic uniformity values obtained in the two methods (A&B) when the source to-camera distance was changed (as a percentage of reference distance in each method) starting from 100% until 42%.

A statistical significance was obtained when both data sets were compared **(p<0.05)**.

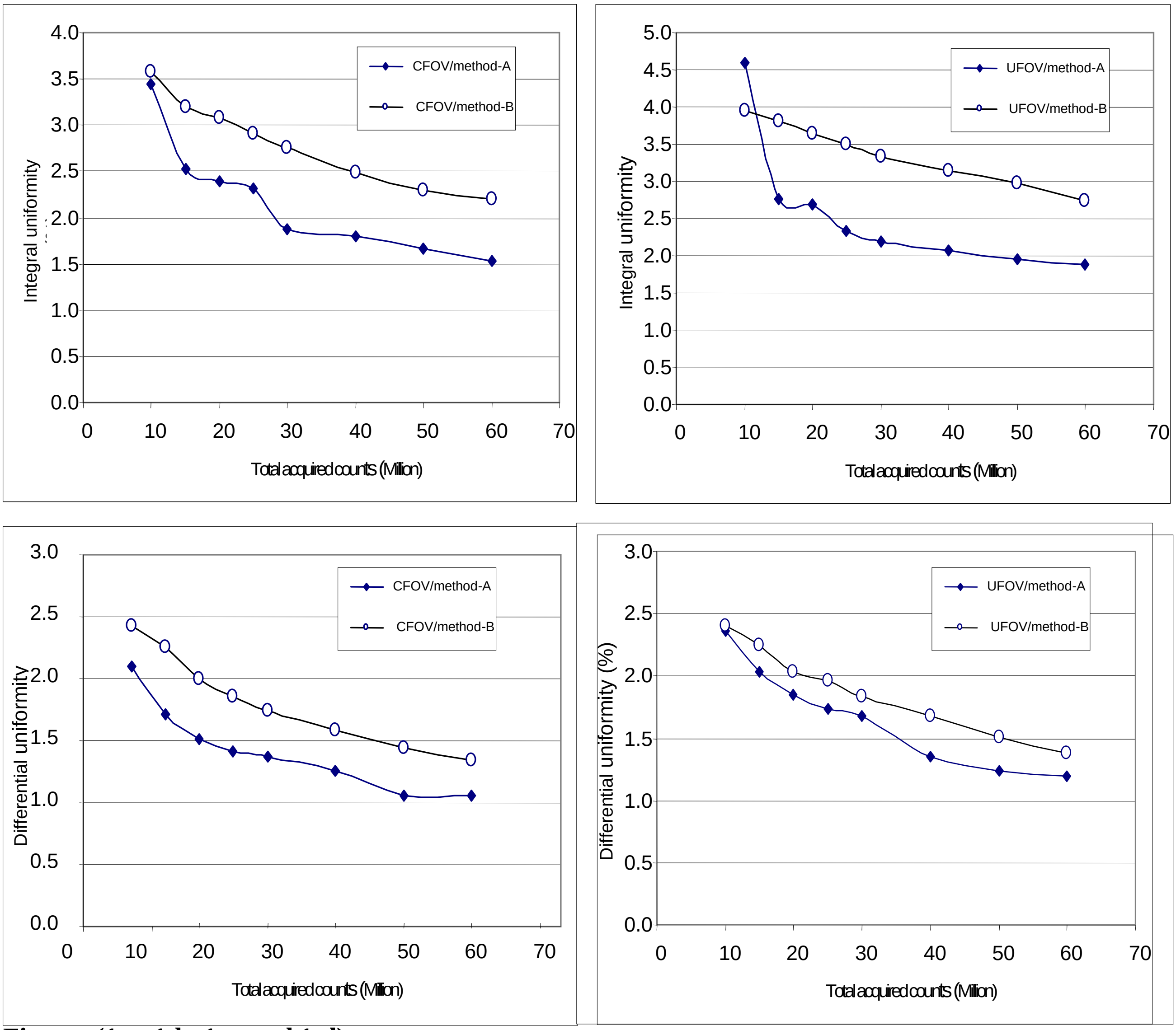
Table (6): the effect of source-to camera distance on intrinsic uniformity using methods A&B

Results of Method-B	Results of Method-A	Uniformity / Field
Improved from 6% to 3.3% (Improvement = 2.7%)	Improved from 3.5% to 2.7% (Improvement = 0.8%)	**IU/CFOV** figure (6-a)
Improved from 7.8% to 3.3% (Improvement = 4.5%)	Improved from 3.8% to 2.7% (Improvement = 1.1%)	**IU/UFOV** figure (6-b)
Improved from 3% to 1.7% (Improvement = 1.3%)	Improved from 3.9% to 2.8% (Improvement = 1.1%)	**DU/CFOV** figure (6-c)
Improved from 2.7% to 1.9% (Improvement = 0.8%)	Improved from 2.5% to 1.7% (Improvement = 0.8%)	**DU/UFOV** figure (6-d)

N.B

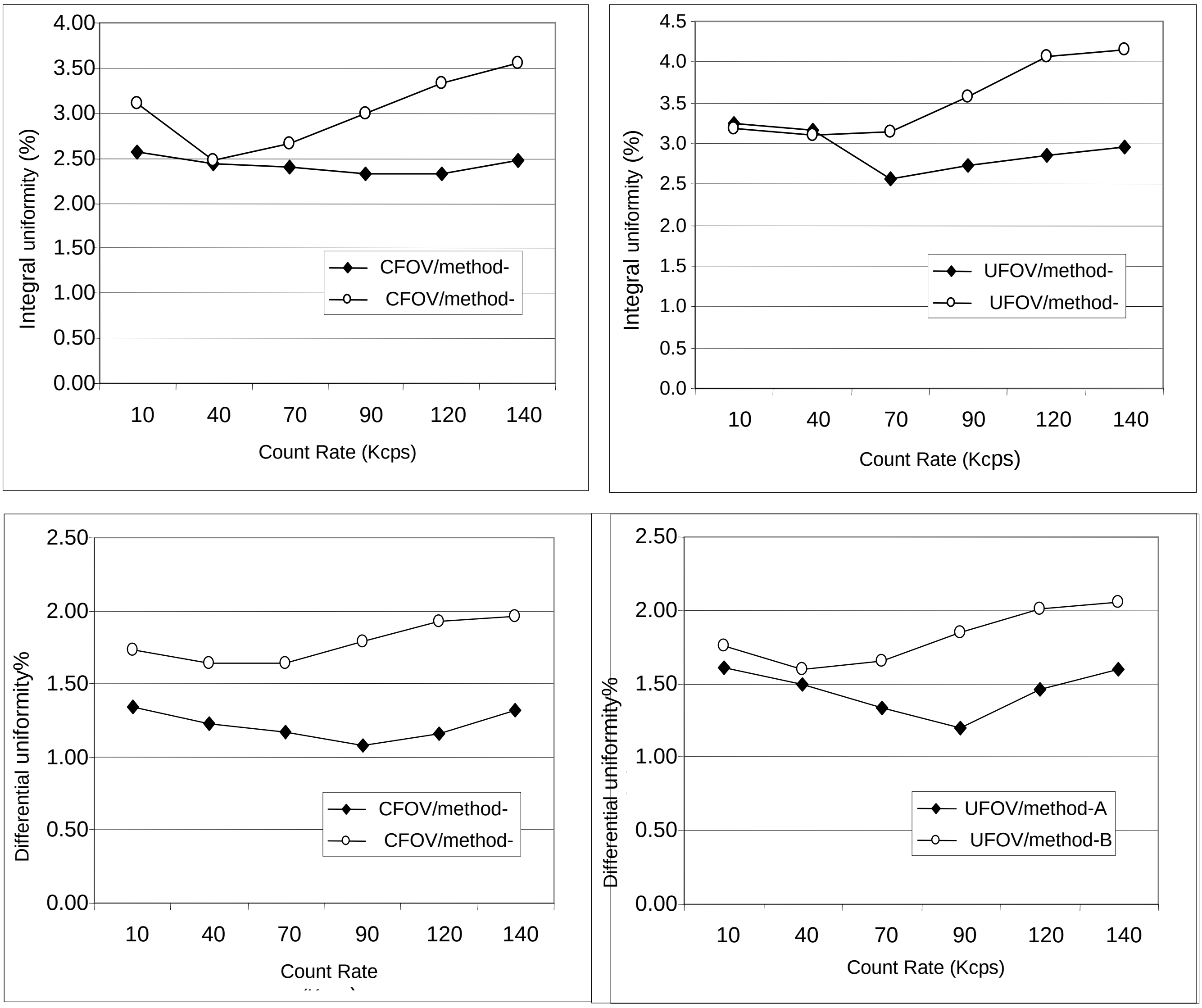
The above mentioned figures for the compared parameters from 1 to 6 are arranged and shown in six groups as the following:

1. Intrinsic uniformity Vs. Acquired counts



Figures (1-a, 1-b, 1-c, and 1-d)
Figure (1-a) Left-Up: shows IU/CFOV versus acquired counts for methods A&B.
Figure (1-b) Right-Up: shows IU/UFOV versus acquired counts for methods A&B
Figure (1-c) Left-Down: shows DU/CFOV versus acquired counts for methods A&B.
Figure (1-d) Right-Down: shows DU/UFOV versus acquired counts for methods A&B.

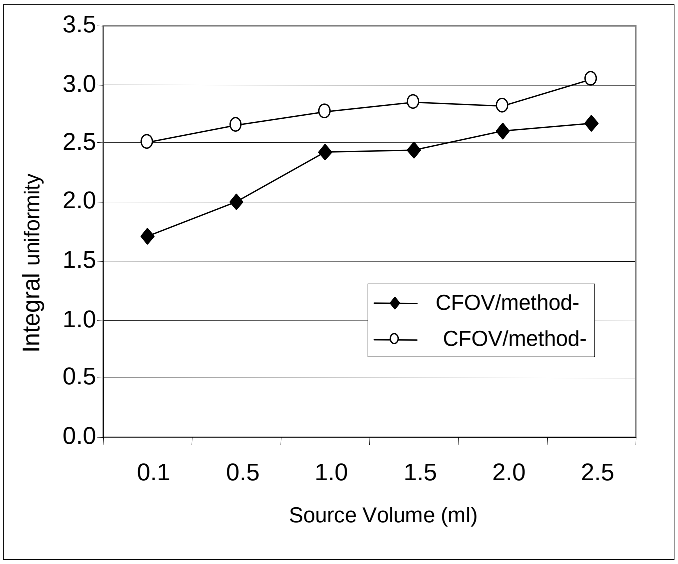
2. Intrinsic uniformity vs. Count Rate

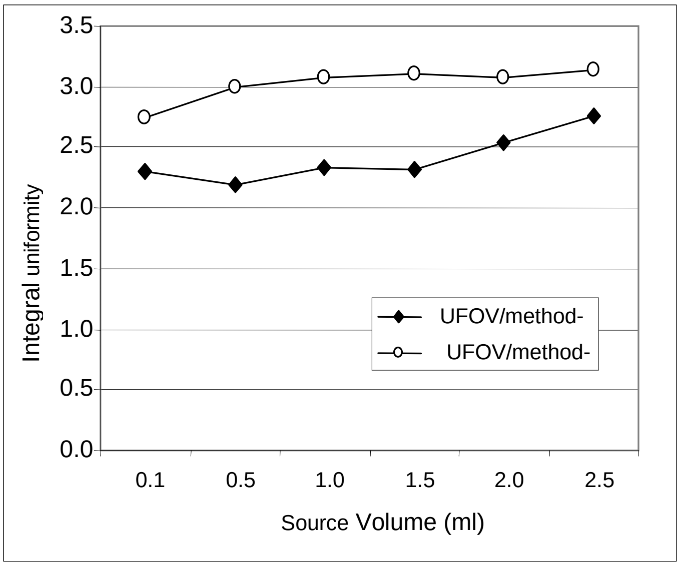


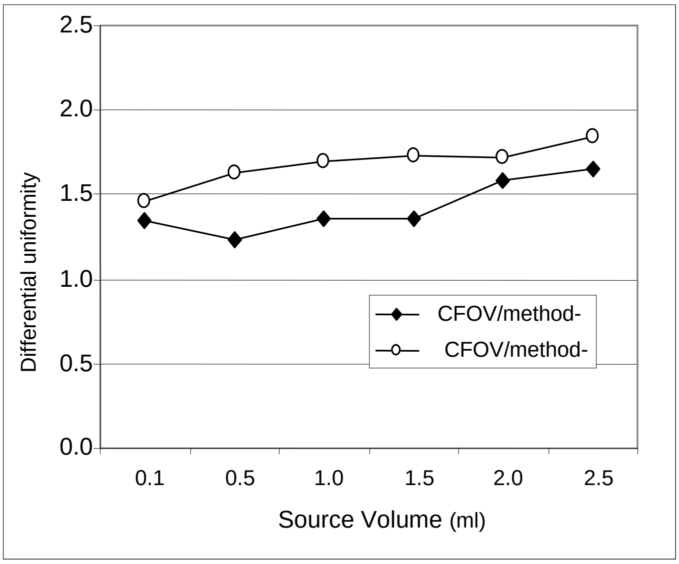
Figures (2-a, 2-b, 2-c, and 2-d)

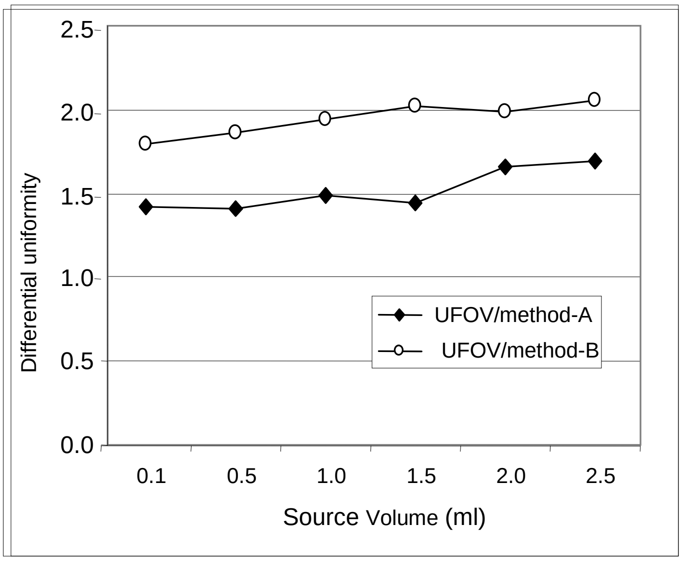
Figure (2-a) Left-Up: shows IU/CFOV versus count rate for methods A&B.
Figure (2-b) Right-Up: shows IU/UFOV versus count rate for methods A&B.
Figure (2-c) Left-Down: shows DU/CFOV versus count rate for methods A&B.
Figure (2-d) Right-Down: shows DU/UFOV versus count rate for methods A&B.

3. Intrinsic uniformity vs. Source volume





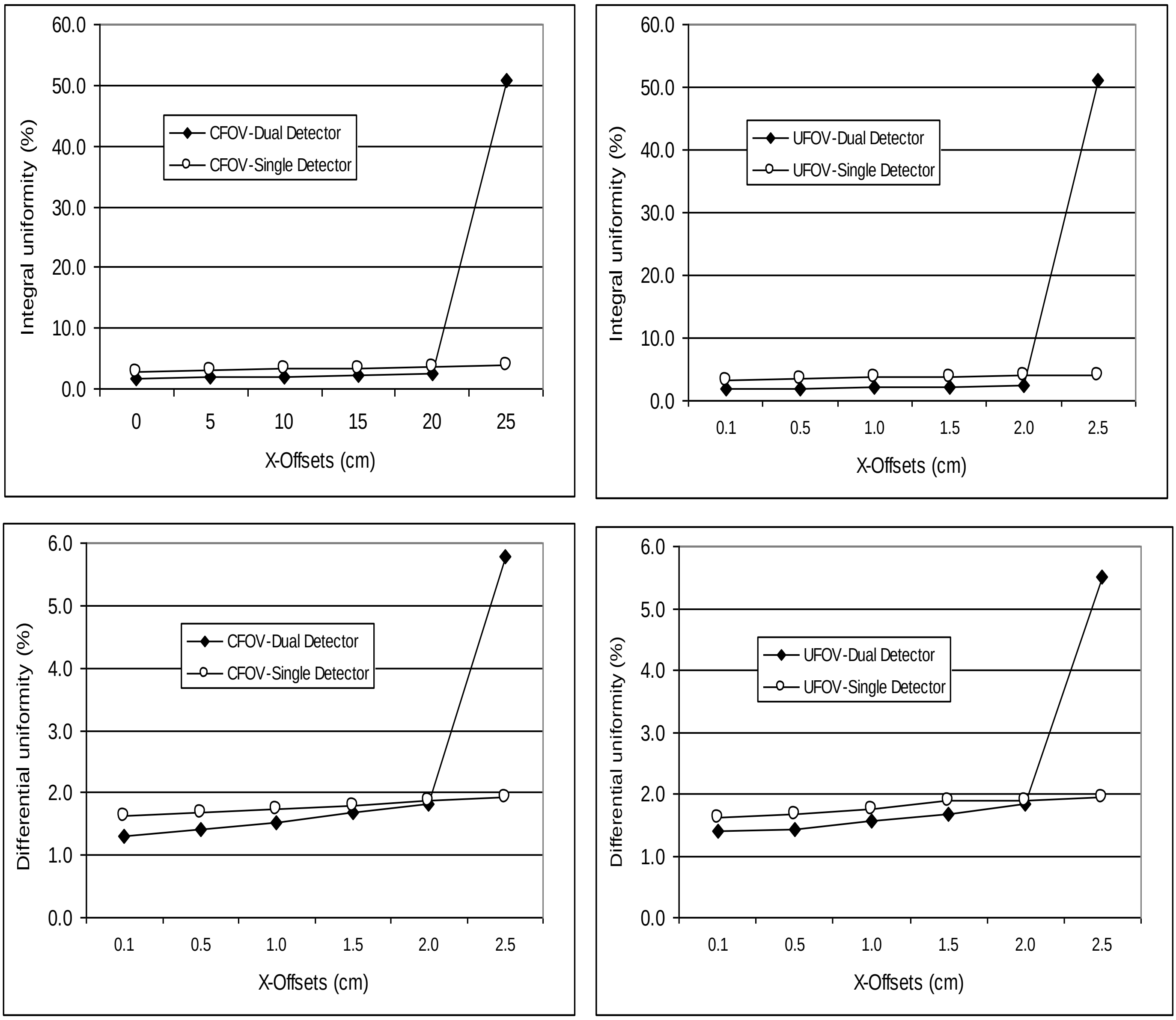




Figures (3-a, 3-b, 3-c, and 3-d)

Figure (3-a) Left-Up: shows IU/CFOV versus source volume (methods A&B).
Figure (3-b) Right-Up: shows IU/UFOV versus source volume (methods A&B).
Figure (3-c) Left-Down: shows DU/CFOV versus source volume (methods A&B).
Figure (3-d) Right-Down: shows DU/UFOV versus source volume (methods A&B).

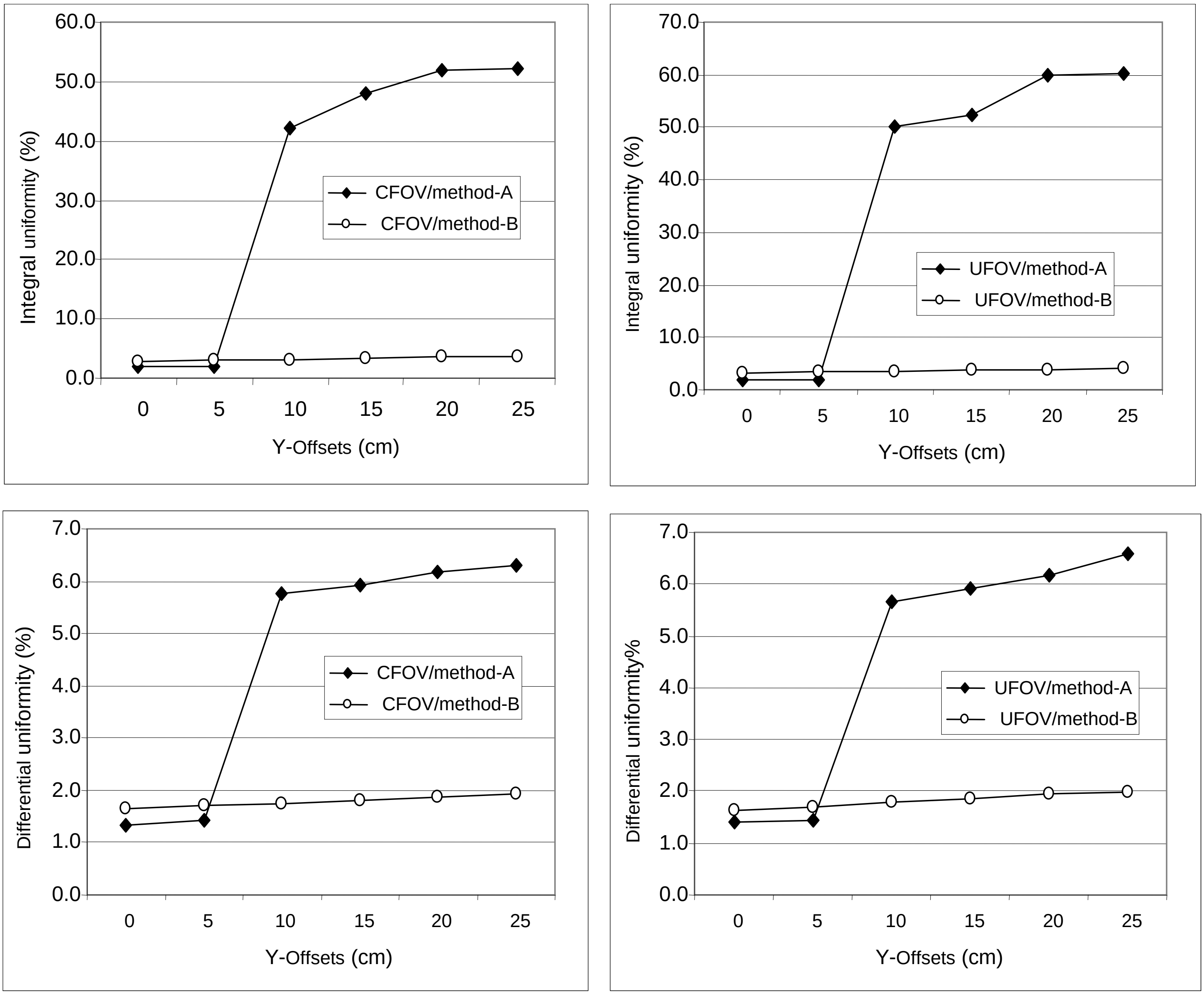
4. Intrinsic uniformity vs. Source offset X-axis



Figures (4-a, 4-b, 4-c, and 4-d)

Figure (4-a) Left-Up: shows IU/CFOV versus Offset centre x-axis (methods A&B).
Figure (4-b) Right-Up: shows IU/UFOV versus Offset centre x-axis (methods A&B).
Figure (4-c) Left-Down: shows DU/CFOV versus Offset centre x-axis (methods A&B).
Figure (4-d) Right-Down: shows DU/UFOV versus Offset centre x-axis (methods A&B).

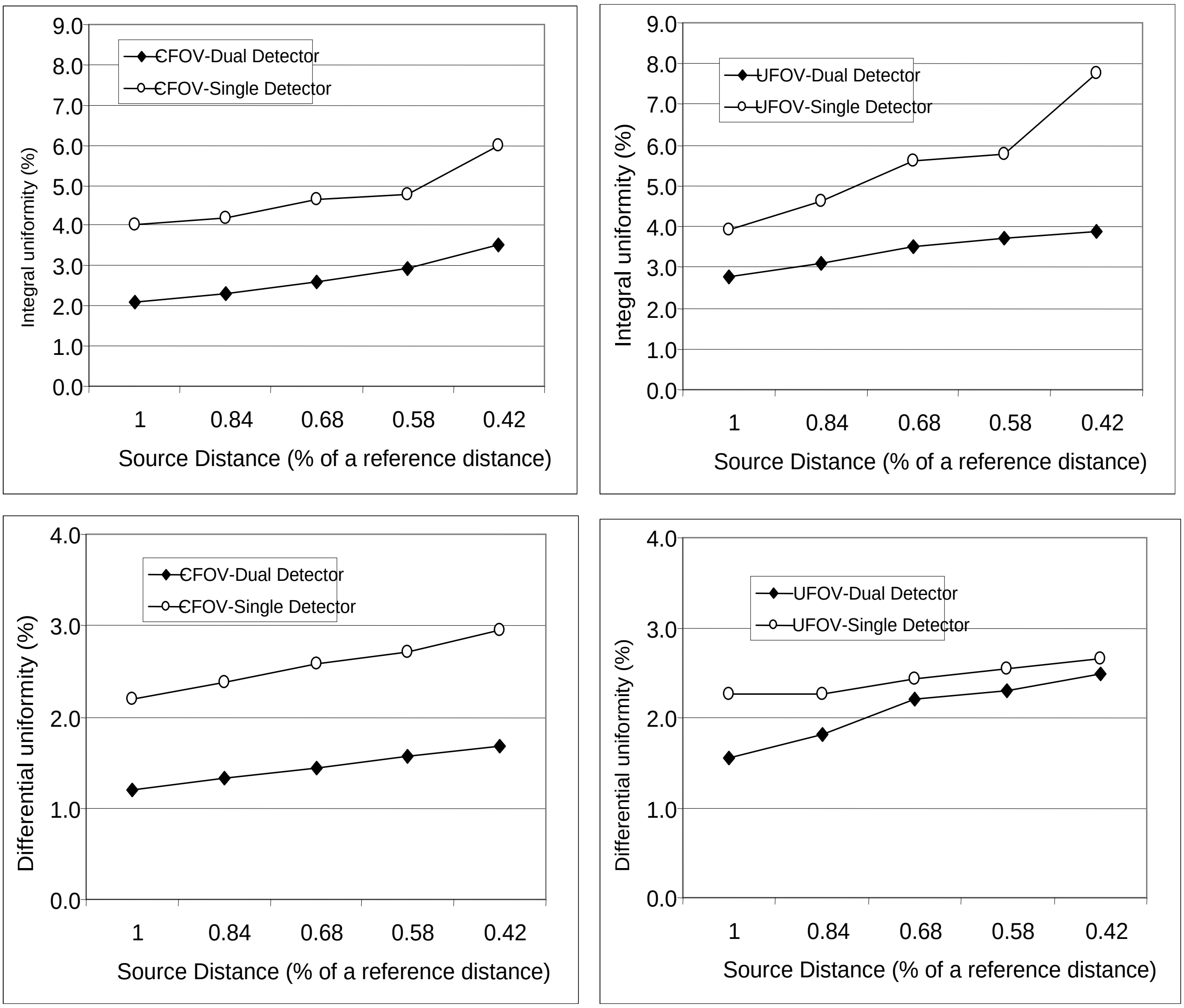
5. Intrinsic uniformity vs. Source offset (Y-axis)



Figures (5-a, 5-b, 5-c, and 5-d)

Figure (5-a) Left-Up: shows IU/CFOV versus Offset centre y-axis (methods A&B).
Figure (5-b) Right-Up: shows IU/UFOV versus Offset centre y-axis (methods A&B).
Figure (5-c) Left-Down: shows DU/CFOV versus Offset centre y-axis (methods A&B).
Figure (5-d) Right-Down: shows DU/UFOV versus Offset centre y-axis (methods A&B).

6. Intrinsic uniformity vs. Source to-camera distance



Figures (6-a, 6-b, 6-c, and 6-d)

Figure (6-a): Left-Up: shows IU/CFOV versus Source to-camera distance (methods A&B).
Figure (6-b): Right-Up: shows IU/UFOV versus Source to-camera distance (methods A&B).
Figure (6-c): Left-Down: shows DU/CFOV versus Source to-camera distance (methods A&B).
Figure (6-d): Right-Down: shows DU/UFOV versus Source to-camera distance (methods A&B).

DISCUSSION

Various protocols (2-8) were suggested for performing QC tests of intrinsic uniformity for a gamma camera system. **Table-7** summarizes the main parameters of those protocols in addition to the present study protocols (A&B). A ^{99m}Tc point source was used to acquire the flood image and all authors suggested a 20% discriminator window around 140-keV gamma camera. It was noticed that the main differences between the various protocols are:-

1- **The number of counts required for the flood image**. One manufacturer[(6)] suggested 15 M counts in a 512 x 512 image matrix size, whereas NEMA[(5)] suggests ≥ 10000 counts in the central pixel of the image (corresponding to ≥ 41 M counts for 64 x 64 matrix size) and the American Society of Nuclear Cardiology[(7)] suggested 4500 counts/cm^2 (corresponding to ≈

11 M counts in a 64 x 64 matrix size while El Kamhawy et al suggested ≥ 15 M counts.

2- **The counting rate at which the intrinsic uniformity test should be performed**. The suggestions for this parameter varied widely from ≤ 10 kcps[(7)] to 70 k cps[(6)]. It is important to check the system at both low counting rates and high counting rates to ensure that the uniformity remains acceptable[(6)].

3- **Source volume** is not specified in references [(2), (3), (5), (6),] however it ranges between <0.1m [(4)] to 0.5ml[(7)].

4- **The offset center x-axis and y-axis** (deviation of point source position from center in directions x, y) is not specified in all references [(2-8)].

5- **The source to camera distance** is = 5 times FOV in references[(4-8)], ≈ 5 times FOV in reference[(7)] and > 5 times FOV in reference [(8)].

6- **Image matrix size**: Sorenson and phelps[(2)], Early and Sodee[(3)] and Klingensmith et al.[(4)], suggest 64 x 64 x 16 matrix size (in which the cardiac SPECT studies are usually performed), whereas Pegasys et al.[(6)] suggested 512 x 512 x 16 and the American Society of Nuclear Cardiology [(7)] and Elkamhawy et. al[(8)] suggested 256 x 256 matrix size. NEMA protocols (5) suggested image matrix size which produces pixel sizes with linear dimensions of 6.4 mm ± 30% (this corresponds to 64 x 64 matrix size for large FOV camera). It is important to ensure that uniformity is acceptable for all clinically used matrix sizes. But, according to the manufacturer standard settings for the present camera, a fixed matrix size = 1024 x 1024 was used in this study.

7- The acceptable value for IU required for SPECT studies is not specified in NEMA (5) and is suggested Pegasys X. (6) for a 512 x 512 matrix size to be < 2.5% for CFOV. Klingensmith et al. (4) recommended the system uniformity of ± 1% to avoid artifacts in reconstructed images.

8- All of the parameters mentioned in references [(2-8)] in addition to the present study method-A are dealing with single head gamma camera, while the present study method-B is dealing with dual head gamma camera and can also be applied successfully in case of single head gamma camera.

Table 7: Protocols Suggested by Various Authors for Performing Daily Intrinsic Uniformity Quality Control for Gamma Camera Systems

Parameter	Sore-nson et al.	Early et al.	Kling - smith et al.	NEMA	Pegasys et al.	Garcia	ElKamh-awy et al.	Present study	
								(A)	(B)
Acquired Counts(M)	2 M	2 M	3 M	≥41 M	15 M	≈11 M	≥15 M	30 M	30 M
Count rate kcps.	<20,000	20,000 - 70,000	<10,000	<20,000	20,000-50,000	10,000-20,000	45,000-50000	50,000-70,000	≈40,000
Source volume	----	----	<0.1 ml	----	----	0.5 ml	<0.3 ml	<0.1ml	≤0.1ml
Offsets (X-axis)	----	----	----	----	----	----	----	<20 cm	≤25 cm
Offsets (Y-axis)	----	----	----	----	----	----	----	<5 cm	≤25 cm
Source to-camera distance	5 times UFOV	5 times UFOV	5 times UFOV	5 times UFOV	8 Feet	>5times UFOV	10 Feet	37.5cm	>5times UFOV
Matrix size	64 x 64 x 16	64 x 64 x 16	64 x 64 x 16	Matrix that gives pixel size≈6.4mm	512 x 512 x16	256 x 256 x16	256 x 256 x 16	1024 x 1024x8	1024 x 1024x8

It's noted that protocols (2-8) were mainly based on conventional method (denoted by method-B in the present study) in which one detector only can be checked for uniformity at a time, while method-A of this study can be used to check the uniformity of two detectors simultaneously. Determination of the optimal acquisition parameters that evaluate the system uniformity is most likely to be system dependant and on-site testing of varying the test acquisition parameters could help to identify the range of variations that may occur in different conditions.

CONCLUSION

According to results of methods (A&B), two protocols A&B were concluded to optimize acquisition parameters for rapid performance of daily gamma camera intrinsic uniformity QC test. The optimized parameters of protocols A&B are mentioned in **Table 7**.

Protocol (A), In case of using method –A:
In this case the test for both detectors was performed simultaneously within 7-10 minutes and the obtained values for IU and DU were 2% and < 1.3% respectively. These values are very consistent with NEMA as well as other recommendations for optimal performance of gamma camera in daily examinations. In addition, such uniformity values are satisfactory to perform SPECT imaging with acceptable results.

Protocol (B), In case of using method-B:
In this case one detector was tested only at a time and hence time required to acquire a uniformity check is doubled. This is a major shortcoming of the single detector method. A time of 10-12 minutes is needed to perform one detector and accordingly more than 20 min is required to carry out the daily uniformity test.

The obtained values for IU and DU are 2.7% and < 1.8% respectively, which are suitable for SPECT and other imaging procedures.

Which method is appropriate for measuring the daily camera uniformity?
Based on the results of the present work taking into consideration the time required to perform the daily quality control, source preparation, and uniformity results, method-A (the manufacturer method) is recommended to be applied on a routine basis. Although method-A outperforms method-B, however, the following remarks are pointed out:

a) Accurate positioning of ^{99m}***Tc***-point source between the centers of the two detectors is required because any small shift (source to camera distance, offsets in x- or y-axis) leads to false results with underscoring the true camera uniformity. It is found that ≥20 cm offset centre shift of the point source in X-direction (horizontal shift) and ≥5 cm offset centre shift of the point source in Y-direction (vertical shift) leads to very poor values of Intrinsic uniformity (Integral and differential uniformities).

b) High precision in handling and preparation of ^{99m}***Tc***-Point source is needed (because very low activity ≈ 20-30 µci is used) in addition of keeping the room background as low as possible.

c) Disregarding the acquisition time, source preparation in method-A is a little bit time consuming rather than in method-B. However, the overall time is short in method-A than method-B.

d) Protocol-B is better for performing intrinsic uniformity QC test for a single head gamma camera since it generally takes short time and also gives good intrinsic uniformity results and has the advantage of preparing the source in a reasonable short time; no much difficulty is required in preparing the source activity (200-400 uCi is easy to prepare than 20-30 uCi), in addition to easy positioning of the radioactive source.

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