Gamma camera intrinsic uniformity in an unstable power supply environment

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Abstract

The main objective of this work was to show that a gamma camera in a developing country could perform efficiently despite electricity outages using intrinsic flood uniformity tests as an index of performance. A *total of 143 intrinsic uniformity test results* for a new gamma camera in use in an environment with unstable power supply are presented. The integral uniformity for the central field of view (CFOV) was found to be between 3.43% and 1.49% (3.29% for acceptance test) while the integral uniformity for the useful field of view (UFOV) was between 4.51% and 1.9% (5.21% for acceptance test). The differential uniformity for the CFOV was between 1.99% and 1.04% (2.25% for acceptance test) while that of the UFOV was between 2.84% and 1.23% (2.63% for acceptance test). *In conclusion*, these results show that the uniformity of the gamma camera under this condition is within an acceptable range for both planar and SPET imaging.

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Introduction

The intrinsic flood uniformity test of a gamma camera is a measure of the response of the gamma camera to a uniform flux of radiation from a point source when the collimator is removed. It is one of the primary tests performed on the gamma cameras [1]. It is also one of the indices used to measure the performance of a gamma camera. Intrinsic flood uniformity test is a part of the quality assurance programme of a nuclear medicine department that ensures high standards of efficiency and reliability in the use of a gamma camera. We thus avoid changes in the performance of a gamma camera system that might affect the interpretation of clinical studies [2].

Two different uniformity parameters, usually measured during this test are: integral uniformity and differential uniformity. These are calculated for both the central field of view (CFOV) and useful field of view (UFOV) of the gamma camera. The integral uniformity has typical values of 2% to 4% [3]. For differential uniformity in most cases, a value of less than 3% is obtained after uniformity correction [4]. When the value for differential uniformity exceeds 3%, maintenance service should be carried out on the gamma camera [5]. Values of differential uniformity in the range 1.0% to 2.5% and values of integral uniformity in the range of 1.5% to 3.5% when the uniformity correction is applied are an indication that the system is working well. Generally, between 10 to 30million count flood images are adequate for verification of non uniformity of the system, for all clinical studies.

For routine planar imaging with a gamma camera, small fluctuations in field uniformity are allowed but for single photon emission tomography (SPET), the demand for uniformity is higher. So high quality flood (30 to 100 million counts) to prevent the occurrence of circular artifacts in the final SPET image are suggested to be acquired [6].

The main aim of this research is to show that a gamma camera in a developing country could perform efficiently despite electricity outages. Thus, we have investigated the performance of our gamma camera using intrinsic uniformity as the index of performance. This study covers a period of two years (2006–2008).

Materials and methods

The gamma camera used is the Siemens e.cam (signature series) SPET system with single head (Siemens Medical Solutions U.S.A, Inc.) which was installed at the center in March, 2006. The camera set up for the flood uniformity test is as in Figure 1. A point source of technetium-99m pertecnetate ($^{99m}TcO^-_4$) of activity ranging from 0.74MBq to 3.7MBq was used each time the test was performed. A small piece of cotton wool was placed in the vial and drops of $^{99m}TcO_4^-$ were placed on the cotton wool while trying not to exceed the cotton's saturation capacity. The collimator was removed and the detector was fully retracted with the gantry rotated so that the detector was at 0°C. The integrated source holder was extended from its storage position on the rear bed and pulled until the source holder was approximately centered.

Figure 1. Set up for the Daily Flood Uniformity Test

The prepared point source in the vial was clamped, with the capped end of the vial, into the source holder making sure that the cotton tip with the activity was approximately centered above the detector. Thirty million counts were acquired using a matrix of 1024X1024 and a zoom factor of 1.0 (these parameters were automatically preset by the camera) after the camera had been peaked for ^{99m}Tc i.e. its energy discrimination window adjusted to be centred on the photo peak of ^{99m}Tc.

The gamma camera performs the uniformity verification automatically. The intrinsic uniformity calibration was carried out monthly (using 200 million counts flood) while the photo multiplier tubes (PMTs) were tuned weekly. This further stabilizes the camera for good uniformity.

Results

The results of the daily intrinsic flood uniformity tests for the period from March 20, 2006 to August 8, 2008 totaling 143 readings are as shown in Figures 2 to 5. From these results, it was clear that the gamma camera had flood uniformity that was within an acceptable range. The integral uniformity for the CFOV lied between 3.43% and 1.49% against the acceptance test value of 3.29% while the integral uniformity for the UFOV lied between 4.51% and 1.9% as against 5.21% for the acceptance test. The differential uniformity for the CFOV had values between 1.99% and 1.04% against acceptance test value of 2.25% while that of the UFOV had values between 2.84% and 1.23% against 2.63% for the acceptance test. The shortest time the camera was on before the intrinsic flood uniformity test was performed was 15min (the time needed for booting of the gamma camera and removal of the collimator) and the test produced a flood uniformity of 2.27% and 2.32% for the integral uniformity for CFOV and UFOV, respectively. The differential uniformity for the same test was 1.34% and 1.34% respectively for the CFOV and the UFOV.

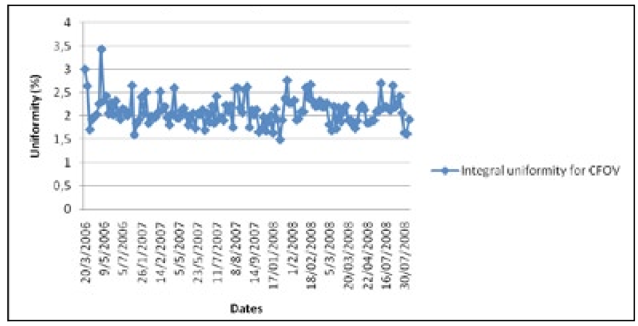

Figure 2. Integral uniformity for CFOV

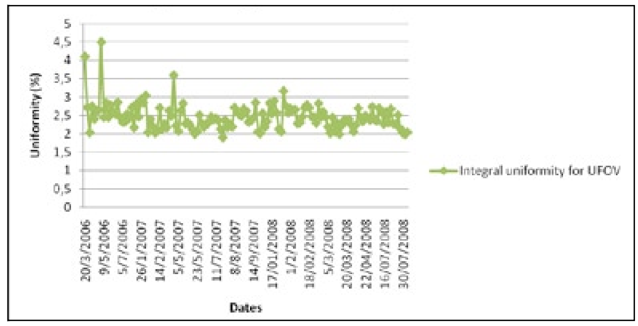

Figure 3. Integral uniformity for UFOV

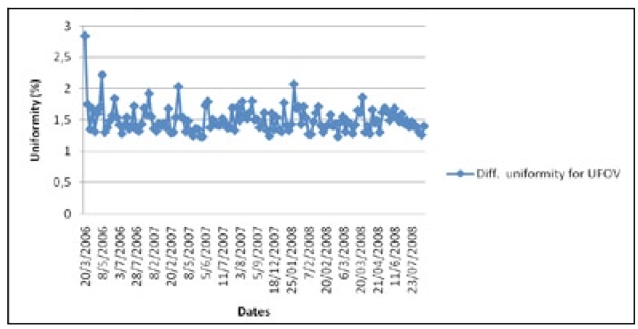

Figure 4. Differential uniformity for UFOV

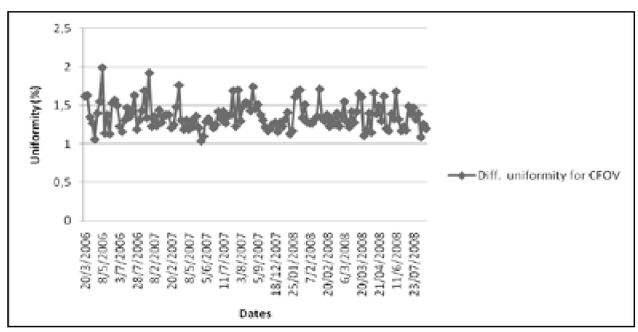

Figure 5. Differential uniformity for CFOV

Discussion

System uniformity is the most sensitive parameter to changes in system performance [7]. One of the things that affect image uniformity is the PMT and detector's performance. Hence, intrinsic uniformity is probably the most important quality control (Q.C.) test that can be performed on a gamma camera system on a daily basis. One of the effects of PMT "drift" is the appearance of hot or cold spots in the flood image. This in a way shows that the uniformity of the images is dependent on the stability of the PMT and sometimes on the associated analogue electronic components. It is also dependent on the stability of the detector. When the uniformity of the camera is ≤2% the camera is considered to have a good uniformity [7].

The PMT and their associated electronics tend to become unstable with time. This and other effects such as that of magnetic fields on the gamma camera can cause the uniformity to change [7]. Variations in PMT response (and non-linearity in X, Y positioning of pulses along the field of view) is the leading cause of deterioration in gamma camera flood uniformity [8] and this occur whenever the PMT become unstable.

The performance/stability of the PMT, the detector and other electronic components are highly dependent on the electric power supply to the gamma camera. Hence, the manufacturer of the gamma camera used in this work recommended in one of the user manuals that for detector stability to be maintained, the gamma camera must be on at all times [9]. Another recommendation is that when power supply is restored after a power failure, the uniformity test should not be performed immediately but after at least 2-4 times the time the power was off (up to maximum of 24h) since the detector needs to warm up and stabilize [10] (a personal communication with fellow Medical Physicists from Finland and Sweden, May 7, 2008).

The International Atomic Energy Agency (I.A.E.A.) in a draft of Guidelines for Performing Quality Control within Nuclear Medicine Centers in AFRA member states recommended that in the event of a power outage, the instructions of the vendor to return the camera to clinical operation should be followed. It also stated the need to allow 24h interval before clinical use of the camera after power failure [11]. Allowing the camera for such periods of time for the required stability to be achieved is very difficult in an environment in which the power supply is not stable. This is often experienced in a developing country such as Nigeria.

At our Nuclear Medicine Centre, the situation is made worse as the uninterrupted power supply (UPS) device supplied with the gamma camera is not able to charge properly and thereby could not hold power for more than 5min, which is only sufficient to shut down the camera. Because of these problems, the gamma camera is generally run on an electric power generator. Such centre therefore, has no choice than to shut down the gamma camera each day after clinical work. This is also because it is said that shutting down newer imaging and computer systems at night prolongs the useful life of many components [12]. The camera is put on for periods ranging between 16min to 2h each day before the daily uniformity verification test which usually comes up before clinical work is carried out. Sometimes due to the work load, this period is mainly used to boot the camera and change the collimator. Our search did not reveal a similar experience elsewhere in the literature.

Unfortunately, due to local problems in electricity supply as discussed above, we had to sidetrack the manufacturer's recommendation of leaving the camera on at all times. In a developing country with poor funding of her health institutions and where power supply is not stable, it may not be cost effective to operate medical equipments for 24h on alternative power generator. In Nigeria where the power supply is erratic with electricity going off for days, it is not feasible to power the gamma camera beyond the period needed for clinical services. From the results presented in Fig. 2 to Fig. 5 above, all uniformity tests performed within the period under review had values that fall within acceptable range. These values show that the camera uniformity is good enough and that the camera can be used with our present clinical work condition.

From our results we have noticed that the more frequently a gamma camera is used, the better is the uniformity, and however, after periods when the camera was not put on for a few days, there were some sharp increases observed in the uniformity values.

In conclusion, the difficulty posed by irregular power supply in a developing country should not prevent the use of a gamma camera for both planar and SPET imaging. Despite the power outages in such countries, the gamma camera should perform efficiently using intrinsic uniformity as an index of performance.

The authors declare that they have no conflicts of interest

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