PHYSICS, Original Artical

Investigation of Multiple Head Registration / Center of Rotation for SPECT Gamma Cameras

Abdelsattar, M.B. Ph.D.; BuHumaid, S.M. M.Sc.; Bahri, A.E. B.Sc.; Al-Suwaidi, J.S. Ph.D.; Ozker, S.K. Ph.D.

Medical Physics Department, Dubai Hospital, Dubai Health Authority (DHA), Dubai, UAE.

Abstract

Purpose: One of the important quality control checks for SPECT Gamma Camera is the centre of rotation (COR). Multiple Head Registration / Center of Rotation (MHR/COR) is also important not only to observe the mechanical errors in the state-of-art Gamma Camera, but also to correct, quantitatively, the errors from the movement of patients and detectors on the SPECT images.

Material and Method: Three gamma cameras (two Siemens and one Philips), were studied using Low Energy High Resolution (LEHR) collimators with protocols provided by the manufacturers based on the international regulations and committees.

In Siemens cameras (Ecam and Duet), MHR/COR was studied using five point sources of Tc99m (1 mCi) each in a special phantom. In Philips camera (Forte), COR was measured using an assembly consisting three point sources of Tc99m (0.5 – 1 mCi) with the Jet stream Quality Assurance (QA) software.

Results: The MHR/COR was studied in Siemens cameras (Ecam and Duet) including the error of X- max., X-min., Y shift and back projection angle with 180 and 90 degrees configurations for 30 months. Ecam results showed high stability through this period but Duet values are slightly varied. The results of COR in Forte camera including the error of X- max., X-min and Y error range with 180 and 90 degree configurations indicated marked changes within 26 months. However these changes were observed within the acceptable limits.

Conclusion: The MHR/COR quality control checks are crucial indication about the mechanical performance of a SPECT camera. It is important to update the correction map of the software to correct the camera heads registration errors and the patients movements. It is recommended for Forte to measure the COR on weekly basis in order to maximize the benefit from the COR calibration correction software.

Key words: **SPECT Gamma Camera; MHR/COR; Quality Control**

Correspondence author
Mohamed Abdelsattar Bayoumi, Ph.D
E-mail: mabayoumi@dha.gov.ae
P O Box: 7272

Introduction

The measurement of several performance parameters of a scintillation camera with Single Photon Emission Computed Tomography (SPECT) system, at the time of installation and thereafter at regular intervals, is necessary to ensure stability compared to original specifications [1]. It is essential to design a quality control programs for new SPECT 1 gamma camera after installation and subsequent operation [2].

The purpose of quality control (QC) is to detect changes in the performance of a gamma camera system that may adversely affect the interpretation of clinical studies. There are large number of factors that contribute to the final image quality including uniformity, resolution, and collimation. With the addition of tomographic imaging, an additional suite of parameters can influence the clinical images such as center of rotation (COR), gantry and collimator hole alignment, rotational stability of the detector head and the integrity of the reconstruction algorithms. The main goal of a QC program is to test the changes in the system performance and the parameters which impact clinical studies [3].

Materials and Methods

Three gamma cameras (two Siemens and one Philips), were studied using LEHR collimators with protocols provided by the manufacturers based on the international regulations and committees recommendations.

Gamma cameras

The general specifications of the three gamma cameras are given in Table 1.

Table 1. Characteristics of the three gamma cameras assessed in this study.

	Forte	E.Cam	Duet
Number of PM's in each detector.	55	59	59
Crystal thickness in inch or (mm)	3/8 - (9.5)	3/8 - (9.5)	1 – (25.4)
Field of view (cm)	50.8X38.1	53.3X38.7	52.8X37.7
Detector angles	90 and 180	90,76 and 180	90, 76 and 180
Software (Acquisition & processing)	Atlas and Pegasys Sys.	e.soft 3.5	e.soft 3.5

Measurements

We followed the International Atomic Energy Agency (IAEA) quality control procedures [9] and the National Electric Manufacturers' Association (NEMA) standard [10]. Siemens [11] and Philips [12] recommendations were also considered during this study.

The multi head registration / center-of-rotation (MHR/COR) were carried out for the E.Cam and Duet using the MHR/COR phantom (Siemens Medical System Inc.). The test was performed at two configurations 180^{o} and 90^{o} with LEHR collimator. A phantom consists of five point sources, each of 37 MBq (1 mCi) of Tc-99m, was used, as shown in Figure 1 (A, B). The phantom was mounted on the imaging table and positioned in the center of detectors field-of-view. One hundred and twenty views were acquired in 360 degree rotation, and each view acquired 50 K counts.

In Philips gamma camera (Forte), COR was measured using an assembly consisting three point sources of Tc-99m (0.5 – 1 mCi), as shown in Figure 2, with the Jet stream Quality Assurance (QA) software.

(A)

(B)

Fig 1. (A): The phantom with 5 point sources. **(B):** between the two collimators in Siemens gamma camera (E Cam and Duit).

2

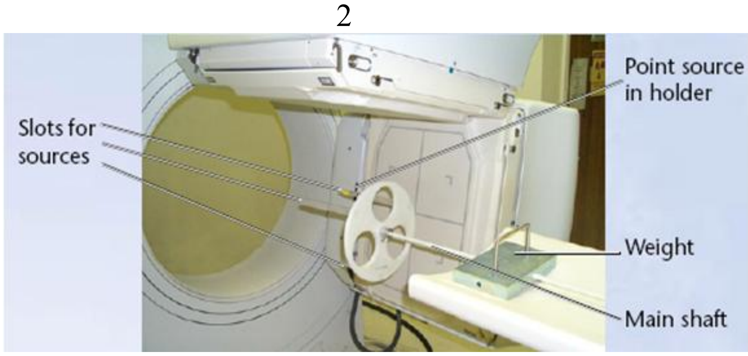

Fig.2: Point sources assembly used with Philips (Forte) gamma camera**.**

Specifications

The specifications for our measurements are mentioned in Table 2 and 3. A conversion from pixels to mm is shown for the comparison purpose.

Table 2. MHR/COR Specification for Ecam and Duet

X Max – X Min	< 1 pixel (4.8 mm)
RMS	< 0.5 pixel (2.4 mm)
Y Shift	≤ +1 Pixel (4.8 mm)
B P Angle	$< 0.8^{o}$

Table 3. The specification of COR QA for Forte

X-Error Range	< 4.5 mm
X-Mean	± 2 mm
Y-Error Range	< 4.5 mm
Mean Y-Difference	± 2mm

X Max: X maximum, X Min: X Minimum. RMS is the root mean square. B P angle is the Back Projection angle. Matrix used 128X128 = 4.8 mm in E cam and Duet.

Results and Discussion

Center of rotation (COR) correction is important for tomography. Errors in COR of as little as 0.5 pixel in a 128 x 128 matrix can result with degradation in image quality[4]. Maximum variation in COR should not exceed + 1.0 mm over the length of the collimator [5-6]. The IAEA Atlas 2003 reported in details the effects of COR offset which indicates the loss of reconstructed spatial resolution and contrast [7]. In modern SPECT systems, the acceptable limit for COR offset is ±1 mm. [7]. The offset error needs to be well below this value, or a COR offset correction must be made.

Many authors suggested different methods to measure the COR. One of the methods to measure COR is by performing a 360 degree acquisition around a point source of Tc-99m[3]. Most manufacturers have a software designed to analyze the acquisition and determine if the COR is within acceptable limits. It is not only important to use the correct value of COR, but it is also essential that this value remains constant as a function of angle [3].

There is another explanation for the COR error which is related to an alignment error between the mechanical center of the rotational gantry and the center of the electronic matrix. It can produce reconstruction artifacts in the image. Small error in center of rotation gantry can generate a loss in spatial resolution and image contrast.

COR checking should be performed frequently, usually on a weekly basis or depending on each manufacturer's recommendation and stability of the system.[8].

Multiple Head Registration (MHR) is another method of COR evaluation in modern SPECT systems (dual-detector) which in addition to

COR offset measurement, the Y shift and Back Projection Angle values are measured. The 3 gamma camera image must be centered in the computer image matrix; otherwise errors in back projection and occur as shown in Figure 1. For detector 1 and 2 are represented in Fig. 3

The results of MHR/COR X- Maximum and X- minimum for E.Cam 180 degree configuration and show that the stability of MHR/COR value is less than ±1 mm.

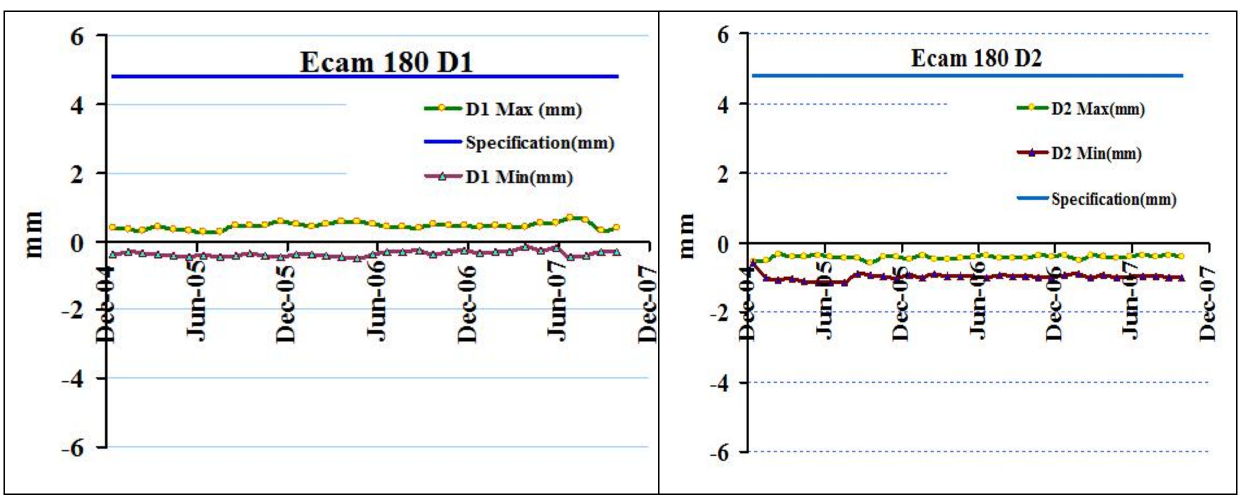

Fig 3: MHR/ COR calibration result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Ecam camera with 180 configuration degree through 30 months.

The results of MHR/COR X- Maximum and X- minimum for E.Cam 90 degree configuration are slightly larger in detector 1, in comparison with the 180 degree configuration, but smaller and more stable in detector 2. All these values are shown in Fig. 4.

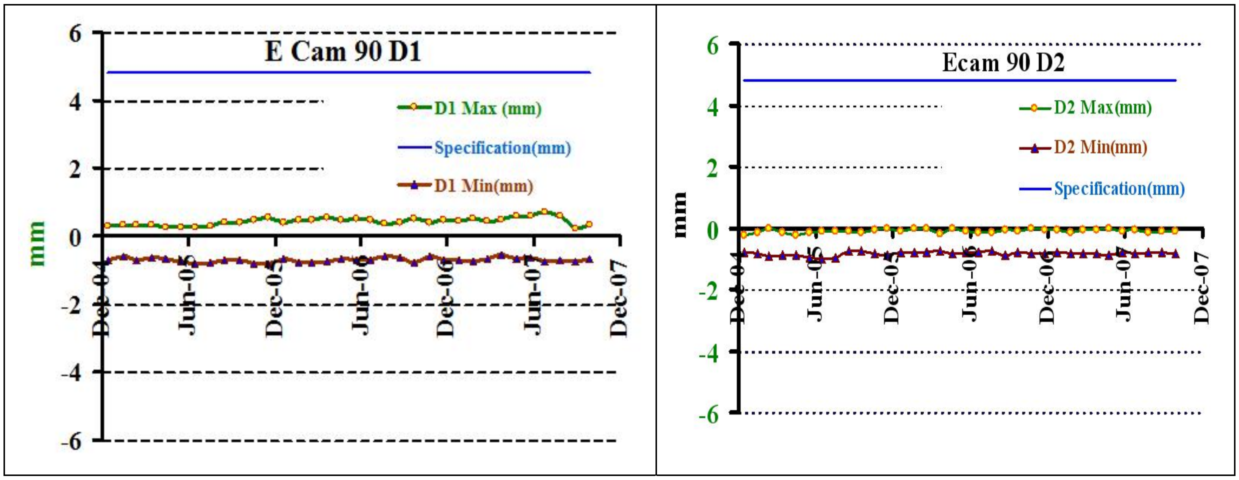

Fig 4: MHR/ COR calibration result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Ecam camera with 90 configuration degree through 30 months.

The results of MHR/COR for Duet 180 degree configuration for detector 1 and 2 are represented in Fig. 5. The value for detector 1 shows that even it is small but it is variable. However, the values in detector 2 are more stable.

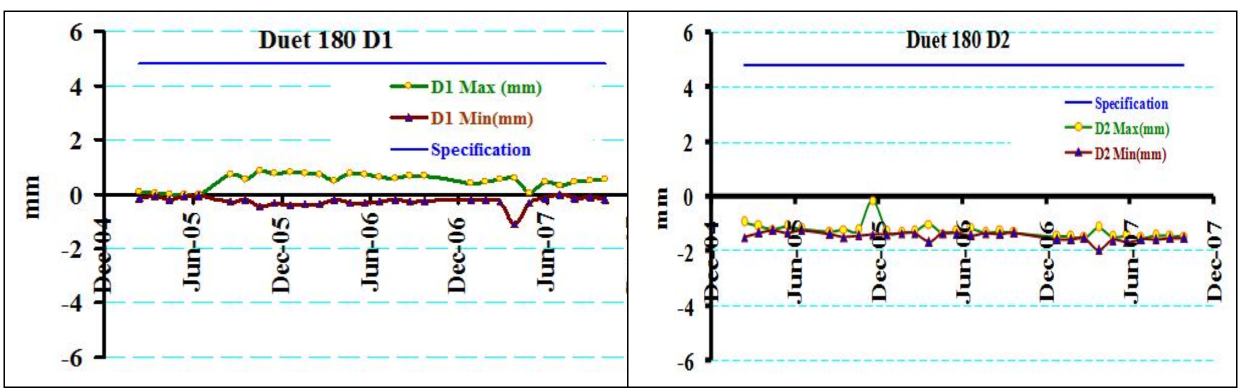

Fig 5: MHR/ COR calibration result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Duet camera with 180 configuration degree through 30 months.

The results of MHR/COR for Duet 90 degree configuration for detector 1 and 2 are represented in Fig. 6. The value for detector 1 shows that it is variable but it is more stable in detector 2.

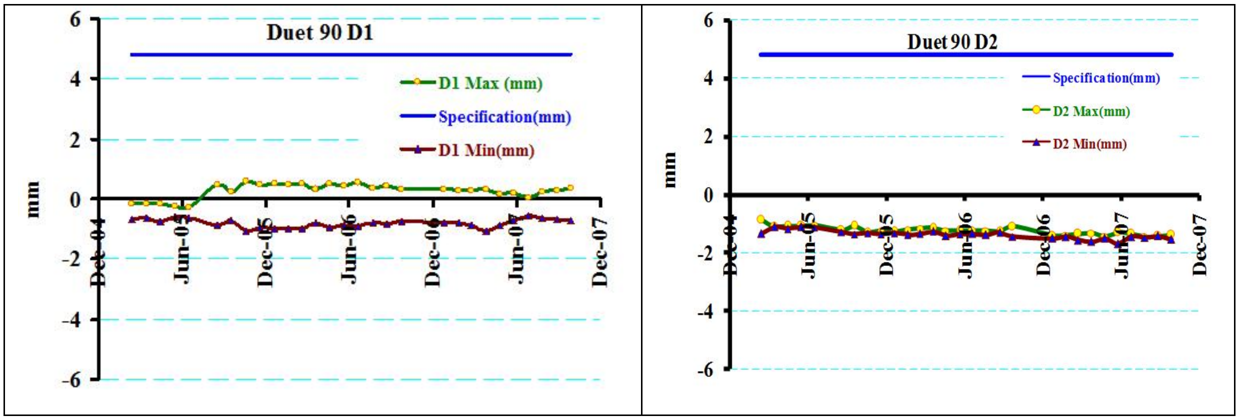

Fig 6: MHR/ COR calibration result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Duet camera with 90 configuration degree through 30 months.

The root mean square (RMS) in mm for E. Cam and Duet in Fig. 7 and 8 shows the small values in detector 1 and detector 2 in the configuration 180, but the value of 90 degree configuration is slightly larger due to the mechanical effect.

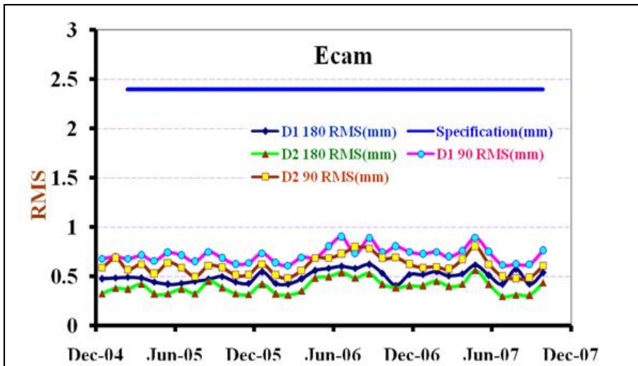

Fig 7: The root mean square (RMS) in mm for detector 1 (D1) and detector 2 (D2) in Ecam camera with 180 and 90 configuration degrees through 30 months.

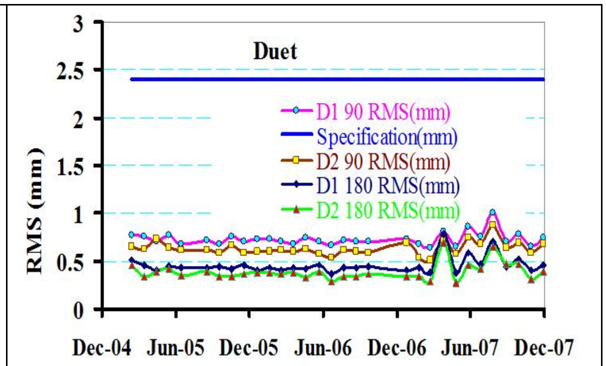

Fig 8: The root mean square (RMS) in mm for detector 1 (D1) and detector 2 (D2) in Duet camera with 180 and 90 configuration degrees through 30 months.

Fig. 9 and 10 show the Y shift values in mm for the E.Cam and Duet with 180 configuration. Although the values are within the accepted, it is very important to record the variation in order to use it in the correction software.

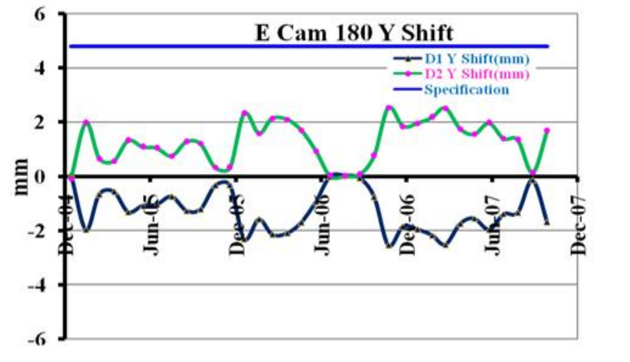

Fig 9: The Y Shift result for detector 1 (D1) and detector 2 (D2) in Ecam camera with 180 configuration degrees through 30 months.

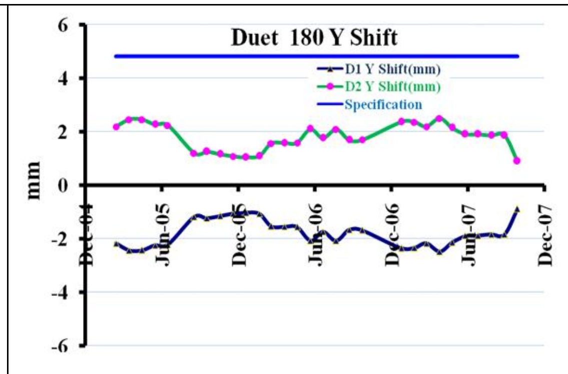

Fig 10: The Y Shift result for detector 1 (D1) and detector 2 (D2) in Duet camera with 180 configuration degrees through 30 months.

Fig. 11 and 12 represent the Back projection angle for E.Cam and Duet. Although the value in Duet is acceptable as shown below where the acceptance limit indicates the maximum and minimum values (± 0.8 angle), the value of E.Cam is highly stable and it is beneficial for the image reconstruction. This is one of the targets of this study which is to monitor the change in gamma camera performance.

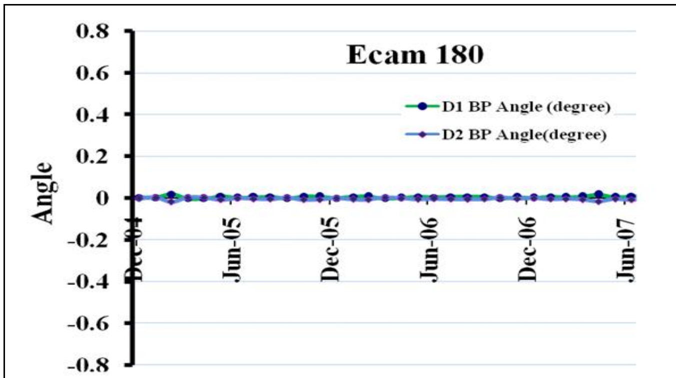

Fig. 11. The Back projection angle result for detector 1 (D1) and detector 2 (D2) in Ecam camera with 180 configuration degrees through 30 months.

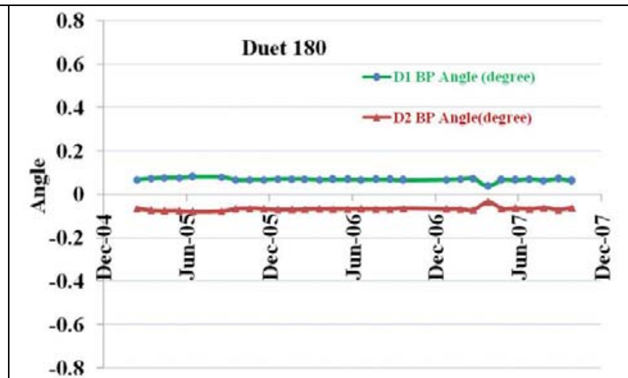

Fig. 12. The Back projection angle result for detector 1 (D1) and detector 2 (D2) in Duet camera with 180 configuration degrees through 30 months

The value of COR X- Maximum, X- minimum in 180 degree configuration for Forte gamma camera is clearly variable with time. In Fig. 13, we drew the solid line as a trend line for the variation. Although this camera correction software is available, but the values are changing and increasing as shown below.

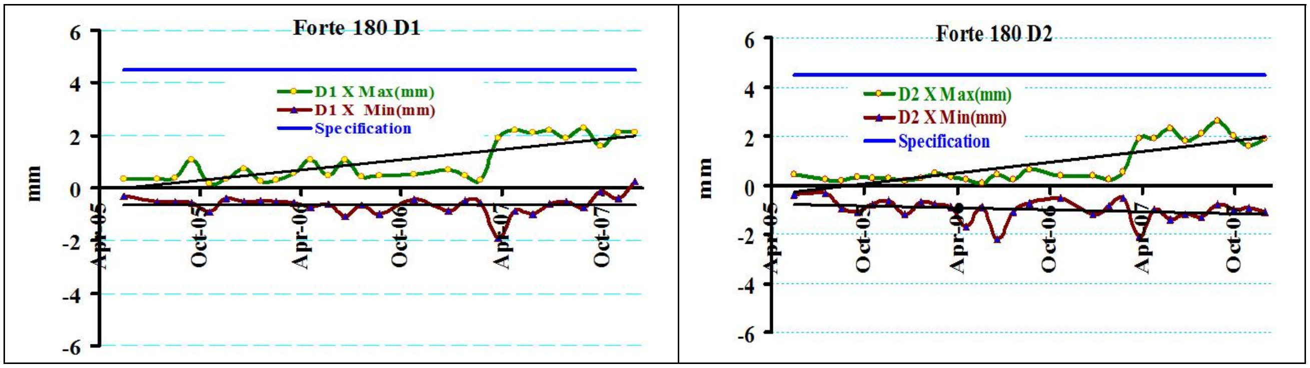

Fig 13: COR QA result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Forte camera with 180 configuration degree through 26 months. The solid line is the statistic trend line for the result.

Fig. 14 shows the COR X- Maximum, X- minimum quality assurance for Forte with 90 degree configuration which has the same behavior as the 180 configuration.

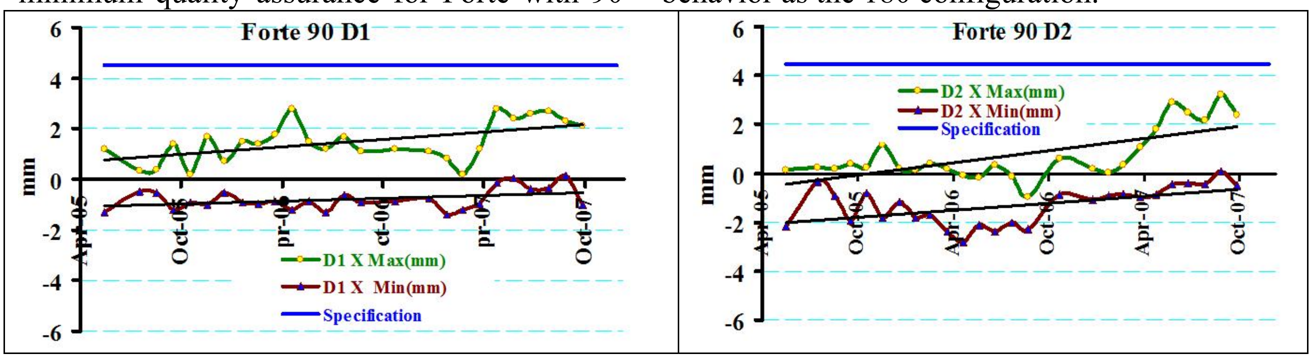

Fig 14: COR QA result of X- Maximum, X- minimum and specification for detector 1(D1) and detector 2 (D2) in Forte camera with 90 configuration degree through 26 months. The solid line is the statistic trend line for the result.

In fig. 15, the X errors mean for Forte in 180 and 90 degree configuration in Fig. 18 shows a marked change for 90 degree configuration.

Fig. 16 shows the mean Y shift for detector 1 and 2 for Forte to be used in the correction value.

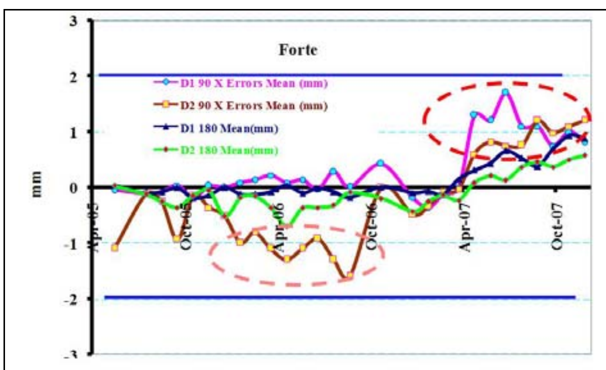

Fig 15: The X errors mean for detector 1 (D1) and detector 2 (D2) in Forte camera with 180 and 90 configuration degrees through 26 months.

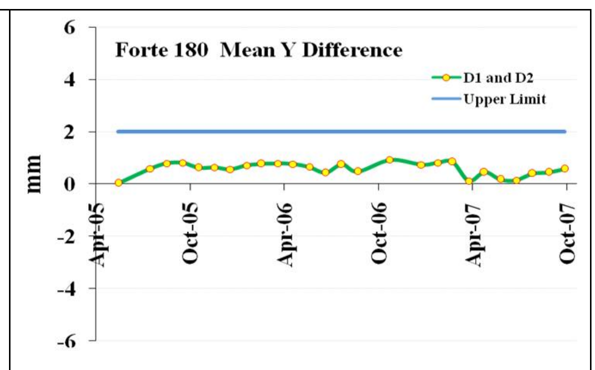

Fig 16: The Mean Y Shift result for detector 1 (D1) and detector 2 (D2) in Forte camera with 180 configuration degrees through 26 months.

From the study results, the recording and analysis of the value of MHR/COR for E.Cam and Duet and COR for Forte is very important to monitor the performance stability of the gamma cameras and observe the variation of its values to be used in the correction map. As example, the E soft software to correct the head registration before (A) and after (B) applied it as shown in Fig17.

(A) **(B)**

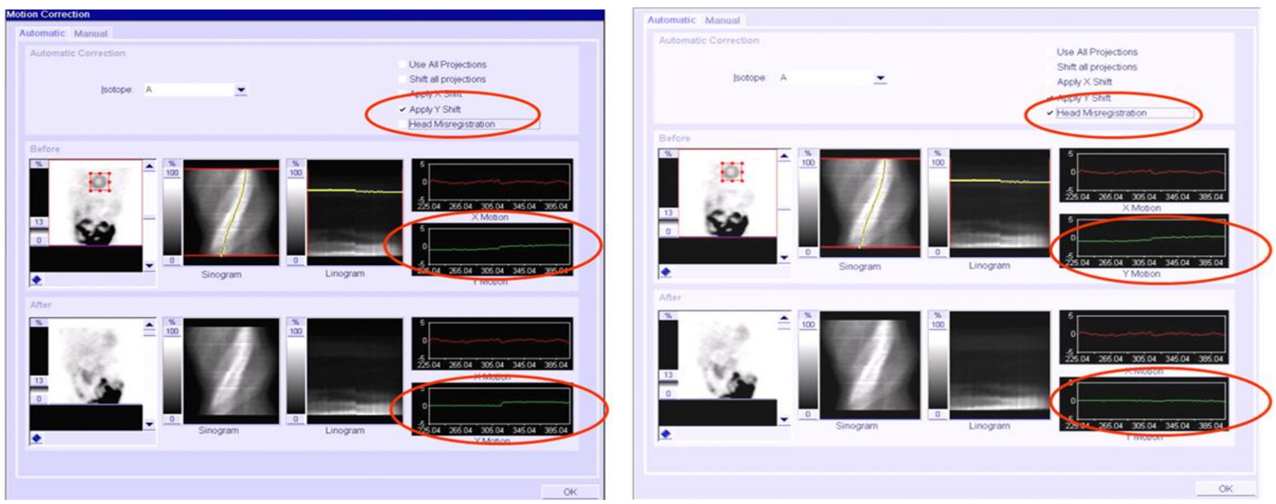

Fig 17: The E soft software to correct the head registration before (A) and after (B) applied it Multiple Head Registration/Center of Rotation (MHR/COR) is important not only to observe the mechanical errors in the state-of-art Gamma Camera, but also to correct the errors quantitatively from the movement of detectors and patients on the SPECT images**.**

The MHR/COR quality control checks are crucial indication about the mechanical performance of a SPECT camera. In the same time, it is important to update the correction map of the software to correct the camera heads registration errors and the patients movements.

It is recommended for Forte to measure the COR on a weekly basis in order to maximize the benefit from the COR calibration correction software.

Conclusions

It is easy to observe poor quality SPECT images of a known phantom, since the structure is known. In clinical images this becomes much more difficult, and degradation of images can be overlooked due to a COR offset. A regular QC check for the integrity of COR offset calibration and correction is essential.

References

1. Murphy P H,: Acceptance Testing and Quality Control of Gamma Cameras, Including SPECT J Nucl Med.,: 28(7), 1221- 1227,1987.
2. Al-Suwaidi J S, Bayoumi M A, Eltom S D, et al: Dubai Hospital Experience with SPECT Gamma Cameras Performance. Int. J. Sci. Res.;: V (16): 557-565,2006.

3. Michael Kieran O'Connor: Quality Control of Scintillation Cameras (Planar and SPECT). 41st Annual Meeting of the American Association of Physicists in Medicine (AAPM), Nashville, Tennssee, July 25-29, 1999.
4. Cerquira MD., Matsuoka D, Ritchie JL, et al: The influence of collimators on SPECT Center of Rotation measurements: artifact generation and acceptance testing. J Nucl Med;: 29: 1393-1397, 1988.
5. Busemann-Sokole E: Measurement of collimator hole angulation and camera head tilt for slant and parallel hole collimators used in SPECT. J Nucl Med: 28:1592-1598; 1987.
6. Malmin R, Stanley P, Guth WR: Collimator angulation error and its effect on SPECT. J Nucl Med: 31:655-659; 1990.
7. IAEA QUALITY CONTROL ATLAS FOR SCINTILLATION CAMERA SYSTEMS. IAEA: Vienna, austria: pp 190-202, 2003.
8. Nuñez, Margarita: Cardiac SPECT. Alasbimn Journal : 5(18): Article N° AJ18-13,2002.
9. IAEA, TecDoc-602, Quality control of nuclear medicine instruments, Vienna, Austria: pp.147, 1991.
10. NEMA NU 1-1994, National Electric Manufacturers' Association: Standards for performance measurements of scintillation cameras., Washington, DC: NEMA, 1994
11. SIEMENS, Operating Instructions, Siemens Medical System, Inc., Hoffman Estates, IL 60195-5203 USA: chapter 7, pp. 1-33, 2000.
12. ADAC, ADAC Forte User's manual, ADAC Laboratories, Milpitas, CA 95035 USA: chapter 11, pp. 1-25, 2002.