Sudan University of sciences and Technology

Faculty of Graduate studies

Assessment of Quality Control of Gamma Camera in El-Nelein Medical Center

تقيم ضبط الجودة لكامير قاما في مركز النيلين الطبي

A thesis Submitted in partial Fulfillment Of The Requirement Of The Master Degree in Nuclear Medicine Technology

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بسم الله الرحمن الرحيم

{لا يكلف الله نفسا إلا وسعها لها ما كسبت وعليها ما اكتسبت ربنا لا تؤاخذنا إن نسينا أو أخطأنا ربنا ولا تحمل علينا إصرا كما حملته على اللذين من قبلنا ربنا ولا تحملنا ما لا طاقة لنا به واعف عنا واغفر لنا وارحمنا أنت مولانا فانصرنا على القوم الكافرين}

صدق الله العظيم

البقره (268)

Dedication

Every Challenging Work Needs self
effort as well as guidance and
support of others especially those who
were close to my heart
My humble effort, I dedicated to my
great Father
(Mohammed Hussein Mohammed)
And Mother (Fatima Massar Ali)
Whose infection Love encouragement ,
and prays of day and night make me
able to get such success and honor
Along with my brothers and sisters
and all my friends

Abstract(English)

This study was preformed to estimate the performance of gamma camera (quality control) system in EL-NILEEN Medical Diagnostic Center in Khartoum (NMDC), department of nuclear medicine**,** single photon emission computed tomography system (SPECT). to check the performance of gamma camera **,**to ensure if the system still working by the same rate of performance by checking the COR and uniformity of gamma camera and System sensitivity .using quality control tests with enhancement of gamma camera system Orbiter 37 gamma camera single head [37PMTs /FOV 387 mm], generator and dose calibrator, has been carried out by reading includes 54 (readings), uniformity **46** readings, sensitivity 6 reading and COR 2 readings and the data was collected from quality control procedure.

The study shows that: from 140 KeV The sensitivity of the camera ranged from 79.9 to 92.1cps/MBq and the acceptable limits is designed according to the conditions of the test.So the sensitivity of the camera remain within NEMA levels, the COR is within the acceptable limit (+ or – 2%) and the uniformity At 15% Tc-99m window the Integral uniformity and Differential uniformity were as following , respectively the integral and differentials uniformity Before correction 3.09, 1.72% After correction 2.3% , 1.84% which at the acceptable limits before and after the correction.

الخلاصة

أجريت هذه الدراسه لتقييم ضبط الجوده لجهاز القاما كاميرا في مركز النيلين للتشخيص الطبي لفحص الاداء لجهاز القاما كاميرا بواسطة إجراء فحوصات ضبط الجوده وهي الحساسية ،محور الدوران و التناسق بإستخدام جهاز القاما كاميرا(اوربت 37)ومضخمات الضوءالمتعددة 37ومجال الرؤيا387 مليمترو المولد ومقياس الجرعات، وقد تم هذا البحث بواسطة أخذ55 قراءة، كان 46 قراءة منها لحساب التناسق،6 قراءات منها لحساب الحساسيةو 2 قراءة لحساب محور الدوران وقد تم جمع هذه البيانات خلال فحوصات ضبط الجوده. ولقد أثبتتت هذه الدراسة التالي مع 140 من طاقة التكنشيوم ان الحساسية في جهاز القاما كاميرا في المدي (79.9-92.1)والحد المقبول مصمم حسب حالة الفحص لذا الحساسية في الجهاز تبقي في حدود وكالة النيما ,ومركز الدوران كان ايضا في الحد المقبول (+او-2%)و في طاقة التكنيشيوم 15 %التناسق التكاملي والتناسق التفاضلي كانا كما يتليان علي التوالي قبل التصحيح (3.09 و1.72)وبعد التصحيح كانا (2.3%و1.84%)وهذا يعني انها في الحدود المقبولة قبل وبعد التصحيح

Acknowledgement

I have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. I would like to extend My sincere thanks to all of them.

First and foremost, I would like to thank My supervisor of this project, **Prof. Mohammed EL-fadil** for the valuable guidance and advice. He inspired Me greatly to work in this project. His willingness to motivate Me contributed tremendously to My project.

and **Dr. Yousuf Hamza Yousuf** ,the RPO of EL-NILEIN medical centre .Without his encouragement and guidance this project would not have materialized.

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LIST OF ABBREVIATION

Abbreviation	Full Name
CT	Computed tomography
MRI	Magnetic Resonance Imaging
QC	Quality control
AAPM	American association of physicists in medicine
IEC	International electrotecnical commission
NEMA	National Electrical Manufacturers Association
NMDC	Nilein Medical Diagnostic Center in Khartoum
COR	Center of rotation
SPECT	Single photon emitted computer tomography
PMTs	Photomultiplier tubs
IAEA	International Atomic Energy Agency
MHR	Multiple Head Registration
LEHR	Low Energy High Resolution
QA	Quality Assurance
NaI (Tl)	Sodium iodide with thallium
CsI	Cesium Iodide
BaF_2	Barium Fluoride
CZT	CZT
LEAP	Low Energy All Purpose
Cpm	Count per minute
FOV	field of view
UFOV	Useful Field of View
LFOV	Large Field of View
ER	Energy resolution
CRC	C Regulatory Commetion

Chapter One

1.1 Introduction

Medical imaging departments are complex and offer a variety of customer services that are constantly changing to meet the need of the patients and physicians they serve .In a typical medical imaging department, the services offered include diagnostic imaging, CT, MRI, ultrasound, and nuclear medicine. In nuclear medicine department gamma camera is the most commonly used instrument, it is also called a scintillation camera or anger camera, which was invented by Hal Anger in 1950. This device used to image gamma radiation emitted by radioisotopes technique known as a scintigraphy ,to view and analysis images of the human body or the distribution of the radiotracer which administered by injection ,inhalation or ingestion**.**

In order to obtain optimum image quality and accurate diagnosis regular inspection of the gamma camera should be done. It is now widely recognized the attainment of high standards of efficiency and reliability in the practice of nuclear medicine; as in other specialties' based on advanced technology, requires an appropriated quality assurance program**.**

The concept of quality in term quality assurance expresses the closeness with which the outcome of a given procedure approaches some ideal, free from all errors and artifacts. The term quality control is used in reference to the specific measures taken to ensure that one particular aspect of the procedure is satisfactory (Busemann, 1993).

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. Clearly, there are a large number of factors that contribute to the final image quality, including uniformity, resolution (both intrinsic and energy), collimation and the hard copy device. In addition, for certain types of studies, other factors such as count rate capability come into play. With the addition of Tomographic imaging, comes an additional suite of parameters that can influence the clinical images - these include system center of rotation, gantry and collimator hole alignment, rotational stability of the detector head and the integrity of the reconstruction algorithms. On a day-to-day basis, there is a limited amount of time that can be reasonably devoted to system QC.

QC schedule for NM instrumentation prepared by a 1979 IAEA advisory group. The acceptance tests recommended from the American association of physicists in medicine (AAPM), the International electrotecnical commission (IEC),and NEMA. The QC Tests should done before the equipment is commissioned which called (acceptance testing) when there is cause to suspect a malfunction or a change in operation of an item of equipment and at specified intervals according to device-specific instructions (periodic testing) . Also Q.C can be done following significant repairs or servicing

The main goal of QC tests to monitor those parameters that are most sensitive to changes in system performance most likely to impact clinical studies.(name,2005)

1.2Problem of the study

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.

Clearly, there are a large number of factors that contribute to the final image quality,

Including uniformity, sensitivity, collimation and the hard

copy device. In addition, for certain types of studies, other factors such as count rate

capability comes into play. With the addition of tomographic imaging, comes an additional suite of parameters that can influence the clinical images - these include System center of rotation, gantry and collimator hole alignment, rotational stability of the detector head and the integrity of the reconstruction algorithms. On a day-to-day basis, there is a limited amount of time that can be reasonably devoted to system quality control (QC). Hence the main goal of a quality control (QC) program should be to monitor those parameters that are; a most sensitive to changes in system performance and most likely to impact clinical studies. There for quality control of gamma camera is important for the quality of the nuclear medicine investigation because a poor quality image lead to inaccurate or inconclusive report. Routine quality control is a necessity for ensuring quality patient care by establishing quality imaging. All instrumentation specific to the operations of a nuclear medicine facility must be quality controlled on a regular basis to assure reliability and safety.

Quality patient care can only be achieved if optimal diagnostic accuracy is demonstrated through appropriate quality control procedure. Poor image quality can lead to many serious and some minor situations. The most serious situation is where a miss diagnosis is made which lead to false negative and false positive diagnosis.

1.3 General objectives

The general objective of this study was to estimate the performance of gamma camera (quality control) system in Nilein Medical Diagnostic Center in Khartoum (NMDC), , that contribute to make sure the gamma camera functioning properly .

1.4 specific objectives :

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- To ensure if the system still working by the same rate of performance and check the changes during a long period of time.
- To observe center of rotation COR in the state-of-art Gamma Camera, and to correct, quantitatively, the errors from the movement of patients and detectors on the SPECT images.

1.5 Hypothesis of the study:

- Performance of the gamma camera is affected by changes in temperature, moisture, time, current , electricity and background. Also the performance can affected by workers so the gamma camera must be calibrated routinely to ensure there are no wrong results which can lead to a wrong interpretation of the image.

  The Gamma camera may experience some uniformity errors (non uniformity) which require further correction to avoid incorrect energy response and the factors affect the uniformity (Changes in photo peak location, photomultiplier tube (PMT) performance, energy and linearity correction, dust, sepal closed.Gamma camera has a mechanical error and misalignment of both gamma camera head which needs correction for center of rotation

1.6 Thesis out Line

This thesis comprises Five chapters. In chapter one, an introduction of quality control in nuclear medicine is given. . In chapter two, review of the current literature on quality control of gamma camera and SPECT systems are presented. And deals with the nuclear medicine technology, included an introduction of nuclear medicine imaging, equipments used in nuclear medicine department e.g. planar gamma camera system, single photon emission computed tomography system (SPECT). In chapter Three , material and methods used in this study are presented. These include method of uniformity (intrinsic), sensitivity, center of rotation. The results and discussion are presented in chapter four.Conclusions and recommendation of the study are given in chapter five.

Chapter Two

Literature review -Previous studies

2.1 General History:

The history of nuclear medicine is rich with contributions from gifted scientists across different disciplines in physics, chemistry, engineering, and medicine. The multidisciplinary nature of nuclear medicine makes it difficult for medical historians to determine the birth date of nuclear medicine. This can probably be best placed between the discovery of artificial radioactivity in 1934 and the production of radionuclide.(Oak Ridge, 1946).

The origins of this medical idea date back as far as the mid-1920s in Freiburg, Germany, when George de Hevesy made experiments with radionuclide's administered to rats, thus displaying metabolic pathways of these substances and establishing the tracer principle. Possibly, the genesis of this medical field took place in 1936, when John Lawrence, known as "the father of nuclear medicine", took a leave of absence from his faculty position at Yale Medical School, to visit his brother Ernest Lawrence at his new radiation laboratory (now known as the Lawrence Berkeley National Laboratory) in Berkeley, California. Later on, John Lawrence made the first application in patients of an artificial radionuclide when he used phosphorus-32 to treat leukemia) Henkin R. et al: Nuclear Medicine. First edition, 1996)/Many historians consider the discovery of artificially produced radionuclide's by Frédéric Joliot-Curie and Irène Joliot-Curie in 1934 as the most significant milestone in nuclear medicine. In February 1934, they reported the first artificial production of radioactive material in the journal Nature, after discovering radioactivity in aluminum foil that was irradiated with a polonium preparation.

Their work built upon earlier discoveries by Wilhelm Konrad Roentgen for X-ray, Henri Becquerel for radioactive uranium salts, and Marie Curie (mother of Irene Curie) for radioactive thorium, polonium and coining the term "radioactivity." Taro Takemi studied the application of nuclear physics to medicine in the 1930s. The history of nuclear medicine will not be complete without mentioning these early pioneers.

Nuclear medicine gained public recognition as a potential specialty on December 7, 1946 when an article was published in the Journal of the American Medical Association by Sam Seidlin. The article described a successful treatment of a patient with thyroid cancer metastases using radioiodine (I-131). This is considered by many historians as the most important article ever published in nuclear medicine.(N-13 Ammonia prescribing information (Drugs.com))

Although, the earliest use of I-131 was devoted to therapy of thyroid cancer, its use was later expanded to include imaging of the thyroid gland, quantification of the thyroid function, and therapy for hyperthyroidism.

2.2 Nuclear Medicine general history

Although the naturally occurring radioisotopes of radon and radium were used in the first quarter of last century, Nuclear Medicine came under prominence during the 1930s and subsequent years with the development of the Cyclotron and Fission Reactor. Artificially produced radioisotopes were immediately used for therapeutic and laboratory procedures. Radiation monitoring equipment were developed which allowed the distribution of the radioisotope to be determined, either in-vivo or in-vitro. These devices output the results as a count-rate over the organ or sample. With improvements in technology that occurred over this time, these devices became more sophisticated and automated systems of scanning were developed - the Rectilinear Scanner.

The output of Rectilinear Scanners was usually recorded on white paper with a series of black marks being printed by a mechanical printer - similar to the conventional dot matrix printer. An alternative was the use of a colour ribbon or light sensitive film. In all cases, the intensity of exposure or depth of colour, corresponded to the concentration of radioisotope in the incident area. In the 1950s, the first gamma camera was produced and which did not rely on continuous motion. This became the predecessor of the present day gamma cameras where the input is stored on the hard disk of a computer and the output can be manipulated and recorded on a variety of media. Single and multi-headed cameras are now common-place in most Nuclear Medicine Departments. The improvements in gamma camera design allowed dynamic - count versus time - studies to be performed as well as static or planar imaging of present day. Tomographic hardware and software, being able to view sections of an organ or allow three-dimensional imagery, have also improved the sensitivity and specificity of Nuclear Medicine techniques far beyond the dreams of the early pioneers.

(IAEA-, Vienna 1991).The history of nuclear medicine is rich with contributions from gifted scientists across different disciplines in physics, chemistry, engineering, and medicine. The multidisciplinary nature of nuclear medicine makes it difficult for medical historians to determine the birth date of nuclear medicine. This can probably be best placed between the discovery of artificial radioactivity in 1934 and the production of radionuclides.(Oak Ridge, 1946).

2.3 A gamma camera

Is an imaging device, most commonly used as a medical imaging device in nuclear medicine it produces images of the distribution of gamma ray emitting radionuclides. A gamma camera is a complex device consisting of one or more detectors mounted on a gantry. It is connected to an acquisition system for operating the camera and for storing the images.

2.3.1 Gamma camera content:

2.3.1.1 NaI (Tl) Crystal:

Sodium iodide with thallium NaI (Tl), the main function of crystal is convert gamma ray to photons of visible light process called scintillation. Amount of light proportional to deposited energy.

The types of crystals :

2.3.1.2 CsI: Tl (Cesium Iodide), **NaI: Tl (Sodium Iodide)** and **BaF_2(Barium Fluoride)**

NaI crystals can be grown in large sizes with few defects. It is fairly rugged for a crystal, easy to machine and has good density and light output. The Iodine in the crystal provides it with fairly high detection efficiency, so NaI detectors remain the primary scintillator detector used.

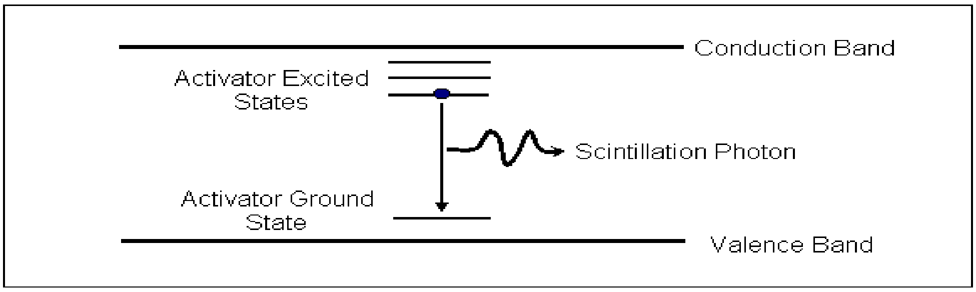


Figure 2.1 shows (inorganic scintillator crystal is doped with a small amount of an activator impurity (in the case of NaI this is thallium).

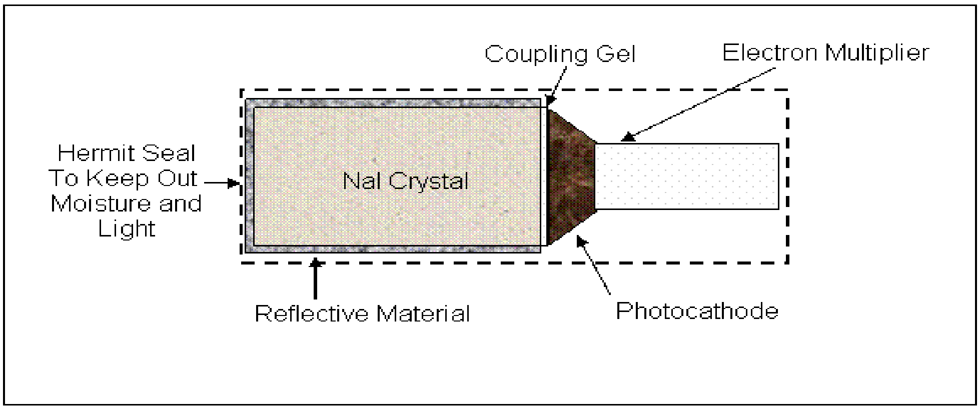


Figure 2.2 the diagram below shows the parts of a standard commercial NaI detector. (http\\physics tamuk.edu)

2.3 1.3 Photomultiplier tubes (PMTs) :

Photomultiplier tubes (PMTs) Is an electronic evacuated glass tube containing a light sensitive photocathode, typically 10 to 12 electrodes called dynodes and an anode. It performs two functions- Conversion of light photons into an electrical signal and Signal amplification (10^6 -10^8)

Figure 2.3 Shows the photo multiplier tube .:(www.high voltage power-supplies .com)

The collimator, usually multi hole collimator and the detector crystal, typically thallium activated NaI scintillation crystal are used and photo multiplier tube array for Signal amplification, the shielding to minimize back ground radiation ,after that the computer analyses the data .

Through this design the simultaneous registration of gamma rays photons is possible the computer further allows dynamic imaging

The system accumulates counts of gamma photons that are absorbed by a crystal in the camera, usually a large flat crystal of sodium iodide with thallium doping in a light-sealed housing. The crystal scintillates in response to incident gamma radiation: when the energy of an absorbed gamma photon is released, a faint flash of light is produced. This phenomenon is similar to the photoelectric effect. Photo multi plier tubes (PMT) behind the crystal detect the fluorescent flashes and a computer sums the fluorescent counts. The computer in turn constructs and displays a two dimensional image of the relative spatial count density on a monitor. This image then reflects the distribution and relative concentration of radioactive tracer elements present in the organs and tissues imaged.

Hal Anger developed the first gamma camera in 1957. His original design, frequently called the Anger camera, is still

widely used today. The Anger camera uses sets of vacuum tubephotomultipliers. Generally each tube has an exposed face of about 3 inches in diameter and the tubes are arranged in hexagon configurations, behind the absorbing crystal. The electronic circuit connecting the photodetectors is wired so as to reflect the relative coincidence of light fluorescence as sensed by the members of the hexagon detector array; all the PMTs which simultaneously detect the (presumed) same flash of light. Thus the spatial location of each single flash of fluorescence is reflected as a pattern of voltages within the interconnecting circuit array.

In order to obtain spatial information about the gamma emissions from an imaging subject (e.g. a person's heart muscle cells which have absorbed an intravenous injected radioactive, usually thallium-201 or technetium-99, medicinal imaging agent) a method of correlating the detected photons with their point of origin is required.

The conventional method is to place a collimator over the detection crystal/PMT array. The collimator essentially consists of a thick sheet of lead, typically 1-3 inches thick, with thousands of adjacent holes through it. The individual a gamma camera, also called a scintillation camera or Anger camera, is a device used lead does not totally attenuate incident gamma photons, there can be some crosstalk between holes.

Unlike a lens, as used in visible light cameras, the collimator attenuates most (>99%) of incident photons and thus greatly limits the sensitivity of the camera system. Large amounts of radiation must be present so as to provide enough exposure for the camera system to detect sufficient scintillation dots to form a picture.

Other methods of image localization (pinhole, rotating slat collimator with CZT (Gagnon & Matthews) and others) have been proposed and tested; however, none have entered widespread routine clinical use.

figure 2.4 shows the gamma camera device

2.3.1.4 The Collimators:

Collimators contain and direct the beam of radiation during exposure. A wide range of collimators have been develop to meet the variety of applications and techniques used. There are 5 basic collimator designs to channel photons of different energies, to magnify or minify images, and to select between imaging quality and imaging speed.

2.3.1.4.1 The Parallel hole collimator:

All holes are parallel to each other. Most common designs are Low Energy All Purpose (LEAP), Low Energy High Resolution (LEHR) and Medium- and High Energy Collimators.

LEAP collimators have holes with a large diameter. The sensitivity is relatively high as where the resolution is moderate (larger diameter holes allow more scattered photons). The average sensitivity of a LEAP is approx. 500,000 cpm for a 1-uCi source, and the resolution is 1.0cm at 10cm from the patent side of the collimator.

LEHR collimators have higher resolution images than the LEAP. They have more holes that are both smaller and deeper. The sensitivity is approx. 185,000 cpm for 1-uCi source, and the resolution is higher with0.65cm at 10cm from the patient side of the collimator Medium Energy Collimators are used for medium energy photons of nuclides such as Krypton81, Gallium67, Indium111. High Energy Collimators are used for Iodine131 and F-18FDG. These collimators have thicker septa than LEAP and LEHR collimators (mainly used with Technetium99m) in order to reduce septal penetration by the higher energy photons.

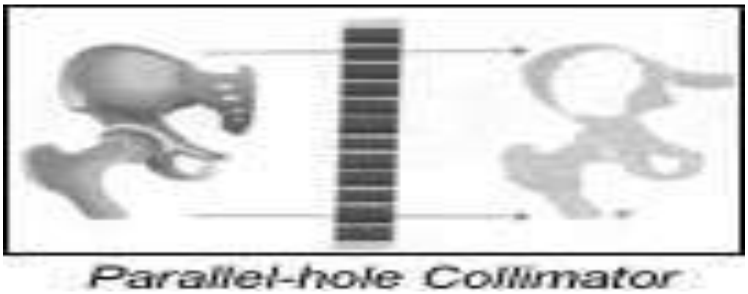


Figure 2.5 : parallel-hole collimator

2.3.1.4.2 Slant hole collimators:

A variation of the Parallel hole is the Slant hole collimator, which has all tunnels slanted at a specific angle. It generates an oblique view for better visualization of an organ, which view is (partly) blocked by other parts of the body. As an advantage, this collimator can be positioned close to the body for the maximum gain in resolution.

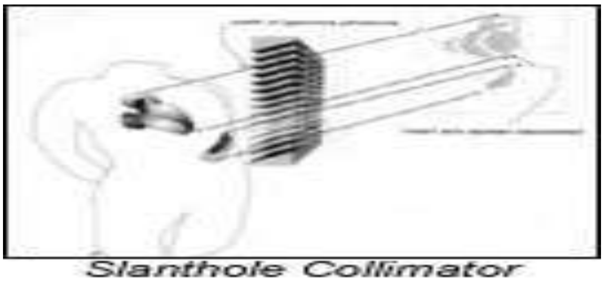


Figure 2.6 : slant hole collimator.

2.3.1.4.3 Converging and Diverging Collimators:

In a Converging collimator the holes are not parallel but focused toward the organ. The focal point is normally located in the center of the field of view (FOV). Some Converging collimators have the focal point off-center near the edge of the FOV, (the so called Half Converging). The organ appears larger at the face of the crystal with a Converging collimator. When the Converging collimator is flipped over you get a Diverging collimator, generally used to enlarge the FOV, for example used with enlarge the FOV, for example used with portable cameras with a small crystal.

Figure2.7: converging collimator.

2.3.1.4.4 Fan beam collimators:

They are designed for a rectangular camera head to image smaller organs like the brain and heart. When viewed from one direction, the holes are parallel. When viewed from the other direction, the holes converge. This arrangement allows the data from the patient to use the maximum surface of the crystal. When the Fan beam is flipped over it is called a Single Pass Diverging Collimator used for whole body sweeps.

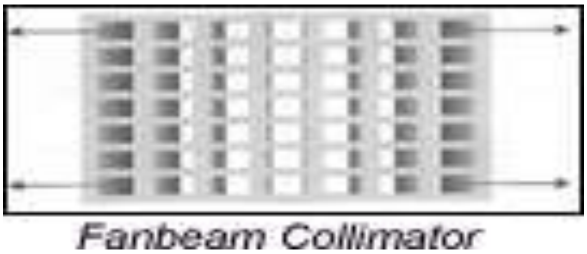


Figure 2.8 : fan beam collimator.

2.3.1.4.5 Pinhole collimators:

These cone-shaped collimators have a single hole with interchangeable inserts that come with a 3, 4 or 6 mm aperture. A pinhole generates magnified images of a small organ like the thyroid or a joint. Most Pinhole collimators are designed for low energy isotopes.

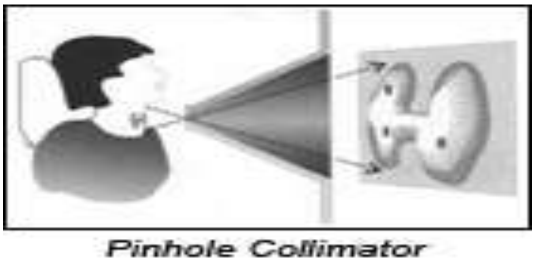


Figure 2.9: pinhole collimator

All above collimators can be tuned for any type of isotope Next to the standard collimator of gamma camera .(name,2005)

2.3.2 Investigation:

2.3.2.1 Uniformity:

The measure of a camera's response to a uniform irradiation of the camera surface. *Intrinsic uniformity* is measured using a radionuclide point source (~150 uCi Tc-99m) placed approximately 5 crystal diameters away from an uncollimated camera. *System* or *Extrinsic uniformity* is measured using a sheet source placed directly on the surface of a collimated camera, 5 to 10 millicuries (mCi) of Co-57 or 25 mCi Tc-99m in fillable-water tank. 5 million counts resulting image should show a uniform distribution across the entire field of view.

Uniformity parameters:

UFOV – useful field of view, CFOV – center field of view

2.3.2.1.1 Integral uniformity

- The difference between the maximum and the minimum pixel value divided by the sum of these two values X 100

❖ = +/- 100 X (Max – Min)/(Max + Min)

2.3.2.1.2 Differential uniformity

- The largest difference between any two pixels within a set of 5 contiguous pixels in a row or column (rate of change)

❖ = +/- 100 X (Hi – Low)/(Hi + Low).

2.3.2.2 Resoluatio:

2.3.2.2.1 Energy resolution:

Is term used to characterize the ability of a gamma camera to distinguish between photons of different energies .ER depends largely on statistical fluctuations in the number of light photons collected from a scintillation event (good light collection efficiency). system energy resolution will be worse - presence of the collimator adds Compton scatter and characteristic lead X-ray (88keV)

2.3.2.2.1.1 Material and Method

- ^{99m}Tc or ^{57}Co point sources
- shielded source
- 2mm copper in front of source (absorbs scatter)
- centered at least 5 X UFOV
- a standard setting for Tc^{99m} is a photopeak of 140 keV and a window of 20%. The window is set between 126 keV and 154 keV .

2.3.2.2.1.2 Result

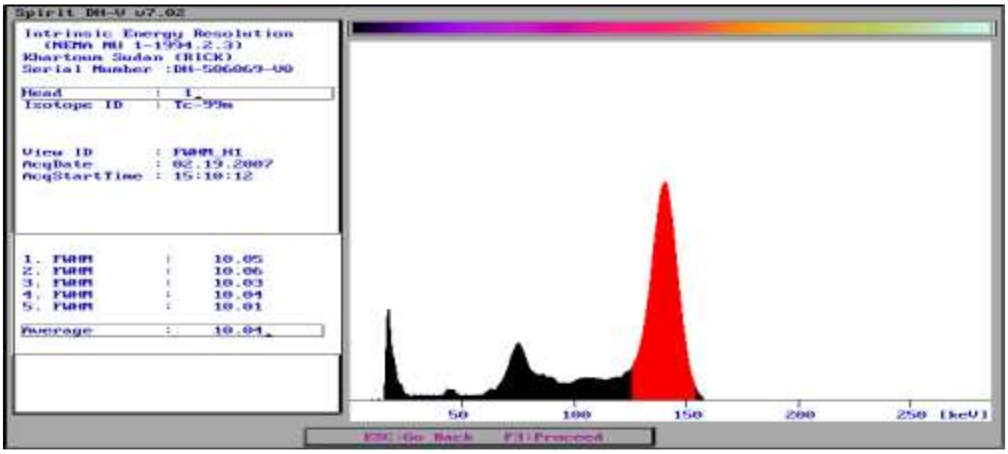


Figure 2.10: demonstrate energy resolution

2.3.2.2.1.3 Calculations & analysis

- The computer screen displays a plot of counts vs. energy and the current location of the window.

- FWHM is measured and

ER =(ΔE/E)X100

=10.04% (in typical range)

- Typical value in the range 9% to 11%.

.3.2.2.2 Spatial Resolution

Is a measure of the sharpness and detail of gamma camera image. a term which characterizes the scintillation camera's ability to accurately resolve spatially separated radioactive source It is due to: Multiple scattering of photons in crystal and Statistical fluctuation in the distribution of light photons among PMTs from one event to the next.

2.3.2.2.2.1 Material and method

2.3.2.2.2.1.1 Intrinsic spatial resolution

- 99mTc shielded point source
- centered at least 5 times the UFOV away
- Pattern test (width of strips approx. 1mm)
- 15% energy window
- < 30kcps
- rotate the phantom by 90°
- repeat acquisition for X and Y direction

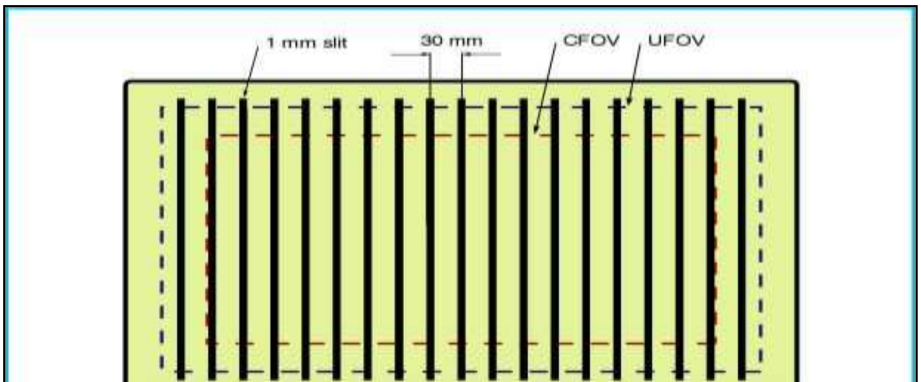


Figure 2.11 demonstrate spatial resolution

2.3.2.2.2.2 Analysis

- The measurements usually are average.
- FWHM and FWTM were measured.
- Typical values of intrinsic spatial resolution is 2.5 to 3.5 mm
- FWHM is within typical value 2.42 and 2.54 for X & Y respectiv2.ely.

2.3.2.2.3 System Resolution

2.3.2.2.3.1 Material and method

- Collimator on.
- source is two 1-mm diameter line sources(T99m), or two point sources placed 5cm apart of 10cm from the collimator.
- 10cm of plastic between sources.
- Image acquired at rate of 30,000cps.
- Repeated for each head
- The system resolution
    - $R_s=\sqrt{R^2{}_c + R^2{}_i}$
- ,R_c: collimator resolution,

- ,R_i: intrinsic resolution

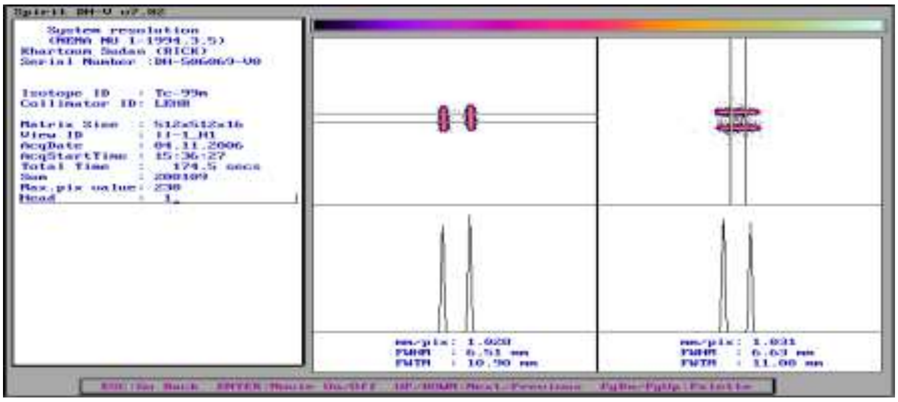


Figure 2. 12: demonstrate system resolution

2.3.2.2.3.2 Analysis

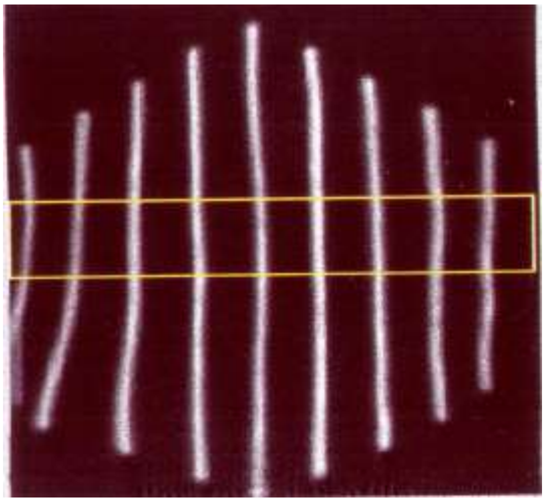
- Determine FWHM & FWTM.

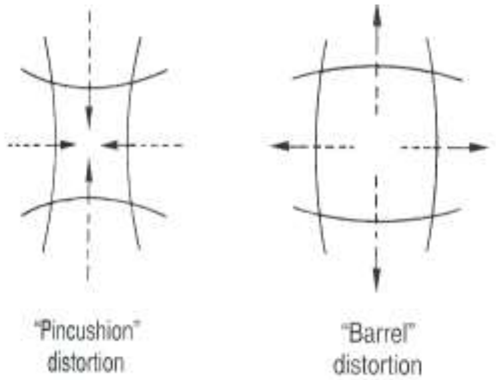
  = 6.51mm and 6.63mm (FWHM in X&Y)

- Typical in the range 8 to 14 for Tc^{99m}.
- Values are off typical value and needs to be corrected.

2.3.2.3 Linearity

The amount of positional distortion or displacement of the measured position of photons relative to the actual position where those detected photons entered the detector. Non linearity of an image that straight-line objects appear as curved line images Causes: Result when X- and Y- position signals do not change linearly with displacement distance of a radiation source across the face of the detector, Sensitivity differences among PMTs and PMT or electronic malfunction**.**





Appearance of straight-line objects with "pincushion" and "barrel" distortions.

Figure 2.13 shows spatial linearity

Two measurements can be made from the resulting image

- The differential spatial linearity (deviation of distance between 2 slits from actual distance)
- The absolute spatial linearity (max. deviation of slits location from true locations).

2.3.2.3.1 Result:

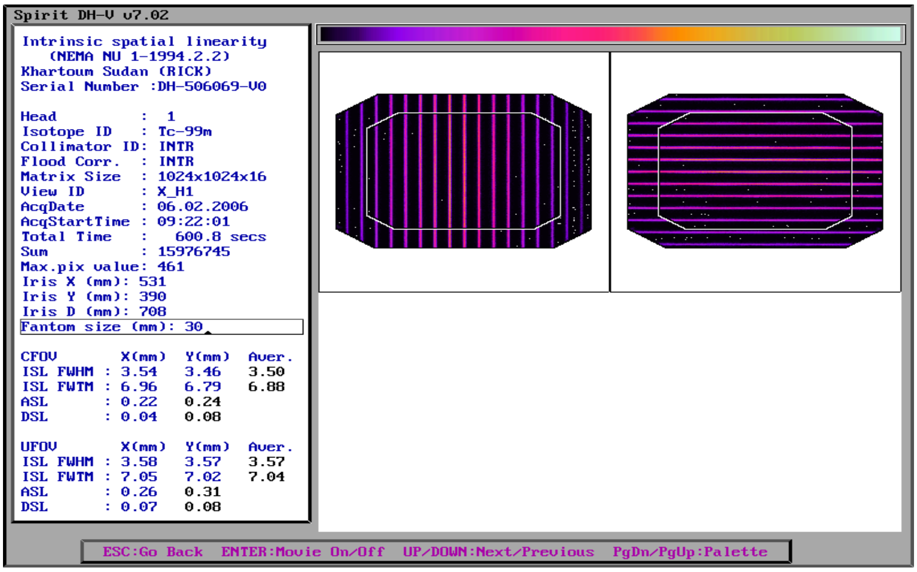


Figure 2.14: shows linearity

2.3.2.3.2 Analysis

- Differential Spatial Linearity (DSL)

  =0.07mm (X), =0.08mm (Y)

- Absolute Spatial Linearity (ASL)

  =0.26mm (X), =0.31mm (Y)

2.3.2.4 SYSTEM ALIGNMENT

For SPECT imaging systems the transaxial alignment of acquired images with the system's mechanical center of rotation is critical to the accurate SPECT reconstruction. Likewise, for multi-head SPECT imaging systems the axial alignment of images from the individual heads is crucial. Both alignments shall be measured and reported in millimeters.

Many systems incorporate automatic alignment corrections into the image acquisition process. These corrections may be enabled for these measurements with the stipulation that the automatic correction values must be obtained and applied in a manner consistent with the standard clinical procedure recommended by the manufacturer. The axial and rotational deviation values shall meet or exceed the specification.

***Test Conditions**

The radionuclides employed for these measurements shall be Tc99m or Co57. The count rate shall not exceed 20,000 counts per second through a symmetric 15% energy window for Tc-99m or 20% for Co57.

***Test Equipment**

The test equipment required for this measurement consists of three point sources less than 2 mm in diameter. The activity of the point sources should vary by less than 10%. High-resolution collimators should be employed for the measurement.

***Measurement Procedure**

The point sources should be suspended in the camera FOV in a plane with the radial and axial positions. It is acceptable for the measurement to be made separately for each
individual point source. The detectors should have a 20 cm radius of rotation. Automatic alignment and uniformity corrections may be enabled as noted above. The pixel size should be set to less than 5 mm.

Images shall be acquired at an even number of gantry angles greater than or equal to four distributed evenly from 0° to 360°. Each detector must include an image acquired at 0° and 180°. For each image the maximum pixel in each point source image should contain no fewer than 20,000 counts.

2.4 Previous study:

In (1976) Hasman and Groothedde also studied gamma camera uniformity as a function of energy and count rate . They found that there is low dependence between uniformity of the image and count rate where the uniformity is very sensitive to window setting around the peak .(Br J Radiol 1976 Aug *)*.

In 2000(Abdelhamid et al) were studied the intrinsic uniformity and relative sensitivity quality control test for single head gamma camera to determine the best parameter for rapiad performance of daily quality control testing of intrinsic uniformity and relative sensitivity for the single head gamma camera system in their nuclear medicine department .The studied parameter were the gamma source activity ,number of acquired counts for the flood image ,source to camera distance ,image matrix size ,and source volume. A set of parameter for rapid performance of daily gamma camera intrinsic uniformity and relative sensitivity was determined . The dead time of the gamma camera system was found to be 4.5 $\pm$ 0.2ms finally they found that the intrinsic uniformity and relative sensitivity quality control testing can be performed in 5__6 min. The dead time of each gamma camera system must be determined experimentally each nuclear medicine department (*www.daviddolphin.com).* 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 ,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. 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 (*Mohamed Abdelsattar Bayoum* , The Egyptian Society of Nuclear Medicine Specialists). (Vol 2, No 2 (2009) Bayou

Chapter Three

Material and Method

3.1 Material

3.1.1 Gamma Camera

Single photon emission computed tomography (SPECT) type Orbiter gamma camera with 37 PM-Tubes, Field Of View 387mm (FOV), camera console Scintron fiber pallet, patient bed carbon fiber pallet and the collimator is low energy general purpose . The Single photon emission computed tomography (SPECT) was installed at Nilein Medical Diagnostic Center in Khartoum (NMDC), department of nuclear medicine in 27/01/2009.

3.1.2. Technetium-99m generator

figure 3.1 shows : technetium-99m generator

A technetium-99m generator, or colloquially a technetium cow or moly cow, is a device used to extract the metastable isotope ^{99m}Tc of technetium from a source of decaying molybdenum-99. ^{99}Mo has a half-life of 66 hours (Frank N. Von Hippel, Laura H. Kahn (December 2006). and can be easily transported over long distances to hospitals where its decay product technetium-99m (with a half-life of only 6 hours, inconvenient for transport) is extracted and used for a variety of nuclear medicine diagnostic procedures, where its short half-life is very useful.

3.1.2.1 Parent isotope source

^{99}Mo can be obtained by the neutron activation (n, γ reaction) of ^{98}Mo in a high neutron flux reactor. However, the most frequently used method requires a uranium target with high enriched uranium-235 (up to 90% ^{235}U), they have not yet found a way to use low enriched uranium (less than 20% ^{235}U).[2] The target is irradiated with neutrons to form ^{99}Mo as a fission product Molybdenum-99 is then separated from other fission products in a hot cell. (Frank N. Von Hippel, Laura H. Kahn (December 2006.

3.1.2.2 Type of 99Mo/^{99m}Tc generators

There are two type of $^{99}Mo/^{99m}Tc$ generators used in nuclear medicine. These are the wet and dry column generator.

3.1.2.3 Principle operation of $^{99}Mo/^{99m}Tc$ generators

Immobilization of ^{9}Mo- sodium molybdate on a column of alumina (Al_2O_3). Due to very high affinity for alumina. 0.9%saline solution (the eluant) is passed through the column and sodium pertechnetate, the daughter of ^{99}Mo decay ,is elute from the column due to its almost total lack of affinity for alumona The pertechnetate is collected in a shielded , evacuated sterile vial and calibrated priors to use . its referred to as the eluate .Quantitative removal of pertechnetate is attributed to the lack of affinity of pertechnetate for alumina , whereas wheres molybdate is essentially completely and irreversibly bound to the alumina. When the eluting the generator , the elution volume shold be carefully controlled so a relatively constant radio concentration is obtained every day.(Fundamentals of Radio pharmacy And Radiopharmaceuticals).

3.1.3. Dose calibrator:

Radioisotope calibrator is a device used in radiological research that measures the total amount of radionuclide in units of curies (Ci) or millicuries (mCi), or in the SI units bequriels (Bq) with an appropriate prefix. It consists of a hollow, lead shielded cylinder, in which samples of radionuclides are lowered for measurement. It can be programmed for 8 specific isotopes or adjusted by dial for isotopes not in the program. It is commonly used to obtain quick measures of the total radioactivity of isotopes prior to administration to patients and animals, or further processing in chemical synthesis. A typical unit is the "CRC-15" model, produced by Capintec. Dose Calibrators are Shielded Ion chambers with preset settings (which can be manually adjusted) for specific isotopes, which can give an approximate yet prompt reading based upon the preprogrammed settings. It is very useful in the clinical environment due to its immediate readings.

Figure 3.2; shows : Dose calibrator

3.1.4. Source

3.1.4.1 Technetium-99m

is a metastable nuclear isomer of technetium , symbolized as ^{99m}Tc, that is used in tens of millions of medical diagnostic procedures annually, making it the most commonly used medical radioisotope. Technetium-99m used as a radioactive tracer can be detected in the body by medical equipment. It is well suited to the role because it emits readily detectable 140KeV gamma rays (these are about the same wavelength as emitted by conventional X-ray diagnostic equipment), and its half life for gamma emission is 6.0058 hours (meaning 93.7% of it decays to ^{99}Tc in 24 hours). The "short" physical half life of the isotope and its biological half life of 1 day (in terms of human activity and metabolism) allows for scanning procedures which collect data rapidly, but keep total patient radiation exposure low. The "m" indicates it is a meta stable isomer, i.e., its half-life of six hours is considerably longer (by 14 orders of magnitude, at least) than most nuclear isomer that undergo gamma decay. The life-time of technetium-99m is very long in terms of average gamma-decay half-lives, though short in comparison with half-lives for other kinds of radioactive decay, and in comparison with radionuclides used in many kinds of nuclear medicine tests. The decay process that produces ^{99m}Tc:

$$^{99}\mathrm{Mo} \rightarrow {}^{99m}\mathrm{Tc} + e{-} + \nu e$$

$$^{99}\mathrm{Mo} \rightarrow {}^{99m}\mathrm{Tc} + \beta{-} + \nu e$$

Where :

(or−B) denotes the electron (beta particle) emitted from the nucleus, and ν e denotes the emitted antineutrino (or more specifically, an electron antineutrino . Most commercial ^{99}Mo/^{99m}Tc generators use column chromatography, in which ^{99}Mo in the form of molybdate, MoO_4^{2-} is adsorbed onto acid alumina (Al_2O_3).

When the ^{99}Mo decays, it forms pertechnetate TcO_4^-, which, because of its single charge, is less tightly bound to the alumina. Pulling normal saline solution through the column of immobilized ^{99}Mo elutes the soluble ^{99m}Tc, resulting in a saline solution containing the ^{99m}Tc as the dissolved sodium salt of the pertechnetate. Tc99m used as a radionuclide point source (~150 uCi Tc-99m) and as flood source in fill able-water tank .

3.2. Method

3.2.1 Study design

This is a quality control study carried out in the nuclear medicine department; we used in this study single head SPECT and .whole body gamma camera.

3.2.2 Sample size

These are samples for quality control reading includes 55 (readings), uniformity46 readings, , sensitivity 6 readings, COR 3 reading

3.2.3 Method of data collection

Primary data collected from quality control procedure that we perform on gamma camera (single head).

3.2.3.1 **Intrinsic uniformity:**

3.2.3.1.1 **Procedure:**

- We use a point source (marker) with activity approximately 0.5mci in 2.3ml/volume.

- We set the point source at a distance of at least five times the maximum camera FOV.
- We obtain 10.000 count image.
- Then we calculate the result of uniformity (differential and integral for both detectors).

3.2.3.2 **Sensitivity:**

3.3.3.2.1 **Procedure:**

- We use 10cm flat dish phantom filled with 0.5mci mixed with normal saline 0.9%.
- Place the source 10 cm from camera surface
- We obtain image for one minute.

3.2.3.3 **Center of rotation:**

3.2.3.3.1 Procedure:

- Get 1mci point source, using a syring cap.
- We get a small piece of cotton which contain the activity.
- We put it in holder “carton” in vertical position .
- We place the holder at 10cm distance from the FOV.
- Start the QC program with full rotation acquisition.
- We observe the reconstructed image.

Chapter Four

Result and discussion

This section will highlight the results related to quality control of gamma camera as well as the sample under study which is consisting of 54 readings. The parameters will be discussed are the sensitivity (6 readings), COR (2 readings), and uniformity (46 readings).

The obtained results were analyzed using Microsoft excel 2007 compatible with widows operating system Xp –professional.

4.1 Result of integral Uniformity:

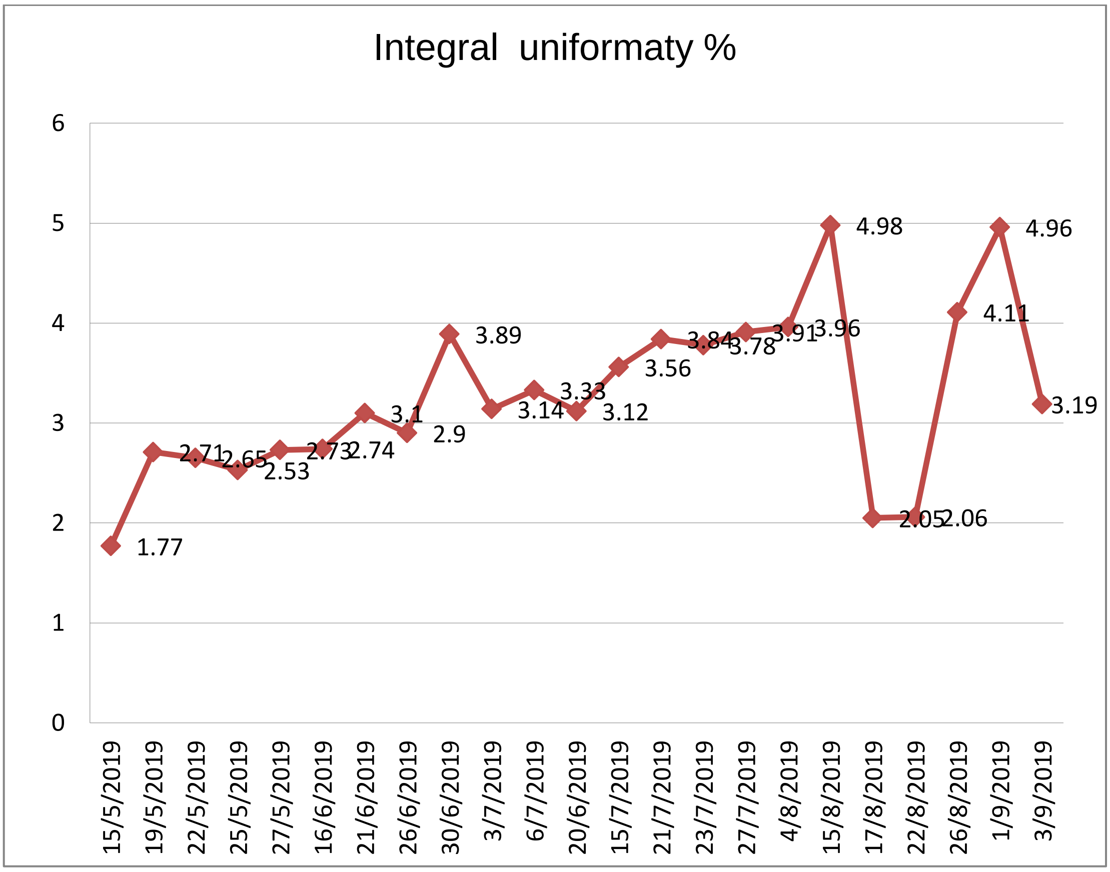


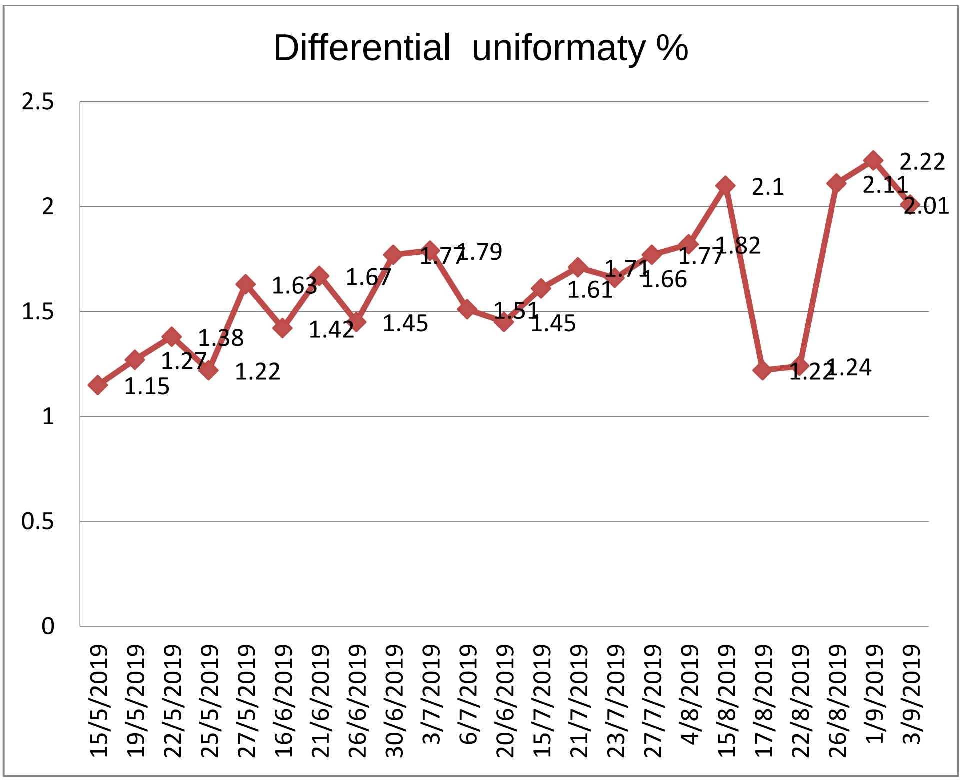
Figure4.1 shows the integral uniformity

Mean	STDEV	Range over time

1.61913	**0.9817**	**0.64– 2.60%**

Since the integral uniformity at acceptance test was 3.09% before correction and 2.3%- After correction. The researcher found that the values of camera uniformity (integral) still within the international acceptable limit (may 2019 up to now) and there was no highly different from acceptance test value.

4.2 Results of Differential Uniformity



F

Mean	STDEV	Range over time
3.203	0 .7498	2.45 – 3.95

r

e4.2 shows: The Differential Uniformity results

From the previous result we noticeable that the change in camera uniformity (differential) not changed over more than three years: 1.72% at acceptance before correction and 1.84% after correction.

4.3 sensitivity result

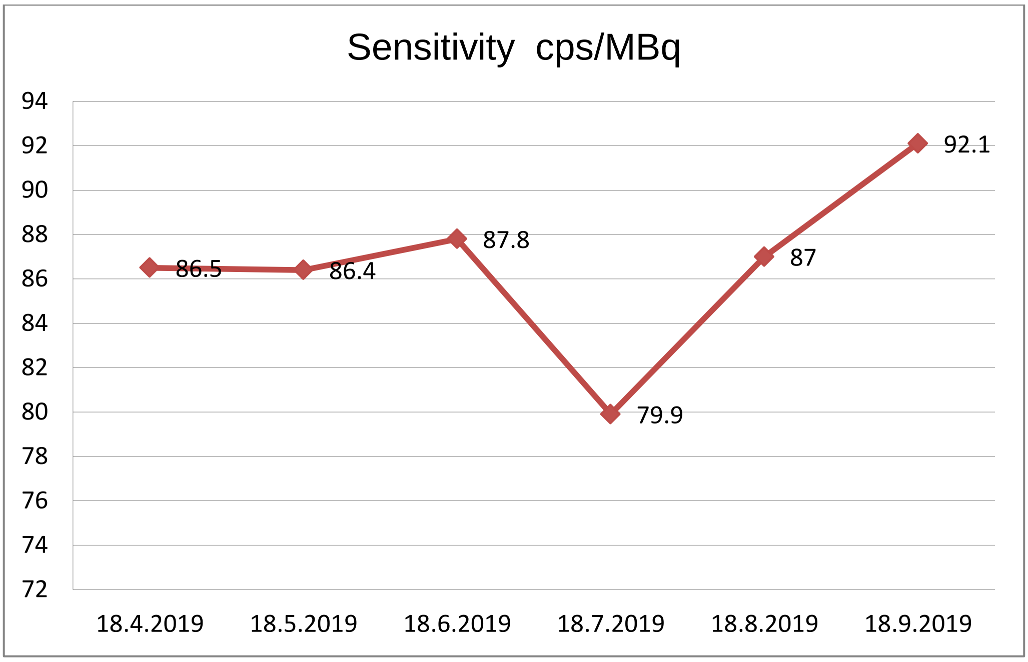


Figure4.3 demonstrate: The change in camera sensitivity over time

The sensitivity of the camera ranged from 79.9 to 92.1cps/MBq and the acceptable limits is designed according to the conditions of the test. So the sensitivity of the camera remain within NEMA levels

4.4 Result of COR:

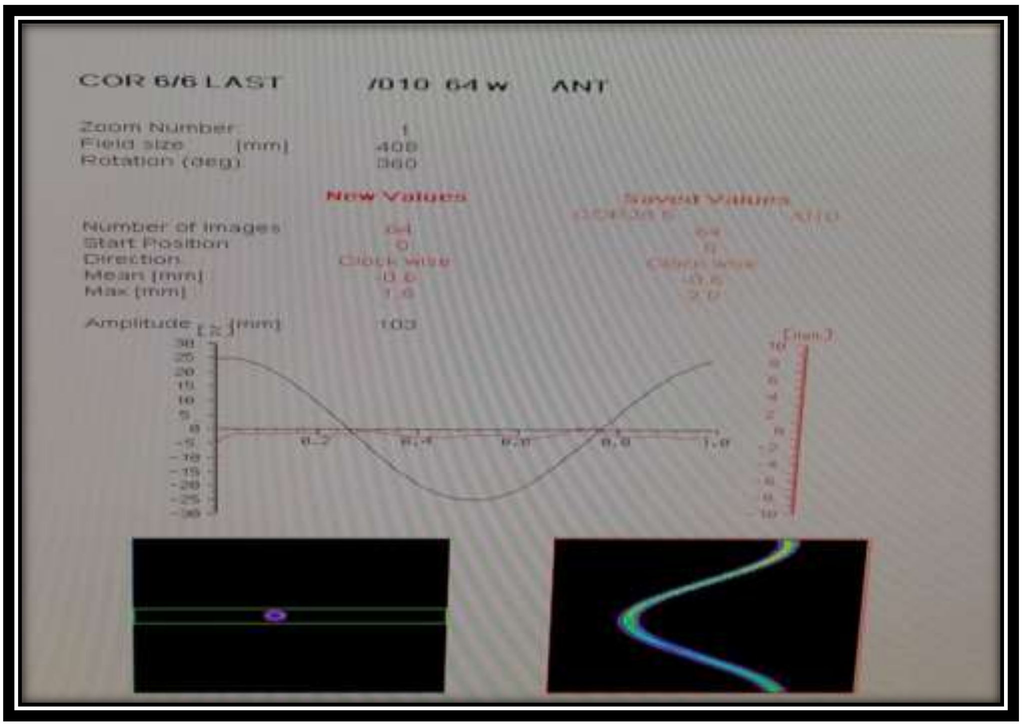


Figure4.4 shows: The COR for detector from May 2019 to June 2019

There was no change in results between the results obtained and acceptance test value. (remember: the researcher found just two reading of COR test).

Chapter Five

Conclusion and recommendation

5.1Conclusion:

As we can see from these three tests of quality control of a single photon emission computed tomography system (single head SPECT System). Found in EL-NILEEN medical center have passed (over 52 months of working). And the center applied Q.C test as possible to keep the camera performance good to ensure the quality of final image.

- In uniformity from measuring uniformity parameters: we noticeable that there is no change in camera uniformity (differential) over more than three years : 1.72% at acceptance before correction and 1.84% after correction.
- the integral uniformity at acceptance test was 3.09% before correction and 2.3%- After correction also within the a acceptable limits .
- The sensitivity of the camera ranged from 79.9 to 92.1cps/MBq So the sensitivity of the camera remain within NEMA levels
- COR: There was no change in results between the results obtained and acceptance test value. (Remember: the researcher found just two reading of COR test).

5.2 Recommendation:

- In the end of the evaluation of the gamma camera in EL-NILEEN medical center we recommend that to make more tests to check the performance of gamma camera and mechanical measurement.
- Further quality control tests must be applied to insure the performance of the camera and to insure that the final image have lack of positive and negative false results.

- The Q.C test must be applied in any nuclear medicine department to insure the final image quality and interpretations.

References

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5- O'Connor, M.K. and Vermeersch, C. (1991) Critical Examination of the Uniformity Requirements for Single Photon Emission Computed Tomography. Medical Physics, 18, 190-197.

6- Young, K.C., Kouris, K., Awdeh, M. and Abdel-Dayem, H.M. (1990) Reproducibili-ty and Action Levels for Gamma Camera Uniformity. Nuclear Medicine Commu-nications, 11, 95-101.

Acq-Date	K counts / s	Integral uni	Differential uni
15/5/2019	42.35	1.77	1.15
16/5/2019	22.16	1.87	1.32
19/5/2019	12.90	2.71	1.27
20/5/2019	39.55	3.09	1.72
22/5/2019	30.99	2.65	1.38
23/5/2019	51.29	2.40	1.63
25/5/2019	38.58	2.53	1.22
26/5/2019	25.31	2.33	1.23
27/5/2019	22.88	2.73	1.63
15/6/2019	20.96	3.26	1.34
16/6/2019	19.88	2.74	1.42
20/6/2019	30.72	2.91	1.77
21/6/2019	31.21	3.1	1.67
22/6/2019	23.28	2.80	1.30
26/6/2019	25.28	2.9	1.45
27/6/2019	29.19	3.21	1.75
30/6/2019	30.72	3.89	1.77
2/7/2019	29.10	3.1	1.81
3/7/2019	28.51	3.14	1.79
5/7/2019	28.45	3.03	1.54
6/7/2019	35.29	3.33	1.51
7/7/2019	25.21	3.30	1.5
11/7/2019	26.25	3.12	1.45

12/7/2019	27.25	3.51	1.6
15/7/2019	29.5	3.56	1.61
16/7/2019	26.22	3.45	1.55
21/7/2019	27.36	3.84	1.71
22/7/2019	28.66	3.88	1.73
23/7/2019	24.22	3.78	1.66
26/7/2019	25.66	3.9	1.77
27/7/2019	29.3	3.91	1.77
3/8/2019	32.12	3.95	1.81
4/8/2019	31.5	3.96	1.82
5/8/2019	29.22	3.97	1.85
15/8/2019	33.12	4.98	2.1
16/8/2019	29.44	4.42	2.0
17/8/2019	31.12	2.05	1.22
21/8/2019	28.21	2.10	1.25
22/8/2019	31.25	2.06	1.24
25/8/2019	26.15	3.56	1.77
26/8/2019	32.14	4.11	2.11
27/8/2019	27.12	2.93	1.21
1/9/2019	32.45	4.96	2.22
2/9/2019	29.06	3.09	2.21
3/9/2019	20.42	3.19	2.01
4/9/2019	21.82	2.25	1.64

- <u>Sensitivity measurement[cps/MBq]</u>

✓ Head 1	18.4.2019	86.5	TC 99m
✓ **Head 1**	**18.5.2019**	**86.4**	TC 99m
✓ **head1**	**18.6.2019**	**87.8**	TC 99m
✓ head1	18.7.2019	79.9	TC 99m
✓ head1	18.8.2019	87.0	TC 99m
✓ head1	18.9.2019	92.1	TC 99m