بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

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Deanship of Graduate Studies and Scientific Research and Publication

Faculty of Pure and Applied Sciences

Physics Department

Assessment of Gamma Camera Performance in Nuclear Medicine Department at Neelien Medical Diagnostic Center

A thesis submitted for partial fulfillment for the requirements of Master degree in Medical Physics

By:

Nidaaldien Yassin Osman Mohamed

B.Sc. Physics Omdurman Islamic University

Supervisor

Dr. AbdelFatah Mohamed Mohamed Ahmed

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الآيـة

قال تعالى: (وفوق كل ذي علم عليم)

صدق الله العظيم

"…and over every lord of knowledge, there is ONE more knowing"

Youssef (12:76)

Dedications

To:

My family

My Teachers

My friends

My colleagues

Acknowledgment

First of all, I would like to thank Allah for giving me the power to complete this work. Then I would like to express my special thanks to my supervisor: Dr/ Abdel Fatah Mohamed Ahmed For his fruitful help. Also I would not forget to thanks the staff member of the physics department, and great thanks to the staff in the nuclear medicine departments in Neelien Medical diagnostic Center. Finally, I would like to thanks my family for prolonged time.

Abstract

This study was performed to assess the performance of gamma camera quality control systems in nuclear medicine at Alneelein Medical Diagnostic Center (NMDC) for following parameters: Energy Resolution, Uniformity, Center of rotation and sensitivity by using ^{99m}Tc.

The result showed that the deviation of gantry rotation(0.1mm) and from 180^0 up to 360^0 the deviation fluctuated between (1.0 to 1.3mm).

The result reveal that extrinsic uniformity for differential and integral were in the accepted limits that established by NEMA for the Neelien Medical Diagnostic Center and the value of energy resolution 7.5% and the energy resolution showed a central peck of the energy at 140 KeV.

Also the result showed that the average of sensitivity is about 77.23.

The research concluded the values of the results of the gamma camera that was obtained from Neelien Medical Diagnostic center was closed to the standard set by International Atomic Energy Agency(IAEA) and the National Electricals Manufacturing Association(NEMA).

المستخلص

تمت هذه الدراسة لتقيم أداء جهاز الجاما كاميرا في وحدة الطب النووي في مركز النيلين التخصصي وفقا للمتغيرات الاتية : نقطة الدوران, حدية الطاقة, التجانس, الحساسية.

وجد أن الانحراف في محور الدوران حوالي 1مم ومن 180الي 360 يكون الإنحراف ما بين 1مم الي 1.3مم .

أوضحت النتائج أن قيمة التناسق التكاملي والتناسق التفاضلي كانت ضمن الحدود المسموحة في المركز. و قيمة دقة الطاقة 7.5% .و دقة الطاقة اظهرت قمة مركزية عند 140كيلوالكترون فولت.

وأوضحت النتائج أيضا أن متوسط الحساسية 77.23.

لخص البحث ألي أن قيم النتائج التي تم الحصول عليها لجهاز الجاما كاميرا في مركز النيلين الطبي كانت ضمن المعايير الموضوعة من قبل الوكالة الدولية للطاقة الذرية و الجمعية الوطنية لمصنعي الاجهزة الكهربائية .

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List of Abbreviations

NM	Nuclear Medicine
QA	Quality assurance
QC	Quality control
PMT	Photo multiplier tube
NaI(TI)	A thallium-activated sodium iodide crystal
SNR	Signal noise ratio
PHA	Pulse height analyzer
FOV	Field of view
UFOV	Useful field of view
CFOV	Central field of view
FWHM	Full width at half maximum
KeV	Kilo electron voltage
COR	Center of rotation
IU	Integral uniformity
DU	Differential uniformity
ER	Energy resolution
SPECT	Single photon emission computer tomography
NMDC	Neelein Medical Diagnostic Center
RS	Relative Sensitivity

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CHAPTER ONE

INTRODUTION

1.Introduction

1. Introduction

Gamma camera is major imaging device used in nuclear medicine. It is a diagnostic instrument which is used to image the radiation from a radiotracer inserted into patient's body. It scans the radiation area of the radiotracer and produces an image. The main purpose of gamma camera is to identify cancer tissues, proper abnormalities and other internal problems inside a patient's body. In the 1950s, Hal Anger conducted studies on medical imaging and from 1952 to 1958; he gradually developed the scintillation camera, also known as the Anger camera.(Hasan et al, 2017).

In general many NM departments have different types of gamma camera such as:

a. Single-headed system: It consists of a gamma camera detector mounted on a gantry that allows the camera head to be positioned in a flexible way over different regions of the patient’s body. Often, a moving bed is incorporated to permit imaging studies of the whole body. The gamma camera head often is mounted on a rotating gantry allowing it to take multiple views around the patient this feature also is necessary for producing tomographic images or cross-sectional images through the body

b .Dual-headed gamma cameras : gamma camera are becoming increasingly popular in these systems two gamma camera heads are mounted onto the gantry usually the two heads can be positioned at a variety of locations on the circular gantry .An obvious advantage of a dual-headed camera is that two different views of the patient can be acquired at the same time (simon et al, 1958),

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. In nuclear medicine process, radionuclides are combined with other elements to chemical compounds or else combined with existing pharmaceutical compounds to form radiopharmaceuticals These radiopharmaceuticals once administered to the patient can be localize to specific organs or cellular receptors. This property of radiopharmaceuticals allows nuclear medicine the ability to image the extent of a disease process in the body based on the cellular function and physiology rather than relying on physical changes in the tissue anatomy. In some diseases nuclear medicine studies. can identify medical problems at an earlier stage than other diagnostic tests. Nuclear medicine in a sense is “radiology done inside out” or “endo-radiology” because it records radiation emitting from within the body rather than radiation that is generated by external sources like X-rays. Gamma Camera used to locate cancerous tumors, minor bone fractures, abnormal functioning of organs and other medical problems. Iodine-i 31 is used to detect thyroid problems Technetium-99 is used to find tumors in the body. Gamma camera give structural and functional image of body organs such as bone scan, Myocardial perfusion, lung scan, kidney function, Thyroid uptake and whole body scans (www.volparadensity.com,2018)

1.2The general components of anger scintillations camera are:

-Collimator

-Detector

-Crystal-NaI(Ti)

-Light guides

-Photomultiplier Tube(PMT)

-Preamplifier & Amplifier

-Pulse height analyzer PHA Image

-Formation Display

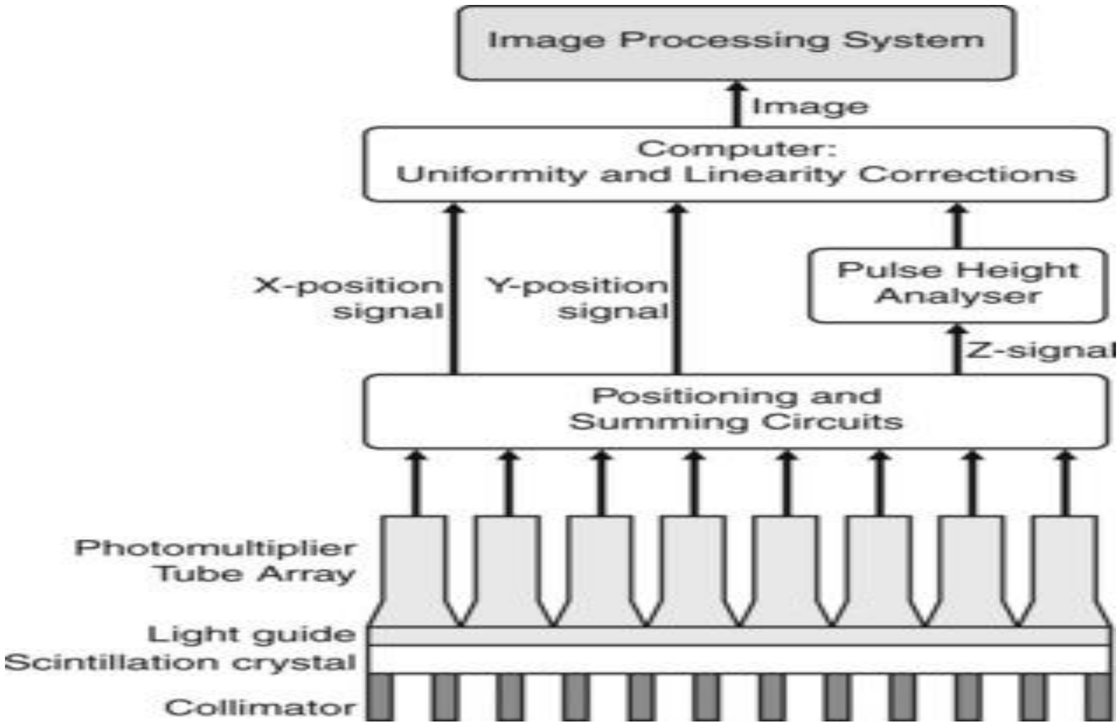


Figure (1-2): show the components of Gamma camera (Rachel, 2006)

(1-2-1) Gamma Camera Collimator

Collimators only allow ray travelling from a certain direction to interact with the crystal. It's made of a sheet of thousands of parallel holes separated by lead septa. The two main parameters describing collimator performance are spatial resolution and sensitivity. Resolution is a measure of the sharpness of the image and is approximately equal to the minimum separation needed between two structures, and the best spatial resolution that can be achieved with a camera fitted with a parallel hole collimator is about 7mm. Sensitivity is a measure of the proportion of those gamma rays incident on the collimator that pass through to the detector, the higher the sensitivity the greater the count rate recorded. Typically the sensitivity for a parallel hole collimator is only 0.1% (hence 99.9% of photons absorbed by the collimator and do not reach the detector). The effectiveness of a collimator in producing an image in the scintillation crystal will depend upon the dimensions of the collimator. The image resolution decreases with distance from the collimator therefore the resolution will be best for the organ that is closest to the collimator. The sensitivity of the parallel hole collimator is independent of the distance of the organ from collimator face. It is not possible to optimize both the spatial resolution and sensitivity of a collimator, and a choice must be made depending upon the type of investigation to be performed (Peter et al, 2005).

Types of Collimator

(a)Pinhole collimator

Is have a single hole, the pinhole usually 2mm to 4mm in diameter in upper right as figure(1-1). Like a camera lens, the image is projected upside down and reversed right to left at the crystal. It is usually corrected electronically on the viewing screen. A pinhole collimator generates magnified images of a small organ like the thyroid or a joint (Rachel, 2006).

(b)Parallel hole collimator

It consists of a lead plate containing a large number of holes. The parallel hole collimator projected image of the same size as the source distribution onto the detector show in upper left as figure(1-1). The parallel hole collimator is used for most studies, other designs of collimator are available for more specialized applications (Peter et al, 2005).

(c)Diverging collimator

Diverging collimator achieve a wider field of view by angling the opposite way, outward toward the organ. This is used most often on a camera with a small crystal, such as a portable cameras in lower right as figure(1-1). Using a diverging collimator a large organ such as the lung can be captured on the face a smaller crystal (Rachel, 2006).

(d)Converging collimator

In the converging collimator the holes are not parallel but are angled in-ward, toward the organ in lower left as figure(1-1). The organ appears larger at the face of the crystal(magnifies the image) (Rachel, 2006).

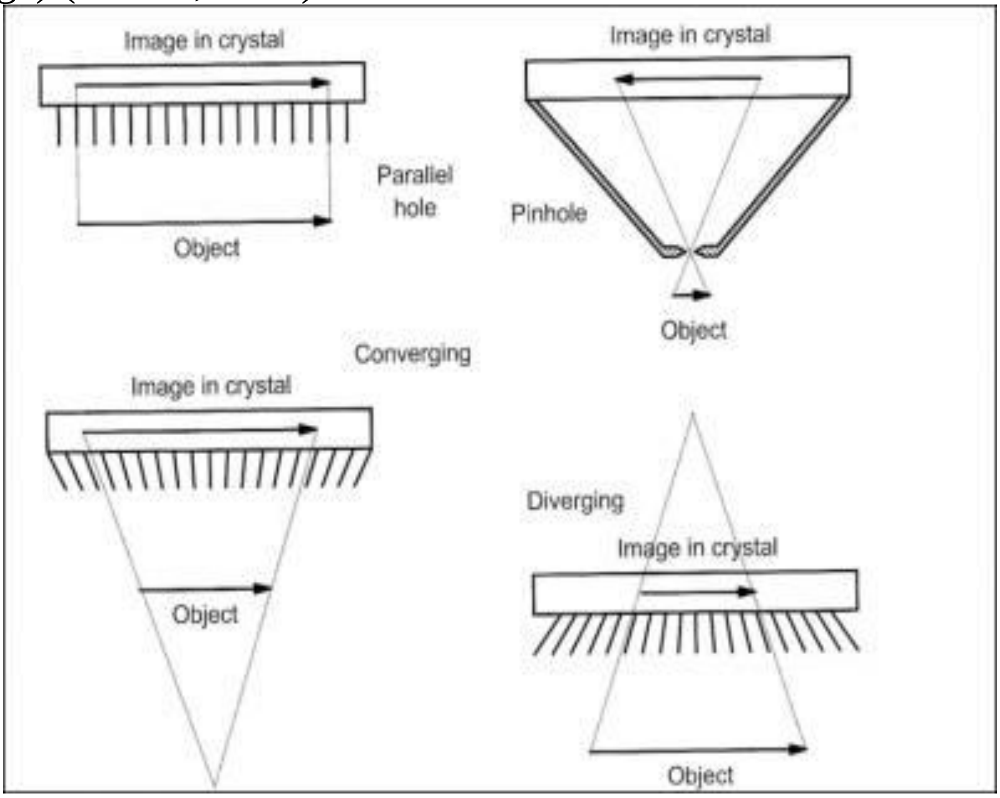


Figure (1-1): show types of the collimator (Rachel, 2006)

(1.2.2)Scintillation detector

The function of the detector assembly to convert the gamma rays into a from that will allow visible image to be produced as in figure (1-2). This process takes place in two stages. The first step is the conversion of the gamma rays into visible light by means of a scintillation crystal, the second these scintillations are turned into electrical signals by the PMTs(Peter et al, 2005).

(1.2.3)Crystal (NaI(TI))

The scintillation crystal used in gamma cameras is made from sodium iodide with trace quantities of thallium added (NaI(TI). Its effectiveness at stopping the gamma depends not only on its density but also on the thickness of the crystal used, only a small fraction of the energy lost by a gamma ray is converted into light, Typically 10% producing about 3000 light photons at a wavelength of 410nm for each 100Kev of gamma ray energy absorbed . The length of each scintillation must be sufficiently short to avoid the overlap of light from consecutive scintillation. The rear crystal surface needs a transparent interface between the crystal and PMTs, this is usually provided by a pyrex optical plate or light guide a few centimeters in thickness(Peter et al, 2005).

(1.2.4)Light guide

Light guide used to allow light to spread out from source position in crystal, originally, light guide was several centimeters thick to improve the uniformity. Increases uniformity of the camera as it spreads the light over a larger region, thus allowing those events not directly under a photomultiplier to have very similar detection efficiency to those under a PMT, but decreases resolution. New cameras have a light guide only about 1cm or less in order to improve resolution, while uniformity corrections are now handled by a microprocessor instead (Peter et al, 2005).

(1.2.5)Photomultiplier tubes (PMTs)

The PMTs are usually arranged in a close packed array to ensure that the smallest possible gaps are left between tubes. Its consist of a photocathode that convert the light into an electrons, dynodes that work on duplicate the number of electrons and anode that collected the electrons and directed it to the position logic circuit. The PMTs not only converts light into an electronic signal (typically by a factor of 10^7) to give a sufficiently large current for the subsequent electronics. Even with this signal amplification preamplifiers built into the PMT are necessary to ensure a sufficient signal-to-noise ratio (Peter et al, 2005).

(1.2.6)PMT Amplification

PMT Amplification total amplification of the PMT is the product of the individual amplifications at each dynode if a PMT has ten dynodes and the amplification at each stage is 5, the total amplification will be approximately 10,000,000. Amplification can be adjusted by changing the voltage applied to the PMT requires high voltage supply(1300V) first dynode(300), and there increment of voltage is 100V, finally reach to anode. Amplitude of pulses is proportional to the number of light photons received by the photocathode of the ray photon absorbed at the detector as in figure (1-2) (Peter et al,2005).

(1.2.7)Preamplifier

Preamplifier Amplify the signals produced by detector (small) match the impedance level between the detector and subsequent component circuits shape the signal pulse for optimum signal processing by subsequent components provide driving force so that pulse will not lost in several feet of cable gain factor 5-20, but NaI(TI) employ 1(no gain). Is placed as close to the detector as possible to maximize the performance (maximize SNR) function (Peter et al, 2005).

(1.2.8)Pulse height analyzer

The PHA used to discriminate between scattered and unscattered photons. The operator defines upper and lower limits on the voltage. These only accept pulses corresponding to within a certain energy. When using radionuclide's that emit gamma rays at different energies, multiple window analyzers need to be employed as shown in figure (1-2). It is important to remember that scattered radiation from the higher energy gammas may overlap into the lower energy photo peaks and this may influence which gamma ray energies should be selected (Peter et al, 2005).

(1.2.9)Image formation

Modern camera systems employ digital display systems. When Z signal corresponding to a particular detected gamma ray falls within the window that has been set on the PHA, then an enable signals is sent and the X and Y signals are recorded. The most common form of image acquisition is called matrix or frame mode. The camera's field of view is divided into a regular matrix of picture elements or pixels. Each pixel is assigned a unique memory location in the computer. The value stored in this location is the number of gamma ray events that have been detected in the corresponding location on the camera face . The number and size of the pixels used is of practical importance and depends on the available computer memory, total number of images to be acquired, number of counts contained in each image and the required spatial resolution. As modern systems can acquire and display static images with array sizes of up to 2048*2048 pixels (Peter et al, 2005)

- **Sources of errors in gamma camera performance**

  The common sources could be synopsis in some parameters such as:

- Damaging of the crystal (crake, loss of obesity due to absorption of moisture)
- Different setting of PHA (effect in uniformity)
- Thick crystal (bad resolution)
- Collimator damage (non uniformity due to crushed lead foil separation)

- Collimator structure artifacts (non uniformity due to large diameter hole, irregular lead foil construction).
- Example of losing quality control in nuclear medicine departments:
- Increase exposure dose in the patient and staff.

1.3 Gamma camera performance and quality control

The performance of gamma camera is characterized by six parameters included spatial resolution, uniformity, linearity, sensitivity, count rate characteristic and energy resolution. To understand gamma camera and routine QC, several terms like intrinsic versus extrinsic (or system) performance and useful versus the central field of view must be illustrated. Intrinsic performance refers to gamma camera performance without a collimator in place while extrinsic performance refers to gamma camera performance with collimator. The useful field of view (UFOV) of a gamma camera is essentially the entire detector(crystal) area while the central field of view (CFOV) corresponds to the inner, or central 3/4 of the crystal area, the CFOV is the portion of the detector actually used in clinical imaging((Peter et al, 2005), (Hans et al, 2007)).

- **Energy Resolution**

Energy resolution it is defined as the ability of gamma camera to distinguish between photons of different energies. The ability of the analyzer to rejected scatter photons is dependent upon the width of the photon peak in the energy spectrum, usually expressed in term of the FWHM. The pulse height analyzer require adjustment to properly center the window of photon energies accepted, the procedure for checking the location of the energy window is to place a viral or syringe containing a small quantity of isotope without collimator and the computer displayed a plot of counts nears energy. The user can then adjust the location and width of the window, for example a standard setting for technetium-99m is a photopeak of 140 KeV and the window of 20% ((Peter et al,2005),(Hans et al,2007)).

- **Uniformity**

Ideally, a scintillation camera should produce a uniform image of a uniform source, this ideal is not met due to imperfections in the collimators, variations in crystal response, difference among PMT response and minor fluctuations in the electrical circuitry. The uniformity of the camera's response can be checked by imaging a flood source. A solid plastic disk manufactured with 5 to 20 mCi of ^{57}Co uniformity distributed throughout its extend or a fluid filled sheet source containing a dilute solution of radioactivity is placed directly on the collimator (extrinsic flood field), and other used a point source suspended several feet at a distance three to four times the diameter of the crystal directly above the surface of the crystal (without collimator or intrinsic flood field), 5 to 30 million count image of the flood is then collected according to the manufacturer's directions (Rachel, 2006).

It is usual to carry out the calculations for both the useful field of view (UFOV) [it is whole usable field of view] and the central field of view (CFOV) [is defined as an area centered on the UFOV], having linear dimensions of the UFOV scaled by factor of 0.75 (Peter et al, 2005).

Integral uniformity is defined as the largest variation (maximum-minimum) in counts over the useful field of view, while differential uniformity is a measurement of the worst case rate of change of uniformity over a limited distance (~5 pixels). Modern gamma camera systems typically have integral and differential uniformities of between 4-7% (Michael K. O'Connor et al, 1979).

- **Center of Rotation**

It is assumed that the camera heads will rotate in a near perfect circle and that heads will remain almost precisely aligned in their opposing positions. It is also assumed that the predicted or electronic center of the path of rotation will match the mechanical or actual center of the camera head rotation. Deviation from either expectation will degrade image resolution and can be seen as a displacement of the center of rotation (COR). Probably the most common cause of apparent displacement of COR is a result of errors not leveling the camera head or bumping the table during data collection. The most common cause of true shift of the COR is electronic malfunction (Rachel, 2006).

- **Linearity**

  Linearity of the gamma camera image is tested by examining the image of the bar phantom obtained with a high resolution collimator in place. The lines in the image should be straight and unbroken, note that linearity here refers to the appearance of the bars as lines. Integral linearity is assessed by calculating the variation in distances between adjacent pairs of line source images, while differential linearity measure the maximum in adjacent segments of array one line image ((Peter et al, 2005), (Hans et al, 2007)).

- **Sensitivity**

  Sensitivity regarded to the detection efficiency of the camera. It is defined as the counting rate obtained per unit activity in a standard source geometry. It is affected primarily by the choice of the collimator and deteriorates as resolution improves for a given camera (Peter et al, 2005).

- **Spatial Resolution**

  The spatial resolution is related to the smallest separation between two point sources which will permit them to be distinguished as two distance sources and is measured by imaging a point or line source in is more usually, the line source is placed parallel to the collimator face and at a given distance from it. The measured quantities are the full width at half maximum (FWHM) is the width of the curve at half the peak count and full width at tenth maximum (FWHM) is the width of the curve at one tenth of the maximum counts, of the resulting curve. The detector system itself has an intrinsic spatial resolution (R_i) and the collimator has a geometric resolution (R_c), the system resolution (R_s) is given by:

$$(R_S)^2 = (R_I)^2 + (R_C)^2$$

In practice performance by using resolution phantom (four-quadrant bar-phantom), this should be done at least weekly ((Peter et al,2005), (Hans et al, 2007)).

Table(1-1) Quality control procedure according to IAEA (International Atomic Energy Agency, 1991).

Test	Acceptance	Daily	Weekly	Half a year	Monthly	Quarterly
Energy spectrum	✓	✓				
Intrinsic uniformity	✓	✓				
Extrinsic uniformity	✓	✓		✓		
Intrinsic energy resolution	✓					✓
Extrinsic energy resolution	✓					
Intrinsic spatial resolution	✓		✓			
Sensitivity	✓			✓		
Center of rotation	✓		✓			

1.4 Problem of the study

The errors caused by a gamma camera used in nuclear medicine may lead to variation in diagnosis; hence it will affect the prognosis of relevant disease and increasing dose exposure for patients, Therefor this work represent quality control in order to optimize patient dose diagnosis process.

1.5 Objectives of the study

1.5.1 General objective

Assessment of Gamma camera performance in nuclear medicine department at Neleelien medical diagnostic center

1.5.2 Specific objectives

- T**o** determine the performance of Gamma camera systems in view of sensitivity, spatial resolution, center of rotation, uniformity and energy response.
- To determine the error percent relative to standard.

1.6 Thesis Outline

The following research will be consists of five chapters, chapter one will deal with introduction, problem of study and objectives. Chapter two will highlight the literature review, Chapter three will shows the methodology upon which the thesis carried out, Chapter four will shows the results and discussion and chapter five will shows the conclusion, recommendation.

CHAPTER TWO

THEORETICAL BACKGROUND

2. Theoretical Review

Single photon emission computed tomography in the year 2001, titled as instrumentation and quality control by Mark, (2001), SPFCT instrumentation is more complex than that used for whole body and planar imaging and requires carful quality control to ensure optimum performance.

Survey on quality control of radiopharmaceutical dose calibrators in nuclear medicine units in the city of Sao Paulo, Brazil by Bessa (2008), to perform a survey on routine quality control tests of dose calibrators at nuclear medicine units in city of Sao Paulo, Brazil and to evaluate the accuracy of measurements of seven dose calibrators activities, utilizing sources of clinically significant radionuclide's at the calibration laboratory. Quality control in department of nuclear medicine, clinical center Banja Luka, RS, Bosnia and Herzegovina by Goran, (2007), the aim of this work was to give a review of situations in the department of nuclear medicine in Banja Luka related to quality control (perform daily, weekly and monthly control equipment). (Goran et al,2007).

Another studies survey on quality control measurements for nuclear medicine imaging equipment in Finland in 2006 by Helina Korpela and Jarkko Niemela (2006), routine quality control is an essential requirement in nuclear medicine in order to ensure optimal functioning of equipment. To harmonies the routine QC of NM imaging equipment in finnish hospitals (planar gamma cameras, SPECT, coincidence gamma cameras, PET), the Radiation and Nuclear Safety Authority (STUK) will publish guidelines on QC in collaboration with several hospital physicists. Recommendations will be provided on routine QC measurements and on the frequency of testing. It is also planned to provide recommendations for the acceptance criteria when assessing different performance parameters for NM imaging equipment. In order to determine what performance parameters of NM equipment are currently measured in hospitals, how frequently they are measured and what acceptance criteria are used, a survey was carried out on the QC of NM equipment in Finland during 2006.(H Korpela et al, 2006).

Another studies evaluation of intrinsic uniformity and relative sensitivity of quality control tests for a single photo emission computed tomography (SPECT) by Mohamed, (2009), the aim of study was to evaluate the optimum parameters (source activity, source volume, source distance, matrix size, number of counts required and count rates) affecting the intrinsic uniformity (IU) as quality control tests for the performance of a single photo emission tomography (SPECT). The relative sensitivity (RS) Diagnostic Center in Khartoum (NMDC), department of Nuclear Medicine. The tests were usually performed by exposure the gamma's crystal to a uniform flux of gamma radiation from a ^{99m}Tc point source. However, according to National Electrical Manufacturers Association (NEMA) protocols, the collimator must be removed before the IU test is carried out. The IU test is performed for correction of many gamma camera problems as soon as they appear, whereas the RS characterizes the stability of response to gamma radiation. RS and IU tests were performed simultaneously in order to determine the elapsed time required acquire the image. A set of parameters for rapid performance of daily gamma camera IU and RS was determined. The dead time of our camera system was found to be 5±0.1 µs.

A field survey of gamma camera in Finland. Comprehensive national study by Karlsson, (1982), the aim of the study was get an idea of the image quality obtained in daily routine and comparison of different gamma camera types.

Dynamic functional studies in nuclear medicine in developing countries by International Atomic Energy Agency, World Health

Organization (1989), the proceeding document some of the trials and tribulations involved in setting up nuclear medicine facilities in general and specifically as regards nuclear medicine applications for the diagnosis of the diseases prevalent in the less developed countries and a session on quality control of the equipment used.(Karlsson,1982).

Another study Deformation of the energy spectrum from ^{99m}Tc source with its depth by Breton, et al,(2004), the aims of study was to planar scintimammography with ^{99m}Tc-Sestamibi is a sensitive, specific and non-invasive method used in complement to X-ray mammography for breast cancer diagnosis. Studies have scatter correction might improve lesion detection and quantization of tumor-to-normal breast tissue activity ratio. Among the strategies used to compute this correction, some are based on the analysis of the energy spectrum of photons.(Breton et al, 2004).

Another study the Appropriate energy window width for gamma camera by Jabbari, et al, (2004), the different methods of scatter correction have been introduced in order to improve the quality of data. However the best method is to avoid recording of scatter photons in acquisition. The only difference between scattered and non-scattered photons is the energy. Pulse height analyzer is the only option available to discriminate primary photons from scattered ones. Energy resolution of the gamma camera is gradually improving consequently the energy window width has to be decreased accordingly. In this study we tried to determine the most appropriate energy window width for present gamma camera systems. The study concluded that the present for most gamma camera the energy window width of 20% is recommended. However occasionally energy window width of 20% and 25% are also used (Jabbari et al, 2004).

CHAPTER THREE

MATERIALS AND METHODS

3. Materials and Methods

3.1Materials and Equipment's:

This study was involving in hospital department of nuclear medicine performing diagnostic NM procedures in Sudan. The equipment used in this study included:

- Gamma camera (SPECT)
- Dose calibrator
- Vials and syringes, point source ^{99m}Tc
- Strips
- ^{99m}Tc generator
- Source holder

Figure(2.1) The gamma camera machine in NMDC(Serial number:2008/43, Made in Germany, Band name MiE {Medical Imaging Electronics})

Figure(2.2) Dose Calibrator NMDC(manufacture: BIODEX model:086-336)

Figure(2.3) ^{99m}Tc generator(dotmed.com)

3.2 Methods

- **Intrinsic energy resolution**

The cameras ability to distinguish between photons of different energies, in particular between primary and scattered radiation usually expressed in terms of the FWHM. The ER is given by:

$$ER\% = (FWHM/\ \text{photo peak center}) \times 100 \qquad (1)$$

Procedure

- Remove the collimator, use Matrix size (128*128)
- Sure the point source in the central of the detectors
- Place the Tc^{99m} point source at distance 5×FOV from the camera head.
- From main menu select patient study and energy resolution test, the energy spectrum will apparent as seen in figure (3.2), after the computer calculate a FWHM. The ER is given by:

$$ER\% = (FWHM/\ photo\ peak\ center) \times 100 \qquad (1)$$

- **Intrinsic uniformity**

The camera ability to detect a uniform source of the radioactivity distribution.

Integral uniformity:

The difference between the maximum and minimum pixel count.

$$IU(\%) = (max - min)/(max + min) \times 100$$

Differential uniformity:

The difference between two adjacent pixels.

$$DI(\%) = (max - min)/(max + min) \times 100$$

Procedure

- Remove the collimator, use matrix size (64*64).
- Sure the point source in the central of the detectors
- Place the ^{99m}**Tc** point source at distance 5×FOV from the camera head.
- From main menu select patient study and uniformity test the computer will calculate the integral and differential uniformity see the result in figure(3.3)

- **Center of rotation**

In this test to verify and correct the alignment of the mechanical and electronic around which the camera rotates.

Procedure

- Replace the point source of ^{99m}Tc in the caught within about 360cm of the axis of rotation.
- Make the camera rotates about 360 degree around point source
- From menu select acquire patient study and COR test,
- **Sensitivity**

Sensitivity is the gamma camera detectors ability to detect the ionizing events that occur in the NaI(TI) crystal. The events recorded as counts per minute (cpm) are calculate and expressed as count per minute per micro curie (µCi) of activity present.

Procedure:

- Measure the activity in the syringe (A_{srl}).
- Put water in the phantom.
- Disperse a syringe activity into a flat plastic and then measure the activity residual in syringe (A_{res}).
- Calculate the activity into the phantom by using equation:

$$A_{cal} = A_{srl} - A_{res} \quad (2)$$

- Place the phantom at distance 10 cm from collimator face, use a matrix size (128*128).
- From the main menu patient acquisition, user test (system sensitivity) and press F3, the computer will calculate the sensitivity.

CHAPTER FOUR

RESULTS,AND DISCUSSION

4.Result, & Discussion

4.1 Result and discussion

This section deals with result of gamma camera performance that specifically related to gantry rotation, uniformity, sensitivity, background measurement and energy resolution that would be highlighted in a form of curves or tables.

Figure(3.1) show the gantry rotation QC, at field size(408), Rotation (360), Number of image(64), start position(0), Direction(clock wise), mean(-0.7) and max(2.0). In this result which is carried out on 11.12.2017, the wave length for the gantry motion has been more deteriorated by 0.15 for the first half cycle and 0.12 for the second half cycle i.e. the average deviation could be as 0.14mm. such deviation is within the tolerance level of gamma camera performance.

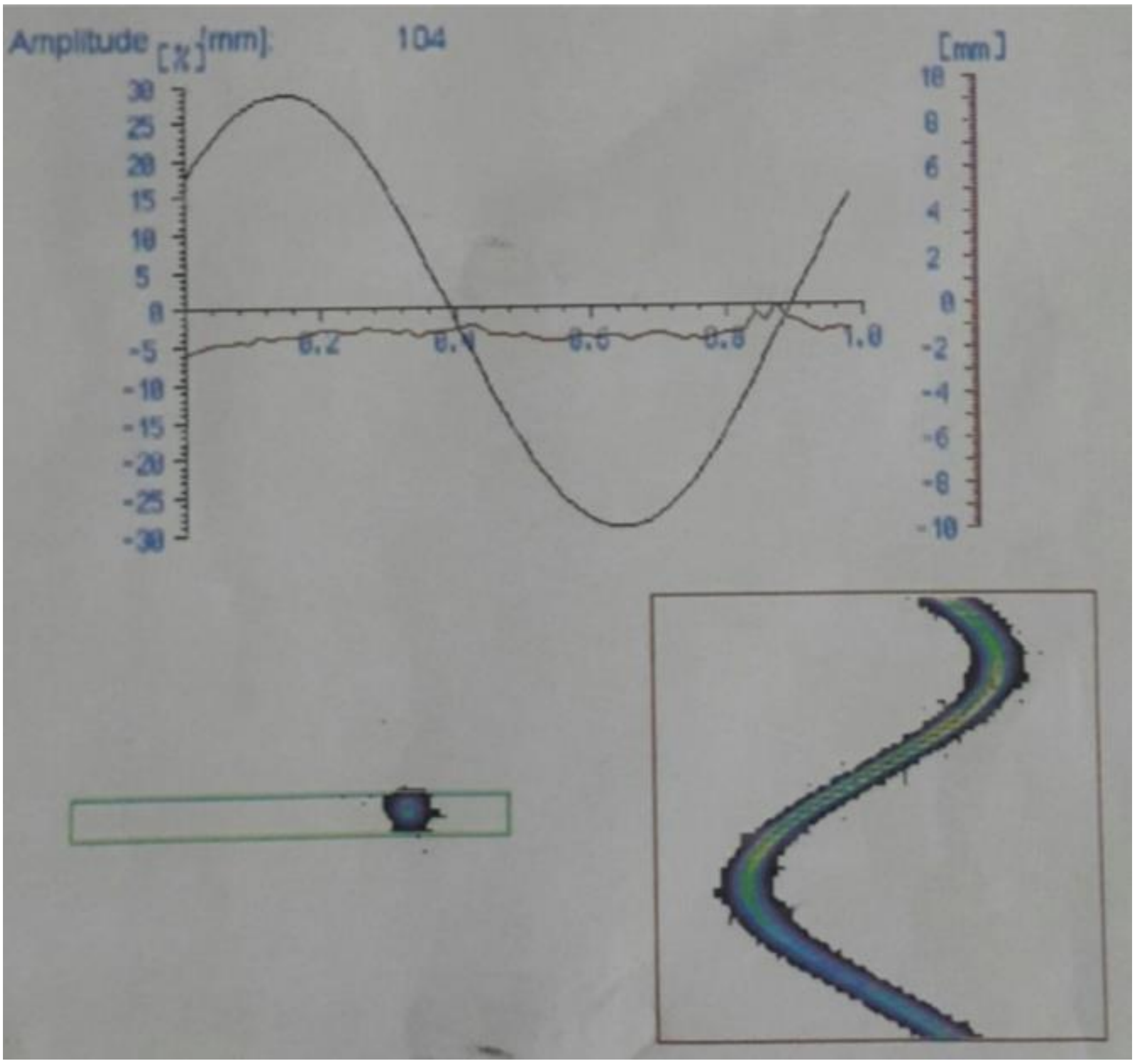
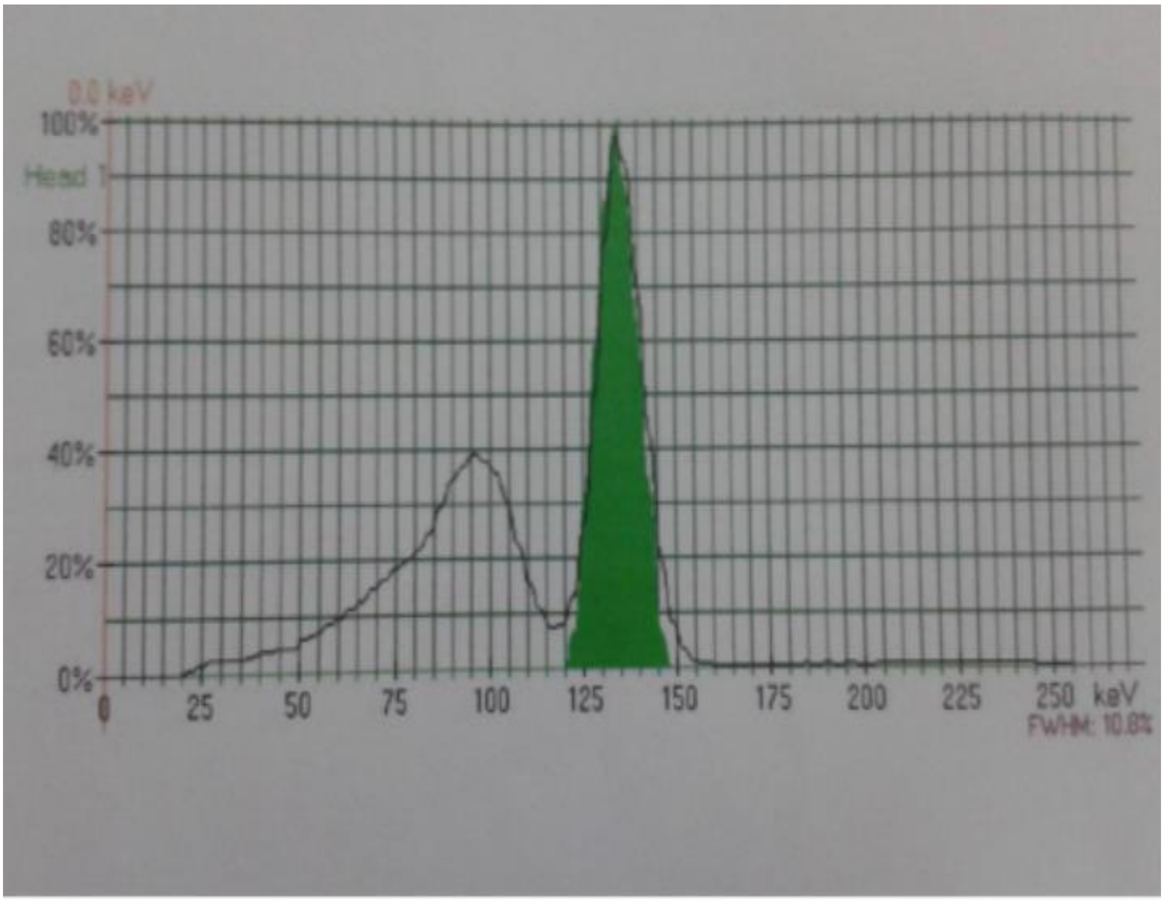


Figure (3-1) The gantry rotation QC, at field size (408), Rotation (360), Number of image (64), start position (0), Direction (clock wise), mean (-0.7) and max (2.0) (11.12.2017)

Table (1.2): Center of Rotation of gamma camera machine (SPECT) in center (NMDC).

Date	11.12.2017
Zoom number	1
Radioisotope	^{99m}Tc
Field size[mm]	408
Rotation(deg)	360
Number of images	64
Start position	0
Direction	Clock wise
Mean[mm]	-0.7
Max[mm]	2.0

Figure (3.2) show the energy resolution QC, at Matrix size (128*128), FWHM (10.8mm), Analyzer (1.9), date (4.1.2018). The following data show the energy spectrum for Tc^{99m} and the window of energy spectrum about 15% for SPECT machine in Alneelain Center. The central peak of energy is 140 KVp and the limit of the window for the energy about 7.5% (±10.5). The average of FWHM about 10.27 and the standard deviation is about 1.5.The energy resolution is calculate from equation (1) given by (Hans, 2007) and found it about 7.4%



Figure(3.2) The Energy Resolution QC, at Matrix (128*128), FWHM (10.8), analyzer (1.9), date (4.1.2018).

Table (1.3) : Energy Resolution of gamma camera machine SPECT in center NMDC for different dates:

A

Date	12.12.2017
Isotope	^{99m}Tc
Matrix	128*128
FWHM	11.4
Analyzer	1.9

B

Date	24.12.2017
Isotope	^{99m}Tc
Matrix	128*128
FWHM	7.4
Analyzer	1.9

C

Date	30.12.2017
Isotope	^{99m}Tc
Matrix	128*128
FWHM	9.1
Analyzer	1.9

D

Date	4.1.2018
Isotope	^{99m}Tc
Matrix	128*128
FWHM	13.2
Analyzer	1.9

$$Xi = \frac{x1 + x2 + x3 + x4 \ldots\ldots\ldots xn}{xn}$$

Xi= 10.27mm

Energy resolution ER = (10.27/140)*100

= 7.4

Table (2.1) (a, b, c) show comparison between the practical and stander Differential Uniformity and Integral Uniformity. For Differential Uniformity we found that the UFOV in the practical is about 2.78% and the stander is about 4.0% the difference between practical and standard 1.22% and the CFOV in the practical is about 2.04% and the standard is about 3.0%. The difference between practical and standard 0.96%. For Integral Uniformity we found that the UFOV in the practical is about 5.07% and the stander about is 3.0% the difference between practical and the standard 2.07% and the CFOV in the practical is about 3.1% and the standard is about 2.5% the difference between practical and the standard is 0.6%

Acquisition	
Head :	1
Study :	Scintil Nema 130314
Acquisition Date :	4.1.2018
Isotope :	^{99m}Tc
Window :	15%
Matrix :	64×64
Acq Time :	11min
KCount/sec :	20.87 kcps
Remarks :	Zoom: 1
	A

Field Of View

Size of FOV : 402mm
Size of MFOV : 338mm
Total Counts in MFOV : 11229 kcnts
Mean in MFOV : 4710 cnts
Minimum in MFOV : 4428 cnts
Maximum in MFOV : 4901 cnts
Standard deviation : 72.11cnts
Coefficient of Variation : 1.53%

(MFOV= Measured field of view)

B

Uniformity

Integral Uniformity (MFOV) : 5.07%

Different Uniformity (MFOV) : 2.78%

Integral Uniformity (MFOV) : 3.10%

Different Uniformity(MFOV) : 2.04%

No pixel with higher deviation then 2.5%, 5% and 10%

Of Mean[%] :

(+/-) 2.5% deviation : 11.45%
(+/-) 5% deviation : 0.17%
(+/-) 10% deviation : 0.00%

C

Table (2.2) : Result of the intrinsic uniformity for Neelien Medical Diagnostic Center hospital compared with IAEA standard.

	Result		IAEA		Accepted
	UFOV	CFOV	UFOV	CFOV	
Differential uniformity	2.78%	2.04%	4.0%	3.0%	Yes
Integral uniformity	5.07%	3.10%	3.0%	2.5%	Yes

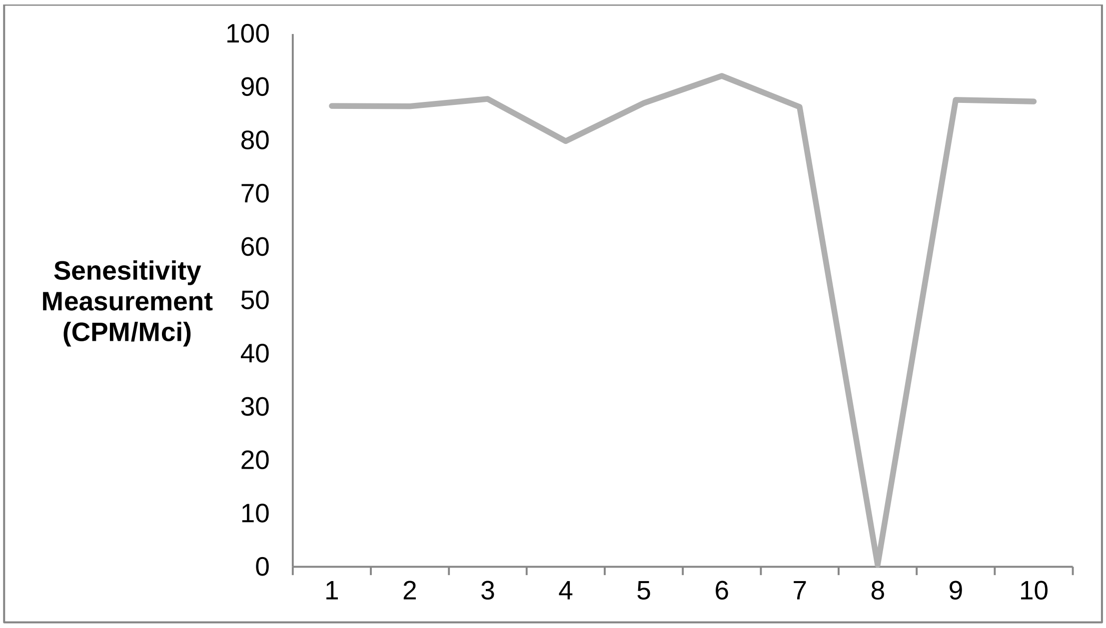
Table (2.3) Sensitivity of gamma camera machine SECT in (NMDC) for different days

Date	Isotope	Sensitivity measurement(CPM/Mci)
25.1.2014	^{99m}Tc	86.5
28.2.2014	^{99m}Tc	86.4
2.9.2015	^{99m}Tc	87.8
27.6.2015	^{99m}Tc	79.9
3.4.2016	^{99m}Tc	87.0
13.5.2016	^{99m}Tc	92.1
3.5.2017	^{99m}Tc	86.3
24.6.2017	^{99m}Tc	0.4
4.1.2018	^{99m}Tc	87.6
12.1.2018	^{99m}Tc	78.3

The average of Sensitivity :

$$Xi = \frac{x1+x2+x3+x4..........xn}{xn}$$

$$Xi = 77.23$$



Figure(3.3) The sensitivity measurement from (2014 to 2018) in Neelien Medical Diagnostic Center

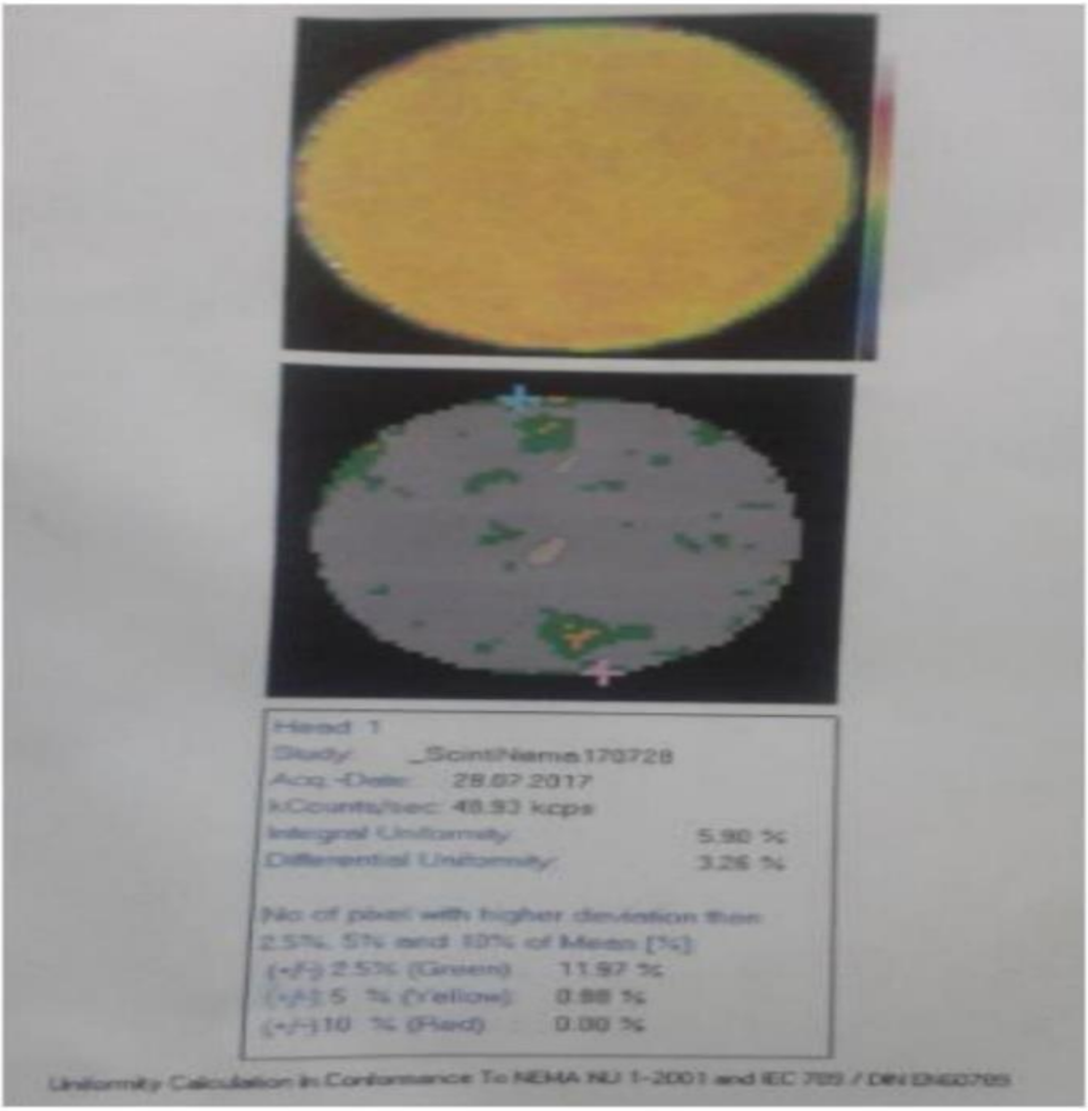


Figure (3.4) The intrinsic uniformity QC in Neelien Medical Diagnostic Center

CHAPTER FIVE

CONCLUSION, AND RECOMMENDATION

5.Conclusion, and Recommendation

(5.1) Conclusion

The following chapter details with the main obtained facts and information after analysis, which could the summered in the following points:

-The data reveals that: the result which is carried out on January 4, 2018, the wave length for the gantry motion has been more deteriorated by 0.15 for the first half cycle and 0.12 for the second half cycle i.e average deviation could be as 0.14mm. such deviation is within the tolerance level of gamma camera performance.

- The data revealed that: during this period the gantry rotation started to deviate from the normal at 90º to reach about 0.4 mm at 135º i.e. at the 3^{td} quadrant and by 180º the deviation approaching to 0.8mm, and from 180º up to 360º the deviation fluctuated between 1.0 to 1.3 mm which is still within the tolerance level of system working.

- The data reveals that: the energy spectrum for Tc^{99m} and the window of energy spectrum about 15% for SPECT machine in Alneelain Center. The central peak of energy is 140 Kvp and the limit of the window for the energy about 7.5%(±10.5). The average of FWHM about 10.27 and the stander deviation about 1.5.

-The data reveals that: the comparison between the practical and standard Differential Uniformity and Integral Uniformity. For Differential Uniformity we found that the UFOV in the practical about 2.78% and the standard about 4.0% the difference between practical and the standard 1.22% and the CFOV in the practical about 2.04% and the standard about 3.0% the difference between practical and the standard 0.96%. For Integral Uniformity we found that the UFOV in the practical about 5.07% and the standard about 3.0% the difference between practical and standard 2.07% and the CFOV in the practical about 3.1% and the stander about 2.05% the difference between practical and the standard 0.6%.

-The data reveals that: the sensitivity for gamma camera, The average of sensitivity around 77.23 and the drop of peak of sensitivity according to the leakage of the current and the decay of the end of the below carve according to the dead time.

(5.2) Recommendations

- Applying a quality assurance (QA) that include quality control tests for gamma camera machines, radionuclide, and dose calibrators, waste management and radiation protection program, is essential to decrease radiation risks for patients and staff.

- Applying the ALARA (As Low As Reasonably Achievable) principle in nuclear medicine diagnostic to reduce the radiation dose for patients.

- Raising the efficiency of technologists through training of quality of the image and prevent repetitions.

- The regular quality control for gamma camera is essential to ensure proper function of the device.

- The surrounding environmental conditions of the test and operation should always be consider and recorded.

(5-3) References

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5.4 Appendix

Quality control procedure according to IAEA(International Atomic Energy Agency, 1991)

Test	Acceptance	Daily	Weekly	Half a year	Monthly	Quarterly
Energy spectrum	✓	✓				
Intrinsic uniformity	✓	✓				
Extrinsic uniformity	✓	✓		✓		
Intrinsic energy resolution	✓					✓
Extrinsic energy resolution	✓					
Intrinsic spatial resolution	✓		✓			
Sensitivity	✓			✓		
Center of rotation	✓		✓			