Sudan University of Science and Technology
College of Graduate Study

Assessment of Gamma Camera Quality Control Performance in National Cancer Institute -Wad Madani

تقييم آداء ضبط جودة جهاز تصوير قاما كاميرا بالمعهد القومي للسرطان ـ ود مدني

A Thesis Submitted in Partial Fulfilment of the Requirements of the Master Degree in Medical Physics

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الاية

بِسۡمِ ٱللَّهِ ٱلرَّحۡمَٰنِ ٱلرَّحِيمِ

قال تعالى:

﴿ وَقُل رَّبِّ زِدۡنِي عِلۡمٗا ﴾

{طه: 114}.

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 (Ahmed AwadEljeed Mohammed)

Mother (Fatima Ahmed Mohammed)

and my husband (Alam Eldeen Mohamed)

Whose infection love encouragement,

and prays of day and night make me able to get such success and honor along with my sister and all my friends.

Acknowledgment

This research wouldn’t have been possible without the blessing of Allah.

I would like to express my thanks and appreciation to all those who gave me the will to complete this thesis,

special thanks to my supervisor Dr. Altayed Wagiallah Eltayeb who eliminated all obstacles from my way to achieve this work and gave me all guidance to do it. Also I would like to thank Mr. Abdelbagi Omer Osman.

Abstract

This study was performed to assess the performance of gamma camera Quality Control system in National Cancer Institute-Wad Madani department of nuclear medicine for the following parameters: uniformity, energy resolution and physical inspection peaking using Tc^{99m}. the samples of this study for quality control reading includes 61 (readings), Extrinsic uniformity 52, Energy resolution 9. Were the data collected in period from January to June 2020.

All results that was obtained from the study have been compared with the acceptance limits with International Atomic Energy Agency and National Electricals Manufacturing Association -2001 standards. The result reveal that the extrinsic uniformity for differential and integral were in the accepted limits that established by NEMA for the hospital, and the value of energy resolution was 5.43%, 5.66%, and the energy resolution showed a central peak of the energy at 140 KeV.

The research concluded that the value of the results of the gamma camera that was obtained from national cancer institute was closed to the standard set by International Atomic Energy Agency (IAEA) and the National Electricals Manufacturing Association(NEMA).

المستخلص

تمت هذه الدراسة لتقييم أداة جهاز الجاما كاميرا في وحدة الطب النووي في المعهد القومي للسرطان، ود مدني، وفقاً للمتغيرات التالية:- التناسق، دقة الطاقة، التفتيش الفيزيائي.

وقد تم هذا البحث بواسطه أخذ 61 قراءة، كان 52 قراءة منها لحساب التناسق، 9 قراءات لحساب دقة الطاقة,وقد تم جمع هذه البيانات خلال فحوصات ضبط الجوده.في الفترة من

كل النتائج المتحصل عليها من الدراسة تمت مقارنتها مع معايير حدود الأمن والسلامة الموضوعة من قبل الوكاله الدولية لطاقة الذرية والجمعية الوطنية لمصنعي الأجهزة. أوضحت النتائج أن قيمة التناسق التكاملي والتناسق التنبايني كانت ضمن الحدود المسموحة في المركز، وقيمه دقة الطاقة 5.4%,5.66%، ودقة الطاقة أظهرت قمة مركزية عند 140 كيلو إلكترون فولت.

لخص البحث إلى أن قيم النتائج التي تم الحصول عليها لجهاز الجاما كاميرا في المعهد القومي للسرطان كانت ضمن المعايير الموضوعة من قبل الوكاله الدولية لطاقة الذرية والجمعية الوطنية لمصنعي الأجهزة الكهربائية.

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List of Abbreviations

CVOF	Central Field Of View
FOV	Field Of View
FWHM	Full Width at Half Maximum
KeV	Kilo Electron Voltage
NCI	National Cancer Institute
NM	Nuclear Medicine
PHA	Pulse Height Analyzer
PMT	Photo Multiplier Tube
QA	Quality Assurance
QC	Quality Control
SPECT	Single Photon Emission Computer Tomography
UFOV	Useful Field Of View

Chapter one

Introduction

Chapter one

Introduction

1.1 Introduction:

The application of gamma camera is a credit for Hal O. Anger who developed the Anger scintillation camera and by 1952 to 1958 Anger scintillation camera replaced rectilinear scanners in the late 1960 that permits more rapid acquisition of images and enables studies. More flexible in its positioning, permitting image to be obtained from almost any angle(Simon, 1958).

Due to over use, environmental climate change, crystal type, modifications of components or replacement, electronic or electrical fluctuation, the performance of nuclear medicine machines may decrease and fluctuate and accordingly the result of medical investigation could vary.

The Quality Assurance(QA) procedures and maintenance program are necessary guarantee the performance (Simon, 1958)

In general, many nuclear medicine departments have different type of gamma camera such as:

1-Single –headed system: It consist 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 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 (Simon, 1958).

2-dual- head gamma cameras are becoming increasingly popular. In these system, two gamma camera heads are mounted onto the gantry. Usually, the two heads can be positioned at variety of locations on the circular gantry. An obvious advantage of a dual-headed camera is that two different views of the patient (Simon, 1958).

Nuclear medicine is a medical specialty involving the application radioactive substance in the diagnosis and treatment of disease.
In Nuclear medicine procedures, radionuclides are combined with existing pharmaceutical compounds, to form radiopharmaceuticals.

To keep the camera performance stable and acquire image of the highest possible quality, the quality the quality control procedures are essential. The camera performance proposed by NEMA standard describes how manufacture arrives at the specification of his camera and how to detect the changes in camera performance that may create the image artefacts and alter patient diagnoses. Therefore, number of quality control test have been designed to insure optimal camera performance. The most commonly performance measured evaluated as the routine gamma camera QC include intrinsic flood filed uniformity test, extrinsic flood field uniformity test, peaking, spatial resolution, energy resolution and center of rotation.

1.2 Problem of the study

Smallest non uniformity degree in the gamma camera image can cause artefact which, is leads to incorrect diagnostic, thus maintaining good uniformity in gamma camera images is very important.

The difference of result obtained from radioisotopes scintigraphy in centre may lead to variation in diagnosis hence it will affect the prognosis of relevant disease.

1.3 Objectives of the study

1.3.1 General objective

To determine the performance of gamma camera systems in view of energy resolution, uniformity and energy response.

1.3.2 Specific objective

- To assessment the error percent (Extrinsic uniformity, energy resolution) relative to standard.
- To test the system response to energy strength.

1.4 Important of the study:

Assessment of gamma camera performance lead to reduce failure in diagnosis

Chapter two

Literature review

Chapter two

Literature review

2.1 Theoretical background

gamma camera also called a scintillation camera or anger camera, is a device used to image gamma radiation emitting radioisotope's, a technique known as scintigraphy. the application of scintigraphy includes early drug development and nuclear medical imaging to view and analyse image of the human body or the distribution of medically injected, inhaled, or ingested radionuclides emitting gamma rays.

a gamma camera consists of one or more flat crystal planes (or detector) optically coupled to an array of photomultiplier tubes, this mounted on a gantry. the gantry is connected to computer system that both controls the operation of the camera as well as acquisition and storage of acquired image. the computer reconstructs and display a tow dimensional image of the relative spatial count density on a monitor. this reconstructed image reflects the distribution and relative concentration of radioactive tracer elements present in the organ and tissues imaged (Gopal, 2012).

2.2.1 Historical background

in 1940 simple information about radioactive source distribution within the brain were taken by single detector at various locations around the head, in 1950 this method was developed by Benedict Cassin

the forerunner of modern nuclear medicine single-photon imaging system, developed in 1958 by Hal Anger and in the late of 1970 gamma camera through the present have been developed to correct some of the uniformities seen older images (Rachel, 2006).

2.3 Gamma camera

This is the principal machine used for nuclear medicine imaging. gamma camera is composed of the following:

1. collimator.
2. detector.
3. Crystal_NaI(TI).
4. Light guides.
5. Photomultiplier Tube(PMT).
6. Amplifier.
7. Pulse height analyser (PHA)Image.
8. Formation Display.

2.3.1 Collimator

Collimators only allow ray travelling from a certain direction to interact with the crystal.it is made of the 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 for a parallel hole collimator is only 0.1% (hence 99.9% of photons are 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 the 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, 2005).

2.3.2 Types of collimator

a- Pinhole collimator

These have a single hole, the pinhole usually 2mm to 4mm in diameter as figure (2-1). 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).

It is sensitivity is low and decreases with distance. It is efficiency depends on the hole diameter and length.

b-Parallel-hole collimator

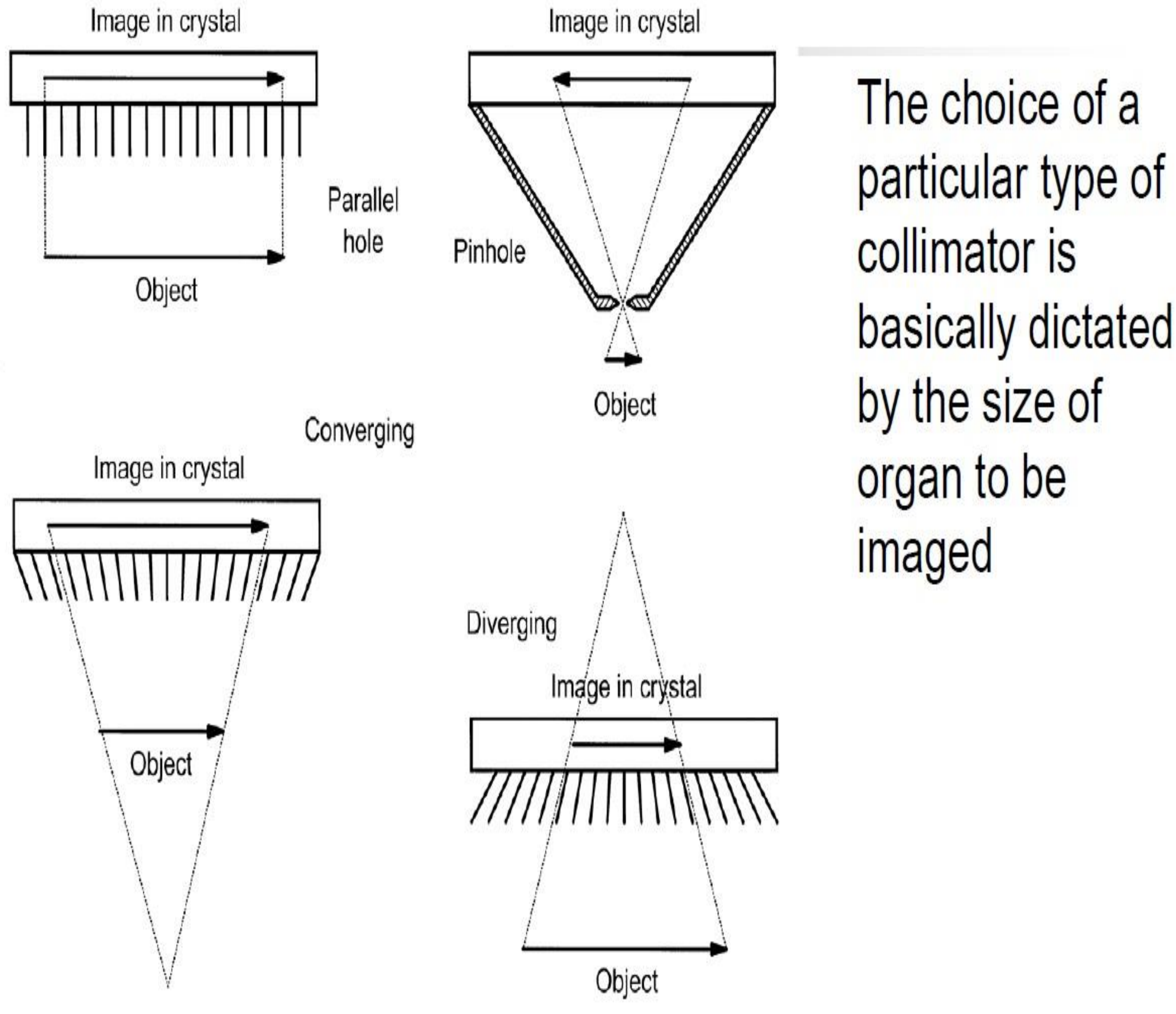
It consists of a lead plate containing a large number of holes. the parallel-hole collimator projected image of the same size as the source distribution on to the detector as figure (2-1). the parallel-hole collimator is used for most studies, other designs of collimator are available more specialized (peter, 2005).

c-Diverging collimator

diverging collimator achieve a wider field of view by angling the opposite way, outward the organ. This is used most often on a camera with a small crystal, such as portable camera as figure (2-1). Using a diverging collimator, a large organ such as the lung can be captured on the face of a smaller crystal (Rachel, 2006).

d-converging collimator

In the converging collimator the hole is not parallel but are angled inward, toward the organ as figure (2-1). The organ appears larger at the face of the crystal (magnifies the image) (Rachel, 2006).



The choice of a particular type of collimator is basically dictated by the size of organ to be imaged

Figure (2-1): Shows type of the collimator (Peter, 2005).

2.3.3 Detector

The function of the detector assembly to convert the gamma rays into a form that will allow visible image to be produced as figure (2-2). 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 oscillations are turned into electrical signals by the PMTs (peter, 2005).

2.3.4 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 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 100 Kev of gamma ray energy absorbed as figure (2-2). The lengthen 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 centimetres' in thickness (peter, 2005).

2.3.5 Light guide

light guide used to allow light to spread out from source position in crystal, originally, light guide was several cm 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 a PMT, but decreases resolution as figure (2-2). New cameras have a light guide only about 1cm or less in order to improve resolution, while uniformity corrections are now handled by microprocessor instead.

2.3.6 Photomultiplier tubes(PMTs)

The PMTs are usually arranged in a close packed array to ensure that the smallest possible gaps are left between tubs. Its consist of a photocathode that convert the light into an electron, dynodes that work on duplicate the number of electrons and anode that collected the 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 as figure (2-2). Even with this signal amplification pre-amplifiers built into the PMT are necessary to ensure a sufficient signal-to-noise ratio (peter, 2005).

2.3.7 PMT Amplification

PMT Amplification Total amplification of the PMT is the product of the individual amplification at each dynode if a PMT has ten dynodes and the amplification at each stage in 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 (~1300 V) first dynode (300), and then increment of voltage is 100V, finally reach to ANODE. Amplitude of pulse is proportional to the no of light photons received by the photocathode of y ray photon absorbed at the detector as figure (2-2).

2.3.8 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 have lost in several feet of cable Gain Factor-5-20, but (NaI(TI)) employ I (no gain) is placed as close to the detector as possible to maximize the performance (maximize SNR) function.

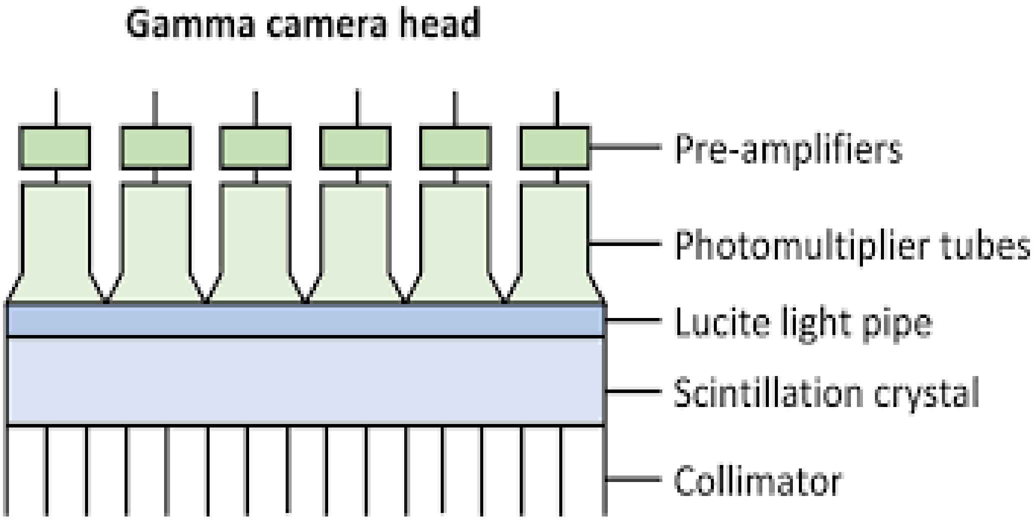
2.3.9 pulse height analyzer (PHA)

The PHA used to discriminate between scattered and unscattered photons. The operator defines upper and lower limits on the voltage. This only accept pulse corresponding to within a certain energy. when using a radionuclide that emit gamma rays at different energies, multiple window analyzer need to be employed as figure (1-2). It is important to remember at scattered radiation from the higher energy gamma’s may overlap in to the lower energy photo peak and this may influence which gamma ray energies should be selected (peter, 2005).

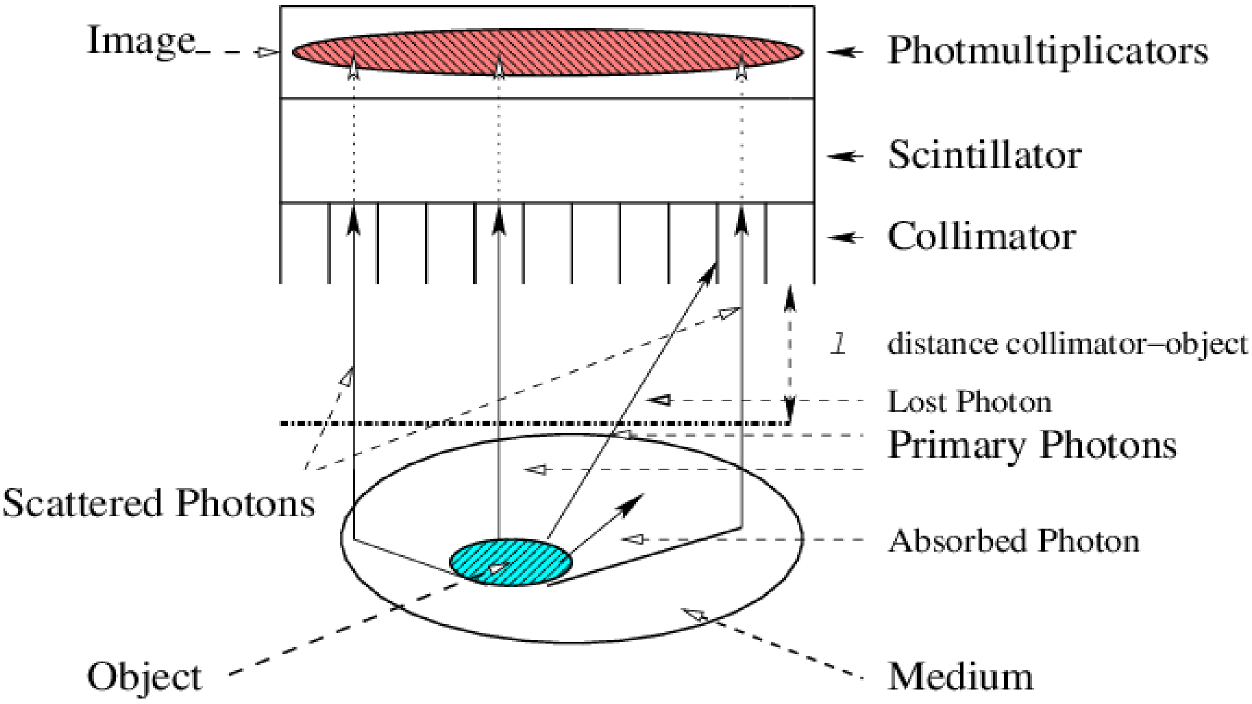
2.3.10 Image formation

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 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 the gamma ray events that have been detected in the corresponding location on the camera face as figure (2-2). 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 and display static image with array sizes of up to 2048x2048 pixels (peter, 2005).



A



B

Figure (2-2): A\Detector head of gamma camera. B\process of image obtained (Peter, 2005).

2.4 Source 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 Pulse Height Analyzer PHA (effect in uniformity).
- Thick crystal (bad resolution).
- Collimator damage (non uniformity due to crushed lead septa or lead foil separation).
- collimator structure artefacts (non uniformity due to large diameter hole, irregular lead foil construction).

2.5 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 performance 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 gamma camera is essentially the entire detector (crystal) area while the central field of view (CFOV)corresponds to the inner, or central, ¾ of the crystal area, the CFOV is the portion of the detector actually used in clinical imaging (Hans et al, 2007) (peter, 2005).

2.5.1 Spatial Resolution

The spatial resolution is related to the smallest separation between two point sources which will permit them to be distinguished as two distinct sources and is measured by imaging a point or line source it 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 (FWTH) is the width of the curve at one tenth of the maximum counts of the resulting curve (Hens et al, 2007) (peter, 2005).

2.5.2 Linearity

Linearity of the gamma camera image is tested by examination 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 refer 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 measured the maximum in adjacent segments of any one-line image (Hens et al 2007) (peter, 2005).

2.5.3 Sensitivity

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

2.5.4 Center of Rotation

It is assumed that the camera heads will rotate in near perfect circle and that heads will remain almost precisely aligned in their opposing position. It is also assumed that the predicated 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). Probability the most common cause of apparent displacement of COR is a result of errors not levelling 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).

2.5.5 Energy Resolution

Energy resolution it is defined as 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 photo 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 vial or syringe containing a small quantity of isotope without collimator and the computer displayed a plot of count veers energy. The user can then adjust the location and width of the window, for example a standard setting for technetium-99m is a photo peak of 140 Kev and the window of 20%(Hans et aI, 2007) (peter, 2005).

2.5.6 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 uniformly distributed throughout its extent 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, 2005).

Integral uniformity is defined as the largest variation (maximum-minimum) in count 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% (O'Connor, 1979).

2.6 Count Rate Characteristic

A gamma camera has a pulse processing time associated with each event. The region is reached in which the response of the camera (observed count rate) is no longer liner with increasing source radioactivity (true count rate). The theoretical linear response is obtained by extrapolation of the data points corresponding to count rates below 10^4 counts per second, it being assumed that no data loss occurs below this rate (peter, 2005).

2.7 National Electrical Manufactures Association (NEMA)

National electrical manufactures association is the trade body of gamma camera manufactures in the USA. They have defined arrange of standard tests for gamma camera performance in their publication (performance manufactures of scintillation camera NEMA 2001). The purpose of that publication is to define a common set of criteria for measuring camera performance that can be used by all manufactures defines two types of standard, performance standards and class standards (NEMA 2001).

2.8 Previous studies

Mark,2001, single photon emission computed tomography in the year 2001, titled as: instrumentation quality control, SPECT instrumentation is more complex than the used for whole body planner imaging and requires careful quality control to ensure optimum performance.

Goran, 2007, clinical center Banjaluka, RS, Bosnia and herzogovina, quality control in department of nuclear medicine, the aim of this work was to give a review of situation in the department of nuclear medicine in Banjaluka related to quality control (perform daily, weekly, and monthly) control of equipment.

Helena kopera and jarkkniemela 2006, Survey on quality control measurements for nuclear medicine imaging equipment in finland in 2006, stated that: routine quality control is an essential requirement in nuclear medicine in order to ensure optimal functioning of equipment, to harmomise the routine quality control of hospitals (planner gamma camera, SPECT, coincidence gamma cameras, PET). The radiation and nuclear safety authority will publish guidelines on quality control in collaboration with several hospital physicists. Recommendations will be provided on routine quality control measurements and on the frequency of testing. It is also planned to provide recommendations for the acceptance criteria when assessing different performance parameter for NM imaging equipment, in order to determine what performance parameters for NM imaging equipment are currently measured in hospitals, how frequently they are measured and what acceptance criteria are used, a survey was carried out on the quality control of NM equipment in finland during 2006.

Mohammed 2009, evaluation of intrinsic uniformity and relative sensitivity of quality control tests a single photon emission computed tomography (SPECT), the aim of study was to evaluate the optimum parameter (source activity, source volume, source volume, source distance, matrix size, number of count required and count required and count rates) affecting the intrinsic uniformity (IU) as quality control tests for the performance of a single photon emission computer tomography (SPECT). The relative sensitivity (RS) was determined also. The study was carried out at the Neelan medical diagnostic center in Khartoum NMDC, department of nuclear medicine. The tests were usually performed by exposure the gamma's crystal to a uniform radiation from a Tc^{99m} point source.

Ghanim 2012, evaluation of quality control program in nuclear medicine department in Sudan, the aim of that study is to evaluate routine quality control tests in nuclear medicine department procedures in Sudan and to compare the results with international guidelines, it includes three gamma cameras machines and three dose calibrators.

Salma 2013, Assessment of Gamma camera performance in nuclear medicine Department-Khartoum, this study was performed to evaluate the gamma camera machine performance and nuclear medicine at Alneelain Medical Center (NMDC) for the following parameters: Energy Resolution, Uniformity, center of rotation and sensitivity by using ^{99m}Tc.

Tagwa 2016, Evaluation of performance of the SPECT Camera in Elnilien Medical Diagnostic centre in Khartoum, the objective of this study is to evaluate the performance of the SPECT Camera in Elnilien Medical Diagnostic centre in Khartoum, the study evaluates the following parameter2: energy resolution, uniformity, sensitivity and linearity. All results that obtained from the study have been compared with the acceptance limits with IAEA and NEMA-2001 standards.

Chapter three

Materials and methods

Chapter three

Materials and methods

3.1 Materials:

The gamma camera used in this work is the Siemens single head gamma camera upgraded by Mediso medical imaging system installed in 1995 at institute of nuclear medicine – university of Gezira. The camera equipped with 37 hexagonal photomultiplier tubs (PMTs) and 300 mm diameter 9.5 mm thick NaI (TI) crystal. The main power supply is 220 volts (single phase) and main frequency of 50 Hz.

- Dose calibration
- Syringes
- Point source Tc ^{99m}
- Gamma camera

3.2 Method of data collection:

Measured were performance for evaluation of image resolution including uniformity, energy resolution and energy spectrum in gamma camera at nuclear medicine department in (National Cancer Institute -University of Gazira, Wad Madani).

These study are samples for quality control reading includes 61 (readings), Extrinsic uniformity 52, Energy resolution 9.

3.2.1 Energy resolution

The camera ability to distinguish between photons of different energies, in particular between primary and scattered radiation. Usually expressed in terms of the FWHM.

Procedure

- Peak the camera for the isotope used (Tc ^{99m})˒ select the window width of 20%, use matrix (512×512) (256×256).
- Sure the point source in the central of the detector.
- Place (Tc^{99m}) point source at distance 5×UFOV from the camera head.
- Acquire a digital energy spectrum.
- Calculate FWHM (keV) as %of peak energy.
- The ER is given by (Hans,2007)

ER%= (FWHM/photopeak center) ×100

3.2.2 Uniformity

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

Integral uniformity:

The difference between the maximum and minimum pixel count.

IU(%)=(max-min)/ (max + min) ×100

Differential uniformity:

The difference between two adjacent pixels.

DU(%)=(max-min)/ (max + min) ×100

Procedure

- Peak the camera for the isotope used (Tc^{99m}) ;select a window width 20%, use matrix (512×512).
- Sure the point source in the central axis of the detector.
- Place the (Tc^{99m}) point source at the 5*FOV from the camera head.
- Calculate integral and differential uniformity form the computer.

3.2.3 spectrum or photopeaking

This procedure apparent as curve to show the relationship between the detected and the measured energy of gamma photon.

Procedure

- Place (Tc^{99m}) point source at distance 5*UFOC from the collimator.
- Make the two head of collimator perpendicular to each other dual head.
- From main menu select and acquire patient study and press computer will calculate and then show the spectrum as figure (4-5)

Chapter Four

Results

Chapter Four

Results

4.1 Results of extrinsic uniformity

Table 4.1 shows Descriptive Statistics for Extrinsic uniformity test**:**

	Mean	STD	Minimum	Maximum
UFOV DIFF	2.008	0.3263	1.7	3.4
UFOV INT	3.280	0.9810	2.4	6.3
CFOV DIFF	1.816	0.2518	1.4	2.5
CFOV INT	2.806	0.7702	2.0	5.3

4.2 Result of energy resolution

Table 4.2 shows Descriptive Statistics of energy resolution using matrix 512× 512:

	Mean	Std. Deviation	Minimum	Maximum
FWHM	7.6150	0.12261	7.50	7.74
Energy Resolution	5.4350	0.08737	5.35	5.52

Table 4.3 shows Descriptive Statistics of energy resolution using matrix 256× 256:

	Mean	Std. Deviation	Minimum	Maximum
FWHM	7.9320	.73056	7.40	9.10
Energy Resolution	5.6620	.52299	5.28	6.50

4.4 Result of physical inspection

Table 4.4 shows descriptive physical inspection:

	Yes	**No**
Checking the computer and it is cables with the device	✓	
Was the electrical cables checked?	✓	
Was the collimator checked?	✓	
Was the head mountings checked?	✓	
Making sure that imaging screen works	✓	
Making sure that the camera works naturally	✓	
Making sure that there is no objective that can hinder the device movement or can collide it	✓	

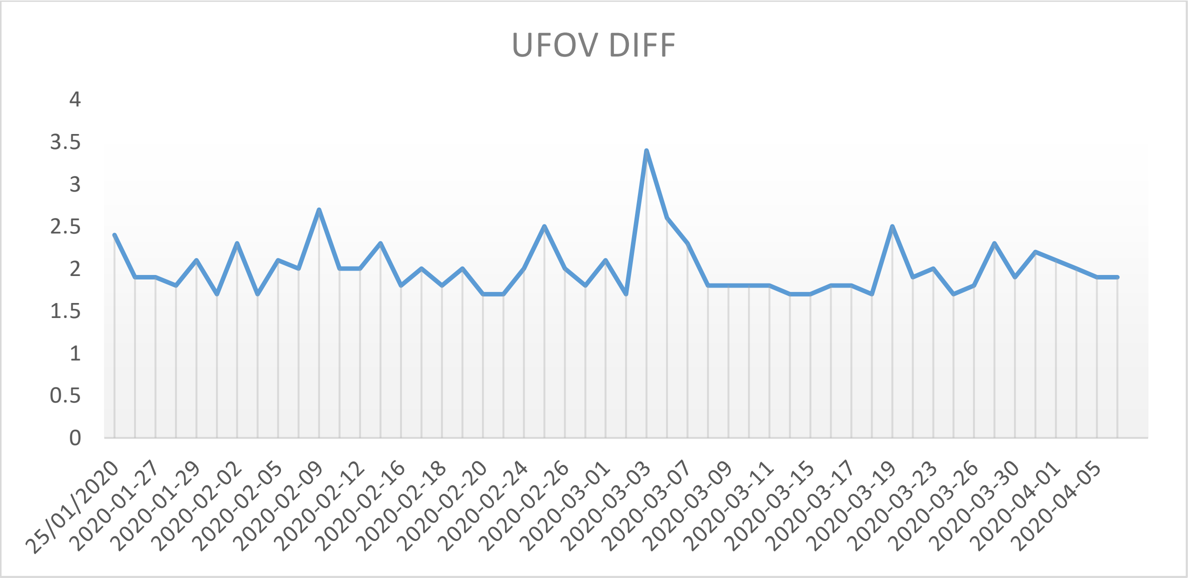


Figure 4.1 shows Extrinsic uniformity of useful field of view for DIFF

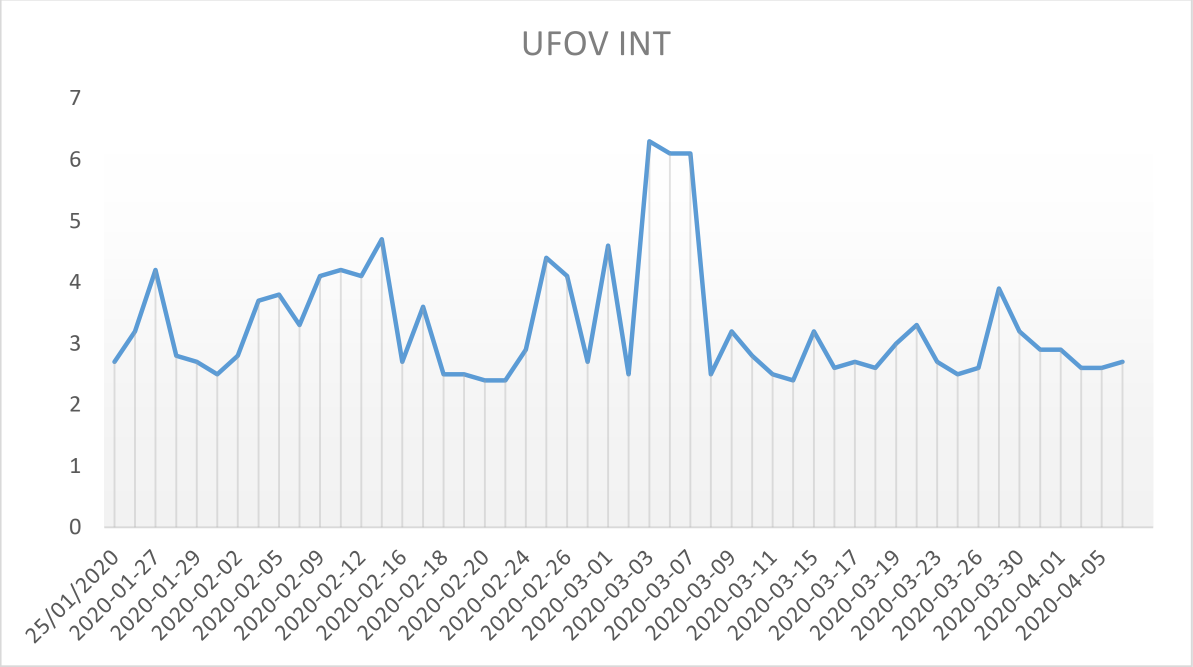


Figure 4.2 shows Extrinsic uniformity of useful field of view for INT

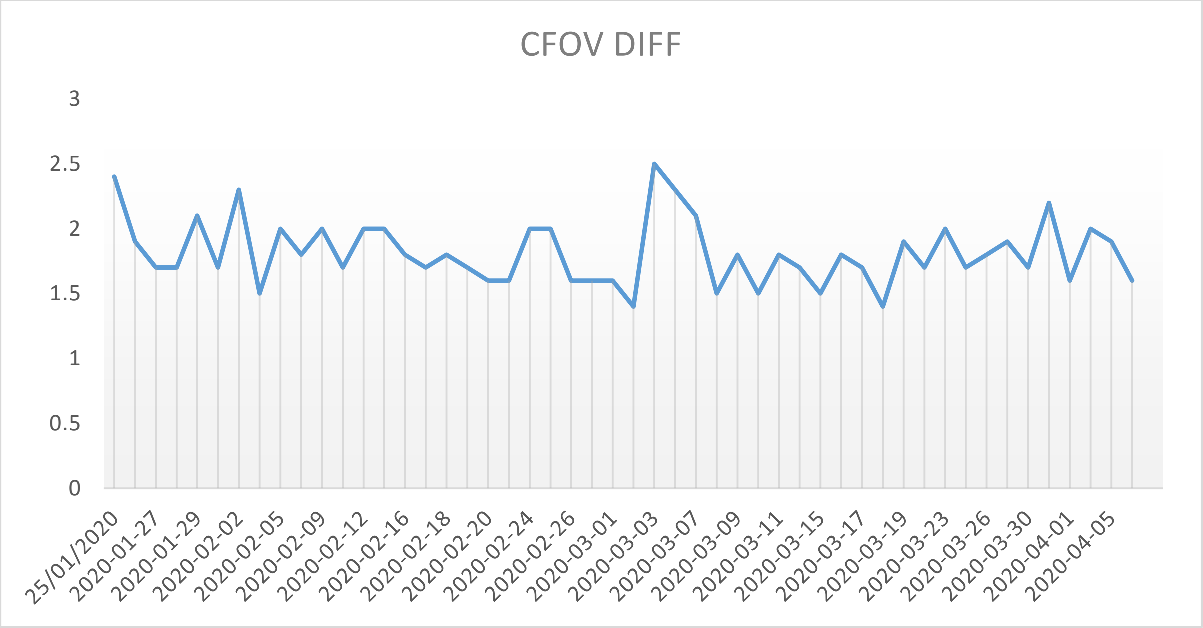


Figure 4.3 shows Extrinsic uniformity of central field of view for DIFF

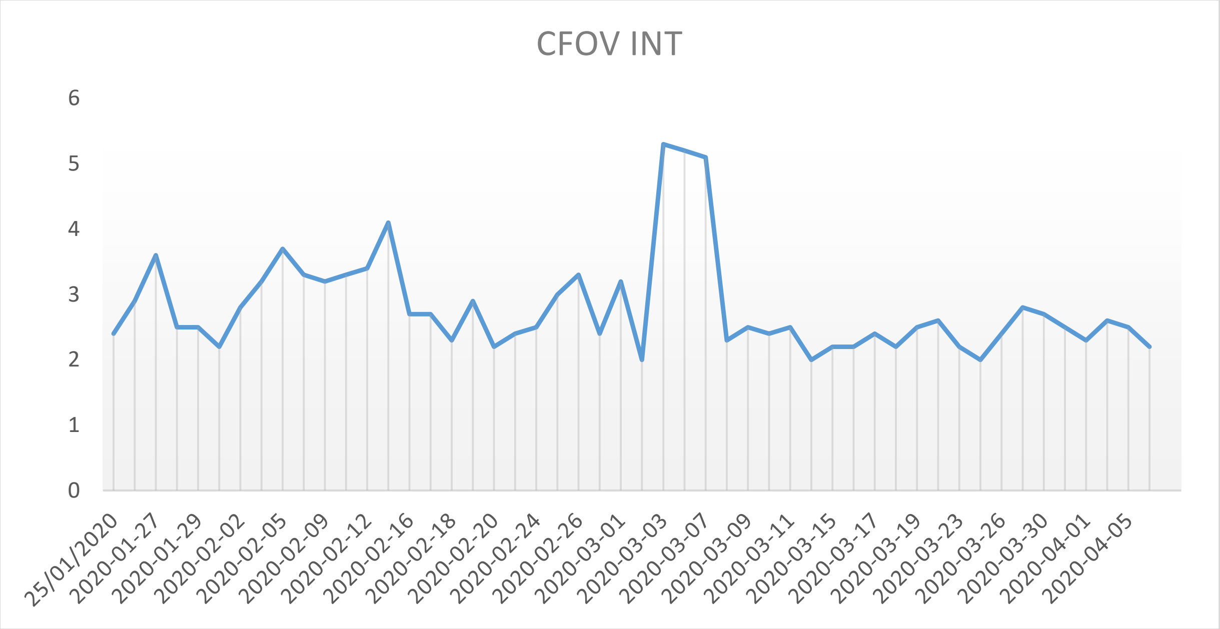
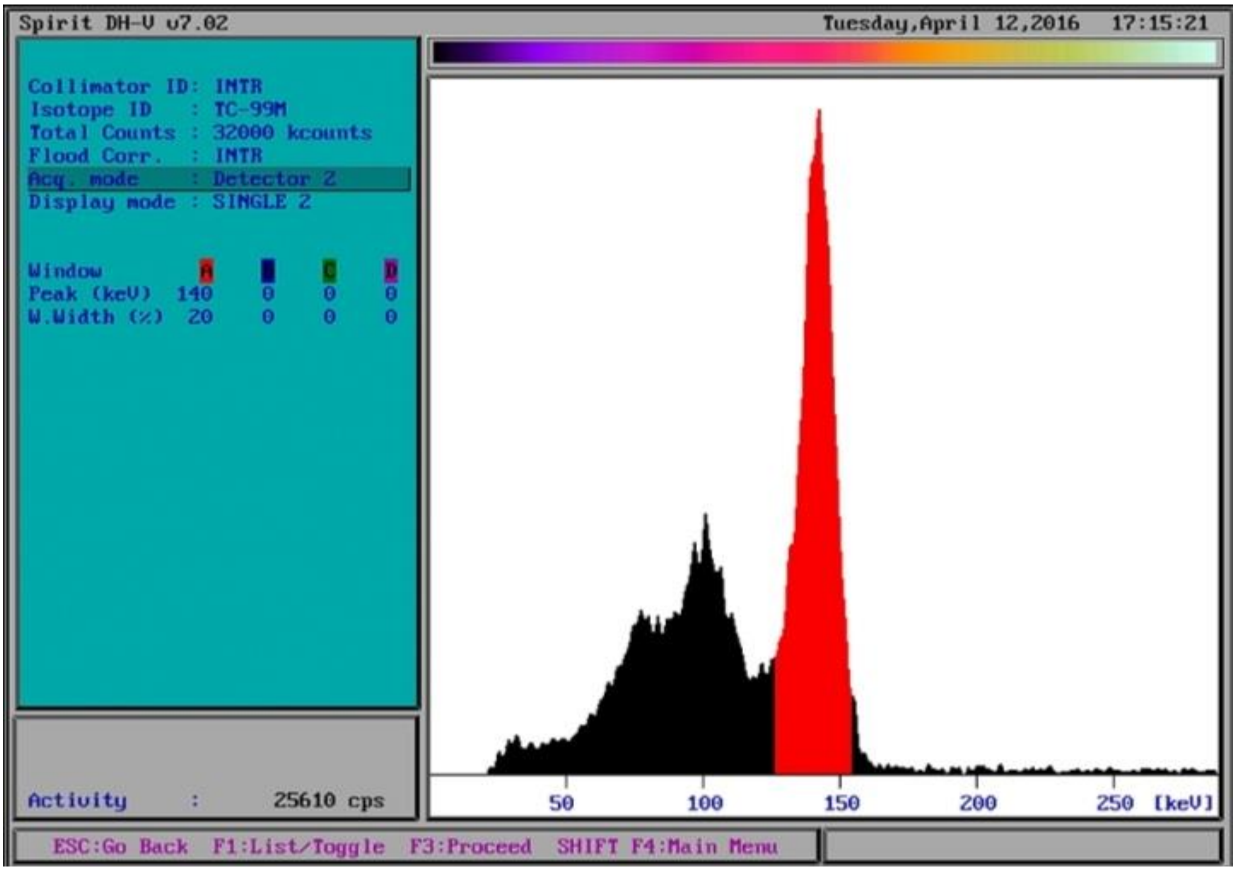


Figure 4.4 shows Extrinsic uniformity of central field of view for INT



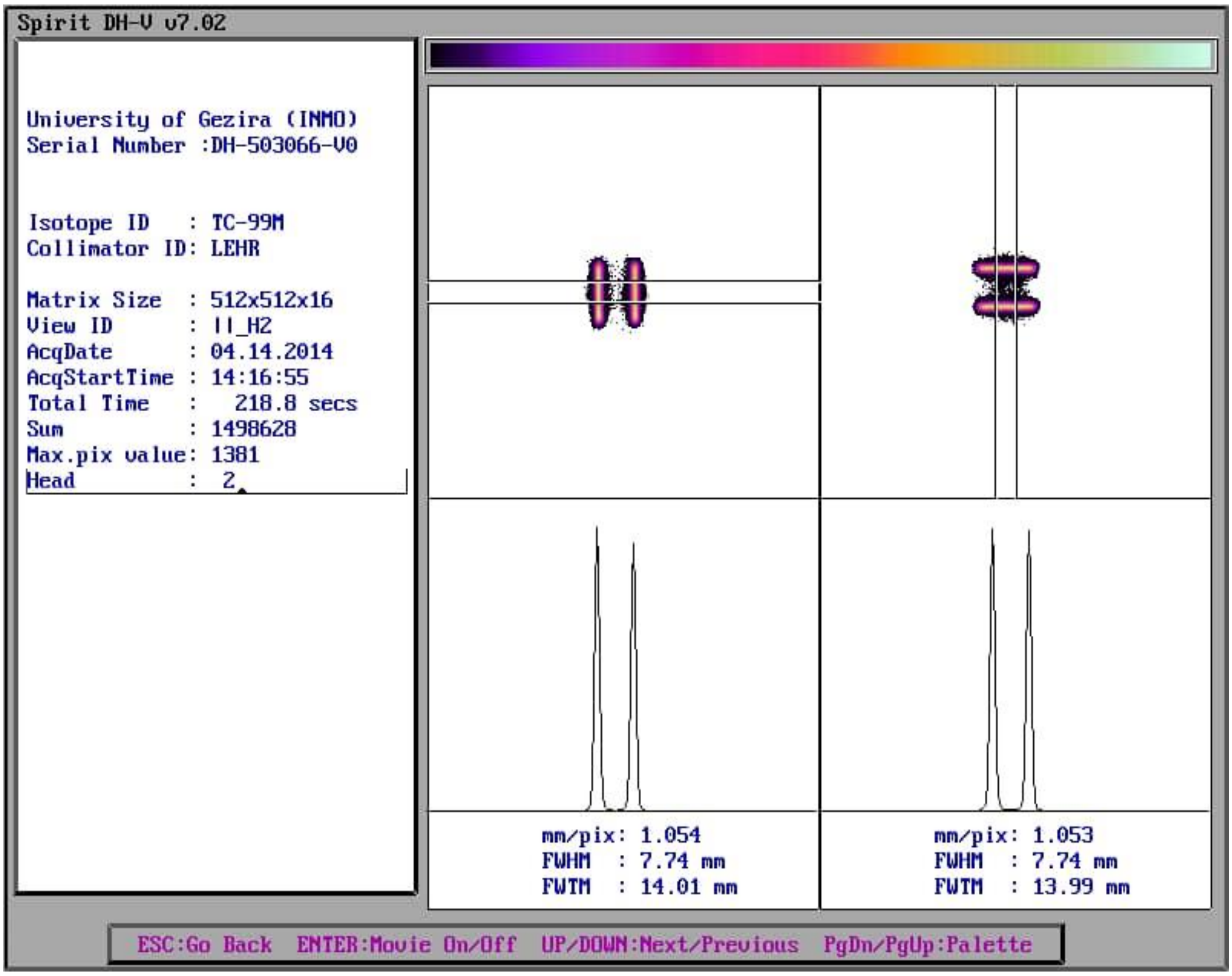
```
Spirit DH-V v7.02                          Tuesday,April 12,2016   17:15:21

Collimator ID:  INTR
Isotope ID    :  TC-99M
Total Counts  :  32000 kcounts
Flood Corr.   :  INTR
Acq. mode     :  Detector 2
Display mode  :  SINGLE 2


Window          A     B     C     D
Peak (keV)    140     0     0     0
W.Width (%)    20     0     0     0

Activity      :        25610 cps
```

Figure 4.5 spectrum of gamma camera machine in(NCI)



```
University of Gezira (INMO)
Serial Number :DH-503066-V0


Isotope ID   : TC-99M
Collimator ID: LEHR

Matrix Size  : 512x512x16
View ID      : ||_H2
AcqDate      : 04.14.2014
AcqStartTime : 14:16:55
Total Time   :   218.8 secs
Sum          : 1498628
Max.pix value: 1381
Head         :  2
```

```
mm/pix: 1.054
FWHM  : 7.74 mm
FWTM  : 14.01 mm
```

```
mm/pix: 1.053
FWHM  : 7.74 mm
FWTM  : 13.99 mm
```

Figure 4.6 energy resolution of gamma camera machine in(NCI)

Chapter five

Discussion, conclusion & Recommendations

Chapter five

Discussion, Conclusion & Recommendations

5.1 Discussion

Table 4.1 shows statistical parameters for all variables presented as mean, STD, min and maximum, for useful field of view DIFF and INT the (mean ± STD) was (2.008±0.33) and (3.28±0.98) respectively. For central field of view DIFF and INT the (mean ± STD) was (1.816±0.25) and (2.806±.077) respectively.

Table 4.2 shows descriptive statistics for full width of half maximum and energy resolution, were the (mean ±STD) (7.615 ±0.12), (5.435±0.09) was for matrix (512 × 512), these results were in the acceptable limits according to NEMA (not more than 10 %) and agree with Mohammed (2009) and Tagwa (2016).

Table 4.3 shows descriptive statistics for full width of half maximum and energy resolution, were the (mean ±STD) (7.932 ±0.52), (5.66±0.52) was for matrix (256 ×256), these results were in the acceptable limits according to NEMA (not more than 10 %) and agree with Tagwa (2016) and Salma (2013)

Figure 4.1 shows distribution of extrinsic uniformity result for useful field of view, were result of uniformity should not be more than 5%(less than 5%), for integral uniformity the mean result was 3.28 and for differential the mean reading was 2.008. which consider on very good result for extrinsic uniformity test.

For central field of view, the reading was very good were the mean result for differential and integral was 1.8116 and 2.806 respectively as shown in figure 4.3 and 4.4.

The energy spectrum test was result for hospitals was in the acceptable limits (140±10 KeV) according by NEMA and agree with Tagwa (2016).

The above result show that crystal of gamma camera gives high performance according to the NEMA protocol.

5.2 Conclusion

Quality control is required to ensure that nuclear medicine equipment is functioning properly. This quality control tests are intended to detect problems before they impact on clinical patient studies for gamma camera machine (SPECT). The researcher managed to evaluate the image resolution of the single photon emission computed tomography working in (National Cancer Institute - University of Gazira, Wad Madani)

The quality of medical images was high and provides good care of patients. A regular quality assurance tests improve quality management of nuclear medicine imaging.

The following chapter data with the main obtained and information after analysis, which could be enumerated in following points: -

- The data reveal that the extrinsic uniformity for differential and integral (UFOV, CFOV) in the accepted limits that established by NEMA-2001.
- The data reveal that the energy resolution showed a central peak of the energy at 140 KeV, and the value of energy resolution was 5.4%.

5.3 Recommendations

- Appling a quality assurance programme (QA) that include quality control test for gamma cameras machines, radionuclide and those calibrators, waste management and radiation protection programme, to decreased the radiation risk for patients and staff.
- Appling the ALRAA (As Low As Reasonability Achievable) principle in nuclear medicine diagnostic to reduce the radiation dose for patients.
- Raising the standards of technologists through training the quality of the image and prevent repetitions.
- The regular quality control of gamma camera is essential to ensure proper function of the device.

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Appendices

Appendix (I)

*Extrinsic uniformity

	useful field of view		**central field of view**		**Peaking test**
	DIFF	INT	DIFF	INT	20% window

*Energy resolution

Isotope	Matrix	FWHM	ER%

Appendix (II)

Photograph of gamma camera machine