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Quality Control Tests of SPECT- CT

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Abstract: The one of the aim of nuclear medicine is diagnosis of an abnormal metabolic activities in target organs. In a routine nuclear medicine imaging procedure, a radiopharmaceutical is used. Radiopharmaceutical's radionuclide part emits gamma radiation. This radiation is dedected by Gamma Camera or Single Photon Emission Computed Tomography (SPECT). A computed tomography (CT) device was added to the SPECT(SPECT- CT). To combine anatomical images. Image quality of this device is important for accurate diagnosis and treatment of diseases. By means of quality control tests, performance changes of device are dedected. A various quality control parameters such as uniformity, sensivity, resolution, linearity have been developed for Gamma cameras, SPECT. Quality control test results are should be verify by comparing acceptable results. In this study, quality control tests of SPECT-CT are performed as proposed by the National Electrical Manufacturers Association (NEMA) and it was aimed to investigate some correction methods.

***Keywords**:* Gamma camera, SPECT, SPECT – CT, Quality control tests

SPECT – BT 'nin Kalite Kontrolleri

Özet: Nükleer tıbbın amaçlarından biri hedef organlardaki anormal metabolik aktivitelerin tanısıdır. Rutin bir nükleer tıp görüntüleme sürecinde, radyofarmasötik kullanılır. Radyofarmasötiğin radyonüklid kısmı gama radyasyonu yayar. Bu radyasyon Gama Kamera veya Tek Foton Emisyon Bilgisayarlı Tomografi (SPECT) tarafından dedekte edilir. Anatomik görüntüleri birleştirmek için SPECT cihazına Bilgisayarlı Tomografi (BT) cihazı eklenmiştir (SPECT – BT) . Bu cihazın görüntü kalitesi doğru tanı ve hastalıkların tedavisi için önemlidir. Kalite konteol testleri sayesinde, cihazdaki performans değişiklikleri belirlenir. Homojenite, sensivite, rezolüsyon, linearite gibi çeşitli kalite kontrol parametereleri gama kameralar ve SPECT için geliştirilmiştir. Kalite kontrol testi sonuçları kabul edilebilir sonuçlarla karşılaştırılarak doğrulanmalıdır. Bu çalışmada, SPECT-CT'nin kalite kontrol testleri National Electrical Manufacturers Association (NEMA) tarafından önerildiği gibi yapılmış ve bazı düzeltme yöntemlerinin araştırılması amaçlanmıştır.

***Anahtar kelimeler**:* Gama kamera, SPECT, SPECT –BT, Kalite kontrol testleri

1. Introduction

Nuclear medicine provides the diagnosis of illnesses and the treatment some diseases byusing radiopharmeucaticals. There are two components to obtain a nuclear medicine

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image. These are a radionuclide which emits gamma radiation and a dedector system that detects gamma radiation emited by patient. Radiopharmaceutical is combined with radionuclide (Technetium – 99m, Iodine -131) and a pharmaceutical which is provided to accumulate radionuclide in target organs [1]. When radionuclide decays, gamma rays are emitted from the target organ of the patient. This radiation is detected by an external dedector system called as gamma cameraoras Single Photon Emission Computed Tomography (SPECT). Thus, metabolic images of organs are created by using these detector systems [2,3]. Gamma camera images are planarimagingsystemwhile SPECT images are tomographic imaging systems. Agamma camera providesradiation distribution in the patient from onlyone specific angle. But, this planarimage have insufficient depth information. On the other hand, in SPECT imaging system, a gamma camera rotates around the patient and provides cross – sectional imaging and this images have depth information.

Computed tomography (CT) whichuses x- rays to obtain cross sectional imaging of area of the interested body, is a digital imaging method. Computed tomography is a highly advanced device compared to the conventional x-ray device. Planar images are obtained with conventional x- ray device whereas CT images is provided with three dimensional cross sectional images. As it in the conventional x ray imaging device, CT uses photoelectric mechanism which is main absorbtionmechanism in the tissue of low energy radiation. X-ray is being held in excess in regions with high atomic number whereas in regions with low atomic numbers, it retains a small amount of x-rays. Thus, CT dedectors detectes the radiations inversely proportional to tissue density. For this aim, x ray tube rotates 360 degrees around the patientand transmists x rays in the form of a narrow beam. CT images determine anatomic locations of organs. [4].

Combination of gamma camera and computed tomography is called as SPECT- CT Hybrid System. There are several advantages SPECT-CT hybrid system used in nuclear medicinecompared to conventional gamma camera. SPECT and CT images are merged to form fusion images. Hybrid imaging systems are merged anatomic information and morphologic information [5].

The main aim of quality controls are to create hight quality images that are showed the distribution of radionuclide in the patient. Image quality of nuclear medicine depends on multiple parameters. Some of these parameters such as spatial resolution, homogenity, noise and contrast are basic for image quality controls of SPECT-CT. Thus, this device's quality controls are separately consist of gamma camera, SPECT camera, CT camera and SPECT-CT camera quality controls. When a gamma camera is used for SPECT imaging, additional parameters should be included in quality control tests [6].

Generally, gamma camera quality control tests are performed by using gamma emitter radionuclides such as ^{99m} Tc which emits gamma radiation. The radionuclides in this form are referred to as reference sources. Leakage may cause radioactive contamination. Thus, these sources should be checked for leakage [6-7].

In this study, periodic quality control tests were performed using ^{99m} Tcfor a SPECT-CT GE trademark NM/CT 670 model SPECT-CT devicein Istanbul University, Faculty of Medicine, Department of Nuclear Medicine(Figure 1).Test results were compared with the NEMA standardsand*International Atomic Energy Agency*(*IAEA*).

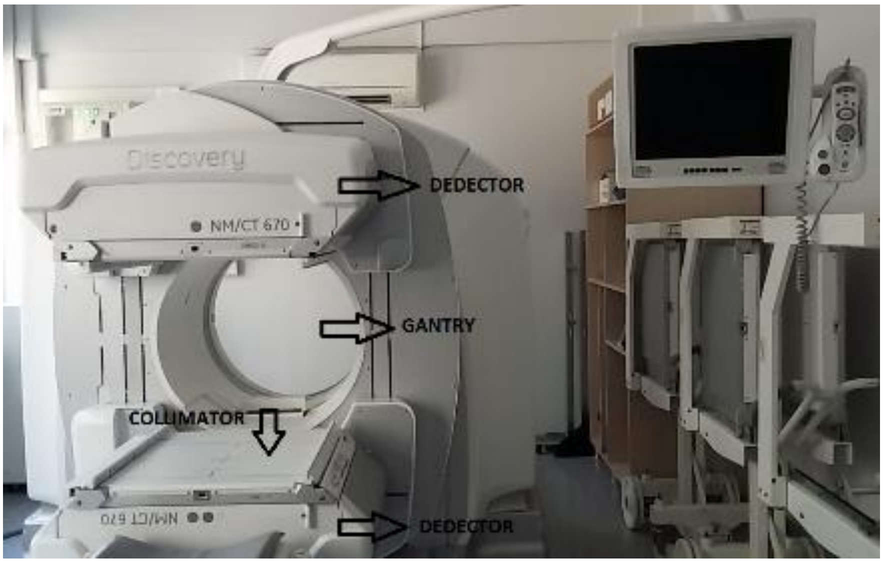

Figure 1. GE NM/ CT SPECT CT device companents

2. Material and Method

2.1 Gamma Camera Quality Control Tests

A gamma camera is a basic nuclear medicine imaging device. In a routine gamma camera imaging procedure, gamma rays emited from patient passes through the collimators. Collimators allow to pass only gamma rays traveling in specific directions. Then, gamma rays interact with thallium activated sodium iodine (NaI(Tl)) cyristal. Gamma rays are converted to scintillator photons in NaI (Tl).After then, scintillation photons are converted to an electrical pulse by photomultipler tubes (PMTs) [8].

Any physical impact in NaI(Tl) crystal may causes in an irreparable damage in gamma camera. Furthermore, this situationmay requests replacement of cyristal. A small defect in collimator will be result asacold spot in gamma camera images. Therefore, quality control of cyristal should be performed carefully.

NEMA is standart for Gamma camera quality control tests. Quality control tests involve spesific phantoms and equipments. In our study, we used NEMA standarts for gamma camera quality control tests. The quality control tests of the SPECT-CT system are described in detail below.

2.1.1 Physical Controls and Background Activity Test

Before quality control tests, devices's physical control should be performed. This test should be performed not only for quality control tests but also for routine patient scan. In physical kontol test; patient table, electrical connection cables, collimators, sodium cyristals are should be checked. Furthermore, temperature and humidity should be measured before quality control tests.

Background radiation in nuclear medicine departments is called as radioactive contamination. Radiactive materials infected on patient table, walls, doors or floor is a radioactive contamination. Radioactive contaminationmay affect quality control testsadversely. Therefore, background levels should be lower than the number 250 in 10 seconds. This tests are performed daily [9].

2.1.2 Photopeak Energy Test

This test measures the intrinsic response of gamma camera versus energy of radionuclides commonly used in nuclear medicine. Gamma energy of ^{99m} Tc is 140 keV. Gamma energydetected by gamma camerashould be compatible with ^{99m}Tcgamma energy as recommended in NEMA. Physicist should be carefull for any damage on the surface of cyristalsbecuse test is performed without collimator. For the test set-up, 1 mCi ^{99m}Tc is placed at a distance of five times the length of the camera field of view (Figure 2).This test is performed for each dedector. Count rate in any testshould not be exceed 30 000 counts/s.If a department uses different radionuclides, this test should be repeated for this special radionuclide. This test is performed daily[7].

Figure 2. Gamma camera position for photopeak energy test.

2.1.3 Intrinsic Uniformity Test

The same setup described above for Photopeak Energy Testis used. Intrinsictly gamma camera uniformity was evaulated without collimator. Intrinsic uniformity test is performed with 1 mCi^{99m}Tcpoint source. Dedectors were rotated 90 degrees and placed aganist radioactive source. To achive homogeneous image, the system is peaked for ^{99m} Tc with a 20 % window. Source was placed at a distance as five times of cyristal dimensions. In 256x256 matrix, 5 millions count is adequate for this test. It isnoted that count rate dosen't exceed 20.000 count/ second [8]. This test should be performed daily. It can also be performed monthly according to count number. Instrinsic uniformity test should be performed for each dedector. There are two important parameters to evaulate this test. These are Useful Field of View (UFOV) and Centered Field of View (CFOV) which is 70 percent of UFOV. Determine the maximum and minimum counts at pixels within UFOV and CFOV, Integral Uniformity and Differantial Uniformity are calculated. Quantitive analysis is used to evaulate tests for this parameters. Generally, Integral and DifferantialUniformities should be 3% <for 5 million counts for camera. This test is also evaulated visually. Radiation distribution should be homogenous for a succesfull intrinsic uniformity test.

2.1.4 Extrinsic Uniformity Test

Extrinsic uniformity test was performed with collimator and used radionuclide's activity was higher than used in intrinsic test. This test was performed to detect homogeneity defects originated from the collimator. In extrinsic uniformity test, tap water and 22 mCi ^{99m} Tc were used in flood phantom (called as planar sheet source). Flood phantom was shaken to create a homogenous distribution. All air bubbles in the phantom was ejected. Then phantom was waited several hours. When activity was 18 mCi, phantom was placed between gamma camera's dedectors (Fig. 3). The system was peaked for ^{99m}Tc with a 20 % window. In 256x256 matrix, 5 millions count are adequate for this test. Test was repeat for each dedector. Test results are evaulated both visually and numerically. Visual assessments evaluate presence of hot or cold spots originated from PMT's defects. This test is performed monthly [9].

Figure 3.^{99m}Tc Planar Sheet Source (water filled) and Extrinsic Uniformity Test Set- up

2.1.5 Spatial Resolution and Linearity Test

4 – quadrant bar phantom was used in spatial resolution and linearity test. In spatial resolution test, we measured how device can distinguish small details. Any defects occurred in spatial resolution affects the homogeneity. Test was performed monthly for each dedector without collimator. ^{57}Co flood source (Activity: 10 mCi, Reference Date: 1-Apr-12) was placed on 4-quadrant bar phantom (Figure 4).This system was placed on NaI(Tl) cyristal. In 128x128 matrix, 10 millions counts were adequate[9]. Bar phantom has four different tickness area. Spatial resolution test is evaluated visually.

Linearity test is related with linearity of bars. This test's protocol is the same with spatial resolution test. If linearity is defected, there are fluctuations in the bars on the phantom. The linearity test is evaulated visually. Spatial resolution and linearity test is performed as six –monthly [8].

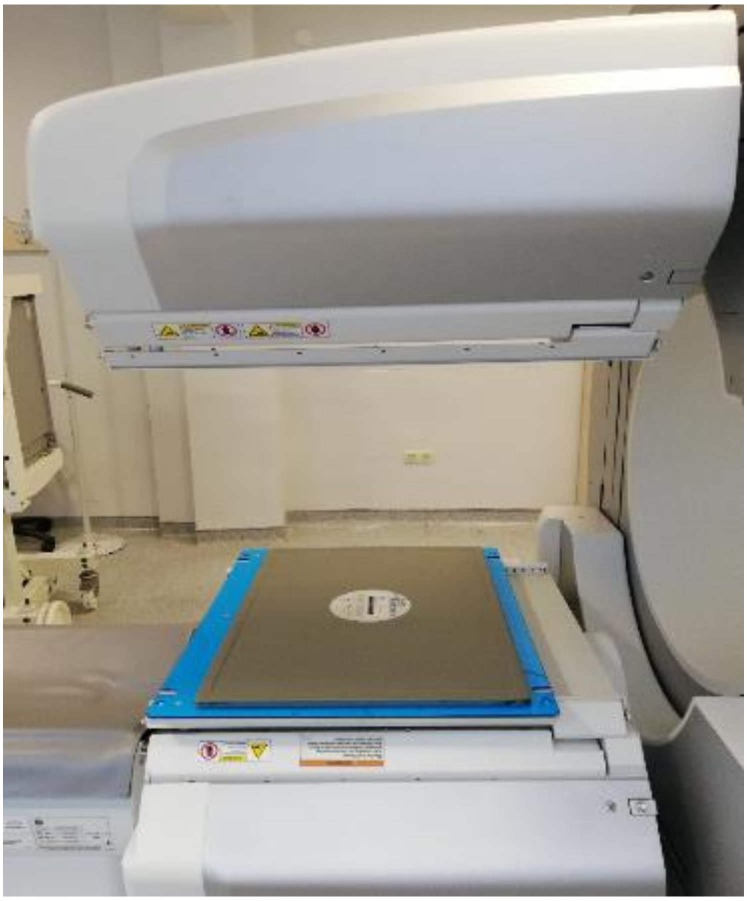

Figure 4. 4 Four- quadrant bar phantom set- up

2.2 SPECT Quality Control Tests

SPECT is used to acquire 3D images of a object. Therefore, SPECT instrumentation is more complex than planar gamma camera imaging. In addition to gamma camera quality control tests, SPECT imaging device requires spesific protocols due to its tomografic imaging. SPECT quality controls includes center of rotation (COR) alignment, SPECT Resolution and Homogeneity Test and Alignment of Camera with Axis of Rotation.

2.2.1 Center of Rotation (COR) Test.

COR quality control test is the most basic test for SPECT imaging device. CORmisalignment causes image – bluring artifacts in SPECT images. Furthermore, uncorrected COR matching causes spatial resolution errors in images. Center of camera'sdedector should be matched with center of images. In 128x128 image matrix, even 0.5 pixel COR errors may lead to defect image quality. In this test, 1 mCi ^{99m} Tc point source was used. SPECT dedectors were rotated 0 and 180 degree around point source [10].According to NEMAstandarts, the mean value of COR offset should be less than 2mm.Weekly check is adequate for COR quality control test [8].

2.2.2 SPECT Resolution and Homogeneity Test

This test was performed for overall system peformance. Jaszczak phantom was used in test [11]. This phantom has different six cold rods (12.7, 11.1, 9.5, 7.9, 6.4, 4.8 mm) and six cold spheres (31.8, 25.4, 19.1, 15.9, 12.7, 9.5 mm) as shown in figure 5. An activity of 22.7mCi ^{99m}Tc was added toJaszczak phantom with tap water. To obtain a uniform Jaszczak phantom, phantom was shacked and itwas waited at hot room in nuclear medicine department. After activity was decreased to 15 mCi, phantom was used for test. Jaszczak phantom was localised on the patient tableas shown in Figure 6.In 256x256 matrix, total 60 images, namely, 60 millons counts, were measured for each dedectorsThis test was evaulated visually. If the smallest sphere of Jaszczak phantom can be observed, the test is considered successful. SPECT Resoultion and Homogeneity test is performed every three or six month [11].

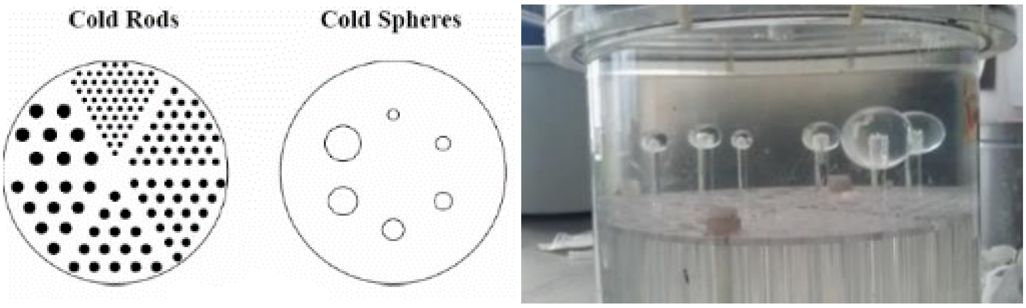

Figure 5. Jaszcazck Phantom

Figure 6. Placement of Jaszcazck Phantom between dedectors.

2.2.3 The Test of Alignment of Camera with Axis of Rotation

The best image that can be obtained in a SPECT device is provided by being parallel to the rotation axis of the detectors. In this test, a phantom was setup to place the point source in the desired position.100 μCi point source was placed a certain distance from the X axis of devicewith the aid of the laser lights on the computer tomography (Fig.7).Test was performed without collimator.

Figure 7. Placement of point source between detectors for testof Alignment of Camera with Axis of Rotation

The position of the phantom above is 0 degrees. The head of the SPECT device was rotated with the increasings of 20 degrees and taken 7 images. For the test result to be acceptable, a linear line should be created when all projection images are overlaid. The test is performed three months.

2.3 Computed Tomography Quality Control Tests

A computed tomography is an important imaging device that is frequently used in radiology. CT device requires regular quality control tests as it cause highest patient radiation dose among all radiological imaging system. Thus, CT tests are important for patients' radiation safety and image quality. But, SPECT-CT is an hybrid system which is consist of a SPECT and CT. Therefore, quality conrol tests for CT areonly performed for SPECT- CT hybrid systems.

2.3.1 Test of Couch Movement

Couch movement test is among the mechanical quality control tests of computerized tomography. Couch movement test is performed to control the movement of computed tomograpy table. Gafchromic filmswereused in the test. The filmswere placed on the patient table.30 kVp and 400 mAs paramaters were selected for irradiation of films. Gafchromic film was irradiated with leaving one-gap section in CT. Testshould be performed monthly [12].

2.3.2 Test of CT Number In Water

Generally, CT number tests are performed to determinethedefectsin images. A homogenous water phantom was used for this test. Used phantom should be centered in the field of view and aligned along the z axis byusing lasers.120 Kvpand 260 mAs parameters were selected for phantom’s axial scannig. To evaluate this test, a field of 100 pixels was drawn at the center of the phantom image. Field should be compatible with CT number of water. Normally, HU is normalized to 0 for water. For this test, HU number of CT for water should be in range of 0±4HU. Test should be performed monthly [13].

2.3.3Test of High Contrast Resolution

High Contrast Resolution test is among the image quality control tests of computed tomography. In this test, imaging ability of CT is tested for smallest objects. Additionally, this test is performed how the CT distinguishes between two high contrast objects placed close together. For this test, a phantom with six barn pattern was used (Fig.8).Used phantom should be centered in the field of view and aligned along the z axis byusing lasers. 120 Kvpand 260mAs parameters were selected for axial scanning. If smallest line of phantom is observed, test is considered successful [13].Test should be performed weekly[14].

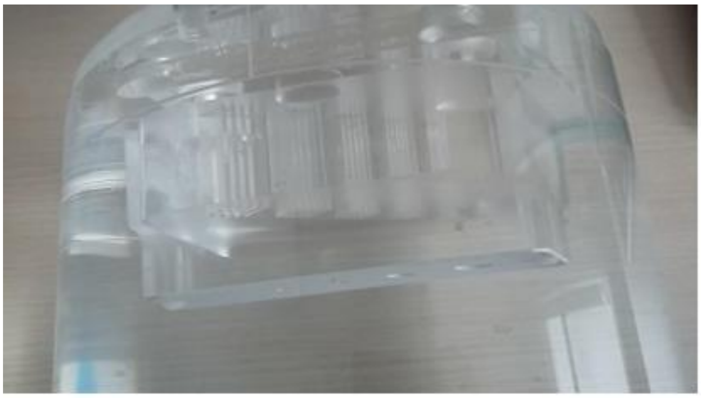

Figure 8. Six barn patternphantom

3. Results

3.1 Gamma Camera Test Results

3.1.1 Physical Controland Background Activity Test Result

Before quality control tests, the system's mechanical parameters were checked. And also, physical controlwere performed before quality control tests. It was determined that there was no mechanical damage on device to start quality control tests. It was decided that the device was ready for routine imaging.

Then, background radiation was measured. Background activity test was performed for each dedector. Background activity was lower than 300 counts per second for each dedector. For dedector 1 and dedector 2, background activity was measured as 200 and 150 counts per second, respectively. Test results are shown in Figure 9.

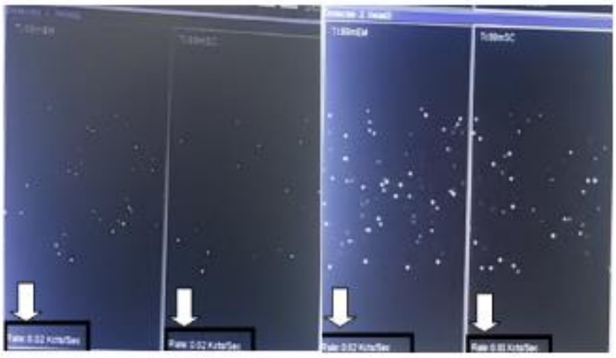

Figure 9. Background activity test results for each dedector.

3.1.2 Photo Peak Energy Test Result

For photo peak energy test, gamma energies were 140.53and 140.54 at "value" coloumn in Figure 10. for dedector1 and dedector 2, respectively. Test results are shown as "passed" in "status" coloumn in Fig. 10. Gamma energy detected by each dedector was compatible with ^{99m} Tc gamma energy (140 keV) [13-16].

Detector 2

Name	Value	Status	Rule
Detector #2 Isotope	Tc99m	N/A	N/A
Detector #2 Energy Peak	140.53	Passed	140.5+-3.0

Detector 1

Name	Value	Status	Rule
Detector #1 Isotope	Tc99m	N/A	N/A
Detector #1 Energy Peak	140.54	Passed	140.5+-3.0

Figure 10. Numerical results of photopeak energy test

When Figure 11 was analyzed for visual assesment of photo peak energy test, it was seen that gamma energy detected by each dedector was compatible with 140 keV. If gamma energy detected by dedector is not compatible with ^{99m} Tc gamma energy, homogeneity defetcs can be occured on images. If the energy peak is lower than 140 keV, PMTs can appear bright on images. So, this can cause the hot spots on images. If energy peak is higher than 140 keV, PMTs can appear weak and this can cause cols spots on images [13].

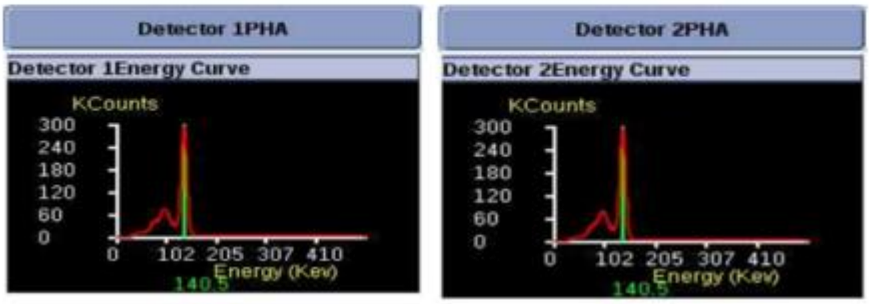

Figure 11. Photopeak energy test results for each dedector.

3.1.3 Instrinsic Uniformity Test Result

According to IAEA reports, Instrinsic uniformity test results were evaulated both visually and numerically as in Figure 12. and 13 [16]. As shown in Figure 13, radiation distribution is homogenous for dedector 1 and 2. Uniformity CFOV and UFOV values are lower than 5.0 and 5.5 as shown at "values" coloumn in Figure 13.

3.1.4 Extrinsic Test Result

As shown in Figure 15, radiation distribution is homogeneous in all images region for both camera.

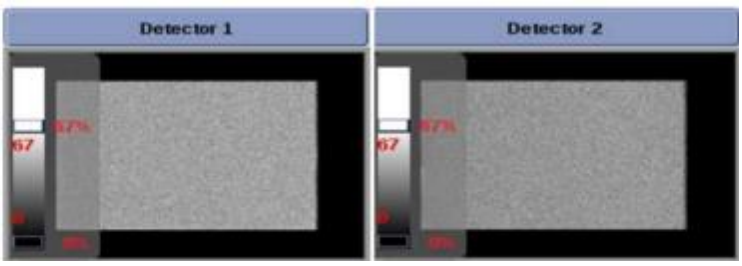

Figure 12. Intrinsic homogeneity test results for visual assesment

Detector 1

Name	Value	Status	Rule
Detector #1 Isotope	Tc99m	N/A	N/A
Detector #1 Energy Peak	140.54	Passed	140.5+-3.0
Detector #1 FWHM	9.24	Passed	<=11.0
Detector #1 Count Rate	45.9	N/A	N/A
Detector #1 Total Count	4000	Passed	>=4000.0 and <=400000.0
Detector #1 Uniformity CFOV	2.60695	Passed	<=5.0
Detector #1 Uniformity UFOV	2.60695	Passed	<=5.5

Detector 2

Name	Value	Status	Rule
Detector #2 Isotope	Tc99m	N/A	N/A
Detector #2 Energy Peak	140.53	Passed	140.5+-3.0
Detector #2 FWHM	9.22	Passed	<=11.0
Detector #2 Count Rate	44.37	N/A	N/A
Detector #2 Total Count	4000	Passed	>=4000.0 and <=400000.0
Detector #2 Uniformity CFOV	3.737939	Passed	<=5.0
Detector #2 Uniformity UFOV	4.99673	Passed	<=5.5

Figure 13. Intrinsic Uniformity Test Numerical Results

An incorrect intrinsic homogeneity test result reported in the literature as shown in Figure 14 [17].PMTs are quite salient in the figure, because this device's dedected gamma energy peak is not compatible with using radionuclide's gamma energy. This is caused some deformation in intrinsic homogeneity test result.

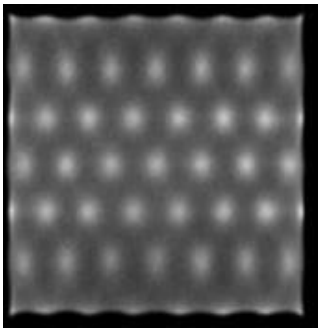

Figure 14. Incorrect intrinsic homogeneity visual test result reported in the literature [17].

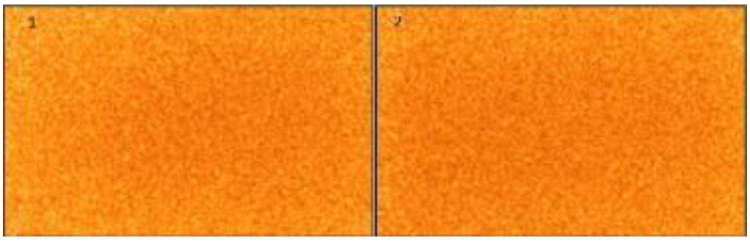

Figure 15. Extrinsic uniformity test results for each dedector.

3.1.5 Spatial Resolution and Linearity Test Result

Spatial resolution and linearity test resultsfor each dedector are given seperately in Figure16, 17, 18, and 19. As shown in Figure 18, each bar of pattern is linear and the smallest bar of pattern can be observed. Addition there was no asymmetry on the lines of phantom. Test is succesfull according to NEMA standarts [15].As shown Figure 20,21, 22 and 23, results of test at “values” column are compatible with “rules” column.

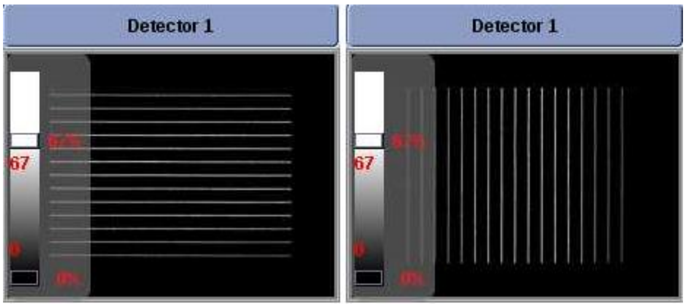

Figure 16. Spatial resolution test result for dedector 1

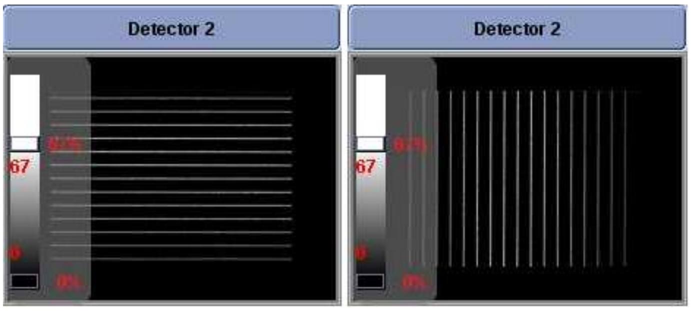

Figure 17. Spatial resolution test result for dedector 2

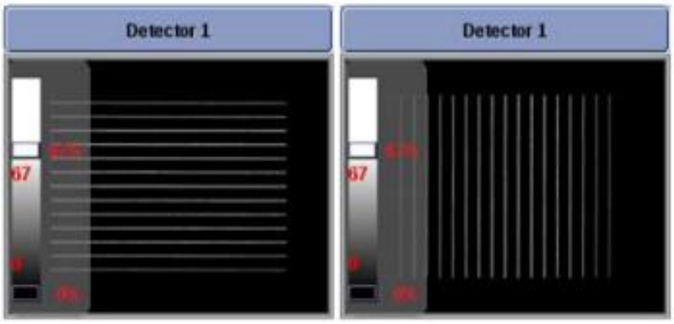

Figure 18. Linearity test result for dedector 1

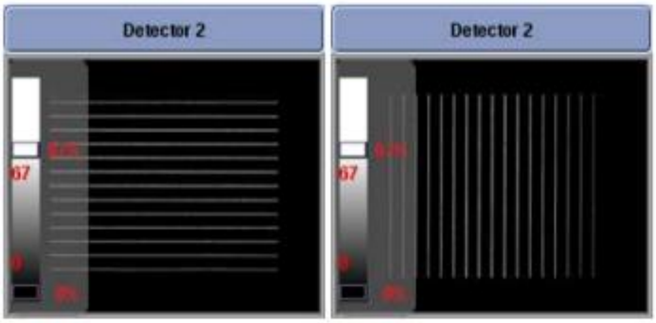

Figure 19. Linearity test result for dedector 2

Detector 1

Name	Value	Status	Rule
Detector #1 CFOV FWHM Average	3.454	Passed	<=3.8
Detector #1 CFOV FWTM Average	6.514	Passed	<=7.1
Detector #1 CFOV FWHM Standard Deviation	0.323	N/A	N/A
Detector #1 Calibration Factor	0.551	N/A	N/A
Detector #1 X CFOV - FWHM Average	3.472	Passed	<=3.8
Detector #1 X CFOV - FWTM Average	6.548	Passed	<=7.1
Detector #1 X CFOV - FWTM Standard Deviation	0.396	N/A	N/A
Detector #1 X CFOV - Maximum	3.896	N/A	N/A
Detector #1 X CFOV - Minimum	3.005	N/A	N/A
Detector #1 X CFOV - FWHM Standard Deviation	0.22	N/A	N/A
Detector #1 Y CFOV - FWHM Average	3.437	Passed	<=3.8
Detector #1 Y CFOV - FWTM Average	6.481	Passed	<=7.1
Detector #1 Y CFOV - FWTM Standard Deviation	0.417	N/A	N/A
Detector #1 Y CFOV - Maximum	3.947	N/A	N/A
Detector #1 Y CFOV - Minimum	2.937	N/A	N/A
Detector #1 Y CFOV - FWHM Standard Deviation	0.237	N/A	N/A
Detector #1 X UFOV - FWHM Average	3.508	Passed	<=3.9
Detector #1 X UFOV - FWTM Average	6.637	Passed	<=7.2
Detector #1 X UFOV - FWTM Standard Deviation	0.406	N/A	N/A
Detector #1 X UFOV - Maximum	4.15	N/A	N/A
Detector #1 X UFOV - Minimum	3.005	N/A	N/A
Detector #1 X UFOV - FWHM Standard Deviation	0.212	N/A	N/A
Detector #1 Y UFOV - FWHM Average	3.526	Passed	<=3.9
Detector #1 Y UFOV - FWTM Average	6.726	Passed	<=7.2
Detector #1 Y UFOV - FWTM Standard Deviation	0.647	N/A	N/A
Detector #1 Y UFOV - Maximum	4.7	N/A	N/A
Detector #1 Y UFOV - Minimum	2.913	N/A	N/A
Detector #1 Y UFOV - FWHM Standard Deviation	0.309	N/A	N/A
Detector #1 UFOV FWTM Average	6.681	Passed	<=7.2
Detector #1 UFOV FWHM Average	3.517	Passed	<=3.9
Detector #1 UFOV FWHM Standard Deviation	0.374	N/A	N/A
Detector #1 UFOV FWTM Standard Deviation	0.764	N/A	N/A
Detector #1 CFOV FWTM Standard Deviation	0.575	N/A	N/A

Figure 20. Spatial Resolution numerical test result for dedector 1.

Detector 2

Name	Value	Status	Rule
Detector #2 CFOV FWHM Average	3.502	Passed	<=3.8
Detector #2 CFOV FWTM Average	6.612	Passed	<=7.1
Detector #2 CFOV FWHM Standard Deviation	0.322	N/A	N/A
Detector #2 Calibration Factor	0.55	N/A	N/A
Detector #2 X CFOV - FWHM Average	3.513	Passed	<=3.8
Detector #2 X CFOV - FWTM Average	6.64	Passed	<=7.1
Detector #2 X CFOV - FWTM Standard Deviation	0.417	N/A	N/A
Detector #2 X CFOV - Maximum	4.008	N/A	N/A
Detector #2 X CFOV - Minimum	3.056	N/A	N/A
Detector #2 X CFOV - FWHM Standard Deviation	0.226	N/A	N/A
Detector #2 Y CFOV - FWHM Average	3.492	Passed	<=3.8
Detector #2 Y CFOV - FWTM Average	6.584	Passed	<=7.1
Detector #2 Y CFOV - FWTM Standard Deviation	0.417	N/A	N/A
Detector #2 Y CFOV - Maximum	3.942	N/A	N/A
Detector #2 Y CFOV - Minimum	2.972	N/A	N/A
Detector #2 Y CFOV - FWHM Standard Deviation	0.229	N/A	N/A
Detector #2 X UFOV - FWHM Average	3.551	Passed	<=3.9
Detector #2 X UFOV - FWTM Average	6.734	Passed	<=7.2
Detector #2 X UFOV - FWTM Standard Deviation	0.41	N/A	N/A
Detector #2 X UFOV - Maximum	4.203	N/A	N/A
Detector #2 X UFOV - Minimum	3.056	N/A	N/A
Detector #2 X UFOV - FWHM Standard Deviation	0.214	N/A	N/A
Detector #2 Y UFOV - FWHM Average	3.584	Passed	<=3.9
Detector #2 Y UFOV - FWTM Average	7.033	Passed	<=7.2
Detector #2 Y UFOV - FWTM Standard Deviation	1.913	N/A	N/A
Detector #2 Y UFOV - Maximum	4.717	N/A	N/A
Detector #2 Y UFOV - Minimum	2.972	N/A	N/A
Detector #2 Y UFOV - FWHM Standard Deviation	0.303	N/A	N/A
Detector #2 UFOV FWTM Average	6.884	Passed	<=7.2
Detector #2 UFOV FWHM Average	3.568	Passed	<=3.9
Detector #2 UFOV FWHM Standard Deviation	0.371	N/A	N/A
Detector #2 UFOV FWTM Standard Deviation	1.956	N/A	N/A
Detector #2 CFOV FWTM Standard Deviation	0.59	N/A	N/A

Figure 21. Spatial Resolution numerical test result for dedector 2.

Detector 1

Name	Value	Status	Rule
Detector #1 CFOV Absolute Linearity	0.345	Passed	<=0.5
Detector #1 CFOV Differential Linearity	0.066	Passed	<=0.1
Detector #1 Calibration Factor	0.551	N/A	N/A
Detector #1 X CFOV - Absolute linearity	0.345	Passed	<=0.5
Detector #1 X CFOV - Differential linearity	0.068	Passed	<=0.1
Detector #1 Y CFOV - Absolute linearity	0.319	Passed	<=0.5
Detector #1 Y CFOV - Differential linearity	0.063	Passed	<=0.1
Detector #1 X UFOV - Absolute linearity	0.394	Passed	<=0.5
Detector #1 X UFOV - Differential linearity	0.073	Passed	<=0.1
Detector #1 Y UFOV - Absolute linearity	0.441	Passed	<=0.5
Detector #1 Y UFOV - Differential linearity	0.077	Passed	<=0.1
Detector #1 UFOV Absolute Linearity	0.441	Passed	<=0.5
Detector #1 UFOV Differential Linearity	0.075	Passed	<=0.1

Figure 22. Linearity numerical tes result for dedector 1.

Detector 2

Name	Value	Status	Rule
Detector #2 CFOV Absolute Linearity	0.179	Passed	<=0.5
Detector #2 CFOV Differential Linearity	0.039	Passed	<=0.1
Detector #2 Calibration Factor	0.55	N/A	N/A
Detector #2 X CFOV - Absolute linearity	0.177	Passed	<=0.5
Detector #2 X CFOV - Differential linearity	0.041	Passed	<=0.1
Detector #2 Y CFOV - Absolute linearity	0.179	Passed	<=0.5
Detector #2 Y CFOV - Differential linearity	0.037	Passed	<=0.1
Detector #2 X UFOV - Absolute linearity	0.258	Passed	<=0.5
Detector #2 X UFOV - Differential linearity	0.047	Passed	<=0.1
Detector #2 Y UFOV - Absolute linearity	0.341	Passed	<=0.5
Detector #2 Y UFOV - Differential linearity	0.048	Passed	<=0.1
Detector #2 UFOV Absolute Linearity	0.341	Passed	<=0.5
Detector #2 UFOV Differential Linearity	0.047	Passed	<=0.1

Figure 23. Linearity numerical test result for dedector 2.

3.2 SPECT Quality Control Test Results

3.2.1 COR Test Result

SPECT imaging occurs with a 360 degree rotation of the gamma camera. SPECT quality controls are related with movement of gantry. In COR test, deflection in both axis (x,y) is examined. In Figure 24, COR results are shown for each dedector and axis. Deflection is within the acceptable limits. If COR test result is not within acceptable limits, dedector's ability to distinguish the smallest objects will degrade.

Name	Value	Status	Rule
Detector #1 Delta X - Detector 1	-0.13462	Passed	>=-0.55 and <=0.55
Detector #1 Delta Y - Detector 1	0	Passed	<=0.0
Detector #1 Delta X - Detector 2	0.45475	Passed	>=-0.55 and <=0.55
Detector #1 Delta Y - Detector 2	-0.04998	Passed	>=-0.55 and <=0.55

Figure 24.COR test results for each dedector

3.2.2 SPECT Resolution and Homogeneity Test Result

For SPECT Resolution and Homogeneity Test, Jaszczak phantom's smallest sphere could be observed, as shown in Figure 25. Thus this test is succesfull acording to IAEA reports [16].

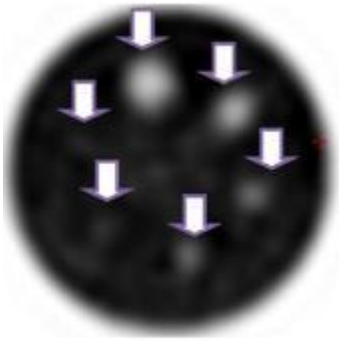

Figure 25. Representation of Jaszczak phantom

An incorret SPECT resolution and homogeneity test result reported in the literature is shown in Figure 26 [17].There is a fluctation on the center of image that defects homogeneity. This is due to high counting rate.

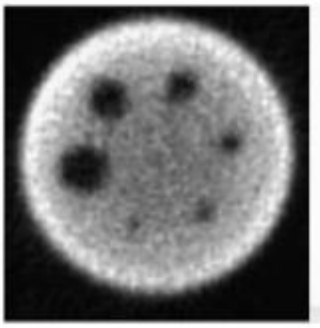

Figure 26. Incorrect SPECT resolution and homogeneity test result reportedin the literature [18]

3.2.3 Alignment of Camera with Axis of Rotation Test Result

For the Alignment of Camera with Axis of Rotation Test, the point to be watched on the images obtained with the test should draw a linear line depending on the changing angle. As shown in Figure 27, all point are on a linear line (on x axis).

Figure 27. Point source images taken based on the varying rotation angle of the SPECT device

3.3 Computed Tomography (CT) Quality Control Test Results

3.3.1 Couch Movement Test Result

For couch movement test, measured gaps on the gafchromic film are 1 centimeter as expected (Figure 28).

Figure 28. Couch movement test result

3.3.2 CT Number in Water Test Result

To observed CT number in water, drawn field is shown in Fig.29. Our measured CT number in water was 0.6 HU. This value will not cause any tomographic artifacts [12].

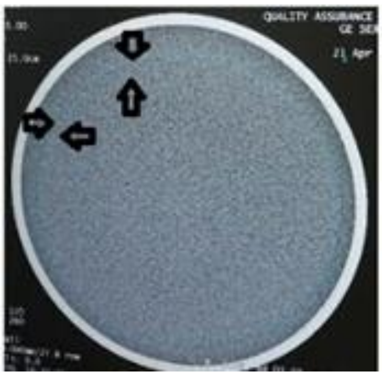

Figure 29. CT number in water test result.

3.3.3 High Contrast Spatial Resolution Test Result

When Figure 30 is analyzed, it can be seen that each bar is observed. The test is successful in this respect.

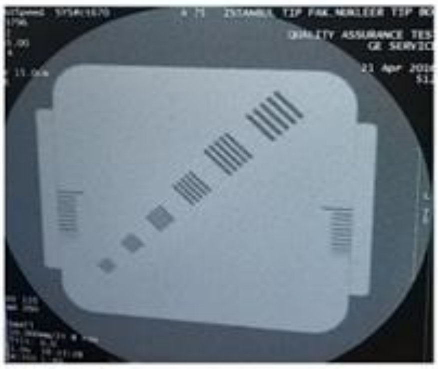

Figure 30. High contrast spatial resolution test result

4. Conclusion and Comment

Quality control tests of imaging devices using radiation is important for the radiation protection and quality controls is also important to ensure a high quality images. By quality control tests, system's defects can be dedected easily. Nuclear medicine departments should have the necessary phantoms for testings. Routine quality controls of device should be started with installation and also, test results should be recorded and continued periodically.

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