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Review on Routine Quality Control Procedures in Nuclear Medicine Instrumentation

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Abstract

Quality control of scintillation cameras starts with acceptance testing of the system. This article reviews some of the routine quality control (QC) procedures for current nuclear medicine instrumentation especially SPECT/CT that interface directly with patients. Three different procedures have been described in this review including uniformity test, spatial resolution test, and center of rotation test.

1. Theory

Nuclear medicine is a medical specialty that involves giving a patient a small amount of a radiopharmaceutical. This makes the body slightly radioactive for a brief time then the camera detects the radiation, which is emitted from the body, and takes images or pictures of how the inside of the body is working (Bailey *et al.*). Many different organs can be imaged depending on the type of radiopharmaceutical used (Salvatori and Lucignani, 2010; Tenhunen *et al.*, 2013). The radiopharmaceutical is most commonly injected into the blood stream through a vein, it also might be given by inhalation or swallowing (Bushberg *et al.*, 2012; Loveless, 2009).

A gamma camera is a machine that has the ability to detect and make images from the very small amounts of ionizing radiation emitted from the patient. Gamma camera system consists of three major components including: collimator, Sodium Iodide (NaI) crystal and array of photomultiplier tubes (PMTs) (Hasan *et al.*, 2017).

Quality assurance and quality control are very important terms used in nuclear medicine (Stabin, 2008). The main aim of quality control is to detect the errors of the system and to react to these errors in appropriate way in order to prevent unnecessary radiation exposure to the patient or inaccurate diagnosis (Sabol *et al.*, 2017). Quality control based on measuring the performance level of the system and then compared it with the existing standards or tolerance values (Agency, 2006).

Basic planar quality control procedures are uniformity (extrinsic and intrinsic) which is done in daily base, spatial resolution (extrinsic and intrinsic) which performed once every six months and center of rotation which performed semiannually as well (Kappadath, 2016).

For SPECT/CT the quality control test for CT done before SPECT and it includes tube warming up and fast calibration to ensure consistent image quality and radiation exposure. QC for gamma camera done after QC for CT. The entire process takes one hour.

2. Mathematics

- Uniformity: the integral uniformity (IU) is given by: IU = $100\left(\frac{Max-Min}{Max+Min}\right)$. The differential uniformity (DU) which is given by: DU = $100\left(\frac{High-low}{High+low}\right)$.
- Spatial Resolution: System resolution (Rsys) is combination of intrinsic and collimator resolution: $R(sys) = \sqrt{R(int)^2 + R(coll)^2}$. The intrinsic spatial resolutions in the X and Y directions in terms of the full widths at half maximum, FWHM, of the line-spread function, using the relationship FWHM = 1.75B where B is the width of the smallest bars that the camera can resolve.
- Center of Rotation: COR calculated by obtain x-axis errors including mean, max, min and range between detector 1 and detector 2. And obtain Y-axis errors including: mean, max, min and range between detector 1 and detector 2 (White, 2009).

3. Quality control tests

3.1. Uniformity:

Uniformity test is performed basically to test how uniform is the system with and without collimator (Halama). It is the most sensitive parameter in the system performance. Any change in photopeak location, photomultiplier tube (PMT) performance, energy and linearity correction will affect image uniformity. The number of counts should be acquired, and the acquisition performed intrinsically and extrinsically. This is done according to the system whether it's being evaluated for its ability to perform planar or tomographic acquisitions. For SPECT/CT it is tomographic acquisitions.

3.2. Intrinsic uniformity:

Intrinsic uniformity test is performed to check the ability of the camera to produce a uniform image when exposed to a homogenous spatial distribution (without collimator). Using a point source ex. (99mTc), the point source should be 5 FOV away from uncollimated detector. This test performed by removing the collimator from the detector head and replaced it by a dummy collimator to protect the detector. The value could be calculating by smoothing the image data in the image processor using smoothing function. Pixels arranged as:

1 2 1

2 4 2

1 2 1

Then locating the pixels around the edge which having a count one half of that in the center pixel. This requires interpolation between pixels adjacent to the half-height position. Then The useful field of view (UFOV) on the digital image defined with a radius which is 95% of the mean half-height radius. Also, the central field of view (CFOV) defined with a radius which is 75% of the mean half-height radius. The maximum (Max) and minimum (Min) counts in the pixels lying within the UFOV and the CFOV determined, the integral uniformity (IU) is given by: IU = 100((Max-Min)/(Max+Min)).

Determine the maximum count difference in any 6 contiguous pixels for each row or column of pixels in the X and Y directions within the UFOV and the CFOV (Sharp *et al.*, 2005). Also, determine the highest value of this maximum count difference in the sets of rows and columns; this will define the differential uniformity (DU) which is given by: DU = 100((High-low)/(High+low)).

Figure 1. uniformity test without collimator but dummy collimator instead.

3.3. Extrinsic uniformity:

To test the uniformity of the system with presence of collimator. Extrinsic measurements can be performed using either a solid disk of Co-57 or a refillable plastic source containing a mixture of Tc-99m and water. As an alternative to a Co-57 sheet source, a Tc-99m sheet source can be prepared by the addition of several millicuries of Tc-99m to a liquid filled plastic sheet source. However, it has disadvantage that it takes long time for preparation of the source.

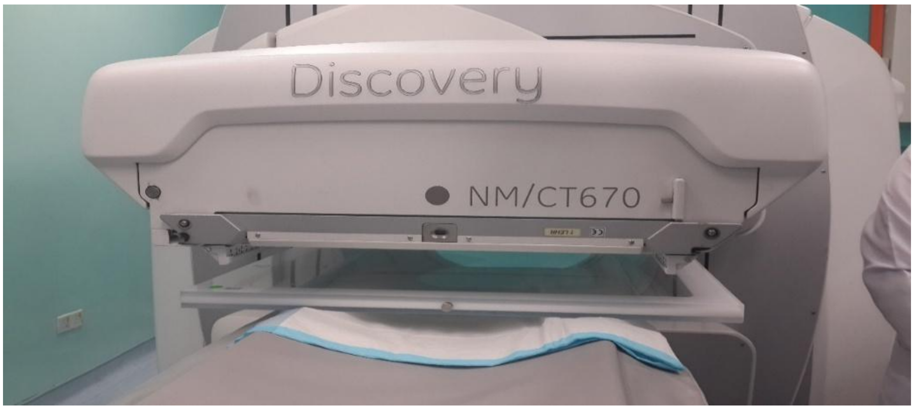

Figure 2. extrinsic uniformity test using flat 99mTc source mixed with water.

3.4. System spatial resolution:

This test carried out once every six months and it should be performed for each parallel hole low energy collimator. To test the spatial resolution of scintillation camera in terms of the FWHM of its line spread function. For this test, a quadrant bar phantom with bar widths of approximately 2,3,3.5 and 4 mm is normally used.

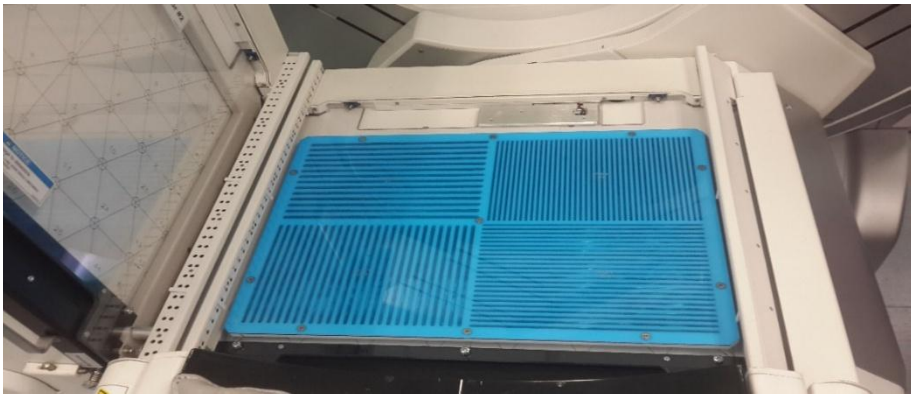

Figure 3. quadrant bar phantom used for spatial resolution test

3.5. Centre of rotation:

Calibration test performs semi-annually to ensure that the camera image exactly matching the centre of the computer image when the images are reconstructed. 99mTc point sources can be used near the axis of rotation.

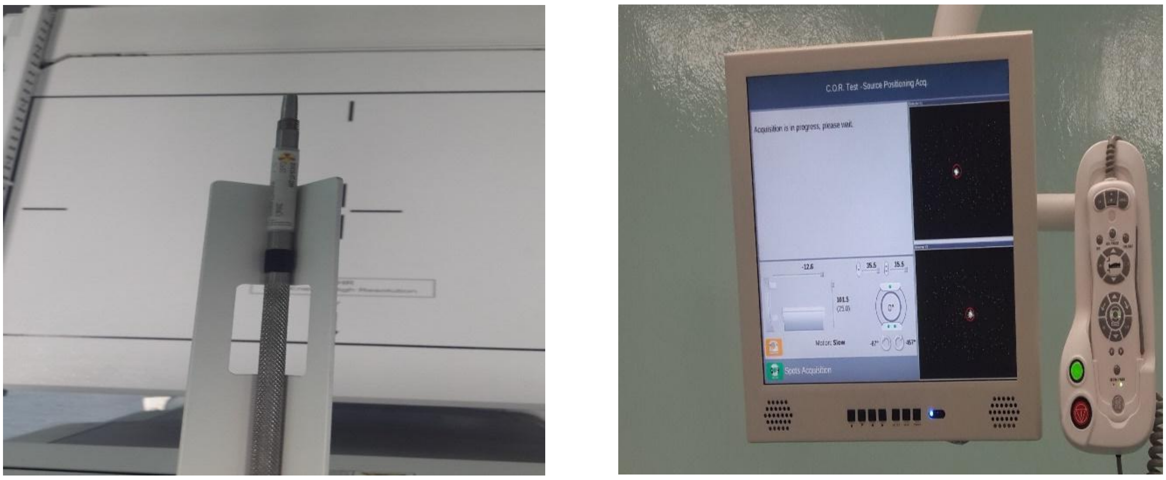

Figure 4. point source at the centre (left), COR test (right)

4. Conclusion

The acceptable range of the integral and differential uniformity for the useful and central of view should be less than 3% in SPECT and should not exceed 5% in the planar projection otherwise artifacts will be produced. No presence of ring bull's-eye and crescent shaped artifacts in the transaxial images is an indication of acceptable range of the uniformity test.

Spatial resolution is very important parameter in SPECT studies. It's commonly qualified from the full width at half maximum (FWHM) of the line spread function. Good spatial resolution of the system indicated when the value obtained for a planar view is the same as FWHM. The tomographic plane resolution is dependent upon the gamma ray energy, the presence or absence of scattering material, the radius of rotation, window width, collimation, as well as the reconstruction filter. These all measurements should be taken into consideration while performing the spatial resolution test.

The centre of the gamma camera in all acquired imaged must be known. Centre of rotation test must be completed monthly.

Centre of rotation for dual head SPECT/CT when the two heads are 180 degrees apart, the centroid for each head should locate at slightly different locations. In the system, the two centroids normally averaged and defined to have one certain midpoint. The differences between the averaged centroids and the COR is the X-axis offset. X-axis offset should be <0.5 pixel. An offset of greater than three pixels requires a service call because uncorrected COR errors produce an image that is unrecognizable.

References

Agency, I. A. E. (2006). *Nuclear medicine resources manual.* International Atomic Energy Agency.

Bailey, D., Humm, J., Todd-Pokropek, A. & van Aswegen, A. Nuclear Medicine Physics: A Handbook for Teachers and Students. Dauer LT, Chapter 20. Management of therapy patients.© IAEA, 2014. STI/PUB/1617 Ayan ve ark. Radyoaktif Hastada Acil Müdahale Durumunda ….

Bushberg, J., Seibert, J., Leidholdt, J., Edwin, M. & Boone, J. (2012).The essential physics of medical imaging [kindle edition]. Philadelphia, PA: Lippincott Williams & Wilkins, a Wolters Kluwer business.

Halama, J. R. QC Protocols Gamma Camera & SPECT Systems

Hasan, M. R., Khan, M. H. R., Rahman, M. R., Parvez, M. S., Islam, M. R. & Paul, A. K. (2017). Quality Control of Gamma Camera with SPECT Systems. *International Journal of Medical Physics, Clinical Engineering and Radiation Oncology* 6(03): 225.

Kappadath, S. C. (2016). SPECT/CT: Basics, Quality Assurance, and Clinical Applications. 1-12.

Loveless, V. S. (2009). Quality control of compounded radiopharmaceuticals. *Continuing Education for Nuclear Pharmacists and Nuclear Medicine Professionals* 15: 7-17.

Sabol, J., Hudzietzová, J. & Šesták, B. (2017). Assessment of the Exposure of Radiation Workers in Nuclear Medicine With Some Results From the Czech Republic. *RAD Assoc. J.* 2(1): 31-34.

Salvatori, M. & Lucignani, G. (2010). Radiation exposure, protection and risk from nuclear medicine procedures. *European journal of nuclear medicine and molecular imaging* 37(6): 1225-1231.

Sharp, P. F., Gemmell, H. G., Murray, A. D. & Sharp, P. F. (2005). *Practical nuclear medicine.* Springer.

Stabin, M. G. (2008). The importance of patient-specific dose calculations in nuclear medicine. *Nuclear Engineering and Technology* 40(7): 527-532.

Tenhunen, M., Lehtonen, S., Heikkonen, J., Halonen, P. & Mäenpää, H. (2013). First-day iodine kinetics is useful for individualizing radiation safety precautions for thyroid carcinoma patients. *Nuclear medicine communications* 34(12): 1208.

White, S. (2009). TU-B-210A-01: Quality Assurance Testing of Gamma Camera and SPECT Systems. *Medical Physics* 36(6Part22): 2719-2719.