Quality Control for Nuclear Medicine Instrumentation at Jeddah Hospitals Saudi Arabia

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Abstract: The purpose of the current study was to verify the quality of nuclear medicine instruments and radiopharmaceuticals of the nuclear medicine department and their ability to perform high quality images to assess the additional value of imaging and to inspect the recommended routine quality control measures that performed by the staff members, physicists and technologist in 4 different hospitals in Jeddah, Saudi Arabia, King Abdulaziz University Hospital (KAUH), Bugshan Hospital, King Faisal Hospital, National Guard Hospital. The study was conducted through a questionnaire which was specifically designed to examine the already existing quality control facilities in these 4 hospitals in accordance with the National Electrical Manufacturers Association (NEMA) measures and standards. Results showed that most of the parameters of the daily routine procedure, prior to each patient procedures, monthly routine procedures, monthly audit and radiation safety procedure were found to be in agreement with the NEMA standards and recommendations. However, the defibrillator/AED check in daily routine procedure and centre of rotation check in monthly routine procedures were found to be not in accordance with the recommendations and standards of NEMA. We conclude that the staff members of nuclear medicine departments of all the 4 hospitals follow the routine quality control tests appropriately as recommended by NEMA except for, the defibrillator/AED check and centre of rotation check.

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1. Introduction

Quality control (QC) is an important element in nuclear medicine as it is fundamentally reliant on the exact, reproducible execution of clinical radionuclide counting and imaging instrumentation. Quality control, which might be characterized as a recognized set of continuous estimations and investigations intended to guarantee that the execution of a technique or instrument is inside a predefined satisfactory range. A broad arrangement of parameters has been created for acceptance testing and performance portrayal of γ-cameras, SPECT and PET scanners, and other nuclear medicine instrumentation[1].

Furthermore, definite information procurement and investigation procedures for this purpose have been declared by the National Electrical Manufacturers Association (NEMA)[2,3], the American Association of Physicists in Medicine (AAPM) [4], the Society of Nuclear Medicine[5] and other governing, consultative, and proficient associations[6-9].

After establishment of the nuclear medicine instrument in the nuclear medicine department, and before it is put into clinical usage, it must endure an exhaustive and watchful acceptance testing. This is to ensure that the instrument's performance is in accordance to the specifications and clinical reason of the equipment. After installing the instrument and performing acceptance testing, routine QC testing must be initiated and should be carried out regularly as long as the equipment is in use[6].

The importance of using Basic QC method lies in the fact that it is delicate to changes in the performance of the equipment. These tests must be executed by fittingly qualified and skilled staff. Additionally, Detailed Documentation of local operating procedures concerning the mentioned routine tests must be done [5-9].

Generally, in nuclear medicine department, the measures for quality control include radiation exposure and nuclear medicine devices such as Survey Meter[10,11] (Fig.1-a,b), dose calibrator[12-14] (Fig. 2-a,b) and Geiger-Mueller Detector[13-15] (Fig. 3) as well as gamma camera[16-19] (Fig. 4).

2. Methodology

The purpose of the present study was to inspect the quality control measures in the nuclear medicine departments of 4 hospitals in Jeddah, Saudi Arabia, as recommended by NEMA measures and standards.

The study was performed through a questionnaire which was distributed to the staff members, physicists and technologist who handle the nuclear medicine instrumentations in nuclear medicine departments at King Abdulaziz University Hospital (KAUH), Bugshan Hospital, King Faisal Hospital and National Guard Hospital. The questionnaire was specifically created focusing on the

staff members to examine the already existing quality control facilities in these 4 hospitals.

A total of 21 survey questions had been created, out of which question 1-5 were designed to assess the daily routine procedures, question 6-7 were intended to evaluate the prior to each patient procedures, question 9-13 were considered to check the monthly routine procedures, question 14-18 were planned to scrutinize the monthly audit while question 19-21 were intended to examine the radiation safety procedures. The questionnaires were distributed to 30 staff members, physicists and technologist of all the 4 hospitals for the survey.

The questionnaires were then collected from the participants and statistical analyses were conducted using Statistical Package for Social Science (SPSS) Statistics Version 21.0 (IBM, Chicago, IL, USA), in order to get accurate results through frequencies and chi-square tests.

3. Results and Discussion

The results of the survey which was carried out on the technologist and staff members who handles the nuclear medicine instrumentation through questionnaire showed that 88% of the technologists checked survey meter as a daily routine. There was a high significant correlation in the results (p=.000) as shown in table (1) and this result is in accordance with the measures introduced by NEMA standards.

The findings also showed that 100% of the technologist validated dose calibrator constancy, as well as peak and tune camera and92% of the nuclear medicine staff members inspected the homogeneity of camera by flood source on a daily basis, which complies with the NEMA standards (Table 2 and 3) [20-23]. However, it was found that 61% of the staff members do not performed defibrillator (ADE) check every day, showing that most of the staff members don't fulfill this measure according to the NEMA recommended measures and standards.

The study also revealed that prior to each patient procedure, 100% of the staff members checked labels to ensure proper radiopharmaceutical and time and 88% checked and recorded the activities in a log book or computer (Table 4), which is in conformity with the NEMA standards (Table 3). Furthermore, 81% of the staff members verified correct patient and correct procedure prior to each patient procedure twice to make sure it is in accordance with the measures introduced by NEMA standards.

The results of the monthly routine procedures showed that, only 58 % of the staff members checked the centre of rotation (Table (5)), indicating that 42% of the staff members were not fulfilling the recommendations and standards of NEMA (Table (2)). The results also exhibited that 81 % of the staff members perform high count flood method and the entire staff members (100%) of the nuclear medicine department verified the uniformity of gamma camera and test for spatial resolution periodical on monthly basis which is in agreement with the measures introduced by NEMA standards (Table (2)). Additionally, 85% of the staff members printed out monthly reports and filed hard copy of the quality of instrument and machines of the department per the recommendations and standards of NEMA.

As the monthly audit of the equipment for satisfactory performance, 100% of the staff members who were surveyed verified that the floods have acceptable quality and 85% confirmed that the bars also have acceptable quality (Table (6)). Furthermore, 88% of staff members declared that the centre of rotation is also acceptable per camera recommendations and there was a high significant correlation in the results (p=.000).

The flood acceptable quality, bars acceptable quality and the centre of rotation acceptable per camera recommendations were all found to be in tune with the NEMA standards (Table (2)). The results also revealed that 92% of the staff members confirmed that the survey meter calibration was up to date and the dose calibrator constancy is acceptable. There was also a high significant relationship in the results (p=.000) and these results correlates with the NEMA recommended measures (Table (3)).

As the radiation safety is an important matter in nuclear medicine department, 100% of the staff members affirmed that they locked and secured all the isotopes inside the hot lab, 92% of the staff member's personnel badges are monitored up to date and 100% agreed that the daily survey and weekly wipes were acceptable (Table (7)) and performed as per the NEMA standards and safety measures. The questionnaire which was used in the survey is given in table (8).

Table (1): Daily routine procedures.

Questions	Answers	Frequencies	Percentage %	p-value
Q1.Survey Meter Check?	Yes No	23 3	88.5% 11.5%	0.000 Significant
Q2. Check the Dose Calibrator Constancy?	Yes No	26 0	100%	
Q3. Peak & Tune Camera check?	Yes No	26 0	100%	
Q4.Check homogeneity of Camera by Flood source?	Yes No	24 2	92.3% 7.7%	0.000 Significant
Q5.Check Defibrillator / AED?	Yes No	10 16	38.5% 61.5%	0.239 Non-significant

Table (2): **The routine QC tests for a gamma camera recommended by NEMA**[20- 23].

Test	Purpose	Frequency	Recommendations
Physical inspection	To check collimator and detector head mountings, and to check for any damage to the collimator	daily	Inspect for mechanical and other defects that may compromise safety of patient or staff; if collimator damage is detected or suspected, immediately perform a high-count extrinsic uniformity test
Collimator touch pad and gantry emergency stop	To test that the touch pads and emergency stops are functioning	daily	Both the collimator touch pads and gantry emergency stop must function if there is an unexpected collision with the patient or an obstacle during motion; the touch pads must be checked each time the collimators are changed
Energy window setting for 99mTc	To check and centre the preset energy window on the 99mTc photopeak	Daily	The test is intended to check the correct 99mTc energy window
Background count rate	To detect radioactive contamination/excess electronic noise	Daily	The background count rate should be stable under constant measuring conditions
Intrinsic/extrinsic uniformity and sensitivity for 99mTc (or 57Co) – visual	To test the response to a spatially uniform flux of 99mTc (or 57Co) photons, for uniformity and overall sensitivity	Daily	Visually inspect either an intrinsic or extrinsic (whichever is most convenient) low count uniformity acquisition; if intrinsic method is selected, each collimator must be checked periodically by an extrinsic uniformity test (preferably with high-count acquisition – see next test); record the cps/MBq to check and monitor sensitivity
Spatial resolution and linearity – visual	To detect distortion of spatial resolution and linearity	Six-monthly	Visual-quadrant bar or orthogonal hole pattern; intrinsic or extrinsic, depending on convenience; if an orthogonal hole pattern is used, the results can be quantified if special software is available

COR alignment	To check that the mechanical and electronic CORs are aligned, i.e. COR offsets are within limits of acceptability, in X and Y directions	Weekly/monthly	The frequency of the test depends on detector COR stability and should be adjusted accordingly; the test should be done for all collimators used for SPECT studies, and for each multiple detector configuration used; ensure that procedure checks both X and Y directions
Overall system performance	To test tomographic uniformity and contrast resolution, and attenuation correction if available	Six-monthly	A total performance phantom (e.g. Jaszczak) should be used; uniformity of reconstructed slices with a uniform activity (no sphere/rod inserts) and contrast resolution of slices with cold spheres or rods should be monitored; if software attenuation correction is available, it should be applied to the images
Sensitivity	To measure the volume response of the system to a source of given activity concentration	Monthly	Perform according to NEMA NU2 standards with a set of sleeved rod sources
Image quality	To check hot and cold spot image quality of standardized image quality phantom	Yearly	According to NEMA NU2 image quality test ; required after system installation, not mandatory during clinical operation

Table (3): **The routine QC tests for other equipment used in nuclear medicine recommended by NEMA**[20- 23].

Test	**Purpose**	**Frequency**	**Recommendations**
Physical inspection	To check system and any source holders and other accessories for damage	daily	The chamber may be concealed, and not accessible for physical inspection, but the loose accessories should be checked
Clock accuracy	To check that the calibrator clock is the same as the time of day	daily	Essential for calibrating radioactivity to a specific time of day; clock time throughout the department must be the same (i.e. all wall clocks and internal computer clocks)
Zero adjustment	To check that the display is at zero when no radioactivity is present	Daily	Record the zero setting (before any adjustment); a drift in "zero" reading may indicate that the instrument needs repair
Background counts	To check background response under operational conditions appropriate for a particular radionuclide; to detect contamination	Daily	Perform the test with the source holder/liner in place in the chamber; remove nearby radioactive sources that might cause an incorrect background reading; check on each radionuclide setting to be used that day
Constancy	To check the stability and reproducibility of the ionization chamber, electrometer, and calibrator nuclide settings	Daily	Measure a long half-life radionuclide, e.g. 137Cs with its own calibration factor; also, obtain relative measurements for each nuclide setting to be used that day

Accuracy	To check the accuracy of the activity reading	Yearly	This requires readings of sources of known activity
Linearity	To confirm that the calibration setting for a particular radionuclide indicates the correct activity over the entire range of use	Six-monthly/yearly	The change in response when the measurement range is changed should be minimal; the range of use should be chosen between the maximum activity to be measured (e.g. in the GBq range for a 99mTc eluate) to the lowest activity to be measured (e.g. 1 MBq) for a particular radionuclide

Table (4): **Prior to each patient procedures**

Questions	Answers	Frequencies	Percentage%	p-value
Q6. Check Label to Ensure Proper Radiopharmaceutical and Time?	Yes No	26 0	100%	
Q7. Check and Record Activity in Log Book or Computer?	Yes No	23 3	88.5% 11.5%	0.000 Significant
Q8. Verify Correct Patient & Correct Procedure (twice)?	Yes No	21 5	80.8% 19.2%	0.002 Significant

Table (5): **Monthly routine procedures**

Questions	Answers	Frequencies	Percentage%	p-value
Q9. Check Centre of Rotation?	Yes No	15 11	57.7% 42.3%	0.433 Non significant
Q10. High Count Flood?	Yes No	21 5	80.8% 19.2%	0.002 Significant
Q11. Camera Uniformity?	Yes No	26 0	100%	
Q12. Print out monthly reports and file a hard copy?	Yes No	26 0	100%	0.000 Significant
Q13. Test for spatial resolution?	Yes No	22 4	84.6% 15.4%	0.000 Significant

Table (6): **Monthly audit**

Questions	Answers	Frequencies	Percentage%	p-value
Q14. Floods acceptable quality?	Yes No	26 0	100%	
Q15. Bars acceptable quality?	Yes No	22 4	84.6% 15.4%	0.000 Significant
Q16. Bars acceptable quality?	Yes No	23 3	88.5% 11.5%	0.000 Significant
Q17. Survey meter calibration up-to-date?	Yes No	24 2	92.3% 7.7%	0.000 Significant
Q18. Dose calibrator constancy acceptable?	Yes No	24 2	92.3% 7.7%	0.000 Significant

Table (7): **Radiation safety procedures**

Questions	Answers	Frequencies	Percentage%	p-value
Q19. All isotopes locked & secure?	Yes No	26 0	100%	.000 Significant
Q20**.** Badge monitoring up-to-date?	Yes No	24 2	92.3% 7.7%	.000 Significant
Q21. Daily surveys & weekly wipes all acceptable?	Yes No	26 0	100%	.000 Significant

Table (8): **The different parts of the questionnaire which was used in the survey**.

Part (1): DAILY ROUTINE PROCEDURES

1-Do you do :Survey Meter Check?

Yes NO

2-Do you do: check the Dose Calibrator Constancy?

Yes NO

3-Do you do: Peak & Tune Camera check?

Yes NO

4-Do you do: Check homogeneity of Camera by Flood source?

Yes NO

5-Do you do: Check Defibrillator / AED?

Yes NO

Part (2): PRIOR TO EACH PATIENT PROCEDURE

1- Do you do Check Label to Ensure Proper Radiopharmaceutical and Time?

Yes NO

2- Do you do Check and Record Activity in Log Book or Computer?

Yes NO

3-Do you do Verify Correct Patient & Correct Procedure (twice)?

Yes NO

Part (3): MONTHLY ROUTINE PROCEDURES

1-Do you check Centre of Rotation?

Yes NO

2-Do you check High Count Flood?

Yes NO

3-Do you check Camera Uniformity?

Yes NO

4-Do you print out monthly reports and file a hard copy?

Yes NO

5-Do you do Test for spatial resolution?

Yes NO

Part (4): MONTHLY AUDIT

Check if item was performed satisfactorily; circle if item needs to be addressed

EQUIPMENT

1- Floods acceptable quality?

Yes NO

2-Bars acceptable quality?

Yes NO

3-COR acceptable per camera recommendations?

Yes NO

4-Survey meter calibration up-to-date?

Yes NO

5-Dose calibrator constancy acceptable?

Yes NO

Part (5): RADIATION SAFETY

1- Radioisotope security: all isotopes locked & secure?

Yes NO

2- Personnel: badge monitoring up-to-date?

Yes NO

3- Surveys: daily surveys & weekly wipes all acceptable?

Yes NO

Figure (1-a): Survey meter [11]

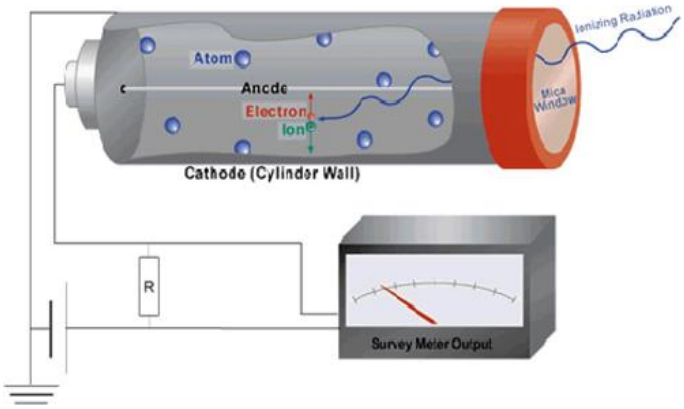

Figure (1-b): The electronic circuit of the Survey meter [11]

Figure (2-a): Shows the Dose calibrator [12]

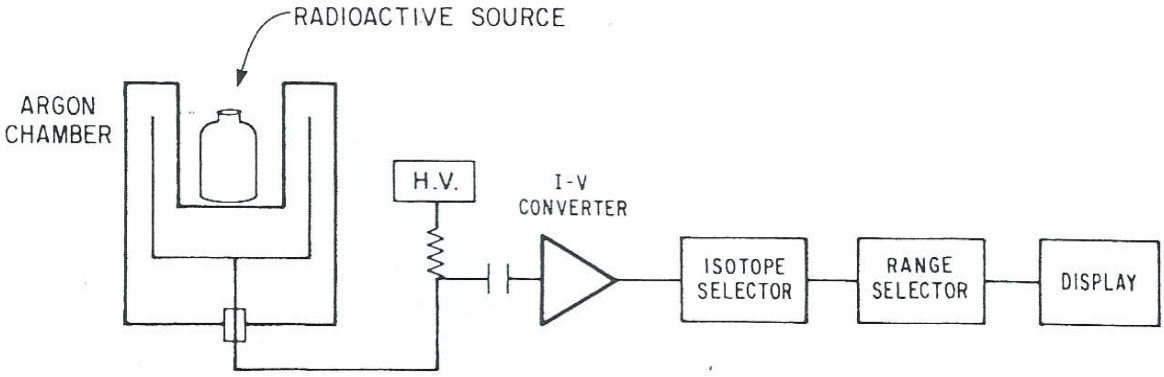

Figure (2-b): Proportionality between the number of photons emitted and the ionization current in Dose calibrator[13].

Figure (3): Geiger Mueller (GM) counter. [15]

Figure (4): Gama camera Device [19]

Conclusion

This research was conducted on the technologist, physicists and staff members through a questionnaire method to measure the quality control of the nuclear medicine instrumentation in the nuclear medicine departments of King Abdulaziz University Hospital (KAUH), Bugshan Hospital, King Faisal Hospital and National Guard Hospital.

The results of the daily routine procedure which includes, survey meter check, dose calibrator constancy check, peak and tune camera check and homogeneity of camera check by flood source were found to be in accordance with the NEMA standards and recommendations, except for the defibrillator/AED check. The results of all the parameters for the prior to each patient procedure check were found suitable with the measures introduced by NEMA principles. Similarly, the monthly routine procedure results were also commensurate with the NEMA recommended standards, however, it was found that the staff members were not fulfilling the recommendations and standards of NEMA in centre of rotation check. All the parameters for the monthly audit of the equipment for satisfactory performance were also found acceptable according to the NEMA measurements. The study also viewed that, radiation safety procedures were performed as per NEMA safety standards.

Based on this study, we recommend that the technologist, physicist and staff members who handle nuclear medicine instrumentations should strictly follow the standards recommended by NEMA especially, in the checking of defibrillator (ADE) on daily basis and checking of centre of rotation as monthly routine procedure.

Limitation of the study: The limitation of the study was the small sample size and the short study duration.

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