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The Quality Assurance for the PET/CT in Nuclear Medicine - Evaluation of the Daily Quality Control of The Positron Emission Tomography

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Quality assurance generally refers to the measures taken to ensure that equipment meets international requirements and recommendations. PET/CT quality control is based on measures used to regularly monitor the performance of the installed imaging equipment in terms of image quality and dose and to ensure effective radiation protection. Indeed, the objective of this study is to evaluate the daily quality control, used on of the Positron Emission Tomography "PET" part of the "PET/CT", after one year without daily quality control knowing that the medical physicist is not present in the institution. Material and methods, it was used the "PET/CT" equipment of the nuclear medicine department of a hospital, and the PET part, the Germanium 68 (Ge-68) source for "QC", and a questionnaire related to quality assurance and radiation protection distributed in the said department. Results of this study, after the "QC" of the "PET", some problems were identified; the correction of the defective modules was performed, and answers were collected from the distributed questionnaires. For the discussion, the absence of implementation of a quality assurance program in the nuclear medicine department, including the establishment of daily quality control procedures and radiation safety training, was attributed to the inexistence of a qualified medical physicist, referring to the questionnaire responses. To conclude, quality assurance in a nuclear medicine department and daily quality control of the "PET", as well as the existence and control of a qualified medical physicist for medical activities with ionizing radiation sources, ensure optimal patient radiation protection.

Keywords: Daily quality control; Medical physicist; Nuclear Medicine; Quality assurance - PET/CT.

Generally, clinical radionuclide counting and imaging instruments in nuclear medicine depend on a certain level of accurate and reproducible performance[1]. Furthermore, by international standards and recommendations, the quality assurance program should include "QC" procedures. These must be performed on a regular and planned basis, by applicable requirements established by regulatory bodies[2]. Indeed "QC" is defined as an essential part of routine nuclear medicine practice. However, over the years many parameters for acceptability testing and performance characterization of the "PET/CT", and other nuclear medicine instruments have been developed. To this end, various associations, regulatory, advisory, and professional organizations (American Association of Physicists in Medicine "AAPM", International Atomic Energy Agency "IAEA", American Society of Radiology "ACR", and others) have published detailed data collection and analysis methods[1]. "PET/CT" plays an essential role in oncology for diagnosis and follow-up, it is essential to check the equipment regularly, especially for consistency and coincidence, as well as maximum energy through "QC" procedures[3, 4]. This technique will continue to play an important role in precision nuclear medicine (4).Indeed, the purpose of "PET" daily quality control is to ensure consistency of detector functionality and to identify any problems, such as a crystal or module failure[5]. The procedure is performed using a phantom with a Ge-68 source in a cylindrical form in most cases to ensure optimal crystal performance[3, 5, 6, 7]. In addition, the purpose of daily quality control is to correlate the data from the sinograms; sinogram control (uniformity) is obtained daily using a Ge-68 source to the values determined during system calibration, for this the recalibration is required if the differences exceed the tolerance levels[8].The main daily quality control steps related to the operating parameters of the detector are coincidence detection, singles, dead time, timing, and energy resolution[9].

One of the main roles and responsibilities of the qualified nuclear medicine physicist is to ensure optimization of the physical aspects of the diagnostic procedure. This task is performed in collaboration with other qualified medical staff [10]. The qualified medical physicist must establish a quality assurance program that will include daily quality control procedures for the equipment in the department that uses ionizing radiation for medical protocols. Personnel of the department should consult with a qualified medical physicist if measured values of daily quality control parameters exceed established tolerances. However, corrective actions should be prescribed to resolve problems raised during daily quality control[11].In addition, a technologist should perform the daily quality control, and it is recommended that these procedures be performed before the clinical use of the scanner[7, 12].

Daily quality control for General Electric Discovery "GE. D" equipment - "PET/CT"

An integrated Ge-68 source in the scanner's field of view is required for daily quality control of "GE. D" equipment "PET/CT"; the source is not visible because it is located behind the scanner enclosure[9]. As mentioned above, the daily quality control of the "PET" is performed sequentially and evaluates coincidences, singles, timeouts, timing, and system energy. A visual and parametric data report on the status of the detectors in the form of an image "sinogram" (Figure.1) after the "PET" daily quality control procedure is completed. A scale of three represents the parametric results obtained during the procedure: green indicates a setting that is within an acceptable range, yellow indicates a recommended setting and red indicates a setting that is outside an acceptable range[13].

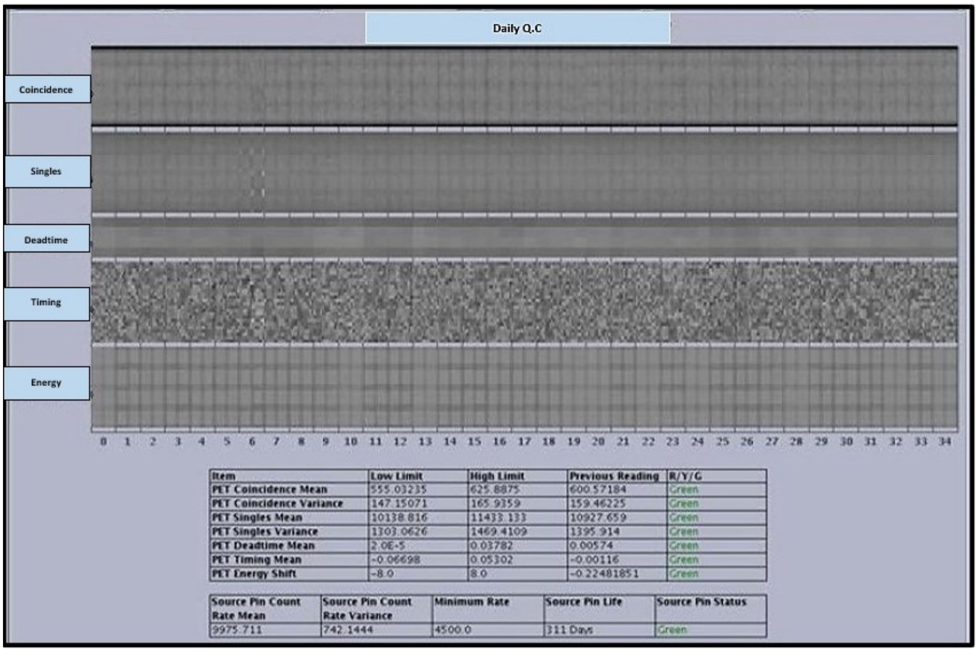

Fig. 1. Example of Sinogram of daily "PET" – "QC" Ge Discovery Technology[13]

The following table provides recommendations for the daily quality control procedures that should be scheduled and performed for the "PET/CT". The purpose of the procedure, the frequency, and comments on the procedure, the type of technology, and the parameters of "QC" are performed in (Table. 1)[14]. In addition, the manufacturer sets the parameters and frequency of "QC" tests for each "PET/CT" system that each qualified medical physicist should follow to perform a control procedure within the standards[15].

Table 1. Daily quality control for "PET" – GE systems[14, 15]

Control	Type of Technology	Purpose	Frequency	Comments	QC parameters
PET Daily QC	GE Systems	Visualize the operation of the detection modules. A display of a sinogram	Daily	Performed with point sources (Source of Ge-68)	Coincidence test Singles test Energy test Timing test Deadtime test

In effect, the objective of this study is to evaluate the "PET" daily quality control in a nuclear medicine department, of the "PET" to the "PET/CT" equipment, after one year without a daily control procedure in the absence of a qualified medical physicist in the department.

MATERIALS AND METHODS

The equipment of this study, especially for the daily quality control has a "PET/CT" (GE. Discovery 610 Elite, USA), which is composed of a computed tomography part and a "PET" part, using crystals of (Bismuth Germanate - BGO). A Ge-68 source was used as recommended for this control. Before the start of the "QC", a questionnaire on the quality assurance program was distributed to the medical staff of the nuclear medicine department to collect responses. Our method is as follows, in the absence of a qualified physicist in the nuclear medicine department, the biomedical engineer of the "PET/CT" manufacturer started the daily quality control procedure after one year without "QC", a report was displayed on the console of the "PET/CT"; sinogram 1; the procedure lasted 11 minutes; (Figure 2). The procedure displayed two errors concerning two modules of the "PET" - crystal scintillator, the object of our work.

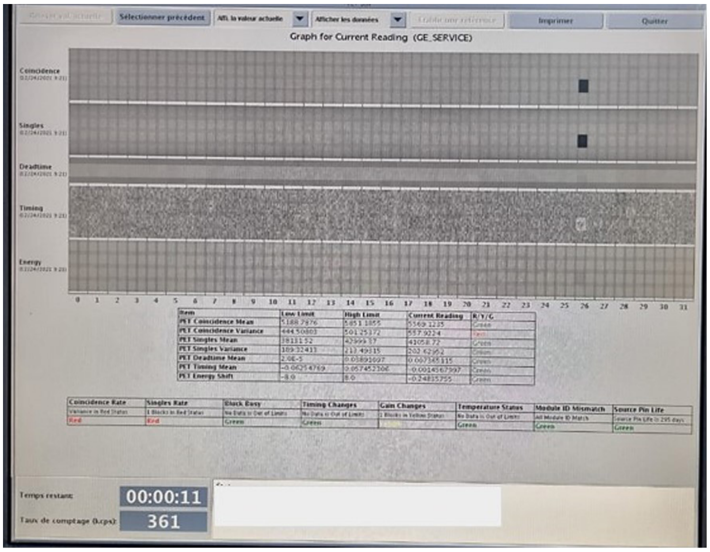

Fig. 2. Sinogram of daily quality control for the (PET)-GE Discovery 610 Elite (study)

Following our method of "QC", the biomedical engineer launched a roadmap (workflow of the process of calibration of the detector) (Figure 3), to remedy the errors found and perform corrective actions, parameters that refer to the recommendation of the manufacturer. The gain than the energy step (Figure 4) reflects the peak energy spectrum for each PET crystal[16], finally, the timing of each crystal which showed the illustration of a failed module (Figure 5).

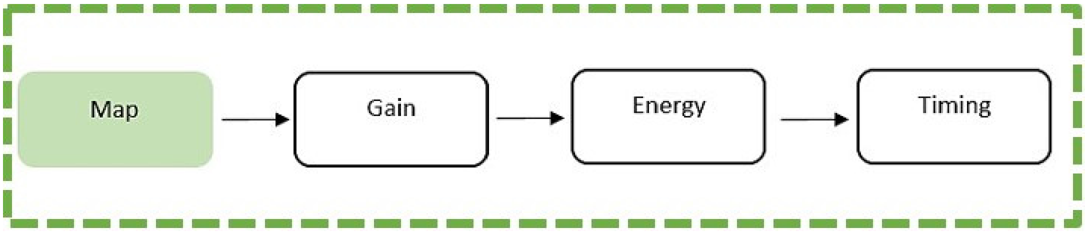

Fig. 3. Roadmap (detector calibration process workflow) -GE Discovery 610 Elite (study)

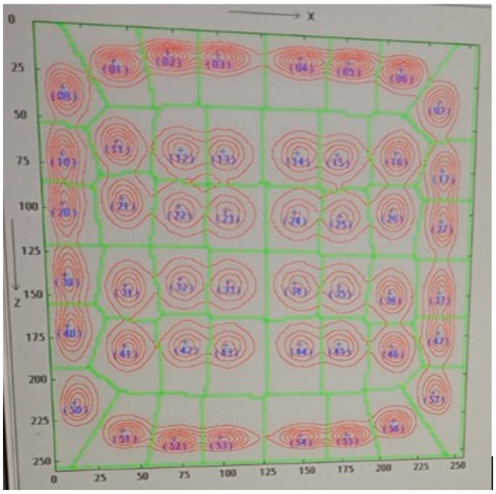

Fig. 4. Energy step –Roadmap of the (QC) (PET)

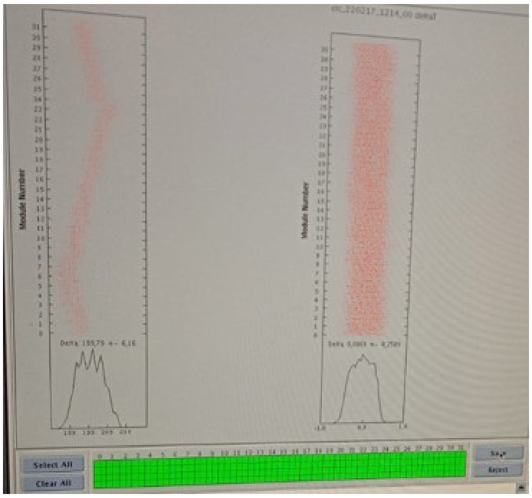

Fig. 5. Timing step – Roadmap of the (QC) – (PET)

However, the questionnaire that was distributed to the staff of the nuclear medicine department focused on the following aspects (training in radiation protection for patients and the implementation of the quality assurance program especially the "QC" procedures in the nuclear medicine department.

RESULTS

At the end of the "QC" procedure, a final report in the form of a sinogram was resulted (Figure 6). Indeed, a positive result, because the failure of the module noted at the beginning of the control, was corrected through the correctives actions performed by the daily quality control procedure especially the steps of the roadmap.

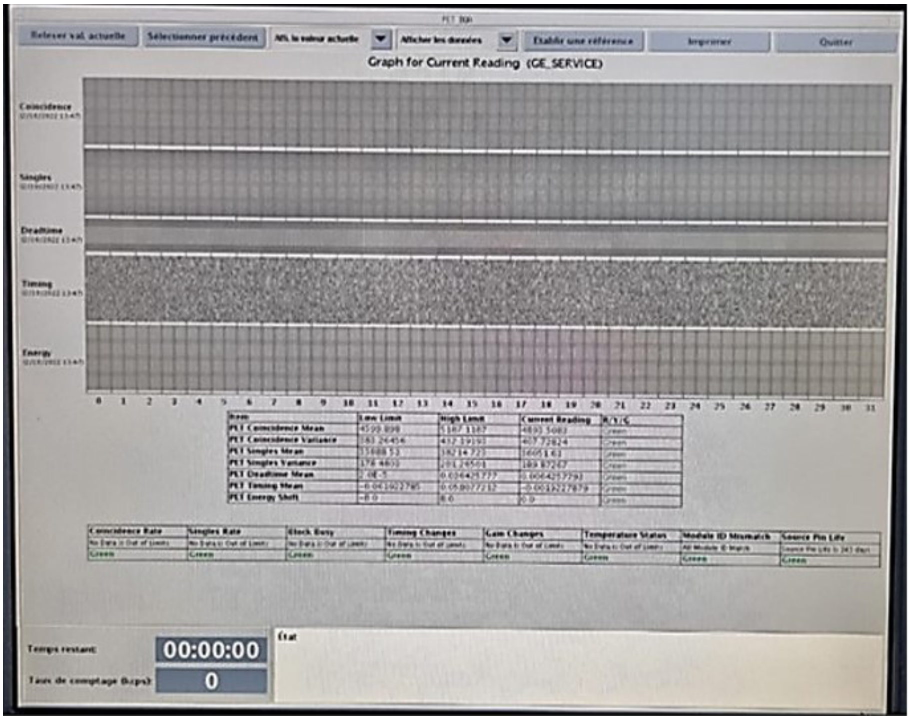

Fig. 6. Corrected sinogram – Daily quality control for the (PET – GE discovery 610 elite (study)

In addition, according to the results collected from the questionnaire previously distributed to the medical staff of the department of nuclear medicine; object of our work; the staff does not have optimal training in radiation protection for patients in addition to the lack of implementation of a quality assurance program and specifically the establishment of "QC" procedures. The results of the questionnaires distributed reflect in (Table 2).

Table 2. Results of questionary (study)

	Training in radiation protection for patients	Optimization of medical protocols (Administering of radioisotopes)	Implementation of the quality assurance program	Establishment of the quality control procedures	Establishment of the daily quality control procedures – PET (One a year)
Nuclear medicine physician	No	Yes	No	No	Yes
Technologist	No	Yes	No	No	Yes
Nurse	No	Yes	No	No	Not concerned

No Yes Not concerned

DISCUSSION

According to the result of the "QC", a procedure performed for the "PET/CT", object of our this study, in particular the corrective actions of a failing module of the "PET", it is important to perform the "QC" with the daily frequency for the GE equipment[13,14,15].In addition, according to the results of the questionnaire distributed to the staff of the nuclear medicine department (nuclear medicine physicians, technologists, and nurses), the implementation of a quality assurance program is absent specifically the realization of "QC" procedures, as well as the establishment of training in radiation protection of the patient, particularly continuous training in the department. Two fruitful results of this study demonstrate the importance of a qualified medical physicist within a nuclear medicine department using ionizing radiation. First, he will ensure the implementation of a quality assurance program[11]and the establishment of the "QC" procedures that represent an essential step of the said program[2]. The procedures will be performed by the "PET/CT" unit technologist and consulted with a qualified medical physicist[11, 17]. Second, he assists in the implementation of training in radiation protection of the patient in the unit, which is also among the steps of the quality assurance program[2].Moreover, it is an important study that affirms the usefulness of the presence of a qualified medical physicist, in particular, a requirement that described the law 142-12 in article 102; at least one qualified medical physicist must be present in each nuclear medicine department[18]. Indeed, a study that will strengthen the academic opinion in Morocco in this field.

CONCLUSION

To conclude this successful study, it is necessary to establish a quality assurance program and implement the culture of radiation safety to ensure patient radiation protection in a nuclear medicine department[2]. Indeed, a quality assurance program should be implemented and should include the procedure for daily quality control of "PET/CT", including the "PET" part[13].In addition, the presence of a qualified medical physicist becomes essential in the nuclear medicine department, to ensure the establishment of daily quality control procedures and to implement radiation safety recommendations through radiation protection training for the patient. A work that will be in collaboration with the staff of the said department[11]. Therefore, it is important to evaluate the daily quality control parameters and take appropriate corrective actions[2] and effective "QC" is an important means of ensuring the repeatability of medical applications[19]. To this end, it is made necessary to perform the said in each medical installation through the sources of ionizing radiation[20], thus ensuring optimization of medical exposures and improved image quality for medical protocols in nuclear medicine.

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Conflict of Interest

All authors declare that there is no conflict of interest.

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