Radiation Exposure in Routine Practice with PET/CT and Automatic Infusion System – Practical experience report

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Abstract— **Specially when handling higher energy radioactive sources, such as F-18, the principle that radiation exposure is to be kept as low as possible must be considered. In the first two months of operation of our PET/CT scanner we were performing measurements of whole-body dose received at different steps of PET diagnostic procedure. We found doses received by radiopharmacist were 0.6 ± 0.7 µSv per day and by physician 1.2 ± 0.4 µSv per patient; both are reduced due to use of automatic F18-FDG infusion system. Doses received by technologist were 1.3 ± 0.9 µSv due to morning QC and 2.5 ± 2.1 µSv was cumulative dose per patient imaging. Estimation on the basis of measurements shows yearly doses would remain well bellow legal limits but large standard deviation implies reduction of doses with routine practice is still possible.**

Keywords— **radiation exposure, PET/CT, automatic infusion system**

I. Introduction

In December 2009 a second system for Positron Emission Tomography – Computed Tomography (PET/CT) scanning in Slovenia was installed in Department of Nuclear Medicine at University Medical Centre in Ljubljana. Introduction of this new technology to the department increased the risk of high staff radiation dose because of higher radiation energy of PET isotopes (511 keV) compared to conventional nuclear medicine isotopes, most common of which is technecium-99m (140 keV). Aim of our study was to measure radiation doses of our staff involved in various steps of PET diagnostic procedure and evaluate its standard deviation.

II. Materials and methods

PET/CT system at University Medical Centre in Ljubljana is Siemens Biograph mCT. Routine work on the PET/CT scanner started in beginning of 2010 and currently twice or three times per week on average 7 patients are imaged. Our study included 115 PET/CT procedures conducted in the first two months of scanner operation.

A. F18-FDG Manipulation and Protection Devices

Classical diagnostic procedures in PET departments begin with morning quality control (QC) of PET (or PET/CT) system, preparation of positron-emitting radiopharmaceutical, injection of radiopharmaceutical to the patient, imaging and occasionally transport of wheel-chair patient to their residing hospital department. All these steps of diagnostic procedure involve radiation exposure that depends on the distance from the radiation source, shielding and the time of exposure.

Lately increasing number of PET centers is replacing manual dosage of radiopharmaceuticals and their application to the patient with the use of automatic infusion systems and thus reducing the radiation exposure of the staff. In our department Medrad Intego PET Infusion System was installed along with the PET/CT system and has thus been used from the beginning of scanner operation. Other forms of shielding of positron-emitting isotope in our department include mainly concrete and lead walls or screens.

Fig. 1 Automatic infusion system used in Department of Nuclear Medicine at University Medical Centre in Ljubljana

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B. Dosimetry

Routinely the staff in our department is monitored for radiation exposure with thermoluminescent dosimeters (TLD) which are changed once per month and will in longer term reflect radiation exposure due to PET/CT procedures compared to our conventional practice. Still because of a time lag the information provided by TLD is not appropriate for current study. We designed our study to record whole-body dose at each working step with electronic personal dosimeters Rados RAD-60S worn at waist level. Doses were collected for each worker after each working day at the PET center. Intermediate values (after each patient) were read out as well.

Our F18-FDG PET procedure was divided into five working steps. The first step was receipt of container with daily amount of F18-FDG, placement of this container into the automatic infusion system and preparation of system for daily use, which included daily QC, tubing setting and priming; this step was done by radiopharmacist. Daily activity placed into the infusion system was 9.7 ± 1.5 GBq and was delivered to the department within tungsten-shielded multi-dose vial that was not opened during placement. The second step was injection of 365 ± 31 MBq activity of F18-FDG into the patient. Activity of tracer infusion for individual patient was automatically measured and calibrated inside the shielded infusion system cart and then automatically delivered directly to the patient. Injection was supervised by physician who afterwards escorted the patient to the waiting room behind the lead wall if needed and after the imaging withdrew the catheter. The third step was daily QC procedure of the PET/CT scanner including test with Ge-68 PET phantom and CT test and was performed by technologist. The forth step included collecting the patient about 30 minutes to 1 hour after tracer infusion, escorting the patient to the PET/CT scanner, positioning within the camera and escorting the patient out of the PET room after the image acquisition. This step was performed by team of two technologists, who spent most of the scanning time in control room supervising the patient over video camera. The fifth, last, step was optional transfer of the wheel-chair patient to their residing hospital department.

Besides whole-body individual dose measured with electronic dosimeter we also performed measurements of dose rate at various distances from the radiation source (patient and F18-FDG vial) with dose rate meter EGG-Berthold LB123.

III. Results

Instantaneous dose rates measured at various distances from the radiation source are presented in Table 1 (F18-FDG vial) and Table 2 (patient).

Table 1 Dose rates (DR) measured from F18-FDG vial with activity 9.7 ± 1.5 GBq

Distance from F18-FDG vial [m]	DR from vial in transport container[μSv/h]	DR from vial placed in infusion system [μSv/h]
0	157 ± 23	1.5 ± 0.3
0.5	43 ± 9	0.5 ± 0.2
1.0	19 ± 7	0.3 ± 0.2
2.0	10 ± 3	background level

Dose rates near F18-FDG vial in transport container are very high but trained radiopharmacist is directly exposed to this dose rate for no more than 10 seconds. Since dose rate from the F18-FDG vial placed in automatic infusion system is reasonably small no special restrictions regarding movement in proximity of infusion system is required. Dose rates at close contact and near patient are also very high, but time of staff exposure to these dose rates varies.

Table 2 Dose rates (DR) measured from patients injected with 365 ± 31 MBq F18-FDG

Distance from patient [m]	DR immediately after injection [μSv/h]
0	135 ± 21
0.5	43 ± 9
1.0	19 ± 7
2.0	10 ± 3

The average doses received at different working steps of PET/CT diagnostic procedure are given in Table 3. All recorded doses are due to F18 radiation, there is no recorded contribution due to CT because during CT operation staff is kept outside the scanning room and walls of the room are sufficiently shielded to keep background dose rate outside.

Whole-body dose received by radiopharmacist during morning infusion system preparation was 0.6 ± 0.7 μSv, whereas physician received 1.2 ± 0.4 μSv per injection to the patient. Both doses are reasonably low, as a result of use of automatic infusion system [1, 2].

Whole-body dose to the technologist during QC procedure of PET/CT system was 1.3 ± 0.9 μSv, but during imaging patients cumulative dose received by two technologists was 2.5 ± 2.1 μSv per patient. We notice large standard deviation of this measured dose which is the consequence of

different patient mobility and therefore great variation in time the technologists spend in proximity of the patient.

On the basis of these dose measurements we estimate additional doses due to PET procedures on a yearly level would reach up to two times the doses received in our conventional nuclear medicine practice (in 2009: physician 0.36 ± 0.30 mSv; radiopharmacist 0.33 ± 0.34 mSv, technologist 0.97 ± 0.42 mSv) but would still remain well within the annual radiation dose limits. Our estimation is based on yearly plan of 250 working days and 1500 patients with 3 physicians, 3 radiopharmacists and 4 technologists working. Continuing with good operators' practice and improving operational skills staff doses may be lower.

In the time of this introductory study transport of the patients to their resident hospital department was conducted in only 10 cases and accounted for radiation dose from 1 μSv to 6 μSv. This value is not easy to evaluate due to small number of cases and great variation of path distance. Transport of patients is expected to be needed in 10-20% of cases in the future and will be performed by out of department service that employs few tens of people therefore very low doses are expected per person. Nevertheless our result implies a note should be issued to suggest the service potentially pregnant workers should not be assigned to transfers of PET patients.

Table 3 Whole-body doses (WBD) received at different working steps and activity of corresponding radiation source. In steps 4 and 5 decay of injected activity is taken into account.

Step	Short description	Activity [MBq]	WBD per procedure [μSv]
1	Infusion system preparation	9680 ± 1487	0.6 ± 0.7
2	F18-FDG injection	365 ± 31	1.2 ± 0.4
3	PET/CT QC	94	1.3 ± 0.9
4	Patient imaging (1 or 2 technologists)	280 ± 50	2.5 ± 2.1
5	Wheel-chair transport	~ 200	1 – 6

IV. Conclusions

Results of our study provide first data regarding routine occupational exposure to radiation in PET diagnostic procedure which has been recently introduced to our department. Measured whole-body radiation doses of our staff showed different level of received doses at five working steps of the procedure.

Automatic infusion system provides safe and accurate dose preparation and infusion of F18-FDG in PET procedure. Radiopharmacist involved in morning preparation is exposed to the highest dose rates, but due to the use of automatic injection system duration of exposure is no more than few seconds. In this regard usage of automatic infusion system virtually eliminates manual dose preparation and occupational risk for radiopharmacist involved in PET procedure is lowered.

Also dose rates at close contact and near patient are very high and draw special attention to received radiation dose of staff handling the patient. Dose depends on the time spent in proximity of patient. Time that physician spends near the patient during F18 tracer application is minimally influenced by patient's condition and can be in the future optimized with increased physician's skills.

On the other hand patient's condition greatly influences the time spent for positioning within the PET/CT scanner and technologist's radiation exposure. Our results show large standard deviation of measured dose and therefore stress necessity of tracing of individual effective doses of technologists which should result in temporary removal of individual from working in PET if recommended dose limit is approached.

References

1. Guillet B, Quentin P, Waultier S et al. (2005) Technologist Radiation Exposure in Routine Clinical Practice with 18F-FDG PET. J Nucl Med Technol 33:175–179
2. Pant GS, Senthamizhchelvan (2006) Radiation Exposure to Staff in a PET/CT Facility. IJNM 21:100-103

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