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Radiation Exposure to the Stuff Working in PET/CT and Cyclotron Facility

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Abstract. Positron Emission Tomography (PET) has been available in number of centers for more than 25 years, but its use was not wide spread until 10 years ago. In Bulgarian PET/CT was installed for the first time in 2009 and the dose on demand cyclotron also for the first time – in 2013 in Nuclear Medicine Department in University Hospital St. Marina in Varna, Bulgaria.

Responsibility of every radiation protection officer is to educate the stuff how to protect their selves from radioactive exposure and to observe and calculate the dose to the people and the stuff.

The purpose of this paper is to show how big the doses of the stuff working in Nuclear Medicine Center including PET/CT and Cyclotron facilities situated in University Hospital St. Marina in Varna, Bulgaria are.

The Department is working now with about 15 patients every day. The dose rates measured with personal TLD's and personal dose rate meters for the last 5 years for the stuff are under 3 mSv. As the average dose is under 1 mSv, and the doses over 1mSv are only for nurses who injected the FDG.

Keywords: radiation exposure, effective dose, PET/CT, Cyclotron, FDG

1 Introduction

The first PET/CT in Bulgaria was installed in 2009 in Nuclear Medicine Department in University Hospital St. Marina in Varna.

In 2010 another PET/CT was installed in Nuclear Medicine Department in University Hospital Aleksandrovska in Sofia.

Till the moment 5 PET/CT facilities were installed in Bulgaria but only three of them are working with patients.

In 2013 the first cyclotron was installed in Nuclear Medicine Department in University Hospital St. Marina in Varna. Till the moment there are three cyclotrons in Bulgaria but only one of them is working with patients and producing FDG for hospital use.

The radionuclide produced in our Cyclotron and used for PET/CT examinations is fluoro-2-desoxyglucose (FDG). FDG is labeled with F-18, whose half life is only 109 min, but it is positron emitting. The energy of annihilation is 511 keV. The radioactive F-18 is the main reason for radioactive exposure to the stuff.

At the cyclotron and PET/CT facilities in Nuclear Medicine Department in University Hospital St. Marina, Varna, the following stuff is working:

- **Physicians** – they are responsible for the whole procedure of the patient, they are planning the patient for PET/CT, analyze the results and diagnose the patients. They do not have any direct contact with isotopes or injected patients except in emergency situations. In that case we do not expect physicians to have high radiation exposure so they are not included in our fallowing statistic. The doses of physicians for the whole five years from PET/CT installation till now are lower than 1 mSv per year.
- **Physicists** – they make every day's verification tests of the nuclear medicine equipment and make sure every machine work properly, they make QC and QA procedures to the nuclear medicine facilities, they calibrate the equipment whether it is needed. Physicists are also radiation protection officers so they make monitoring of radiation exposure of all the areas (controlled and uncontrolled) in the department and are responsible for dosimetry in the department. The doses of physicists for the whole five years from PET/CT installation till now are lower than 1 mSv per year, so they also are not included in our following statistic.
- **Chemists** – they are working at the cyclotron – they are responsible for FDG producing and transporting it to the quality control and injection room (it is one and the same room).
- **Clinical technologist**s – they are responsible for FDG quality control procedures
- **Nurses** – they are responsible for patient injecting with radioisotope
- **Technologists –** they are responsible for PET/CT procedure including patient positioning and imaging

The Department is working five years now with about 15 patients every day. Around 2000 patients undergo PET/CT

procedures at the Department every year. As we has almost the same number of patient very year and the same stuff we can make statistic and comparison of effective dose from radiation exposure caused by FDG production, injection and PET/CT procedures with FDG. The effective doses measured with personal TLD's and personal dose rate meters for the last 3 years for the stuff are given below.

2 Radiation Exposure to Chemists

Chemists are working at the cyclotron. They are involved to the whole production mechanism of FDG, and also some of the quality control procedures that are automatically made in quality control module of the cyclotron complex system. They are operating with every syringe filled of FDG that is produced from the cyclotron and transport it to the injecting room.

How to decrease radioactive exposure [1,2]? There are two things made in 2013 to reduce the exposure:

- Installation of video camera for monitoring the FDG production. In this way the chemist will not stay all the time in the controlled area
- Using shielded container for dose transportation from preparation room to the injecting room

After calculating the data from dose exposure of the chemists working at the cyclotron during period of two years from 2013 and 2014, we decided that an extra shielding to the chemical module will be very important to decrease the dose exposure to operators [3].

Another two things are made in 2015 (during the upgrade of the cyclotron complex system) to reduce the exposure:

- Installation of software for remote access, now we can operate the cyclotron from uncontrolled area and go to the controlled area only for a few time to take the syringe with the FDG and to change the dose synthesis card.
- An extra shield was installed in front of the chemical synthesis module. This shield is made of 5 cm lead and lead glass.

Advantages :

- Reduced time remain in the controlled area. The working process is observed outside the controlled area
- Allows working during emergency situation. Observing the process from distance until the dose rate goes to normal levels
- Decreasing many times the dose rate after the extra shield of the chemical module

Data analysis :

Information for effective doses to chemists for one year, are given in the tables below. Table 1 and Table 2 contain data for effective doses to chemists and equivalent doses for arm measured with TLD dosimeters. Table 3 contains data for effective doses to chemists measured with individual portable Dose Rate Meters-Gamma Twin, Graetz.

Table 1. Effective doses to chemists from TLD dosimeters

	Effective dose to chemists for 1 year, mSv/y		
Year	Chemist "I"	Chemist "II"	Chemist "III"
2013	2.03		
2014	1.63	1.30	0.79
2015	0.54	0.45	0.26

Table 2. Equivalent doses for arms to chemist from TLD dosimeters

	Equivalent dose to arms, mSv/y		
Year	Chemist "I"	Chemist "II"	Chemist "III"
2013	10.08		
2014	8.48	4.93	3.79
2015	14.09	4.69	4.09

Table 3. Effective doses to chemist measured with Gamma Twin individual Dose Rate Meters

	Effective dose to chemists for 1 year, mSv/y		
Year	Chemist "I"	Chemist "II"	Chemist "III"
2013	1.2		
2014	1.72	0.78	0.58
2015	0.71	0.47	0.21

Results :

Effective dose to chemists decreases more than 50% after installation of the extra shield of doses calibrator.

3 Radiation Exposure to Clinical Technologists

Clinical technologists are working in the FDG Quality Control laboratory. They are responsible for FDG quality control procedures. They measure the injection activity, and make some tests: radiochemical identity (half life) test, radionuclide purity test (using multi channel analyzer) and test for endotoxins in the FDG solution.

How to decrease radioactive exposure? There are two things made to reduce the technologist exposure:

- In 2013 year, 3.2 cm equivalent lead glass has been installed in front of endotoxin test machine. It is more than enough according to the fact that for endotoxin test are used activities in the range of kBq. This shield reduces the dose rate to background levels.
- In 2014 year, shield for doses calibrator has been made. The shield is made of 5 cm lead bricks around the doses calibrator. These 5 cm lead shield practically reduce the dose rate to background levels.

Advantages :

- Decreasing many times the dose rate after the extra shield of the doses calibrator

Data analysis :

Effective doses to technologists for 1 year, are given in Table 4. These data are measured with the TLD dosimeters.

Table 4. Effective doses to technologists from TLD dosimeters

	Effective dose to technicians for 1 year, mSv/y		
Year	Technologist "I"	Technologist "II"	Technologist "III"
2013	0.45	0.26	
2014	0.16	≤ 0.1	≤ 0.1
2015	0.19	0.11	≤ 0.1

Results :

Effective dose to technologists decreases more than 50% after installation of the extra shield of doses calibrator.

4 Radiation Exposure to Nurses

Nurses are working with patients. Unlike the chemists and clinical technologists who are working with radioactive nuclide FDG in liquid form as an injecting solution, nurses are working and are irradiated from gamma rays from the patient (injected with the same radioactive solution of FDG). The difference here is that the patient (as a source of radioactive exposure) is not point source and it is moving. In that case to achieve dose reduction for the stuff will be more difficult.

How to decrease radioactive exposure? There are few things made to reduce the nurse's exposure:

- All the patients has blood line taken before the FDG injecting
- Lead shield for the syringe are used during the injection procedure

After calculating the data from dose exposure to nurses during period of almost two years (2013–2014), we decided that an extra shield between nurses and patients will be very important to decrease the dose exposure.

- In 2014 year, whole body shield for nurses has been made. The shield is made of 5 cm lead bricks and 5 cm equivalent lead glass.

Advantages :

- Reducing exposure time during patient injecting operations
- Decreasing many times the dose rate after the extra shield for nurses

Data analysis :

Effective doses to nurses for 1 year, are given in Table 5. These data are measured with the TLD dosimeters.

Table 5. Effective doses to nurses from TLD dosimeters

	Effective dose to nurses for 1 year, mSv/y		
Year	Nurse "I"	Nurse "II"	Nurse "III"
2013	2.05	1.81	1.40
2014	0.92	0.62	0.30
2015	0.75	0.30	0.26

Results :

Effective dose to nurses decreases more than 50% after installation of the extra shield of doses calibrator.

5 Radiation Exposure to Technologists

Technologists are working at the PET/CT. They are responsible for patient positioning at the PET/CT and making the whole diagnostic procedure. They are irradiated from gamma rays from the patients (injected with FDG) on one hand and on the other hand from X-rays from X-ray tube of the CT part of PET/CT.

How to decrease radiation exposure? There are two things made to reduce the technologist's exposure:

- Audio video system for observing and communicate with the patients from safe distance was installed in 2009.
- During patient positioning, technicians do not enter the procedure room. They give the instructions to the patient from a safe distance using audio system installed in the PET/CT facility. There are some exceptions while technologist has to help patient for example patients with hearing problems or in bad physical condition.

Advantages :

- Audio video systems allows reducing to minimum close contact with the patients and respectively decreasing technologist's exposure

Data analysis :

Effective doses to technologists for 1 year, are given in Table 6. These data are measured with the TLD dosimeters.

Table 6. Effective doses to technologists from TLD dosimeters

	Effective dose to technicians for 1 year, mSv/y	
Year	Technologist "I"	Technologist "II"
2013	0.21	0.,38
2014	≤ 0.1	0.12
2015	0.0	0.17

Results :

Effective dose to technologists decreases a little. The reason for this may be the fact that during the time from PET/CT installation till now technologists has learned how to work faster, more precise and accurate.

6 Conclusion

In the conclusion of this article we can say that effective dose to stuff is lower than the effective dose limits [4,5]. The maximum value of effective dose at the beginning was less then 3 mSv/y for a nurse, and less than 2 mSv/y for the rest of the stuff. After installing new shielding during 2014 and 2015 year decreasing with more than 50% of the effective dose are observed. Now the average effective dose to stuff is under 1 mSv per year.

References

[1] European Council Directive 96/29/EURATOM of 13 May 1996 on "basic standards" for the protection of the health of workers and the general public against the dangers arising from ionizing radiation.

[2] European Council Directive 97/43/EURATOM of 30 June 1997 on health protection of individuals against the danger of ionizing radiation in relation to medical exposure.

[3] Recommendation of International Commission on Radiation Protection (ICRP), Report # 60.

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