

ESTIMATION OF DOSES FROM PATIENTS UNDERGOING TREATMENTS WITH RADIOPHARMACEUTICALS

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Abstract. *The diagnosis and treatment with radiopharmaceuticals are important moments in clinical practice. In this case, it is especially important to take measures to protect the people who will have contact with a patient with introduced radiopharmaceuticals. In this article, the evaluation of the patient doses and their change over time in the diagnosis with radiopharmaceuticals was made. What was considered was the case in the diagnosis of patients with radiopharmaceutical Fluorine-18 by positron emission tomography and radiopharmaceutical Technetium-99m by gamma camera.*

Key words: *Biological action, ionizing radiation, radiation protection*

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1. INTRODUCTION

Taking into account the biological action of ionizing radiation, its use for diagnosis and treatment in medicine is gaining more and more momentum. Nowadays, there is a lot of talk for the benefit of irradiation at small doses - radiation hormesis. However, the irradiation which people receive must be rigorously monitored and reduced to a minimum [1]. The development of modern science and technology leads to the appearance of an increasing number of new technologies and methods using ionizing radiation for medical purposes [3]. New generations of medical devices replace the old ones and the dose load for the patients from ionizing radiation is less harmful. The modern equipment needs well-educated and trained medical and non-medical personnel to work with this equipment.

The trend observed worldwide is especially relevant for Bulgaria. The University Hospital St. Marina in Varna is one of the leading hospitals in this respect. In 2009, the upgrade and introduction of modern medical equipment using ionizing radiation began here, and it has been done ever since.

The medical X-ray equipment and the gamma camera were entirely replaced. For the first time in Bulgaria a new PET/CT equipment was commissioned (2009). The cyclotron complex for the production of the radiopharmaceutical FDG with radionuclide F-18 (used in the PET/CT examinations) was commissioned in 2013 and this kind of equipment was entirely new for Bulgaria. In 2015, two linear accelerators for cancer treatment were commissioned and in 2016, a third one was commissioned. In the course of any medical procedure where ionizing radiation is used, the patient is informed in advance about the benefits and harms of

respective procedure. In case of treatment involving ionizing radiation, the patient is prompted to declare his written consent for the respective procedure. When open sources of ionizing radiation are used, the patient is properly informed about how to act during his/her contacts with other people after the end of the examination.

Such procedures are the injection of a radiopharmaceutical for the examination with PET/CT or gamma camera. These patients are advised to limit their direct contact, especially with small children and pregnant women. The requirement is needed in order to reduce the exposure of people in contact with the patients during the next few days. If the patient is a mother who breastfeeds her baby, it is strongly recommended to stop breastfeeding during this period of time and to minimize the contact with the baby.

If the patient is a pregnant woman, a team of specialists decides precisely if there is the necessity of using a procedure involving radiopharmaceuticals. The procedure is performed only when the life of this woman depends on the immediate diagnostics of the disease. In all other cases, the procedure involving radiopharmaceuticals is postponed until after the baby is born. If the patient is a child, the rules are even more stringent. The procedure is performed after a thorough collection and processing of multiple pieces of information about the child, including obtaining information from the parents.

All these rules are fixed in the written form called “Informed consent”, that is specific for each procedure. The patient must read this form before the respective examination or treatment and must approve it by applying his signature.

Aside from the information in this form, the patient receives verbal information from a specialist in the clinic about the actions before, during and after

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finishing the examination with radiopharmaceuticals or the iodine therapy. Boards with the above information are placed on a noticeable place in the clinic for nuclear medicine and metabolic therapy. Beside the information boards, the patients receive leaflets containing specific information about the respective procedures. Following these procedures, the patient protects other people in his vicinity from unnecessary, unwanted dose load from ionizing radiation.

In the following description, we will show how to change the values of the absorbed dose to the patient after the procedure with radiopharmaceuticals. In these calculations, we report only the half-lives of radioactive isotopes in radiopharmaceuticals. However, from these calculations, it is clear that these patients had an excessive radioactive dose. It is quite high in the first hours after the procedure. Therefore, direct contact with these patients, especially in the first hours after the procedure, would be dangerous to people around them. This applies especially to children who are the most radiosensitive.

2. FOR PATIENTS EXAMINED BY A PROCEDURE USING THE INJECTION OF A RADIOPHARMACEUTICAL

Patients who are examined by a PET/CT equipment or a gamma camera undergo such a procedure.

2.1. Patients injected with the radiopharmaceutical FDG with radionuclide F-18

In the Clinic for Nuclear Medicine and Metabolic Therapy at the University Hospital in Varna, as a radiopharmaceutical for the PET/CT examination, the radionuclide Fluorine-18 (F-18) is used. In this radiopharmaceutical, some glucose atoms are marked and glucose is the most quickly absorbed substance by cancerous tumors. The radiopharmaceutical being injected intravenously to the patient is FDG - fluorodeoxyglucose. The activity injected to the patient is calculated according to his weight - 4,81 MBq per kg. In this way, a patient of 80 kg will be injected with 384,8 MBq. The half-life of F-18 is 1.83 h [5]. From the moment of the injection until the time when the patient leaves the hospital, about 1.5 hours pass. The residual activity to the patient after leaving the hospital is 218,67 MBq (here we use the expression $A = A_0 e^{-\ln 2t/T}$) [2]. For the gamma constant for F-18 we use 0,1527 R.cm² /Mbq.h [6]. For a medium like air, the connection between the unit for dose rate (P_x) - Roentgen (R) and the unit for dose (D) - Gray (Gy) is given by the equation $D = f \cdot P_x$, where $f = 873 \cdot 10^{-5}$ Gy/R. The radiation weighting factor (w_R) for the background radiation coming from F-18 is 1. The connection between the units for absorbed dose - Gy and the equivalent dose - Sievert (Sv) is $Gy = 1Sv$. Here we will calculate the dose per minute in μSv, received by people in the vicinity of the patient, staying at a certain distance and for a certain interval of time after his leaving of the clinic. In Table 1, the changes of the doses of patients with F-18 are calculated, after living the clinic: at the 5th, 15th and 30th minute and at the first, the second, the 12th and the 48th hour.

Table1. Dose in μSv per minute, received by a person staying at a given distance in a specific moment of time from a patient injected with 384,8 MBq FDG.

The activity has decreased to 218,67MBq at the time of leaving the hospital. The red color denotes higher doses (that the person can accumulate if he or she is staying near the patient and does not follow the instructions given in the hospital). In that case, the dose accumulated by the person will be above the limit, and green color - doses under the limit.

Time \ Distance	Dose [μSv] per minute at a distance				
	0.2 m	0.5 m	1.0 m	1.5 m	2.0 m
0 minutes	12146.10 ⁻⁴	1943.10 ⁻⁴	1349.10 ⁻⁴	599.10 ⁻⁴	337.10 ⁻⁴
5 minutes	11872.10 ⁻⁴	1899.10 ⁻⁴	1319.10 ⁻⁴	586.10 ⁻⁴	329.10 ⁻⁴
15 minutes	6148.10 ⁻⁴	984.10 ⁻⁴	683.10 ⁻⁴	304.10 ⁻⁴	171.10 ⁻⁴
30 minutes	5602.10 ⁻⁴	896.10 ⁻⁴	622.10 ⁻⁴	276.10 ⁻⁴	156.10 ⁻⁴
1 hour	4631.10 ⁻⁴	741.10 ⁻⁴	515.10 ⁻⁴	229.10 ⁻⁴	129.10 ⁻⁴
2 hours	3175.10 ⁻⁴	508.10 ⁻⁴	353.10 ⁻⁴	157.10 ⁻⁴	88.10 ⁻⁴
12 hours	61.10 ⁻⁴	10.10 ⁻⁴	7.10 ⁻⁴	3.10 ⁻⁴	2.10 ⁻⁴
24 hours	0,80.10 ⁻⁴	0,10.10 ⁻⁴	0,09.10 ⁻⁴	0,04.10 ⁻⁴	0,02.10 ⁻⁴
48 hours	0,20.10 ⁻⁴	0,03.10 ⁻⁴	0,02.10 ⁻⁴	0,008.10 ⁻⁴	0,004.10 ⁻⁴

2.2. The patients with radionuclide Technetium - 99^m

For the examination with a gamma camera, the patients are being injected with Technetium - 99^m (Tc-99^m). Depending on the examined organ, the patient is injected with a different activity. The calculations which we are going to make, are for a patient injected with the activity of 740 MBq, to whom an examination on the bone structure is performed. The half-life of Tc-99^m is 6.01 hours.[7] From the moment of the injection to the leaving of the hospital, normally 2.5 hours pass. After this time, the residual activity in the patient will be 552,04 MBq. (we use the expression $A = A_0 e^{-\ln 2t/T}$) [2]. For the gamma constant for Tc - 99^m we use 0,0195 R.cm² /MBq.h. [7]. The considerations about the used unit, made for F-18, are valid also in this case. What dose per minute in μSv would be received by people in the vicinity of the patient at certain distance and in a given moment of time after living the clinic: at the 5th, 15th and 30th minute and at the first, the second , the 12th and the 48th hour? This information is given in Table 2. In Table 2, the changes of the doses in patients with Tc - 99^m are calculated.

Table 2: Dose per minute in μSv, received by a person at a given distance and in a given time from a patient injected with Tc - 99^m with initial activity of 740MBq. The residual activity is 552,04 MBq when the patient leaves the hospital. The red color denotes higher doses (that the person can accumulate if he or she is staying near the patient and does not follow the instruction given in the hospital). In that case, the dose accumulated by the person will be above the limit, and green denotes doses under the limit dose.

Time \ Distance	Dose [μSv] per minute at a distance				
	0.2 m	0.5 m	1.0 m	1.5 m	2.0 m
0 minutes	12146.10^{-4}	1943.10^{-4}	1349.10^{-4}	599.10^{-4}	337.10^{-4}
5 minutes	11872.10^{-4}	1899.10^{-4}	1319.10^{-4}	586.10^{-4}	329.10^{-4}
15 minutes	6148.10^{-4}	984.10^{-4}	683.10^{-4}	304.10^{-4}	171.10^{-4}
30 minutes	5602.10^{-4}	896.10^{-4}	622.10^{-4}	276.10^{-4}	156.10^{-4}
1 hour	4631.10^{-4}	741.10^{-4}	515.10^{-4}	229.10^{-4}	129.10^{-4}
2 hours	3175.10^{-4}	508.10^{-4}	353.10^{-4}	157.10^{-4}	88.10^{-4}
12 hours	61.10^{-4}	10.10^{-4}	7.10^{-4}	3.10^{-4}	2.10^{-4}
24 hours	$0.80.10^{-4}$	$0.10.10^{-4}$	$0.09.10^{-4}$	$0.04.10^{-4}$	$0.02.10^{-4}$
48 hours	$0.20.10^{-4}$	$0.03.10^{-4}$	$0.02.10^{-4}$	$0.008.10^{-4}$	$0.004.10^{-4}$

CONCLUSIONS

The above estimation of the doses is very rough. Here, only the half-life is taken into account. Not taken into account are the biological half-life and the effective biological half-life. The contribution of these factors to the dose estimation would not have a significant meaning in this case.

In Bulgarian law, the safe upper limit of the dose rate that a person subjected to the impact of the source of ionizing radiation can get is given in the Law on Safe Use of Nuclear Energy [4] and the Regulation on the Basic Norms of Radiation Protection [5]. Persons having contact with a radioactive patient fall into the category "population". **For this category, in the Regulation on the Basic Norms of Radiation Protection [5], the given limit of the dose is 1mSv for 1 year. This value is $19.10^{-4} \mu\text{Sv}$ for one minute.** Comparing this limit dose for one minute and the calculations made, the following conclusions can be made:

1. Higher initial values and a faster decrease of the received dose are observed for the case of the administration of F-18. For the examinations with Tc – 99^{m} , the initial values are lower but the dose decreases more slowly. Thus, the patients who received F-18 can release the radioactive isotope more rapidly than the patients with the procedure with Tc– 99^{m} .
2. The received doses per minute at the moment of leaving the hospital differ for patients with F-18 and for patients with Tc – 99^{m} . It is accepted that in order to be sure that the isotope is released from the body, at least 10 half-lives must pass. In this case, the patients, after the procedures with F-18, must follow the restrictions for at least 20 hours after the examination. Those who passed the scintigraphic examination with Tc – 99^{m} must

follow the restrictions for at least 60 hours after the examination.

3. Here, the biological half-lives are not taken into account, but nevertheless, the result is very significant. **For both kinds of examinations, it is absolutely necessary for the patients to follow the recommended safety rules after the performed procedures with radiopharmaceuticals.** The patients with F-18 are more dangerous in case of close contact in the first hours after the examination, but this is true only for a short period of time. The patients with Tc – 99^{m} are dangerous for a longer time, but in the beginning, the radiation emitted from them is lower.

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