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Original

Referral to radioisotope examination as a source of additional radiation exposure for staff. Referral as a source of radiation exposure

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Abstract

BACKGROUND: Every exposure of human to ionizing radiation increases the likelihood of deterministic sequelae. At the same time, it is associated with the risk of stochastic effects. Consequently, this can lead to cancer, mainly of the hematopoietic system. Organs or tissues show a different affinity for gamma radiation. There are many technical and organizational measures which minimize the impact of this radiation on people and especially on the staff of the nuclear medicine laboratory.
MATERIAL AND METHODS: The study was based on 208 referrals to the scintigraphic laboratory, which were executed between 26.09.2018 and 13.11.2018 in the Department of Nuclear Medicine of Military Medical Academy Memorial Teaching Hospital of the Medical University of Lodz — Central Veterans' Hospital. Referrals concerned scintigraphic tests of bones, salivary glands, parathyroid glands, myocardial perfusion, somatostatin receptor analogues, renoscintigraphic and lymphoscintigraphic tests. In case of each referral, radiation power was measured at a distance of approx. 10 cm with the use of a calibrated Geiger-Muller detector. Measurements were performed immediately after the end of the last examination each day. Daily measurement of the background radiation dose was also a standard procedure. For calculations, this value was averaged to 0.18 μSv/h. Based on the above measurements, a statistical analysis of all data was performed. Obtained data was also analysed after it was ascribed to the person complexing radiopharmaceuticals on a given day. The annual dose for a radiopharmacist is 0.12 mSv, for a technician 0.35 mSv and for a doctor 0.45 mSv.
RESULTS: The average radiation dose received every working day by the staff was 11.49 μSv/h. After considering the average distance from the potential source of exposure (50 cm), this power decreased to 0.46 μSv/h. In order to calculate the quarterly and annual radiation dose, it was assumed that the employee worked 250 days a year.
CONCLUSIONS: Medical records may pose additional personnel exposure to ionizing radiation. Physicians are the most vulnerable group of employees. The way of radiopharmacists work contributes to the contamination of medical records.

KEY words: radiation exposure; radiation protection; lens exposure to radiation; medical staff exposure to radiation

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Introduction

In 1896, H. Becquerel discovered the phenomenon of radiation. Two years later, M. Sklodowska-Curie and her husband Piotr isolated polonium and radium. Since then, continuous progress has been observed in the understanding of radioactivity and first attempts to use it in the medicine have been made. The discovery of artificial radioactivity in 1934 was the breakthrough event for the development of nuclear medicine. It enabled the replacement of natural radioactive isotopes with artificial ones.

Ionizing radiation brings undeniable benefits in therapy and diagnostics. Open sources of radiation are commonly used in the field of nuclear medicine.

A gamma radiation is an information carrier in radionuclide diagnostics, the quanta of this radiation are emitted by short-lived radionuclides introduced into the organism by means of injected radiopharmaceuticals. The role of a radiation emitter can be played by a radioactive element or by a compound containing a radioactive atom in its structure [1].

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Each exposure of human to ionizing radiation increases the probability of deterministic sequelae. At the same time, it is associated with the risk of stochastic effects. In consequence, this can result in cancers, mainly of the hematopoietic system. Organs or tissues show a different affinity towards gamma radiation. There are many technical and organizational measures that minimize the impact of this radiation on people and especially on nuclear medicine laboratory staff. In case of stochastic sequelae, the severity of the effects does not depend on the amount of absorbed dose. The frequency of these sequelae rises as an absorbed dose increases. In turn, deterministic sequelae may occur when the threshold dose is exceeded. Particular attention is paid to the problem of lens opacities. The severity and frequency of deterministic sequelae increase with increasing absorbed dose [2, 3].

The energy of 30 eV can lead to the ionization of cells and, in consequence, to DNA damage. The human body contains about 10^{14} cells. Annually, people who are not occupationally exposed to radiation, absorb a dose of about 1 mS, which can result in 10^{16} ionizations. It can be roughly said that for every cell in the body, each year there is one ionization in the DNA molecule [4].

The staff of the nuclear medicine laboratory belong to the occupational group which is particularly exposed to ionizing radiation. Accidental use of a contamination meter near referrals for examination has revealed the presence of ionizing radiation coming from them. This made the authors of this work to broader analyse the degree of personnel's exposure to ionizing radiation coming from the patient's medical records.

Aim of the work

The aim of the study was to assess the exposure of radiopharmacist, technician and physician to additional radiation coming from referral for medical examination. Moreover, we planned to determine the causes of referrals contamination in the course of the examination.

Materials

The study was based on 208 referrals to the scintigraphic laboratory, which were executed between 26.09.2018 and 13.11.2018 in the Department of Nuclear Medicine of Military Medical Academy Memorial Teaching Hospital of the Medical University of Lodz — Central Veterans` Hospital. Referrals concerned scintigraphic tests of bones, salivary glands, parathyroid glands, myocardial perfusion, somatostatin receptor analogues, renoscintigraphic and lymphoscintigraphic tests. The appropriate activity of ^{99m}Tc isotope obtained from the molybdenum generator was used for each type of examination.

In case of each referral, radiation power was measured at a distance of approx. 10 cm with the use of a calibrated Geiger-Muller detector. Measurements were performed immediately after the end of the last examination each day. Daily measurement of the background radiation dose was also a standard procedure. For calculations, this value was averaged to 0.18 μSv/h. Based on the above measurements, a statistical analysis of all data was performed. Obtained data was also analysed after it was ascribed to the person complexing radiopharmaceuticals on a given day.

The assessment of personnel exposure has taken into account the time and the distance from the potential source of radiation. On the basis of own observations, the average time which an employee spent near referrals was estimated. In the Laboratory of Nuclear Medicine, radiopharmacist, technician and doctor have direct contact with referrals. The above employees spent 1, 3 and 4 hours, respectively, in the closest vicinity of referrals. It was found that during carrying out occupational duties, the distance between the potential source of exposure and the workplace varies within 50 cm.

Material and methods

One of the main tasks was to separate important data characterized by a high dose rate, from those which dose rate slightly exceeded the level of background radiation. It was also necessary to estimate their share among all documents. For this purpose, the SPC (Statistical Process Control) method was used which enabled the creation of Control Charts that allow for the calculation of the target value and the Control Limit above which all data are treated as significant deviations from the target value (they are called Special Variables) [5]. In this study, the control card is a graph of the variability of the measured dose rate over time, which contain also UCL (Upper Control Limit). Shewart's control charts are mainly used in process engineering as part of the quality management system. For the first time, they were used in the study of Shewart and colleagues in the 1920s. However, they are more and more frequently used in medicine now [6].

Normality tests carried out with the use of STATISTICA program have shown that the represented distribution of data significantly differs from the normal distribution. The value of p parameter obtained when the Kolmogorov-Smirnov and Lillefors test were performed, did not exceed the significance level. This did not allow to accept the hypothesis about the normality of analysed distributions. This conditioned the use of median control cards (Me-R) in case of which median is the target value. The target value should be understood as the optimal value on which the data should be focused. In this study, the target value corresponds with the background radiation level (0.18 μSv/h). The upper control limit was calculated on the basis of the following formula.

$$UCL = Me + A_2R$$

where:

UCL — upper control limit,

CL — central line,

Me — median,

R — average range,

A_2 — a constant, depending on the amount of data (its values are available in the SPC manual [7]).

All data above the control limit were used to calculate the average effective dose received by medical personnel. At the beginning, the average dose rate was calculated for each day of personnel work. These data were calculated taking into account the distance between the workplace and the source of exposure. For this purpose, the association between dose rate decrease and the square of the distance was used. Subsequently, the daily, quarterly and annual equivalent doses received by specific personnel were calculated. The calculations were made on the basis of the following formula:

$D(t) = \int_0^t \dot{D}(t)dt$
where:
D(t) — equivalent does,
$\dot{D}(t)$ — dose rate,
t — time to exposure to radiation.

Results

The results of measurements of dose rate coming from referrals which were performed in the period from September 26, 2018 to November 13, 2018 are shown in Chart 1.

The upper control limit (UCL) is 4.97µSv/h. Points No. 4, 7, 21, 33, 48, 49, 85, 162, 163, 173, 175 and 178 had a high dose rate exceeding the control limit. Point 45 (D = 273 µSv/h) was removed due to the fact that it was associated with radiation incident resulting from a leak occurring within the connection between a needle and a syringe. The average dose rate value received every workday was 11.49 µSv/h. After taking the average distance from the potential source of exposure (50 cm) into account this dose rate decreased to 0.46µSv/h. In order to calculate the quarterly and annual dose, it was assumed that the employee worked 250 days a year.

The statistical analysis also included two employees responsible for the complexing of radiopharmaceuticals. Therefore, the maximum and minimum values, median, mode, as well as the upper and lower quartiles were calculated for each distribution. The results are shown in Table 2.

Additionally, we calculated quarterly and annual doses received additionally by specific medical personnel in a case when the radiation incident was taken into account (point 45; D = 273 µSv/h was earlier deleted from Chart 1). The data are presented in Table 3.

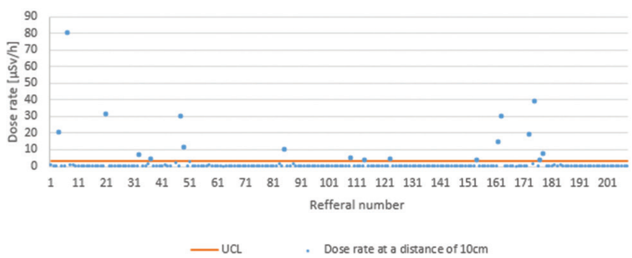

Chart 1. Values of dose rate coming from referrals

Discussion

The personnel of the nuclear medicine laboratory is particularly exposed to ionizing radiation; any additional ionization may lead to the exceeding of deterministic sequelae threshold and it increases the risk of stochastic effects. The elimination of all additional sources of exposure definitely improves the radiation safety of personnel. In our study, we indicated an additional non-obvious source of exposure to ionizing radiation coming from medical documentation — referrals.

The analysis of graph 1 shows that 6% of all studied referrals could have caused significant radiation exposure. The calculated quarterly dose in case of radiopharmacist was 0.03 mSv, in case of the technician was 0.09 mSv, and for physician 0.12 mSv, while the annual dose was equal to 0.12 mSv, 0.35 mSv and 0.46 mSv, respectively. According to the esrox study, 99% of medical workers receive an annual effective dose below 5 mSv and 93% — below 2 mSv [8]. People employed in PET/CT laboratories in which ^{16}F isotope is the main source of radiation are particularly exposed to radiation. The dose in case of PET/CT technician is 6 mSv, in case of radiopharmacist = 1 mSv and for other employees, it is below 0.1 mSv [9]. However, it should be kept in mind that performing PET tests in the nuclear medicine laboratory is associated with greater exposure to radiation than SPECT/CT tests in which technetium is used. It can be clearly seen that PET examinations caused a dramatic increase in both whole body dose equivalents and hand dose equivalents for all categories of personnel [10]. Doses calculated in this study are only estimates.

Moreover, we would like to emphasize the importance of reporting radiation incidents. In this study, during calculations, we omitted one of the referrals which contamination resulted from such an incident (point 45 on the graph, D = 273 µSv/h). If the employee failed to report this event and the standard route of documentation processing is used, the doses received by the staff (Tab. 3) would be more than four times greater.

Of all referrals that could cause significant radiation exposure, only one was assigned to radiopharmacist No. 2, while all

Table 1. Daily, quarterly and annual equivalent dose, received additionally by the staff of the nuclear medicine laboratory

Medical personnel	Radiopharmacist	Technician	Physician
Everyday dose	0.46 µSv	1.38 µSv	1.84 µSv
Quarterly dose	0.03 mSv	0.09 mSv	0.12 mSv
Annual dose	0.12 mSv	0.35 mSv	0.46 mSv

Table 3. Quarterly and annual doses received additionally by specific medical personnel when the referral contaminated during radiation incident was taken into account

Medical personnel	Radiopharmacist	Technician	Physician
Daily dose	1.56 µSv	4 µSv	8.31 µSv
Annual dose	0.39 mSv	1 mSv	2.08 mSv

Table 2. Basic statistical parameters after the inclusion of radiopharmacist

	Min.	Max.	Mode	Median	Upper quartile	Lower quartile	Data > UCL	Amount
All referrals	0.1	80	0.18	0.18	0.36	0.16	12	208
Radiopharmacist 1	0.1	80	0.18	0.21	0.45	0.17	11	121
Radiopharmacist 2	0.1	9.9	0.18	0.18	0.22	0.16	1	87

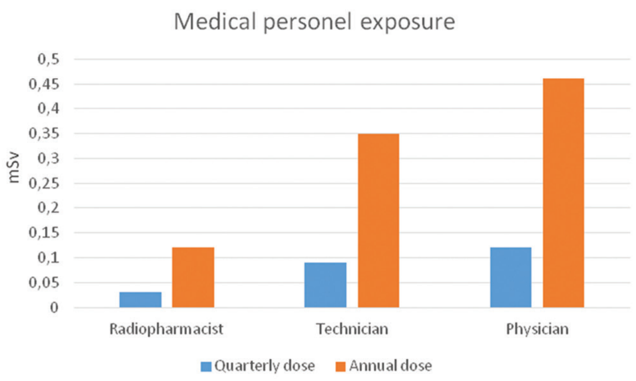

Chart 2. Quarterly and annual dose, received additionally by specific healthcare professionals

others (11) came from pharmacist no. 1. Similar conclusions were drawn following the comparison of the values of the median, the upper quartile, and especially the maximum value. The way in which every of these two employees worked with radiopharmaceuticals was of key importance for the contamination.

The obtained results and the calculated personnel exposure differ from the dose values in the dosimetric reports. In this study, it was assumed that all employees were employed full-time. However, the team of Nuclear Medicine Laboratory includes also part-time employees. There is also a rotation of staff between work positions. Therefore, doses established on the basis of individual dosimetry are much lower. It should also be noted that the reports do not include quarterly doses below 0.1 mSv.

The authors would like to draw particular attention to the danger associated with the transfer of residual radiopharmaceuticals from medical records to the vicinity of eye lenses by an unaware employee. Lenses are particularly sensitive to radiation which can cause a deterministic effect in the form of turbidity and even cataracts [11–14]. In relation with the emergence of new data from epidemiological studies in 2011, ICRP proposed to reduce the annual limit dose for this organ from 150 to 20 mSv per year which is calculated as the average dose from 5 years [15]. The dose cannot exceed 50 mSv per year for occupationally exposed persons; this dose is also used in the European Commission directive of 2013 [16].

Conclusions

— Medical records may be a source of additional exposure for personnel to ionizing radiation.
— Physicians are the most vulnerable group of employees.
— The manner of radiopharmacists work contributes to the contamination of medical records.
— Systematic trainings provided by a radiological protection inspector are highly important.

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