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ResearchArticle

Environmental Radiation Doses from Patients Undergoing Tc-99m DMSA Cortical Renal Scintigraphy

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Abstract:

Ionizing radiation is often used for imaging in health applications. One of them is scintigraphic method. one of the radiation emitters used in nuclear medicine is technesium-99m (Tc-99m). This isotope releases gamma rays at about the same wavelength as conventional X-ray diagnostic equipment, with 140 keV gamma ray energy which has a ideal short half-life ($t_{½} = 6$ h) for diagnostic nuclear imaging. Before imaging, the patient is injected with Tc-99m. After injecting Tc-99m, the patient begins to emit radiation to the environment. Determination of this radiation dose emitted by the patient is very important for public health. The main objective of this study was to determine the environmental radiation doses in patients undergoing Tc-99m DMSA cortical renal scintigraphy. In this study, the radiation dose rate emitted by the patient about 5, 35 and 68 minutes after Tc-99m injection was measured at different distances from the patient. As a result of this study, the mean radiation dose at 5.07, 35.60 and 68.57 minutes after injection was found to be 5.06 μSvh^{-1}, 4.76 μSvh^{-1} and 4.18 μSvh^{-1} at a distance of 100 cm from the patient's chest level, respectively. The results are important in terms of knowing the radiation dose to which the patient will be exposed.

1. Introduction

People are constantly exposed to natural radiation throughout their lives. However, in some cases they may be exposed to artificial radiation. Most of the artificial radiation exposed to the population is due to medical applications. Determination of the radiation level in medical applications is a prerequisite for radiation protection in public health. In recent years, many studies have been conducted to determine the radiation level in medical applications.
Technetium-99m (Tc-99m) is the most commonly used radionuclide in nuclear medicine for diagnostic imaging in order to evaluate disease state as well as to monitor the effects of treatments. This isotope releases gamma rays at about the same wavelength as conventional X-ray diagnostic equipment, with 140 keV gamma ray energy which has a ideal short half-life ($t_{½} = 6$ h) for diagnostic nuclear imaging. Patients can be injected with a small amount of Tc-99m and within 24 h almost 94% of the injected radionuclide would have decayed and left the body, limiting the patient's radiation exposure [1]. During this time patient also radiates gamma ray environmental radiation to accompanying persons near the patient and to nuclear medicine workers. Tc-99m is chemically bounded to various bioactive chemical substances, producing radiopharmaceuticals which are used for functional imaging of many organs. When Tc-99m bounded to Dimercaptosuccinic acid (DMSA) which is an antidote to heavy metal toxicity, composed Tc-99m Dimercaptosuccinic acid (Tc-99m DMSA) is used for static renal imaging of renal cortical structure. The tracer is concentrated

in the proximal tubular cells of the kidney. Tc-99m DMSA enters the proximal tubular cell either by glomerular filtration and subsequent reabsorption or by direct uptake from the peritubular capillaries [2]. As Tc-99m DMSA is largely bound to serum proteins [3]. it is accepted as the glomerular filtration is insignificant and uptake occurs at peritubular side of the cell [4]. By the uptake mechanism Tc-99m DMSA is fixed in renal cortex showing renal parenchymal integrity or damage. Scintigraphy with Tc-99m DMSA is in favour as a reference method for the assessment of renal parenchymal lesions and estimation of differential renal function [5]. Urinary tract infection (UTI) is a relatively frequent disease in children even in new born and young babies as well in diabetic individuals with increased risk of paranchymal damage and renal scarring [6-7] Renal cortical scintigraphy with Tc-99m DMSA has been accepted as “gold standard” for renal cortical scarring imaging for many years [8]. Renal cortical scintigraphy with Tc-99m DMSA is the method of choice to detect acute pyelonephritis and cortical scarring. It is mostly used in children with urinary tract infection safely, even in young babies with low doses [9]. Tc-99m DMSA intravenous given doses in adults is about 4-5 mCi (about 185 MBq) and it is calculated in children according to child dose algoritmas [10]. The effective radiation dose and the dose received by the organs after intravenous administration of Tc-99m DMSA in adult and child patients is documented [11-12].

Patients are imaged after 2 to 4 hours after the administration of Tc-99m DMSA. During this waiting time and during imaging procedure, patients are accompanied by nuclear medicine workers and children are also accompanied by their parents or caregivers. After imaging procedure completed, patients leave the department. Adults are warned to keep far away from public and their close contacts at least 24 hours but especially children are accompanied by their parents or caregivers. Both nuclear medicine workers and patient accompanying people receive external radiation overspread from patient to environment. Although patient received effective and organ doses for Tc99-m DMSA are well documented in the literature, the external radiation doses spreading from patient to peripheric region and accompanying persons are not well examined.

We tried to analyze environmental radiation doses from patients undergoing Tc-99m DMSA cortical renal scintigraphy, taking in consideration that most of the patients are in little childhood who need close care of their parents, relatives or nursery maid.

2. Materials and Methods

This study was performed in 24 (11 female and 13 male) randomly selected patients at Okan University hospital in Istanbul. The ages of the patients were varied range from 4 to 88 years, with a mean age of 40.12 years. The patients' weights were varied range from 18 to 102 kg and their average weight was 64.68 kg. The patients were given radioactivity according to the protocols of Istanbul Okan University. The amounts of radioactivity vary according to the weight of the patient. The mounts of radioactivity injected into patients were varied range from 103.62 MBq to 203.58 MBq, with an average of 168.61 MBq. Exposure rate due to radiation emitted from the patient was measured approximately 5 minutes, 35 minutes and 68 minutes after injection of radioactive material. The radiation dose rate was measured at twelve locations for patients. Head-level radiation dose rate measurements were made at a distance of 25 cm (anterior), 50 cm (anterior), 100 cm (anterior) and 200 (anterior) cm from the patient's head. Foot-level and chest-level measurements were also made at the same distance points of 25 cm, 50 cm, 100 cm and 200 cm from the patient’s chest and foot level (Fig. 1). GM counter (Inspector Nuclear Radiation Monitor Deluxe Dose Rate CPT.5250-0047) used in radiation dose rate measurements. Calibration (Inspector Nuclear Radiation Monitor Deluxe Dose Rate CPT.5250-0047) was done by Turkish Atom Energy Association in June 2018. Informed consent was obtained from all participants included in the study according to the approval of Istanbul Okan University, Research Ethics Committee.

3. Results and Discussion

The amount of radioactivity injected into the patient varies according to the patient's weight. The radiation emitted from the patient varies according to the amount of radioactivity given to the patient. The amount of radioactivity injected into all patients varied range from 103.61 to 203.57 MBq, with an average of 168.61 MBq. At 5.07, 35.60 and 68.57 minutes after injection, the average radiation dose rate at different distances from the patient's head level is shown in table 1. In addition, the radiation dose rate measurement range and normalized dose rate are also shown in Table 1. At 5.07, 35.60 and 68.57 minutes after injection,

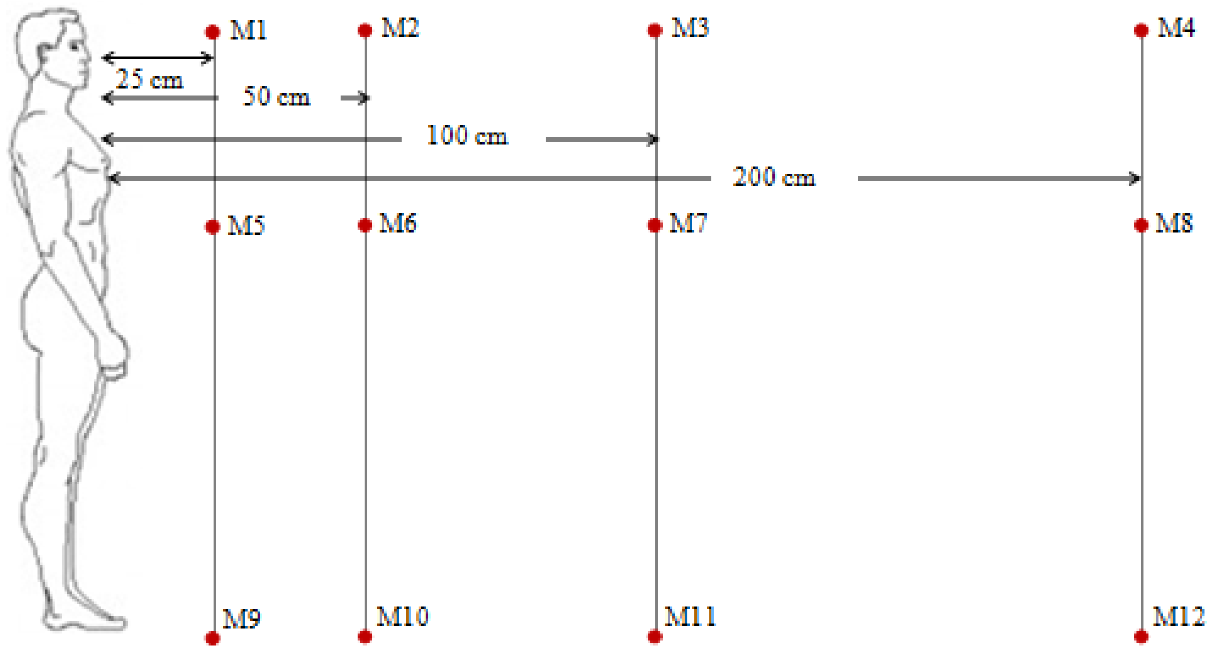

Figure 1.*TLD locations in CT imaging (1,2,3 and 4 points are representing 10 cm, 20 cm, 30 cm and 40 cm from the origin point, respectively)*

average radiation dose rate at a distance of 100 cm from the patient's head level are 5.47 µSvh^{-1}, 4.53 µSvh^{-1} and 4.41 µSvh^{-1} respectively. At 5.07, 35.60 and 68.57 minutes after injection, the average radiation dose rate at different distances from the patient's chest level is shown in table 2.

Table 1. *Mean Dose Rate and Normalized Dose Rate for Different Distance from Head*

Location (Distance from patient) (cm)	**Time after the injection (min)**	**Mean Dose Rate (µSvh^{-1})**	**Dose Rate Range (µSvh^{-1})**	**Normalized Mean Dose Rate (µSvh^{-1}MBq^{-1})**
25	5.07	20.59	5.12-31.56	0.123
	35.60	16.76	3.89-26.98	0.100
	68.57	13.47	3.13-27.09	0.080
50	5.07	9.00	5.64-12.46	0.054
	35.60	7.53	4.73-11.35	0.045
	68.57	7.00	4.32-10.73	0.042
100	5.07	5.47	3.96-8.45	0.033
	35.60	4.53	3.47-7.12	0.027
	68.57	4.41	3.12-6.31	0.026
200	5.07	3.35	2.93-5.42	0.020
	35.60	3.47	2.54-6.01	0.021
	68.57	2.88	1.35-4.33	0.017

Table 2. *Mean Dose Rate and Normalized Dose Rate for Different Distance from Chest*

Location (Distance from patient) (cm)	**Time after the injection (min)**	**Mean Dose Rate (µSvh^{-1})**	**Dose Rate Range (µSvh^{-1})**	**Normalized Mean Dose Rate (µSvh^{-1} MBq^{-1})**
25	5.07	52.59	23.87-111.13	0.313
	35.60	39.06	17.64-63.87	0.232
	68.57	36.35	4.95-52.31	0.216
50	5.07	11.24	6.89-18.97	0.067
	35.60	9.76	6.51-18.64	0.058
	68.57	9.29	6.12-17.53	0.055
100	5.07	5.06	3.58-7.96	0.030
	35.60	4.76	3.14-6.98	0.028
	68.57	4.18	3.03-7.02	0.025
200	5.07	2.65	1.97-4.75	0.016
	35.60	2.65	1.63-5.03	0.016
	68.57	2.24	1.26-3.83	0.013

In addition, the radiation dose rate measurement range and normalized dose rate are also shown in Table 1. At 5.07, 35.60 and 68.57 minutes after injection, average radiation dose rate at a distance of 100 cm from the patient's chest level are 5.06 µSvh^{-1}, 4.76 µSvh^{-1} and 4.18 µSvh^{-1} respectively. At 5.07, 35.60 and 68.57 minutes after injection, the average radiation dose rate at different distances from the patient's foot level is shown in table 3. In addition, the radiation dose rate measurement range and normalized dose rate are also shown in Table 3. At 5.07, 35.60 and 68.57 minutes after injection, average radiation dose rate at a distance of 100 cm from the patient's foot level are 4.35 µSvh^{-1}, 4.24 µSvh^{-1} and 3.71 µSvh^{-1} respectively. The radiation dose rate at 25 cm from the patient's head, chest and foot level is shown in figure 2. In this figure, it is seen that as the time increases, the mean radiation dose rates decreases. At the head and foot level, there is a strong correlation between mean radiation dose rates and time at a distance of 25 cm from the patient. But, at chest level, there is a moderate correlation. The correlation coefficient at head, chest and foot level is R^2=1, R^2=0.875 and R^2=0.943 respectively. The radiation dose rate at 50 cm from the patient's head, chest and foot level is shown in figure 3. In this figure, it is seen that as the time increases, the mean radiation dose rates decreases. At the head, chest and foot level, there is a strong correlation between mean radiation dose rates and time at a distance of 50 cm from the patient. The correlation coefficient at head, chest and foot level is R^2=0.933, R^2=0.917 and R^2=0.931 respectively.

The radiation dose rate at 100 cm from the patient's head, chest and foot level is shown in figure 4. In this figure, it is seen that as the time increases, the mean radiation dose rates decreases. At the chest and foot level, there is a correlation between mean radiation dose rates and time at a distance of 100 cm from the patient. But at the head level, there is a moderate correlation. The correlation coefficient at head, chest and foot level is R^2=0.823, R^2=0.963 and R^2=0.887 respectively. The radiation dose rate at 200 cm from the patient's head, chest and foot level is shown in figure 5. In this figure, it is seen that as the time increases, the mean radiation dose rates decreases.

Table 3. *Mean Dose Rate and Normalized Dose Rate for Different Distance from Foot*

Location (Distance from patient) (cm)	**Time after the injection (min)**	**Mean Dose Rate (µSvh^{-1})**	**Dose Rate Range (µSvh^{-1})**	**Normalized Mean Dose Rate (µSvh^{-1}MBq^{-1})**
25	5.07	11.12	5.68-22.54	0.066
	35.60	9.82	4.93-41.16	0.058
	68.57	7.00	3.98-13.54	0.042
50	5.07	7.35	3.87-11.52	0.044
	35.60	7.24	4.33-10.86	0.043
	68.57	6.88	4.12-10.21	0.041
100	5.07	4.35	3.57-6.97	0.026
	35.60	4.24	2.94-6.53	0.025
	68.57	3.71	2.51-6.32	0.022
200	5.07	2.29	1.84-3.52	0.014
	35.60	2.12	1.62-3.37	0.013
	68.57	1.76	1.12-3.01	0.011

At the head and chest level, there is a moderate correlation between mean radiation dose rates and time at a distance of 200 cm from the patient. But at the foot level, there is a strong correlation.

25 cm

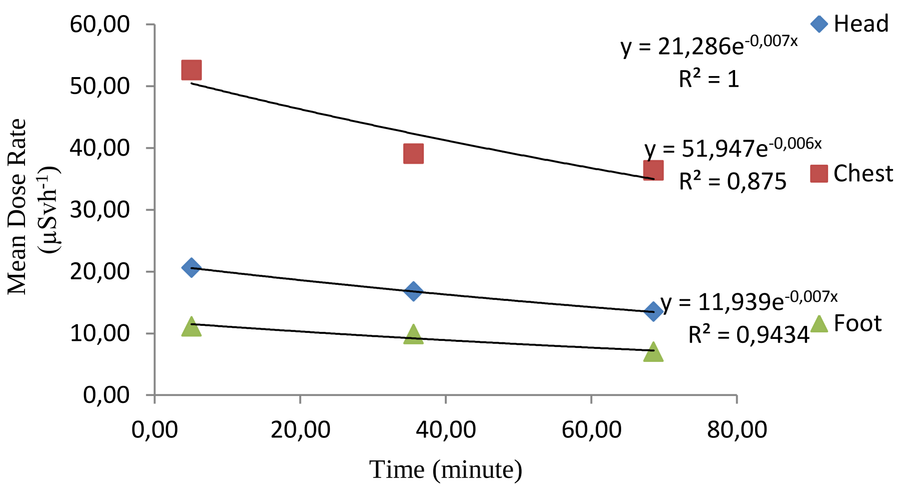

Figure 2. *Mean dose rate by time 25 cm from the head, chest, and foot of the patient*

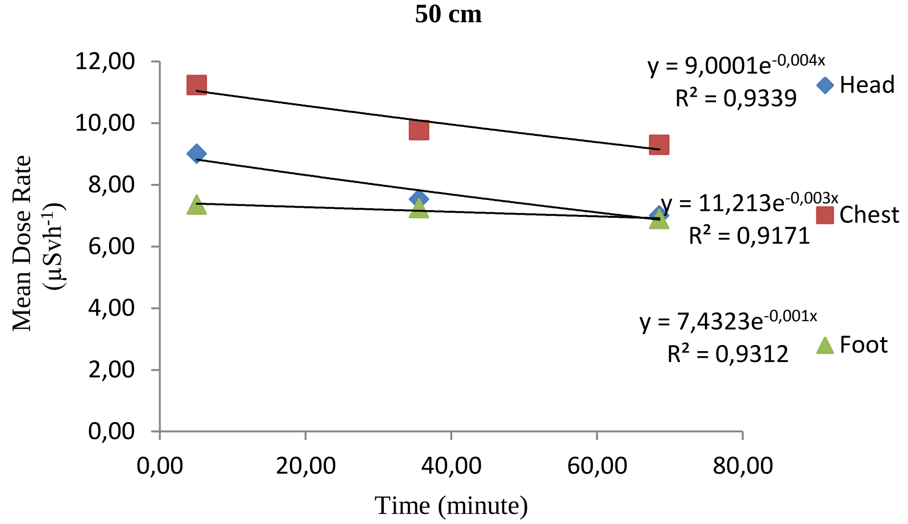

Figure 3. *Mean dose rate by time 50 cm from the head, chest, and foot of the patient*

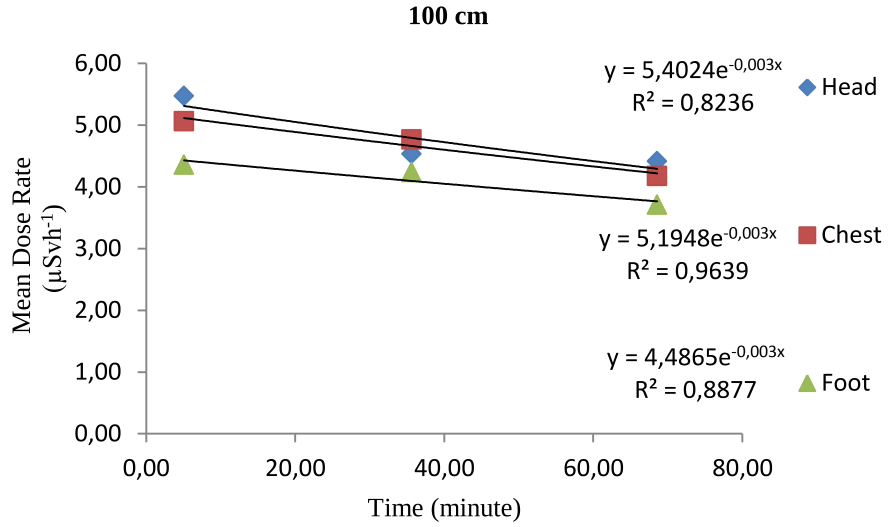

Figure 4. *Mean dose rate by time 100 cm from the head, chest, and foot of the patient*

The correlation coefficient at head, chest and foot level is R^2=0.607, R^2=0.768 and R^2=0.960 respectively

At different times after injection, the average radiation dose rate against the distance from the patient's head level is shown in figure 6. In this figure, as the distance from the patient increases, the average radiation dose rate decreases. There is a strong correlation between radiation dose rate and distance in 5.07, 35.60 and 68.57 min. The correlation coefficient between the radiation dose rate and distance from the injection at 5.07 min, 35.60 min and 68.57 min is R^2 = 0.981, R^2 = 0.950 and R^2 = 0.989 respectively.

At different times after injection, the average radiation dose rate against the distance from the patient's chest level is shown in figure 7. In this figure, as the distance from the patient increases, the average radiation dose rate decreases. There is a strong correlation between radiation dose rate and distance in 5.07, 35.60 and 68.57 min. The correlation coefficient between the radiation dose rate and distance from the injection at 5.07 min, 35.60 min and 68.57 min is R^2 = 0.956, R^2 = 0.956 and R^2 = 0.966 respectively.

At different times after injection, the average radiation dose rate against the distance from the patient's foot level is shown in figure 8. In this figure, as the distance from the patient increases, the average radiation dose rate decreases. There is a strong correlation between radiation dose rate and distance in 5.07min. But there is a moderate correlation between radiation dose rate and distance in 35.60 and 68.57 min. The correlation coefficient between the radiation dose rate and distance from the injection at 5.07 min, 35.60 min and 68.57 min is R^2 = 0.902, R^2 = 0.855 and R^2 = 0.710 respectively.

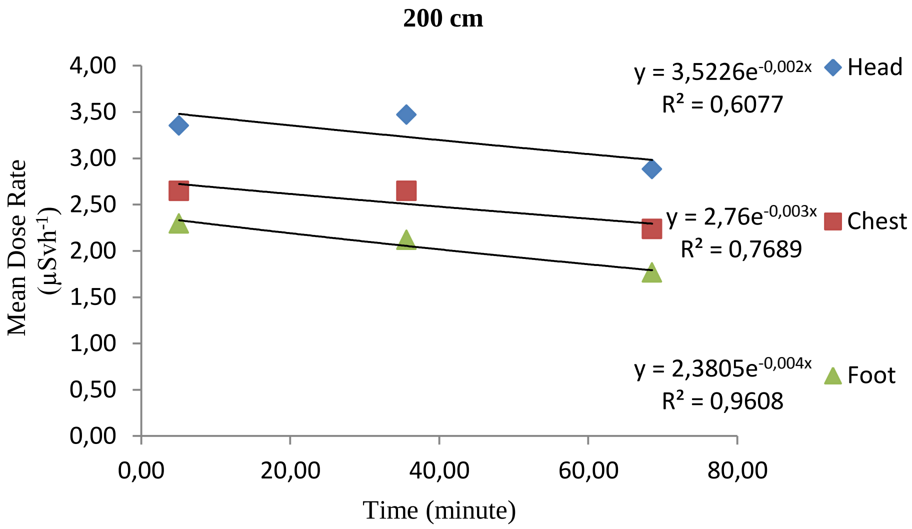

Figure 5. *Mean dose rate by time 200 cm from the head, chest, and foot of the patient*

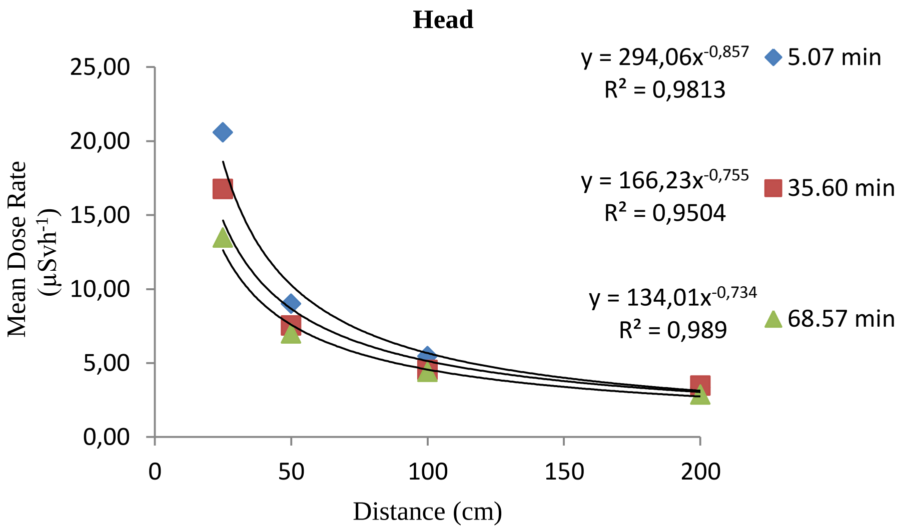

Figure 6. *Mean dose rate by distance from patient head level at 5.07, 35.60 and 68.57 minute*

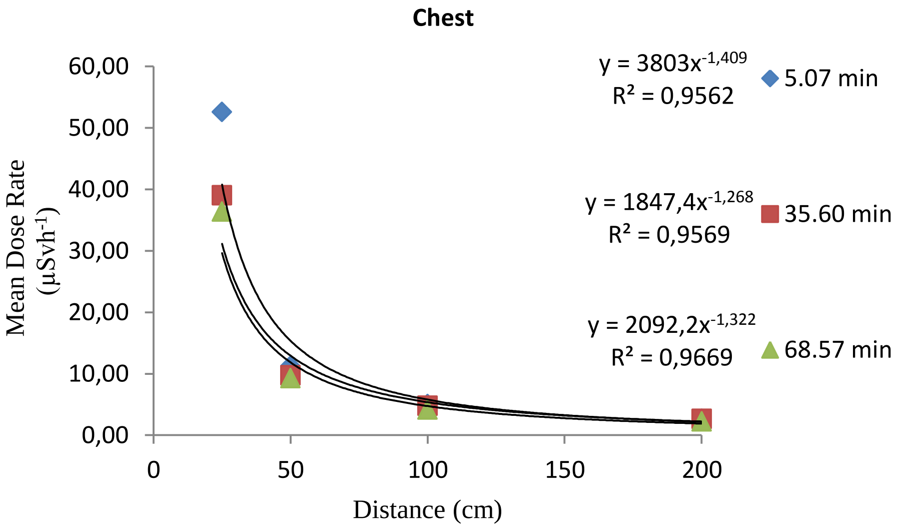

Figure 7. *Mean dose rate by distance from patient chest level at 5.07, 35.60 and 68.57 minute*

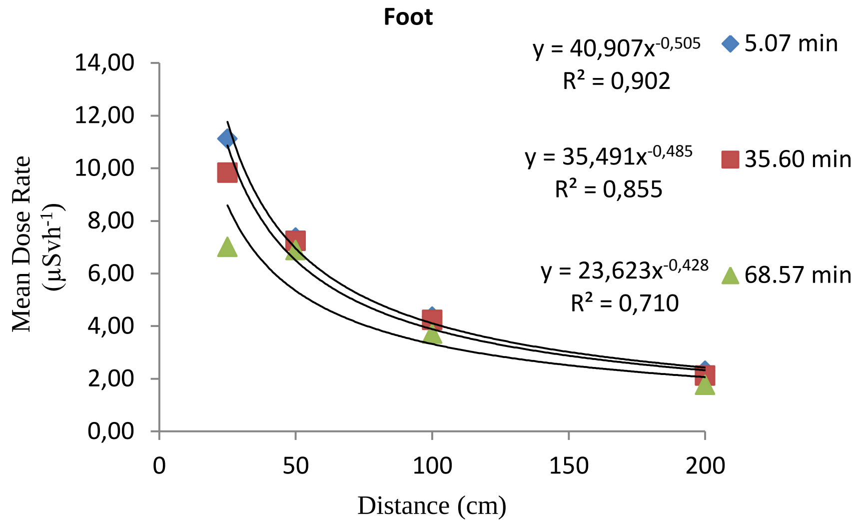

Figure 8. *Mean dose rate by distance from patient foot level at 5.07, 35.60 and 68.57 minute*

The radiation dose rate from Tc-99m injected patients was measured by Günay et al. in 2019 [13]. In this study, radiation dose rate was determined at different distances and at different times after the injection of radiopharmaceuticals to cardiac patients. In our study, radiation dose rate was determined after injection of radiopharmaceutical in kidney patients. In both studies, gamma-transmitting Tc-99m was used as radiopharmaceutical. In the study performed by Günay et al., while the patient was injected with 391 MBq of radioactive material, 168 MBq was injected in this study. Therefore, for similar distance and time, the radiation dose rate in our study was lower than that of Günay et al.(Table 5).

Table 5. *Comparison of mean dose rate and normalized mean dose rate by other studies*

Location Level	**Distance from patient (cm)**	**Time after the injection (minute)**	**Mean Dose Rate (μSvh^{-1})**	**Normalized Mean Dose Rate ($\mu Svh^{-1} MBq^{-1}$)**	**Reference**
Head	100	7.6	8.81	0.022	[13]
		36.5	7.72	0.019	
		66.4	7.51	0.019	
Head	100	5.07	5.47	0.033	This Study
		35.60	4.53	0.027	
		68.57	4.41	0.026	
Chest	100	7.6	9.07	0.023	[13]
		36.5	7.93	0.020	
		66.4	7.83	0.020	
Chest	100	5.07	5.06	0.030	This Study
		35.60	4.76	0.028	
		68.57	4.18	0.025	
Foot	100	7.6	8.43	0.021	[13]
		36.5	7.01	0.018	
		66.4	6.87	0.017	
Foot	100	5.07	4.35	0.026	This Study
		35.60	4.24	0.025	
		68.57	3.71	0.022	

4. Conclusion

In this study, environmental radiation doses were determined in patients undergoing Tc-99m DMSA cortical renal scintigraphy. In this study, the radiation dose emitted by the patient at different times after Tc-99m injection was measured at different distances from the patient. As a result of this study, the mean radiation dose at 5.07, 35.60 and 68.57 minutes after injection was found to be 5.06 μSvh^{-1}, 4.76 μSvh^{-1} and 4.18 μSvh^{-1} at 100 cm distance from the patient's chest level. At a distance of 200 cm, 5.07, 35.60 and 68.57 minutes after the injection the radiation dose spread to the environment was found to be 2.65 μSvh^{-1}, 2.65 μSvh^{-1} and 2.24 μSvh^{-1}.

Radiation professionals should be exposed to less than 10 μSv h$^{−1}$ dose rate [14]. But for public, this exposed radiation rate is 1 μSv h$^{−1}$.

According to the results obtained from this study, radiation professionals should stay at least 50 cm away from the patient. For public, these distances should be longer. It was also emphasized that the permissible dose rate for the public ≤ 1 μSv h$^{−1}$ at 2 m distance from the patient cannot be fulfilled 68 minute after the start of Tc-99m injection.

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