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Evaluating Estimated Dose outside the Patients Undergoing Myocardial Perfusion Imaging with ^{99m}Tc-MIBI

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ABSTRACT

Introduction: It is important that estimated doses from patients administered radiopharmaceuticals in nuclear medicine by hospital staff but other people in connection to patients need radiation protection. The purpose of this study was to measure the dose rate with increasing distance from patients to estimate the average effective dose in hospital staff and companions of patients.
Material and Methods: Myocardial perfusion scanning was performed using Technetium 99m-methoxy isobutyl isonitrile (99mTc-MIBI) (in 2 groups of stress and rest). We measured the external dose rate for 48 patients (23 men and 25 women) at 4 distances and 5 times. Doses are estimated for a range of scenarios, in hospital staff, public transportation, and family contacts. Finally, the obtained data were compared to the trigger level introduced by the International Commission on Radiological Protection 53 and 62 (ICRP). Data analysis was performed using SPSS version 24.
Results: The distance of the times when patients need family or hospital staff to be with them was divided into 4 categories (injection to scanning, using public transport, emergency patients during injection to scanning ,and emergency patients after finishing medical procedures) **.**
Conclusion: In all scenarios ,effective doses were obtained at less than 100 µSv according to ICRP guidelines. Due to the significant increase of the uptake in the heart and skeleton, after injection, the dose rate per MBq in the stress rate before 1hr decreases more slowly than the rest test, and the effective dose of hospital staff in stress procedure is more than rest procedure.

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Introduction

Routine nuclear medicine procedures have rapidly developed all over the world. Nuclear medicine has used a kind of radioactive isotopes for example Thallium(^{201}Tl), Technetium-99m (^{99m}Tc), Fluorine-18 (^{18}F)***, etc*** [1]. One of the most useable radioactive isotopes is ^{99m}Tc used for a kind of scans for example myocardial perfusion imaging. They are widely used for a myocardial perfusion imaging scan to measure the amount of blood being supplied to ***the*** heart by Thallium chloride and Technetium 99m- methoxy isobutyl isonitrile (^{99m}Tc-MIBI). The scan is done in two parts. Part one is rest procedure with normal breathing and heartbeat and the second part is stress procedure after exercising on a treadmill or exercise bike or injection of Dipyridamole, Adenosine, and Dobutamine, with faster breathing and more intense heartbeat [2, 3].

So an important source of exposure for nuclear medicine technologists nurses and the People who are in contact with patients are patients who have received 99mTc-MIBI radiopharmaceutical. Therefore for deciding on sensible and suitable precautions against unnecessary radiation exposure for hospital staff and other people to contact these patients, we must get information about radiation due to exposure from patients. During the time between injection of 99mTc-MIBI radiopharmaceutical and imaging, staff outside the nuclear facilities may be involved in the care of the patients for example intensive care unit (ICU) staff, i.e. Maybe, a relative or a friend attends to care a specific patient. But the estimated doses are greatly depending on the pattern of contact, but are always much less than the trigger level of 300 µSv[4].

The guiding principle of radiation safety (time, distance, and shielding) is as low as reasonably achievable (ALARA). This principle means that you should try to avoid the dose even if you will receive a small dose [5]. At different conditions (time, distance,

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typical procedures), the estimates of values for the potential dose reported from patients can provide the basis for better information about radiation levels to nuclear medicine technologists, nurses, and family members. It can also help promote hospital staff safety and as well as reduce inappropriate anxiety.

The first aim of this study was to measure dose rate with increasing distance from patients that received ^{99m}Tc-MIBI until 24 hours after injection. All of the patients in this study had the same procedures: myocardial perfusion scanning performed using ^{99m}Tc-MIBI (in stress and rest separately).

The second aim was to estimate the average external dose in stress and rest separately to four technologists from this specific scan involved in imaging and injection and visiting relative's patients and a family or companion of patients.

The last aim was to compare external dose to threshold introduced by the International Commission on Radiological Protection (ICRP) and an evaluation of the difference of its between stress and rest.

Materials and Methods

In this study, the external dose rate measurements were performed at the Nuclear Medicine Department, Imam Hossein Hospital, Shahroud city by taking the exposure of the patients as the source of radiation in the year 2020. We measured the findings for the first 48 continuous patients (23 men, 25 women; the mean age was 55 ±12.9 years for men and 50 ± 8.4 years for women [age range, 31-75 years]).

The patients were divided into 2 groups:

1- The patients who were referred for the first time (stress) for diagnostic myocardial perfusion scan, and
2- The patients who were referred for the second time (rest).

All of the patients received technetium 99m-methoxy isobutyl isonitrile (^{99m}Tc-MIBI) radiopharmaceutical. Table 1 shows the average dose and age in 2 groups of patients who received ^{99m}Tc-MIBI. Pharmacologic stress testing was performed through treadmill exercise (12 patients-25%) or special medication (Dipyridamole) (14 patients–29%). Blood pressure was checked during the stress procedure. Also, pharmacologic rest testing was performed for (22 patients (46%).^{99m}Tc-MIBI was injected into a vein of the arm of all patients and an appropriate scan was performed [6, 7]. We checked that the patient would not feel any pain from the injection region. After the injection, the patient must sufficiently drink milk and water which reduces the radiation dose in the background of the body and improves the quality of his/her scan[8, 9]. During scanning, it is important to avoid body movement to decrease blurring in the images. The patients were instructed to stay away from children and pregnant women for some time.

The distance of time between the 2 tests (stress and rest) was 48hr on average. The middle body was selected to measure the external radiation dose (exposure) at 4 distances (0.25m, 0.5m, 1m, and 2m) (Figure 1). The procedure of Mohiduzzaman et al. (as a methodological guide) was used to measure the radiation dose from patients [10]. In this regard, first, the background environment was measured in the room where the patient's dose rate will be calculated [11]. All measurements were obtained with a handheld dosimeter (BICRON surveyor 2000 TM, USA) in five different intervals of times (10 min, 30 min, 1 hr, 10 hr, and 24 hr) after injection when calibrated according to the Nuclear Regulatory Commission (NRC) guidelines by Cs-137 [12, 13].

Table1. Characteristics of the study population

Test	Sex	Average age (year)	Weight (Kg)	Average of dose (mCi)
Stress	Women	(35-61) 49.46±7.87	(49-81) 68.3±10	(12.74-18.63) 15.72±1.47
	Men	(31-74) 52.77±12.99	(62-88) 74.3±7.9	(13.3-18.15) 15.74±1.13
Rest	Women	(36-70) 50.75±1.32	(45-81) 65.83±9.25	(12.8-16.9) 14.75±1.32
	Men	(33-75) 58.1±12.36	(55-100) 79±13.2	(12.9-17.11) 14.68±1.12

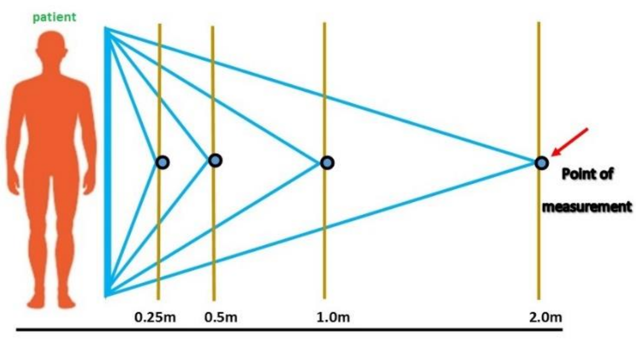


Figure 1. Method of measurement, we measured exposure of the patients with the hand-held dosimeter at several distances from the patient.

The choice of dose measurement times was designed according to the times of attending in the nuclear medicine center to perform the procedure of ^{99m}Tc-MIBI Radiopharmaceutical (less than 2hr after injection) and in times of to be with family or other people (after 2 hr to 24 hr). We tried to consider the strictest scenario for each category so that no information would be lost.

Three replications were selected for each experiment. Data were subject to statistical analysis. The data had normal distribution based on the Kolmogorov-Smirnov test (p>0.05). Tukey's test at a confidence level of 95% was used to compare the effect of each variable on the 2 groups separately. Data analysis was performed using SPSS version 24 (SPSS Inc., Chicago, Ill., USA) and Microsoft Excel 2013(USA).

Results

In our study, first was measured count per second (CPS) and then values were converted to $\mu Sv\ h^{-1}$(5cps equals 1 $\mu Sv\ h^{-1}$). 0.07 $\mu Sv\ h^{-1}$ was measured for the background dose rate. Thus, the mean dose rates (μSv/hr ± SD and μSv/hr/MBq ± SD) were obtained as a function of distance. All measurements were performed at times of 10 min, 30 min, 1 hr, 10 hr, and 24 hr after injection in the standing position figure [1]. The measured dose rates values at distances of 0.25, 0.5, 1.0, and 2.0m are presented in Table 2.

According to Table 2, the maximum external dose rate value was measured as 13.21±1.15 μSvh^{-1} in Group 1(stress) and 9.97±0.97 μSvh^{-1} in Group 2(rest) at a distance of 0.25m 10 min after the radiopharmaceutical injection, and the minimum dose rate value was measured as 0.62±0.04 μSvh^{-1} in Group1 (stress) and 0.42±0.01 μSvh^{-1} in Group2 (rest) from a 2.0m distance 24 hr after injection. The values of the dose rate per unit activity for each time and distance after measurement are listed in Table 3. In this section, the greatest value was found as 33.08±1.41$\mu Sv\ h^{-1}MBq^{-1}$ for Group 1 and 23.43±1.66 $\mu Svh^{-1}MBq^{-1}$ for Group 2 at 0.25 m in 10 min after administration. A significant difference was observed between Groups 1 and 2 (p <0.001) in this spatial condition (0.25m and 10 min). (Table3) The reduction of the dose rate in terms of 4 distances (0.25, 0.5, 1, and 2m) is shown in Figure 2. Also, the diagram of the values of dose rate per unit activity in terms of distance for each time separately (10min, 30min, 1hr, 10hr, 24hr after injection) is shown in Figure 3. There have been reported several controversial result in this field but our result is adapted with the most of them [4, 10, 12, 14].

Doses were estimated for People who were in contact with patients for example patients' co-workers and families. In this section, received dose data for patients and hospital staff in nuclear medicine (nurses and technologists) were calculated separately, and these results were compared with the report described by the International Commission on Radiological Protection (ICRP; Table 4))[15].

The distance of the times when patients need family or hospital staff to be with them was divided into 4 categories (injection to scanning, using public transport, emergency patients during injection to scanning, and emergency patients after finishing medical procedures). The area under the curve (dose rate per unit activity and time) was measured as an effective dose.

We calculated the distance of the times of presence of hospital staff in less than 0.5 meters of patients is 15.47min in stress and 10.31 min in rest. The average time was considered 2 hr in the emergency patients from injection to scanning. The duration that patients are with family or companion is associated with travel on public transport 4 hours are measured in each patient and the emergency patients after finishing medical procedures 24hr [4, 16]. Therefore 3 times (10, 30min and 1hr) were selected for the first and second categories and the last two times (10, 24hr) for the third and fourth categories.

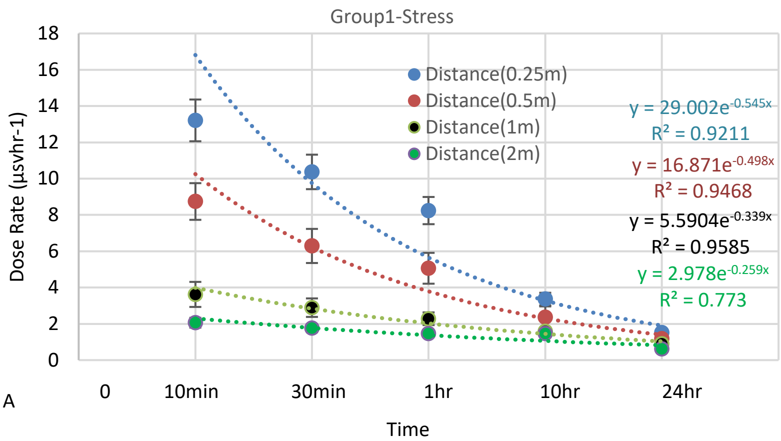
The result of this finding and comparing 2 groups were shown in table 4. The calculated times for the presence of the hospital staff and family or companion matched the finding of Marissa L. Bartlett et. Al [4].

For 2 groups, doses roughly estimated less than 100 μSv in public people but in the first category, for technologists and nurses, maximum the effective doses were near 2.765 μSv for 15.47min in Group1 (Stress) and for 10.31 min 0.873 μSv in Group2 (Rest) and for the second category were near 8.9 μSv in Group1 and 6.49μSv in Group2 for 2hr with each patient. The maximum effective doses for the third category measured 19.52μSv in Group1 and 13.52μSv in Group2 at 0.25meter distance and are associated with travel on public transport (for 4 hours) on the same day as the scan. In the last category for family or companion the emergency patients, Average absorbed effective dose were 94.9 μSv for a stress test and 81.8 μSv for rest (at 0.25meter distance and 24 hours contact) are calculated to be significantly less than the report described in ICRP (the annual exposure dose is recommended public dose limit of 1 mSv per year) [17]. A significant difference was observed between the 2 groups stress and rest in all categories (P-value reported in all distances (Table 4))

Table 2. External Dose Rates (µSvhr-1) in all of the times for all distances 1: stress and 2: rest

		Distance			
Time	Group	0.25	0.5	1	2
10min	1	13.21±1.15	8.74±1.11	3.62±0.69	2.06±0.27
	2	9.97±0.97	5.98±0.95	3.09±0.56	1.31±0.13
	P_{value}	<0.001*	<0.001*	<0.001*	<0.001*
30 min	1	10.37±0.99	6.29±0.95	2.89±0.51	1.76±0.22
	2	7.6±1.83	4.42±0.77	2.66±0.46	1.13±0.09
	P_{value}	<0.001*	<0.001*	0.007*	<0.001*
1 hr	1	8.24±0.75	5.06±0.97	2.28±0.35	1.47±0.12
	2	6.62±1.03	3.39±0.48	2.18±0.36	0.97±0.05
	P_{value}	<0.001*	<0.001*	0.086	<0.001*
10 hr	1	3.36±0.45	2.37±0.39	1.58±0.18	1.46±0.18
	2	3.09±0.92	1.62±0.30	1.33±0.31	0.72±0.05
	P_{value}	0.067	<0.001*	0.003*	0.056
24 hr	1	1.52±0.13	1.18±0.15	0.90±0.08	0.62±0.04
	2	1.15±0.20	0.89±0.14	0.65±0.151	0.42±0.01
	P_{value}	<0.001*	0.948	<0.001*	<0.001*

* Significant value



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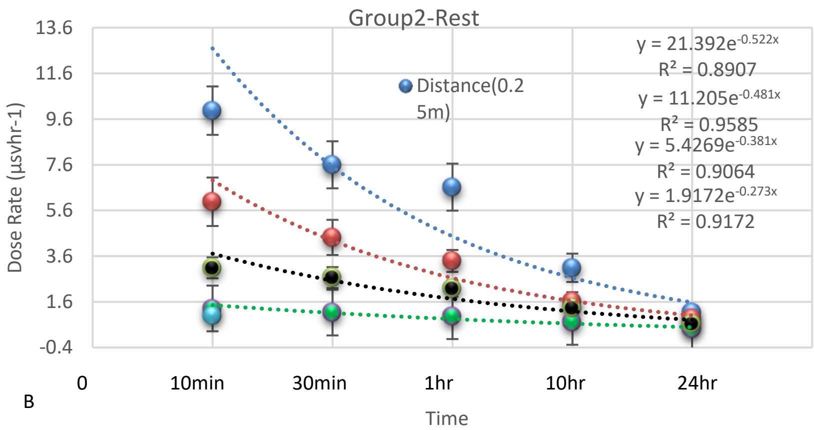

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Figure 2. A) Group1-stress and B: Group2-rest external Dose Rates (µSvhr-1) in all of the times for all distances

Table 3. Dose rate per unit activity (µSv h^{-1} MBq^{-1}) for each distance and time after administration for Group1(stress), Group2(rest) *Significant value

Time	Group	Distance			
		0.25	0.5	1	2
10min	1	33.08±1.41	23.64±1.15	14.07±1.19	5.19±0.47
	2	23.43±1.66	17.05±1.13	9.26±0.73	3.09±0.29
	P_{value}	<0.001*	<0.001*	<0.001*	<0.001*
30min	1	25.93±1.20	18.49±1.36	11.21±0.97	4.43±0.35
	2	19.94±1.36	14.39±0.97	8.24±0.78	2.66±0.27
	P_{value}	<0.001*	<0.001*	0.003*	<0.001*
1hr	1	20.63±0.87	12.47±1.2	7.64±0.81	3.67±0.33
	2	15.57±1.03	10.95±1.23	5.14±0.64	2.29±0.17
	P_{value}	<0.001*	<0.001*	0.06	<0.001*
10hr	1	9.08±0.97	5.91±0.85	3.93±0.95	1.83±0.47
	2	8.67±0.81	3.78±0.83	3.12±0.58	1.69±0.299
	P_{value}	0.396	<0.001*	0.001*	0.084
24hr	1	3.78±0.82	2.92±0.12	1.52±0.12	0.91±0.14
	2	2.7±0.11	1.85±0.14	1.51±0.18	0.97±0.11
	P_{value}	<0.001*	<0.001*	0.952	0.894

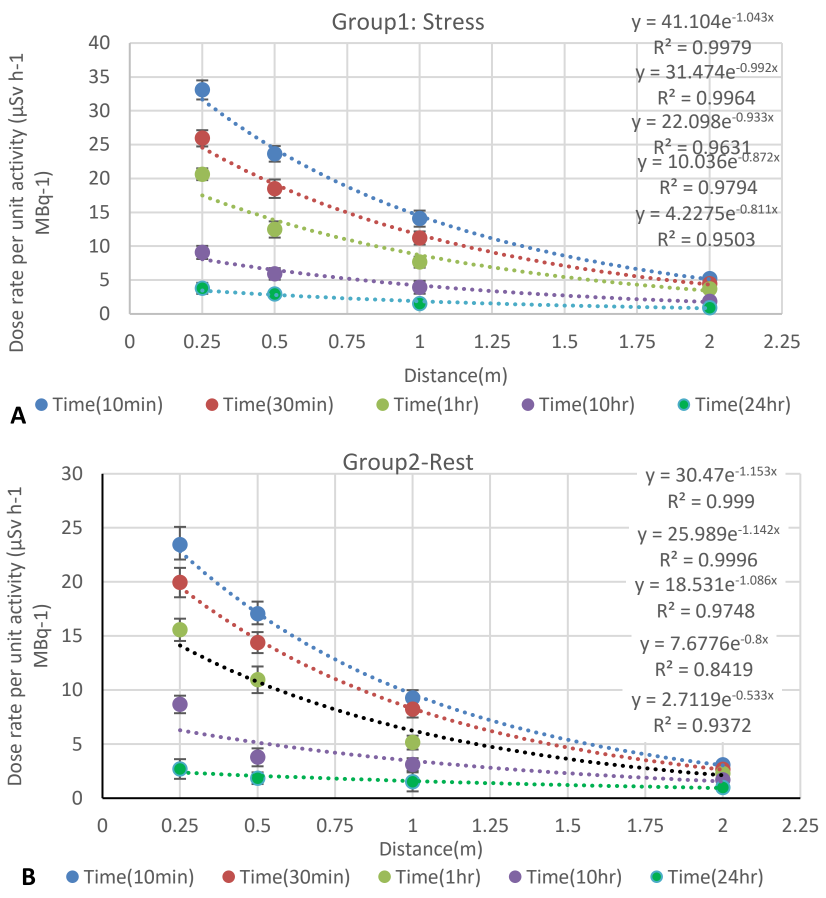

Figure 3. Dose rate per unit activity (µSv h^{-1} MBq^{-1}) for each distance and time after administration for A: Group1-Stress, B: Group2-Rest

Table 4. Average absorbed effective dose (µSv) of hospital staff and relative patients in a 99mTc-MIBI Scan from patients at different distances. A: 15.47 min for stress and 10.31min for rest are calculated as the average times of contact technologists and nurses for each patient's scan. B: In emergencies patients who need nurses to always take care of them during doing scan 99mTc-MIBI (between injection to imaging 2hr) C: 4hr are selected for family or companion with patients in public transport. D: In emergencies for the patients who need family or companions to always take care of them during 24 hr after injection 99mTc-MIBI.

		0.25m	0.5m	1m	2m
A	Stress	2.7653	1.779	0.761	0.468
	Rest	0.873	0.552	0.365	0.179
	P_{value}	0.045	0.046	0.015	0.053
B	Stress	8.937	5.75	2.458	1.513
	Rest	6.495	3.904	2.199	0.95
	P_{value}	0.002	0.003	0.000	0.005
C	Stress	19.52	12.48	6.36	4.18
	Rest	13.54	8.56	5.66	2.78
	P_{value}	0.002	0.003	0.014	0.003
D	Stress	94.942	63.627	37.107	25.756
	Rest	81.8	43.801	31.823	16.517
	P_{value}	0.005	0.003	0.000	0.004

Discussion

According to theoretical predictions and physical half-lives, a period of about 6 hr is expected for ^{99m}Tc-MIBI after 24 hr to be greatly reduced. We showed that after 24 hr in together group the value of dose rate decreased to less than 1 µSvh^{-1}. Because biological half-lives were less than physical half-lives and Lung Kwangpan assessed maximum value 3.3±1.1 hr for liver[18, 19]. Effective dose calculations have been performed in 4 categories in the strictest possible scenarios to reduce the possibility of error due to the variation in the dose received. After intravenous injection measured dose rate for all distances in Group1 (stress) was more than Group2 (rest) and revealed the significant difference between Group1 and 2 unless in times of 10 hr and 24 hr due to the approaching dose of background which these insignificant values can be justified. When ^{99m}Tc-MIBI was injected to do a stress procedure, there was a significant increase in the uptake in the heart and skeletal muscles, and after injection, there was a lower uptake in all other organs and tissues. Thus, the dose rate per MBq in stress rate before 1 hr decreases more slowly than the rest test and effective dose of hospital staff in patient's stress test more than patient's rest test. Our results match the reports of ICRP Publication 80 [4, 20]. But Tuncay Bayram et.al showed that the external dose rates per procedure measured at various distances from the patient for rest more than stress protocol and our findings contradicted these results [21].

Sattari et al. determined that the maximum values of external dose rates of 99mTc-MIBI were 43.1µSv/h ±11.9 respectively, at 5 cm from the patients and this report was for stress and rest procedures together [22]. In our study the difference in radiation dose between 2 groups (stress and rest procedures) was significant. This result would affect staff work planning.

The average absorbed effective doses (µSv) of hospital staff (15.47 min in stress and 10.31min in rest contact to patients) and relative or companion of patients (maximum 4 hr contact to patients) in a ^{99m}Tc-MIBI scan from patients at different distances were shown to be very low into annual effective dose reported by ICRP (1 mSv annually of public persons and 55 µSv per day for radiation workers). However, other sources such as syringes, radiopharmaceuticals, and other radioisotopes and radiopharmaceuticals are utilized in the departments of nuclear medicine, which should be added to the absorbed dose to radiation workers and relative patients.

Conclusion

This study investigated the hospital staff and relative patient effective doses (µSv) in diagnostic nuclear medicine departments. To the best of our knowledge, this study for the first time, compared exposure dose rate in 2 group that received 99mTc-MIBI radiopharmaceuticals. We showed that the exposure dose rate was more in the stress procedure than the rest procedure. Thus, it imposed a higher dose on the person in contact. The doses that were measured in this study were always lower than the annual dose limits recommended by ICRP and concerned international organizations.

The results of this study should help specify the differences in their techniques and select the rotation time of technologists in various procedures.

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