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Patient's Radiation Dose in the Waiting Area During Nuclear Cardiac Perfusion and Bone Scans in Nuclear Medicine Departments.

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ABSTRACT:

Objective: The aim of the work was to estimate the radiation exposure of patients in waiting room during nuclear cardiac perfusion and bone scans.

Method: Radalert 100x™ survey meter was used for measuring the dose rate of all groups. {GP1 (n=300, cardiac scan) and GP2 (n=300, bone scan)} during the waiting time in the waiting room before scan process. The collected dose rate from all patients was measured at 6 different positions (A, B, C, D, E and F) in the waiting room. ALoka digital dosimeter was used for personal an effective dose calculation of patients of GP1 and GP2.

Results: The average effective doses of patients at positions (Cardiac: A:401.2.1 ±30.1 µSv and B:432.5 ±22.6 µSv) and (Bone, A:950.3±45.1 µSv and B:905±18.5 µSv) were highly significant (P<0.000) against other positions (Cardiac, C: 349.7 ±19.2 µSv, D:340.6±39.0 µSv, E:360.4±15.8 µSv and F:320.7±25.6 µSv) and (Bone, C: 688±33.5 µSv, D:704.2±27.3 µSv, E:711±55.7 µSv and F:668.4±50.6 µSv). The measured effective doses were correlated with the accumulated effective dose (measured by ALoka dosimeter) that showed a positive correlation (r =0.91, 0.95) for Gp1 and Gp2 respectively).

Conclusion: The design of the waiting room and the position of patients are highly affecting on the accumulated patient’s effective dose. The size of the waiting room must be carefully considered in the facility design.

Key Words: Radiation -Exposure- Cardiac Perfusion- Bone Scan- The Waiting Room-Nuclear Medicine-Effective Dose.

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INTRODUCTION:

Nuclear medicine is one of today's most advanced diagnostic and therapeutic techniques in medicine. It is focused on the study of human physiology, cell functions, and emergency changes in diseases [(1)].

There are several common nuclear medicine scans considered in the nuclear department through which the patients are source of radiation exposure to hospital staff, public and family members [(2)].

The stochastic effects of ionizing radiation are a significant point in nuclear medicine. Time, distance, and shielding are the basic principles to reduce radiation exposure. In the limited and narrow patient waiting areas, the distance between patients can be used as a useful precaution to protect them from the risks of radiation [(3)].

In cardiac and bone scans, the patients wait 1 to 3 hours prior to the scanning process after radiopharmaceutical administration. Patients are present at the same time in the waiting area which causes a higher level of radiation exposure. The emitted radiation from patients increases the risk of developing cancer.

For that the design of waiting area is considered in international guidelines of international commission radiation protection ICRP and International Atomic Energy Agency IAEA [(4)].

A little information about the radiation doses to attending patients with nuclear medicine when they are going through their investigation.

Also, for hospital staff, family members or friends may be included. The information collected using the digital area monitor, which is in the nuclear scanning units [(5, 6)], does not consider the length of time the patient or visitor waits in the waiting process and therefore gives a reading of the radiation level only during the presence or passage of the radioactive patients, and the doses acquired because of exposure are not calculated [(7, 8)].

The three main parameters for radiation protection are the time, distance, and radiation shielding used to minimize exposure to radiation. In crowded and small nuclear medicine departments, though, applying distance and time as an effective strategy is the main tools to reducing radiation exposure. The waiting area must be shielded to prevent any exposure to working staff or relatives. The waiting areas in nuclear medicine center are normally be designated as supervised areas. The spaces among all patients are significant factor to reduce the radiation risk according to inverse square law [(9, 10, and 11)].

In some governmental hospitals and private centers for nuclear medicine, there are small areas of waiting rooms, in addition to the absence of standard dimensions of waiting room in the local regulations. For these reasons, this paper shed the light on the radiation exposures of patients in most common nuclear medicine procedures.

This research aims to evaluate the effective dose and the exposure for patients in the waiting room for both bone scan and cardiac perfusion scan patients in nuclear medicine

MATERIALS AND METHODS:

Place and duration of study: The study was carried out in the Faculty of Medicine, Cairo University Hospitals, Gamma Camera Unit in Critical Care Medicine and Nuclear Medicine Departments during the period from June 201 ٨to April 2020. In the present study, a number of 600 patients (Age = 60±14 years, weight = 75 ±15 kg) were selected, half number of the patients (GP1) were referred to cardiac perfusion scan, whereas the other half (GP2) were referred to bone scans. GP1 and GP2 were injected with 20±2 mCi of ^{99m}Tc-MIBI and 19±5 mCi of ^{99m}Tc MDP respectively, At least six patients waited one hour for Gp1 and 2 hours for GP2 in the waiting room (area =6 m^2) before the scan, as shown in ***Figure (1)***. According to ***(Figure 1)***, patients were seated at the A, B, C, D, E and F positions. The distance from position A to F is equal to the distance of A to E (20 cm), while the distances from A to other positions (B C, D) are 150 cm, 180 cm, and 180 cm, respectively.

Exposure measurements:

A standard survey material (Adalbert 100 XTM, IMI-International Medcom, USA) that is calibrated annually at the National Institute of Standards, Giza Governorate, Egypt, is used to measure the dose rate at all patient positions (GP1 and Gp2). The dose rate reduction factor (Rt) was calculated using the following formula [9]**:**

$$R_t = 1.44x\frac{T_{1/2}}{t}x\,[1 - e^{-\frac{0.693t}{T_{1/2}}}] \quad \textbf{(1)}$$

Where the tracer half-life time is T1/2, and the estimated total stay time is t. Using the following formula, the total estimated effective dose was calculated:

The total estimated effective dose = Dose rate × Stay time × dose rate reduction factor (R_t). **(2)**

Table (1): Patient characteristics and study parameters**.**

Total =600	Cardiac patients		Bone patients	
	Male	**Female**	**Male**	**Female**
No.	165	135	148	152
Age, year	59±5.4		60±9	
Height, cm	170.5±6.4		169.6±6.1	
Wight, kg	90.4±14.3		89.4± 16.2	
Injected Dose, mCi	20±2.1		19.5±2.6	
Body Mass Index (BMI), kg/m^2	29.7±3.2		30.4±5.3	
Body Surface Area, (BSA), m^2	1.89±0.1		1.94±0.3	
Waiting time (hr.)	1.0 ± 0.20		2 ± 0.30	
NO of patients per day	12± 3		10 ± 5	
Dose reduction factor (R_t)	0.997 ± 0.23		0.891±0.18	

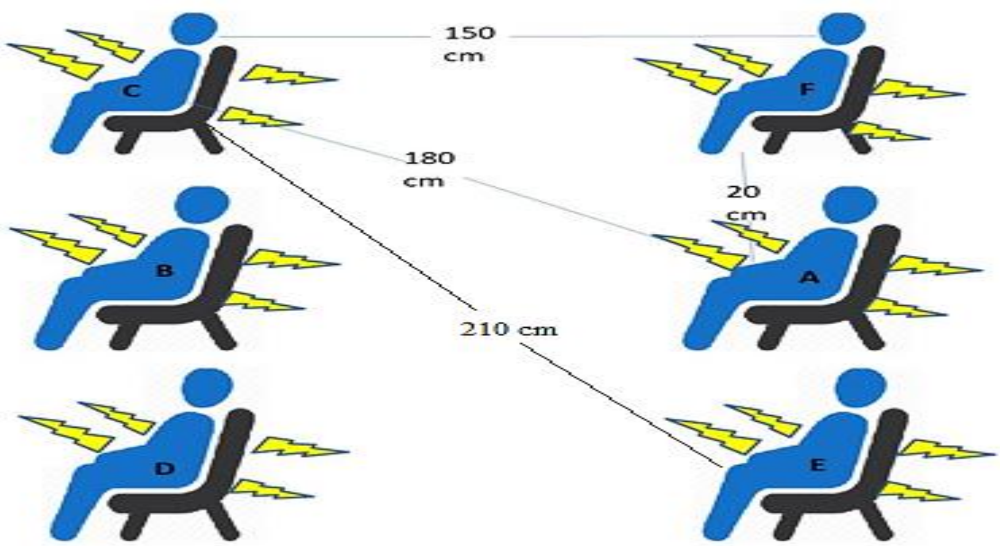

Figure (1): The positions of patients (GP1 or GP2) in the waiting room showing the distances in cm.

Dose rate is recorded in units of μSv/hr by the Adalbert 100x survey meter at all positions. Based on the measurement of the average period spent for each position, stay time was estimated to be one hour for cardiac patients and two hours for bone scan patients

Effective Dose measurements

The effective doses are determined by using personal digital dosimeters (Alok dosimeters) ***(Figure 2)***.

All patients were instructed to wear the dosimeter during waiting hours only. Each dosimeter was measured by radiation protection expert.

The effective dose received by total body of patients was calculated by the following equation:

Effective accumulated dose = Equivalent dose x tissue weighting factor Where, Tissue weighting factor =1 for whole body. **(3)**

Figure (2): Alok Digital Dosimeter is used for effective dose measurements.

Statistical Analysis: The mean values of all groups were expressed as mean ± SD. ANOVA test was used to compare between the various groups studied. P value ≤ 0.05 was defined as statistically significant. Statistical analyses were performed with statistical software (IBM SPSS Statistics Version 21).

RESULTS:

Table (2) and (3) for comparing the effective dose using multiple comparisons by the ANOVA test between patients attending in the waiting room. The comparisons showed statistically significant differences and lower effective doses for patients on the extremities inside the room, while patients (seats) in the middle got effective radiation doses. Very high compared to other seats, and this is also consistent with the inverse square law, which confirms the importance of the distance between patients' seats For GP1 and GP2, the dose rates of patients at A and B positions are highly significant.

Against other positions (C, D, E and F). ANOVA and multiple comparisons (Tukey HSD) of mean± SD of effective doses within the waiting room revealed a high significant statistic results. Multiple comparisons showed a significant difference between the effective doses according to the patient's location, as the greater the distance between the seats, the lower the effective dose. ***Figures (3, 4, 5 and 6)*** revealed the dose rate for cardiac and bone patents as well as the effective dose.

The effective dose is highly significant for patients at A and B positions against others ***(Tables 2 and 3)***.

Table (2): ANOVA and multiple comparisons (using post-hoc test) of mean± SD of Effective Dose for cardiac patients (waiting room) for the 6 chair positions.

Multiple Comparisons (Tukey HSD)					
(I) GROUBS	**(J) GROUBS**	**Mean**	**Std. Deviation ±**	**Mean Difference (I-J)**	**Sig.**
A	B	401.2	30.1	-31.5	0.410
	C			51.4	0.034
	D			60.4	0.008
	E			40.7	0.151
	F			40.7	0.151
B	A	432.5	22.6	31.5	0.410
	C			82.85	0.001
	D			91.9	0.001
	E			72.19	0.001
	F			72.19	0.001
C	A	349.7	19.7	-51.4	0.034
	B			-82.8	0.001
	D			9.0	0.997
	E			-10.7	0.992
	F			-10.7	0.992
D	A	340.6	39.0	-60.4	0.008
	B			-91.9	0.001
	C			-9.09	0.997
	E			-19.79	0.854
	F			-19.79	0.854
E	A	360.4	15.8	-40.7	0.151
	B			-72.1	0.001
	C			10.7	0.992
	D			19.7	0.854
	F			0.0	1.000
F	A	320.7	25.6	-40.7	0.151
	B			-72.1	0.001
	C			10.7	0.992
	D			19.7	0.854
	E			0.0	1.000

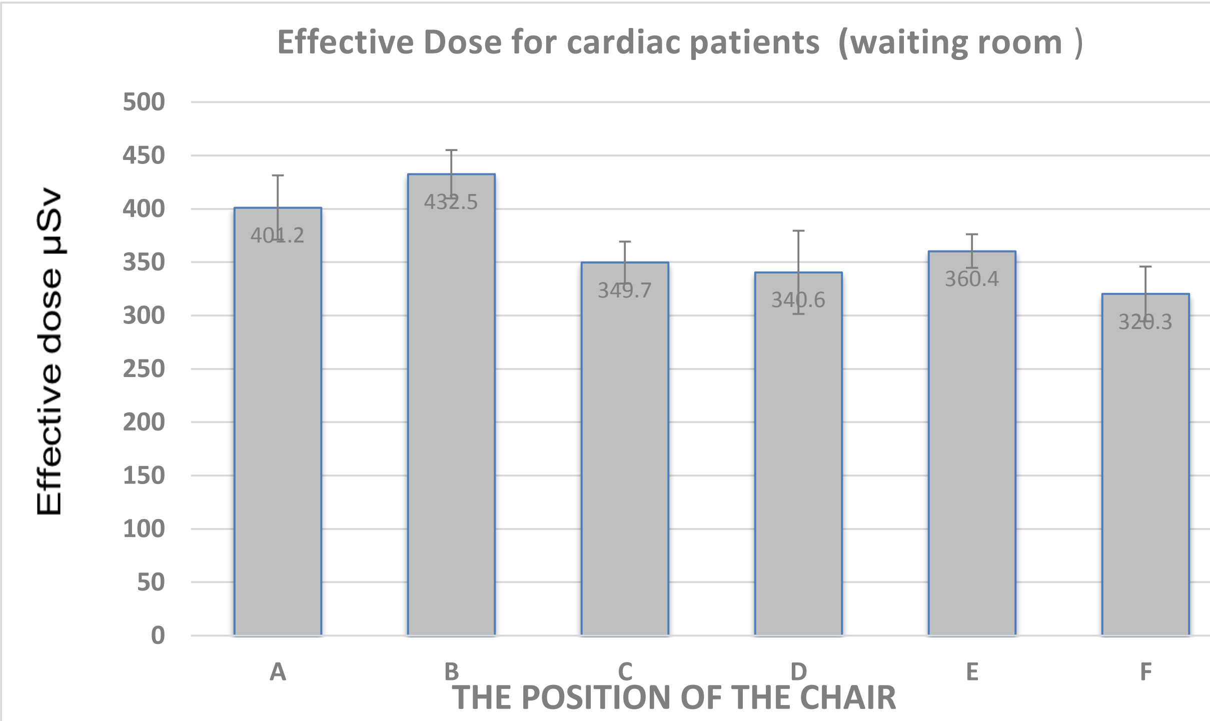

Figure (3): The dose rate of cardiac patients in different positions (A, B, C, D, E and F) of the waiting area. The data are represented by mean value ± Sd.

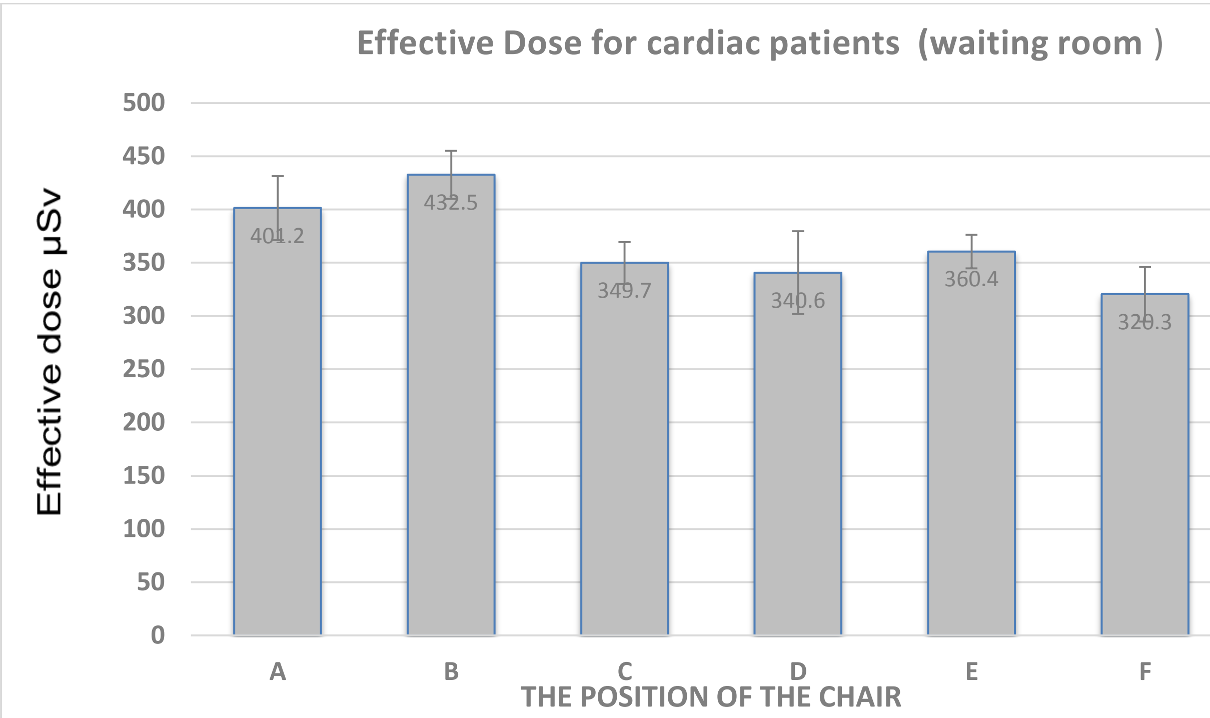

Figure (4): The effective dose of Cardiac patients in different positions (A, B, C, D, E and F) of the waiting area. The data represented in average value ± Sd.

Table (3): ANOVA and multiple comparisons (using post-hoc test) of mean± SD of Effective Dose for Bon patients (waiting room) the chair 6 positions.

Multiple Comparisons (Tukey HSD)					
Dependent Variable: Effective Dose for Bon patients (waiting room)					
GROUBS(I)	**(J) GROUBS**	**Mean**	**Std. Deviation**	**Mean Difference (I-J)**	**Sig.**
A	B	950.3	45.1	45.3	0.001
	C			262.3	0.001
	D			246.1	0.001
	E			239.3	0.001
	F			230.22	0.001
B	A	905.0	18.5	-45.3	0.001
	C			217.0	0.001
	D			200.8	0.001
	E			194.0	0.001
	F			184.9	0.001
C	A	688.0	33.5	-262.3	0.001
	B			-217.0	0.001
	D			-16.2	0.231
	E			-23.0	0.028
	F			-32.10000*	0.001
D	A	704.2	27.3	-246.1	0.001
	B			-200.8	0.001
	C			16.2	0.231
	E			-6.8	0.947
	F			-15.9	0.249
E	A	711.0	55.7	-239.3	0.001
	B			-194.0	0.001
	C			23.0	0.028
	D			6.8	0.947
	F			-9.1	0.820
F	A	668.4	50.6	-230.2	0.001
	B			-184.9	0.001
	C			32.1	0.001
	D			15.9	0.249
	E			9.1	0.820

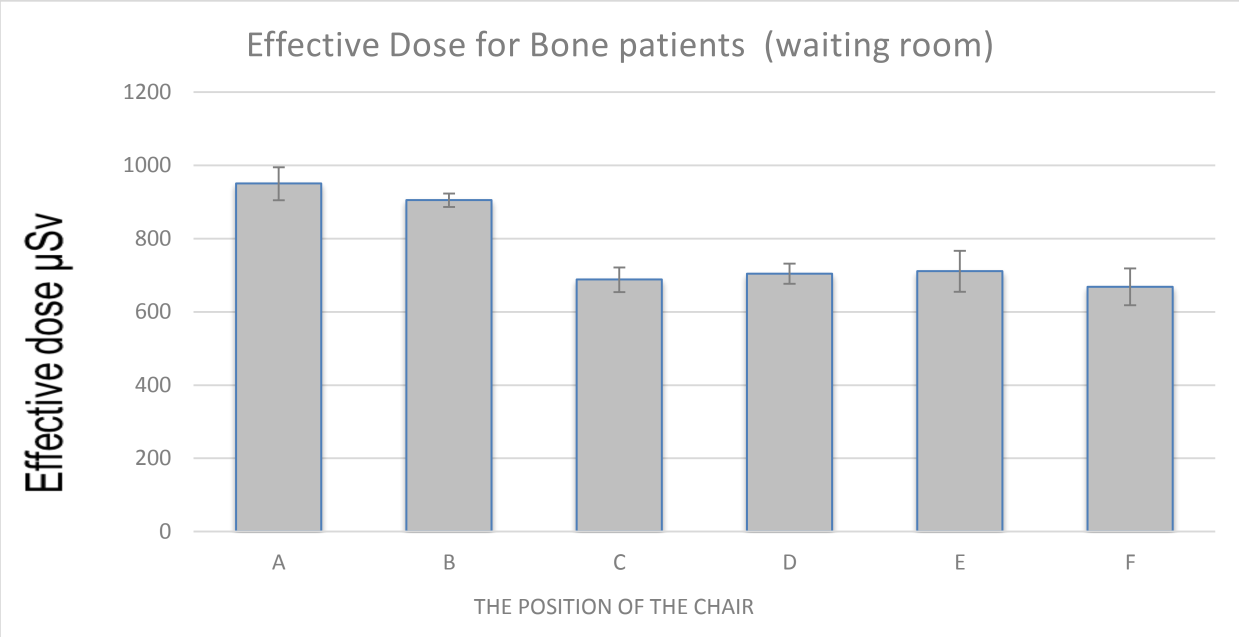

Figure (5): The dose rate of Bone patients in different positions (A, B, C, D, E and F) of the wa average value ± Sd.

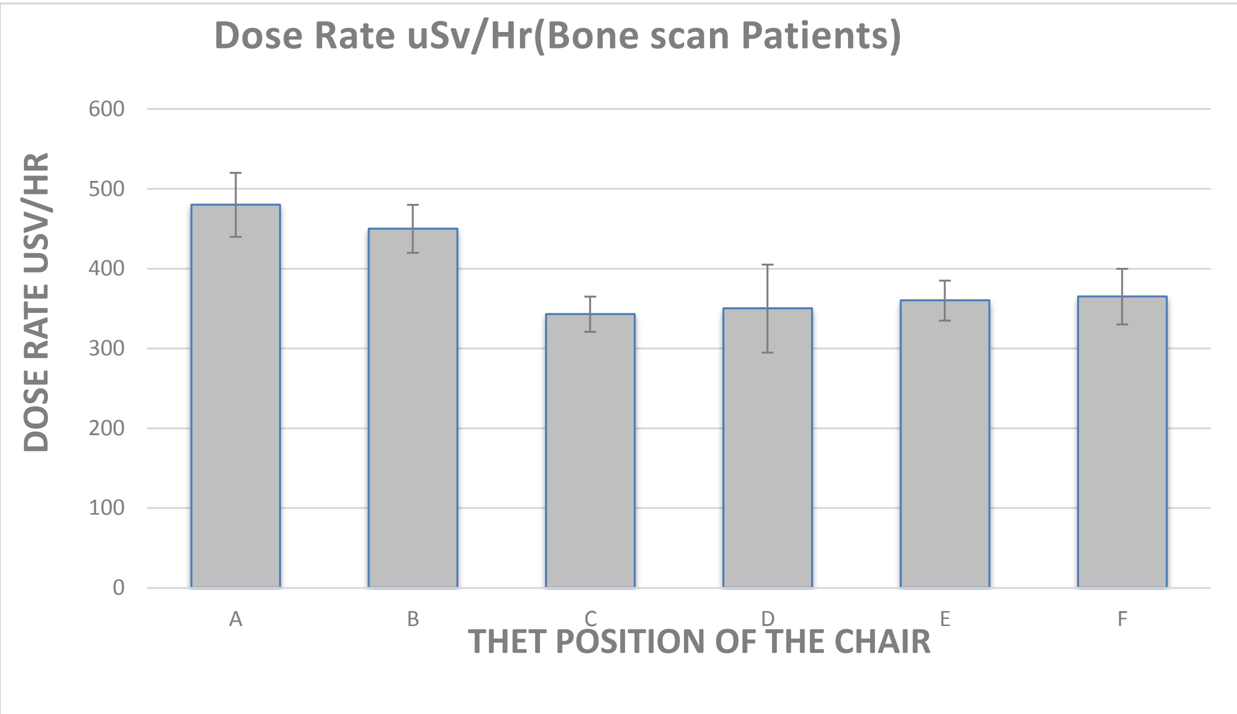

Figure (6): The effective dose of Bone patients in different positions (A, B, C, D, E and F) of value ± Sd.

The average effective doses of GP1 and GP2 are shown in ***(Tables 4 and 5)***, respectively. There is a positive correlation between the measured effective doses by Adalbert with Aloka dosimeter, where r =0.91, r=0.95 for GP1 and GP2, respectively.

Table (4): The effective doses of GP1 (Cardiac Patients) measured by ALOKA dosimeter.

Positions of Patient	Waiting Time(hr.)	Equivalent dose(μSv)	±SD	Effective accumulated dose (μSv) = equivalent dose x tissue weighting factor
A	1± 0.15	215	27	152
B	1±0.15	161	23	161
C	1± 0.15	107	14	107
D	1±0.15	113	15	113
E	1± 0.15	121	16	121
F	1± 0.15	116	17	116

Table (5): The effective doses of GP2 (Bone scan Patients) measured by ALOKA dosimeter.

Positions of patients	Waiting Time(hr.)	Equivalent dose(μSv)	±SD	Effective accumulated dose = equivalent dose x tissue weighting factor (μSv)
A	2± 0.25	233	47	233
B	2±0.25	229	30	229
C	2± 0.25	145	28	145
D	2±0.25	136	35	136
E	2± 0.25	150	27	150
F	2± 0.25	161	22	161

DISCUSSIONS:

The nuclear medicine department is considered a high-risk area for both workers and patients due to the use of radioactive materials in the diagnosis and treatment of oncology patients and others, which leads to a high level of radiation in the work environment [4].

Regulations and minimum standards at a local, state, and national level can vary between countries. During the design process, consideration must be taken to follow national/international standards that regulating radiation safety requirements, shielding, and handling of waste, hot lab gamma camera/minimum requirements.

The department of nuclear medicine examines many patients every day, resulting in a crowded waiting area (waiting room) and this creates exposure to patients and staff. Because of the injected radioactive patient who is injected with a radioactive substance becomes a source of ionizing radiation, and due to his/her movement to enter the bathroom or his transfer to imaging on gamma camera devices, he/she becomes a source of exposure to those inside the nuclear medicine departments, especially the workers [4,12]. The lack of radiation exposure communication can also result from a lack of expertise and knowledge healthcare professionals, including doctors, radiographers, and technologists in the field of nuclear medicine. The outcomes of recent research findings [13, 14, and 15] and a systematic review of 14 peer-reviewed articles in 2013 have also shown a lack of physician knowledge and a tendency to underestimate medical imaging exposure to ionizing radiation [16].

This paper shed the light on the effective doses of patients in the waiting area. In the waiting room, the patient's effective dose is affected by distance from other patients, the administrated activity, the residence time, and the radiation attenuation. So, the room design is the main factor affecting on patient's effective dose in the waiting room. According to the inverse square low, the greater distance from radiation source, the less dose rate at this distance [11]. For this reason, the patient's effective dose (GP1 and Gp2) at positions A and B was significantly higher than others; on the other hand the patient's effective dose (GP1 and GP2) at positions C and D was less significant against other positions. The results showed positive correlation between the measured data by the Radalert 100x, and the cumulated effective dose measured by Alok digital dosimeter.

The residence time (T) for GP2 (bone scan) from was 2 hours, so the patients' effective dose is increased significantly at positions A and B ($P<0.05$) in comparison with cardiac patients GP 1 (T=1 hr.).

Our results are in correlation with Gomez-Palacios et al who studied radiation doses in the surroundings of patients undergoing nuclear medicine diagnostic by measurements of the dose rate at 0, 0.5 and 1 m from the surface were carried out in 79 patients, corresponding to the most regular studies: Tc^{99m} cardiac reinjection, Tc^{99m} cardiac single injection, Tc^{99m} bone scan, Tc^{99m} pulmonary studies, and 201Tl-cardiac studies (17).

For the various working shifts and hospital locations, doses were calculated for staff, surrounding patients, and the collective effective doses.

For staff, the estimated dose for 1 y was 518 µSv in the cardiology section and 338 µSv in the short-stay section, respectively.

The mean dose per stay was estimated for patients to be 8.5 µSv in the cardiology section. For a double cardiac patient injection analysis, the maximum dose that a patient might obtain from a radioactive patient is 499 µSv. For the entire hospital, the overall collective effective dose was measured as 0.063 person-Sv (18).

It is recommended that the distance between patients during radiopharmaceutical incorporation be increased and distributed according to the diagnostic procedure. Instead of public transport, patients must be encouraged to use private facilities. It might be necessary to apply restrictions, depending on the number of outpatients in nuclear medicine attended by a doctor each year.

CONCLUSIONS:

Firstly, we estimated the radiation exposure of patients in waiting room during nuclear cardiac perfusion and bone scans.

For that the design the waiting room and the position of patients are highly affecting the accumulated patient's effective dose.

The size the waiting room must be considered in radiation protection regulations. From our results, the recommendations came out to bring the attention to the nuclear medicine staff and radiation safety experts about the following: The workload (maximum number of patients per day) should be taken into consideration not only for radiation shielding calculation but also for patient radiation protection. We suggested that the design of the waiting room should be wide as much as you can to increase the spaces among patients waiting for the scanning procedure.

Individual chairs are recommended such that the distance between each patient is as large as possible. A strict release criterion should be followed and implemented for patients before release to outside the department. All staff should not go through the waiting area except in an emergency case. Using remote communications with patients could largely mitigate an exposure to unnecessary radiation doses to workers. The relatives should be a way from the waiting area till the end of scan process.

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