Study of Exposure Rates from various Nuclear Medicine Scan at INMAS, Dhaka

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ABSTRACT

The aim of present study was conducted to measure external radiation exposures at various distances from the middle body of the patient for various scan. A special type of Gamma camera is used to detect the radiations from patients for having images. In this study the observation was conducted on about 106 patients and a Minirad series 1000#001749 survey meter is used to measure the exposure. It is noted that exposure rates of ^{99m}Tc-MDP whole body scan is higher than any other scans and exposure rates are 40.85 µSv/hr at a distance of 0.25 m & 5.97 µSv/hr at 2m distance. On the other hand lower dose rate are observed in ^{99m}Tc- DMSA renal scan and found at a distance of 0.25 m is 7.80 µSv/hr & 1.73 µSv/hr at 2m distance. The exposure rates were observed to be significantly varied with the activity of radiopharmaceuticals and it decreases with increasing distance from patient.

Keywords: *Radiopharmaceuticals, Exposure rate, Dose, Isotopes, ^{99m}Tc, Radiation, X-Rays,* radionuclides.

I. Introduction

Every human being is continuously exposed to a certain amount of radiation, called background radiation or simply background, occurring naturally in the environment in which he/she lives. Soon after the discovery of X-rays by Roentgen in 1895 and of natural radioactivity by Becquerel in 1896, it became apparent that ionizing radiation was not only useful for the diagnosis and treatment of disease but also harmful to human tissues [1-4]. It has been recognized since early studies on X-rays and radioactive minerals that exposure to high levels of radiation can cause clinical damage to tissues of the human body [5-10]. The annual background radiation is measured from various human activities [11]. The main among these is diagnostic radiology (0.39 mSv), and second one is nuclear medicine (0.14 mSv) [1]. The natural background radiation arises from both external and internal sources. The external sources are Cosmic rays, radioactive isotopes etc. The main internal sources are ^{40}K and ^{14}C in the body. These radionuclides enter the body through food and water and there is no way to avoid them. The external exposures are caused by γ-rays and neutrons from sources outside the body[12-15]. Internal exposures arise from the sources of α, β particles and the γ-rays that have entered the body in one way or another [16-17].

The main sources of energetic radiations are the radioactive isotopes. The nuclei of certain isotopes are unstable and decay by emitting α and β particles. These nuclear rearrangements are very frequently accompanied by the emission of γ-rays of various wavelengths [18-22]. This behavior of nuclides is known as radioactivity. Different isotopes of the same element may show different radioactivities. The radioactive element of high atomic number may change into another isotope which is also radioactive and in this way a decay series arises[23-27]. Nuclear medicine is a reliable branch of medicine and medical imaging that uses radioactive isotopes and relies on the process of radioactive decay in the diagnosis and treatment of disease[28-30]. Radionuclides can have both beneficial and harmful effects on living organisms. Radionuclides with suitable half-lives are used in nuclear medicine for both diagnosis and therapy [2].

Until recent times, we do not have adequate information on the exposure rates received from radioactive patients, their attendant or the personnel associated in nuclear medicine department. Occupational workers often don't maintain the radiation protection and safety rules. Even the patients' attendants don't aware about the radiation hazard. In view of this prevailing situation in the country, it may be considered as a baseline study for the nuclear medicine department[31-34]. Hence considering the importance, the present research has been undertaken to achieve the following objectives:

- To measure the exposure rates received from the radioactive patients.
- To ensure minimal hazard to personnel in nuclear medicine department.
- To propose a suitable programme for radiological protection on the management of radioactive patients.

II. Material and Methods

The study was conducted for 106 patients at the Institute of Nuclear Medicine and Allied Sciences (INMAS), Bangladesh Atomic Energy Commission, Dhaka Medical College Hospital Campus, Dhaka-1000. In this study Thyroid scan, Bone scan, Renal scan, Renogram, Brain perfusion and Cardiac scan were done using 99mTc, generated from 99mMo. External radiation exposures were measured by using Minirad series 1000#001749 survey meter [35-38].

At first, height and weight of the patients were measured. They were allowed to have some water prior to the scan. No scan is performed on pregnant women because of the risk of exposing the fetus to radiation. These tests are also not recommended for breastfeeding women. Nuclear medicine procedures may be time consuming and may take hours to days for the radiotracer to accumulate in the part of the body and imaging may take up to several hours to perform. Some patient may be allergic to the chemicals used for the scan and those are sensitive to the chemicals may occur nausea, vomiting and headaches [3].

III. Results and Discussion

The patients were given a small radioactive injection in a vein in his arm and a brief scan was performed. The patient would not feel any ill-effects from the injection. After the injection the patient needed to drink plenty and wash out frequently. These both reduced the small radiation dose he/she received and improve the quality of his/her scan. It is important to avoid any movement of the body during scanning, as it may blur the images and may give poor results of scanning. The patient should avoid close contact with children and pregnant women for some time[39-43]. There are different types of radionuclide were used. Different ones tend to collect or concentrate in different organs or tissues. So, the radionuclide used depends on which part of the body is to be scanned [4]. External radiation exposures for various scans were measured at various distances (0.25, 0.50, 1.0 and 2.0 m respectively) from the middle body of the patient in three different interval times: 20 minutes, 40 minutes and 2 hrs after injection. Chart-1 & Chart-2 represents the findings for all scans of 20 min and 40 min respectively, and Chart-3 represents the findings for bone scan and renal scan for delayed 2 hrs. The detailed observations of the study are given below:

Bone Scan

A bone scan is used to examine the bones for damage caused by cancer or another disease[44-46]. The scan helps find cancer that started in the bones, as well as cancer that metastasized to the bone from other parts of the body. The maximum dose is 900 MBq and the minimum is 100 MBq [5]. In this procedure, the patient is injected (usually into a vein in the arm or hand, occasionally the foot) with an average dose of 740 MBq of 99mTc-MDP (methylene diphosphonate) and then scanned with a gamma camera, and images of the bone are obtained approximately 2 hours later. It takes 30 minutes to complete the scan[47]. In bone scan 37 patients were studied; 8 of which are male and the rest are female. The average age of them was 49 years. Exposure rate for bone scan from different distances are shown in Table-1. The exposure rate is 40.85, 26.65, 14.76 and 5.97 μSv/h when the distance is 0.25, 0.5, 1.0 and 2.0 m for Immediate injection (20min) and the exposure rate is 24.51, 19.76, 5.70 and 3.76 μSv/h when the distance is 0.25, 0.5, 1.0 and 2.0 m for 40 min post injection. The image (Fig-1) below shows bone scan image after ^{99m}Tc-MDP administration.

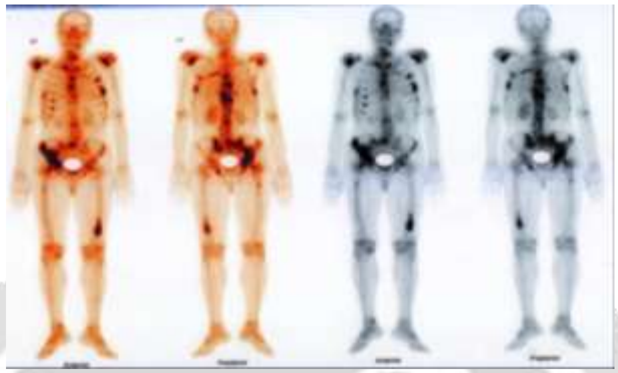


Fig-1: Bone scan image after ^{99m}Tc-MDP administration

Table-1: Exposure rate for bone scan from different distances

Survey meter reading (micro sivert/hour)			
Distance (meter)	Immediate injection (20 min)	40 min post injection	Delayed 2 hours
0.25	40.85	24.51	19.35
0.5	26.65	19.76	10.05
1.0	14.76	5.70	3.82
2.0	5.97	3.73	1.54

Renogram

DTPA (diethylenetriamine penta-acetic acid) scan is a test for functional evaluation of kidneys and the urinary tract. It is also a good test to follow up, improvement in kidney function following specific treatment. The maximum dose is 555 MBq and the minimum is 55.5 MBq [4]. Counts in pre-injection and post-injection syringes were measured for 60 seconds at 30 cm from the Gamma-Camera to determine the total amount of activity injected. Rapid injection of average dose or 179.08 MBq of 99mTc-DTPA was given through an end welling butterfly needle in an antecubital vein and was followed by infusion of 20 ml of normal saline and will take 30-35 minutes. We have approached to 19 patients for renogram; 10 of which are male and the rest are female. The average age of them is 39.16 years. Exposure rate for renogram from different distances are shown in Table-2. The result shows that the exposure rate has decreased along with increasing distance and time also (20 min, 40 min). The image (Fig-2) below shows renogram imageafter ^{99m}Tc-DTPA administration.

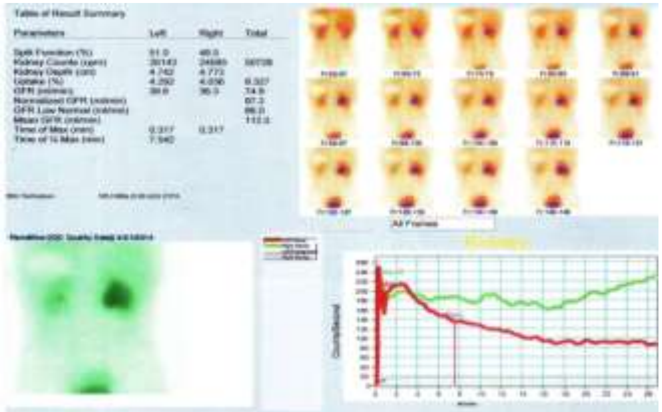


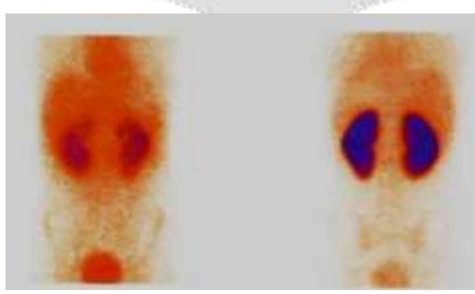
Fig-2: Renogram image after ^{99m}Tc-DTPA administration

Table- 2: Exposure rate for renogram from different distances

Survey Meter Reading (micro sivert/hour)		
Distance (meter)	Immediate injection (20 min)	40 min post injection
0.25	14.16	11.79
0.5	8.08	6.37
1.0	3.95	3.05
2.0	2.08	1.45

Renal Scan

For the DMSA Scan, the patients are allowed to the dose from 20 MBq to 180 MBq [6]. In this technique, the patient is injected with an average dose of 97.31 MBq of ^{99m}Tc-DMSA (Dimercaptosuccinic acid) and then scanned with a gamma camera, and images of the kidneys are obtained approximately 2 hours later. A cannula was inserted into the vein and allowed to stay there for the duration of the test[48]. Through this cannula, the radiopharmaceutical injected was detected by the gamma camera to provide clear images of the kidneys[49]. The patients were given a second injection through the same cannula of a diuretic called frusemide (Lasix) that caused the kidneys to make more urine by decreasing the amount of water that the kidneys resorb as part of the filtering process. We have approached to 15 patients for renal scan; 10 of which are male and the rest are female. The average age of them is 15.93 years. From Table-3, the exposure rates are 7.80, 6.17 and 3.83 µSv/h from the same distance of 0.25 m after 20 min, 40 min and 2 hrs respectively. The image (Fig-3) below shows renal scan image after ^{99m}Tc-DMSA administration.



Anterior posterior

Fig-3: Renal scan image after ^{99m}Tc-DMSA administration

Table -3: Exposure rate for renal scan from different distances

Survey Meter Reading (micro sivert/hour)			
Distance (meter)	Immediate injection (20 min)	40 min post injection	Delayed 2 hours
0.25	7.80	6.17	3.83
0.5	5.45	4.00	2.40
1.0	3.13	2.23	1.23
2.0	1.73	1.13	0.57

Brain Perfusion

The maximum dose for this type of scan is 1110 MBq and the minimum is 370 MBq [7]. In this cases, the patient is injected with an average dose 370 MBq of ^{99m}Tc-ECD (N, N´-1, 2-ethylenediyl-bis-L-cysteine diethylester) and then scanned with a gamma camera. We have approached to 5 patients for brain perfusion; 2 of which are male and the rest are female. The average age of them is 35.4 years. Table - 4 shows the Exposure rate for brain perfusion from different distances. The image (Fig-4) below shows brain perfusion image after ^{99m}Tc-ECD administration.

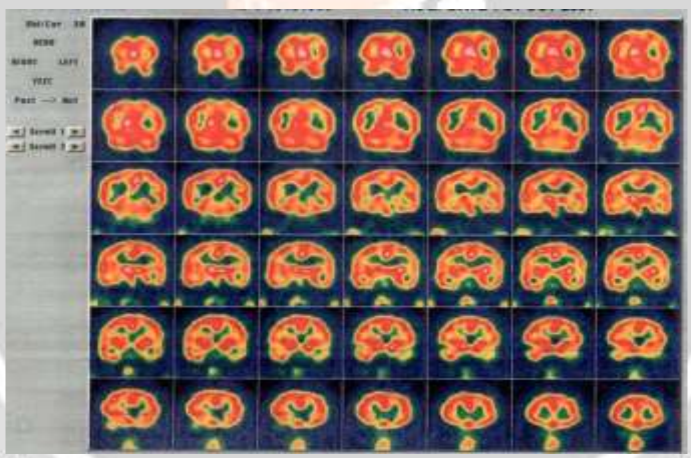


Fig-4: Brain perfusion image after ^{99m}Tc-ECD administration

Table -4: Exposure rate for brain perfusion from different distances

Survey Meter Reading (micro sivert/hour)		
Distance (meter)	Immediate injection (20 min)	post injection 40 min
0.25	20.80	14.20
0.5	14.00	8.40
1.0	7.80	4.10
2.0	3.80	1.90

Cardiac Scan

In a myocardial perfusion scan a radionuclide that concentrates in heart muscle is used by an injection into a vein. The radionuclide travels through the bloodstream and into the heart muscle. As the radionuclide moves through the heart muscle, areas that have good blood flow take up the radionuclide well. Areas that do not absorb radionuclide very well may have a poor blood supply due to narrowed heart arteries, or may have been damaged by a heart attack. So, heart muscle tissue with a good blood flow will emit more gamma rays than areas with a poor blood flow or damaged tissue[50]. The maximum dose is 850 MBq and the minimum is 100 MBq [8]. In this practice, the patient is injected with an average dose of 370 MBq of ^{99mTc}-MIBI (methoxyisobutyl isonitrile), and images of the cardiac scan are obtained approximately 20 minutes later. We have approached to 10 patients for cardiac scan. The average age of them is 55 years. Exposure rate for cardiac scan from different distances are shown in Table -5. The image (Fig-5) below shows cardiac scan image after ^{99m}Tc-MIBI administration.

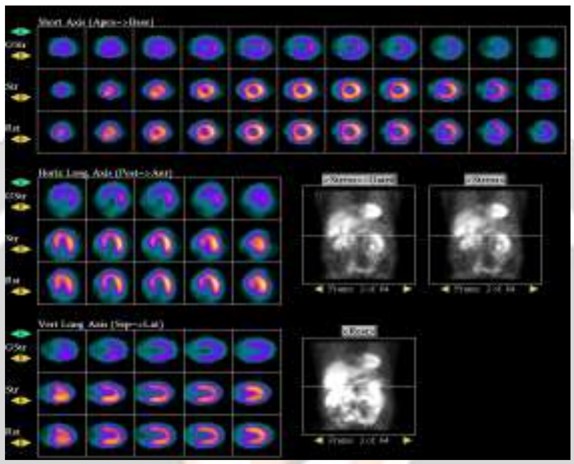


Fig-5: Cardiac scan image after ^{99m}Tc-MIBI administration

Table- 5: Exposure rate for cardiac scan from different distances

Survey Meter Reading (micro sivert/hour)		
Distance (meter)	Immediate injection (20 min)	40 min post injection
0.25	20.00	10.75
0.5	8.00	5.00
1.0	3.50	2.00
2.0	2.00	1.00

Thyroid Scan

A thyroid scan provides information about the function and structure of the thyroid gland. The scan involves injection of a radiopharmaceutical into a vein in patient arm and imaging with a gamma camera. The dose ranges administered from 18.5 MBq to 150 MBq [9]. For this cases, the patient is injected (usually into a vein in the arm or hand, occasionally the foot) with an average dose 111 MBq of ^{99m}Tc-pertechnetate and and then scanned with a gamma camera, and images of the thyroid are obtained approximately 20 minutes after injection. It takes 5-10 minutes to complete the scan. We have approached to 20 patients for thyroid scan; 3 of which are male and the rest are female. The average age of them is 35 years. Table -6 shows that the exposure rate is 11.32, 6.85, 3.90 and 2.00 μSv/h when the distance is 0.25, 0.5, 1.0 and 2.0 m for Immediate injection (20min) and the exposure rate is 7.1, 4.3, 2.53 and 1.15 µSv/h when the distance is 0.25, 0.5, 1.0 and 2.0 m for 40 min post injection. The image (Fig-6) below shows thyroid scan image after ^{99m}Tc-pertechnetate administration.

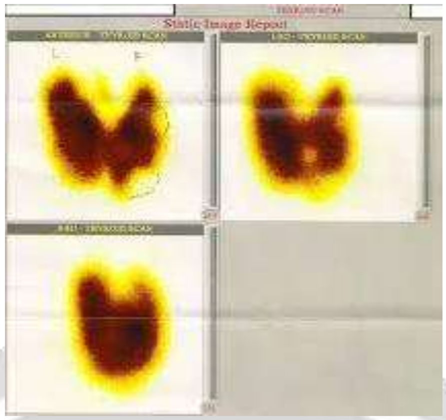


Fig-6: Thyroid scan image after ^{99m}Tc-pertechnetate administration

Table- 6: Exposure rate for thyroid scan from different distances

Survey Meter Reading (micro sivert/hour)		
Distance (meter)	Immediate injection (20min)	40 min post injection
0.25	11.32	7.1
0.5	6.85	4.3
1.0	3.90	2.53
2.0	2.00	1.15

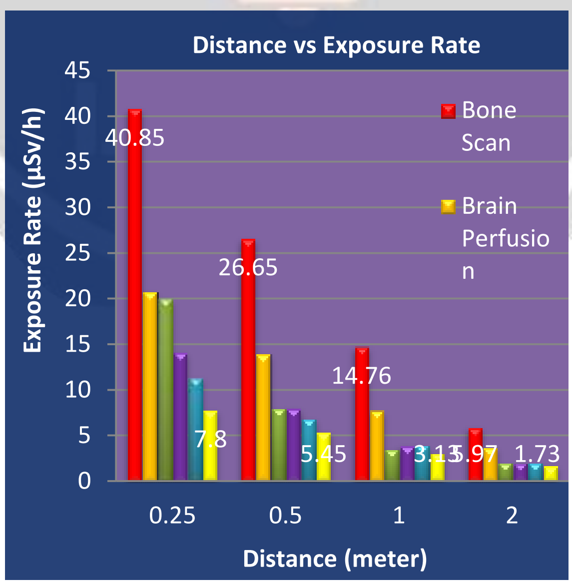


Chart-1: Exposure rates within 20 minutes after injection for all scans

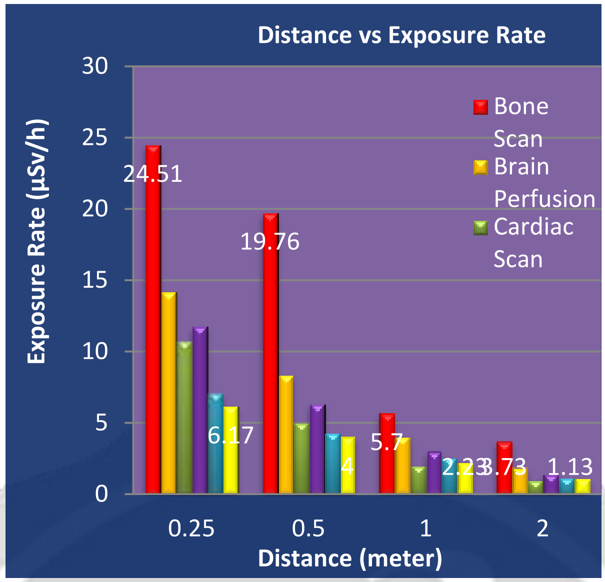


Chart-2: Exposure rates 40 minutes post injection for all scans

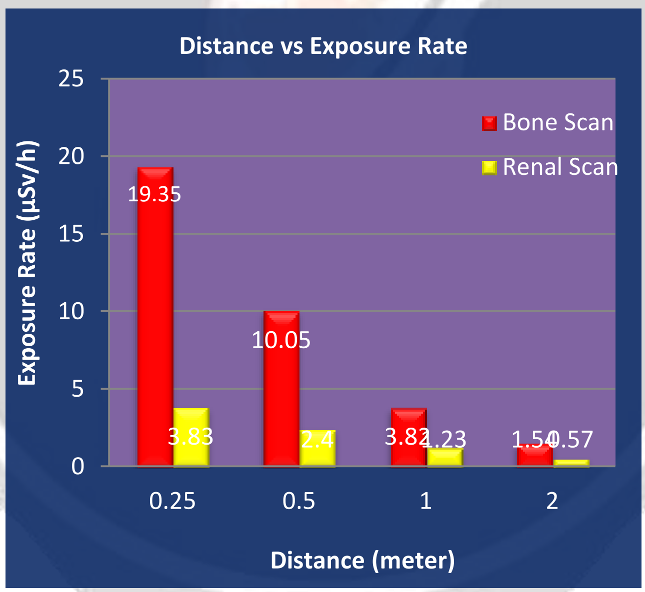


Chart-3: Exposure rates delayed 2 hours after injection for 2 scans

IV. Conclusion

Exposure rates of different scans from various time spans as well as various distances have been obtained by the study. Exposure rates measured within 20 minutes of the injection vary for different scans. The maximum distance was 2m and the highest exposure rate was 5.97 µSv/h found for the bone scan, but the exposure rate from brain perfusion imaging and the rest scans were almost same. From the study the exposure rates were observed to be significantly varied with the activity of radiopharmaceuticals & distance from the source. The variation of the exposure rates for different scans from the same distance is caused for various doses for different scans. Also, the exposure rate decreases when time from the injection period increases. This is basically due to the decay activity and increase in excretion of radiopharmaceutical. Hence, same amount of doses are administered to different patients, but individuals receive different exposures from them. Accordig to ICRP, the maximum exposure for nuclear medicine staff is 55 μSv per day [10]. The internationally acceptable annual dose limit for public is 1 mSv/yr [11]. This limit expresses the sum of total doses from all the sources for a year. Calculations show that doses for shorter distances to which exposures for more than few hours placed in public at a position exceed the public dose limit. Under these circumstances hospital authority should be conscious about the safety of the public while delivering such treatments to patients.

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