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Research Article

STUDY OF THE EXPOSURE RATE FROM THE PATIENTS INJECTED WITH RADIOPHARMACEUTICAL

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Abstract

Nuclear medical imaging is done by injecting very small amount of radiopharmaceutical to the patient. The radiations from patients are detected by special type of Gamma camera that works with computer to yield precise pictures of the organs being imaged. The Technetium-99m, injected to renal scan patient, is the source of radiation to the individual near to patient. Thus the individual receives exposure from the patient. The exposure received by public in the imaging center from renal scan patients has been calculated. The exposure rate at the center is measured to check whether an individual near to the patient is below the internationally acceptable public dose limit. Public receive low amount of average exposure of (3.7 ± 1.7) μSv/h at 1m distance for delayed scan. However, public receives high amount of exposure of (234.4 ± 74.8) μSv/h at shorter distance of 0.25 m after immediate scan are not subject to dose limits of the occupational radiation worker. The exposure received at shorter distance is higher from the patients. Thus the hospitals providing radiation treatments must take account of the public dose limit for individuals accompanying treated patients.

Keywords: Exposure rate; Gamma Camera; Renal Scan; Survey Meter; Radiopharmaceutical

Introduction

In nuclear imaging, the radiopharmaceutical is injected into the body especially in the organ concerned which is frequently applied for the estimation of absorbed doses in nuclear medicine that determines the amount as well as distribution of radiation energy deposited in the tissues by radionuclide within the body (Gupta *et al.*, 2013). In this study, imaging is performed under a gamma camera that works with computer to provide very precise picture about the area of the body being imaged. The radiopharmaceutical is excreted by human excretory system within 24 hours of injection (Sampson, 1999). The most widely used radionuclide is Technetium-99m (^{99m}Tc). ^{99m}Tc is favored choice of the medical profession because the type of radiation it emits allows the practitioner to image internal body organs. Its half-life is six hours which is long enough for a medical examination and short enough to allow a patient to leave the hospital soon afterwards. ^{99m}Tc is generated from Molybdenum-99 (^{99}Mo) which has a half-life of 66 hours, allowing it to be transported over fairly long distances (Sharp *et al*., 2005).

In a ^{99}Mo-^{99m}Tc generator, the parent ^{99}Mo activity in the form of Molybdate ion (MoO_4^{2-}) is bound to an alumina (Al_2O_3) column. The daughter ^{99m}Tc activity, produced in the form of $^{99m}TcO_4^-$ (pertechnetate), is not strongly bound to alumina and is eluted from the column with 5 to 25 ml of normal saline. About 75% to 85% of the available ^{99m}Tc activity is extracted in single elution. ^{99m}Tc activity builds up again after an elution and maximum activity is available about 24 hours later (Chery *et al.*, 2003).

Generator produced ^{99m}Tc is available in the form of Sodium pertechnetate (^{99m}Tc-$NaTcO_4$) which has oxidation state of 7^+. TcO_4 is chemically non-reactive and has no ability to label any compound by direct addition. So, reduction of Tc^{7+} to a lower oxidation state is required. The reduction process is obtained using a number of reducing agents where stannous chloride is mostly preferred as a reducing agent.

Radiation hazard is due to external and internal radiation exposure. Radiation exposure causes serious health hazards such as genetic disorder, cancer, leukemia, sterility etc. Public and radiation officers should be aware of radiation hazards (Andrews, 1974). Doses should be given under internationally acceptable norms of ALARA (as low as reasonably achievable) principle.

Materials and Methods

Patients

Patients of Bir Hospital, Kathmandu, with renal scan were chosen as sample for this study. At first, height and weight of the patients were measured.They were allowed to drink

some water prior to the scan to make the patient well hydrated to achieve optimum kidney function.

Radiopharmaceutical

Technetium-99m, generated from Molybdenum-99 was used as radiopharmaceutical in the renal patients. The most commonly used ^{99m}Tc- labeled renal imaging agent is DTPA which stands for Diethylenetriamine Pentaacetate. DTPA is produced commercially as a pentasodium or calcium salts in the presence of an appropriate amount of stannous chloride for the reduction of the added free Technetium (Khan, 1992).

Imaging and Scanning

Since the nuclear medicine renal Scan can be performed with 2 different substances - DTPA or MAG3 (Mercaptoacetyltriglycine). Here we are concerned with DTPA renal scan. In a Nuclear Medicine Renal Scan, images are made of the delivery of fluid into the kidneys via the bloodstream, concentration of wastes in the kidney and excretion or flow from the kidneys through the ureters and filling of the bladder (ICANL, 2007; Steves and Wells, 2004). For the DTPA Scan, the patients are allowed to lie down on the scanning bed, with the gamma camera under the bed. It is important to avoid any movement of the body as it may blur the images and may give poor results of scanning. The imaging itself is painless. A small injection in a vein was given, usually in the arm. A cannula (thin plastic tube) was inserted into the vein and allowed to stay there for the duration of the test. Apart from the initial prick this should not cause any discomfort. Through this cannula, the radiopharmaceutical (^{99m}Tc DTPA) was injected which was detected by the gamma camera to provide clear images of the kidneys. 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. There was also an increased flow of urine through the ureters which made any obstruction of the ureters easier to see. The frusemide helps the kidneys to work harder, so the bladder fills faster (Steves and Wells, 2004; Sprawls, 1981). At the end of the scan, patients were told to urinate to empty the bladder. The cannula was removed before the patient left the department. Exposure rate from such patients were measured after 30 minutes and 3 hours of injection at 1 m and 2 m distances.

Exposure rate measurements

2001190 FH40F1 model survey meter was used for this research work to obtain the exposure rate (Iddings, 2001). Survey meter was placed at a distance of 1 m and 2 m from the patients injected with ^{99m}Tc with detector facing towards patients. The radiation level was shown in the display. The data at the corresponding time and distance were collected.

Results and Discussion

The exposure rates obtained are categorized according to age groups and gender. They are classified in the age groups of 0-20, 20-40 and 40-60 including 63 years old. The average exposure rate and standard deviation of these groups are calculated which have been compared with ICRP recommendation dose limits on exposure to radiation and finally analyzed whether the exposure received is hazardous or not.

Measurement of radiopharmaceutical activity

The elution activity of Technetium-99m at different time from Technetium generator are recorded. The activity, exposure, time and amount of radioisotope eluted are presented in the Table 1. The decay curve of the activity as the function of time is shown in Fig.1.

Table 1: Activity, exposure, time and amount of radioisotope eluted

S.N.	Time (hrs)	Elution of ^{99m}Tc (mCi)(a)	% of initial activity
1	0	110	100%
2	24	76	69.09%
3	48	42	38.18%
4	69	13	11.81%
5	93	12	10.90%

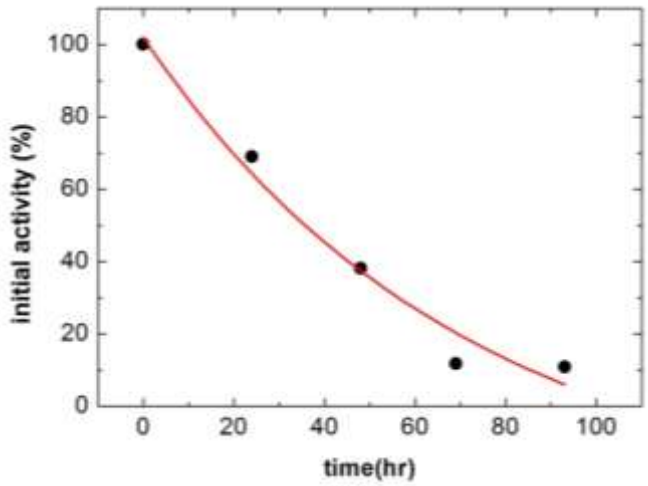

Fig. 1: The decay curve of the initial activity as a function of time.

Using inverse square law and the exposure rates at 1m and 2m distances, average corrected exposure rate is calculated at 0.5 m, which is again used to calculate average exposure rate at 0.25 m for both immediate and delayed scan. These data are categorized in the age group of 0-20, 20-40, and 40-60 including one 63 year patient according to gender (Table 2). The bar diagrams below (Fig. 2 A and B) represent mean exposure rates according to age groups and gender for immediate and delayed scan.

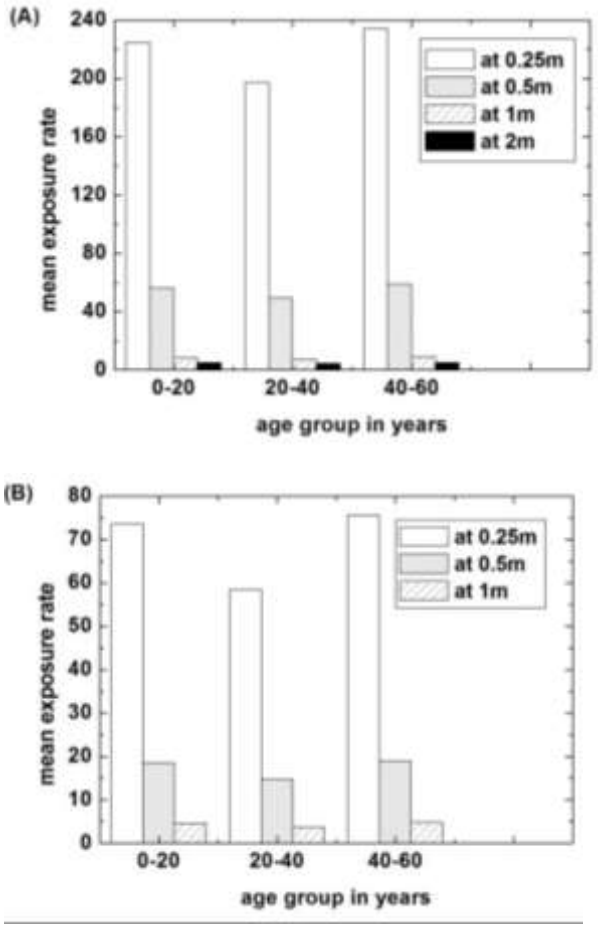

Fig. 2: The mean exposure rate (μSv/h) at different distance with age variation: (A) immediate scan and (B) delayed scan.

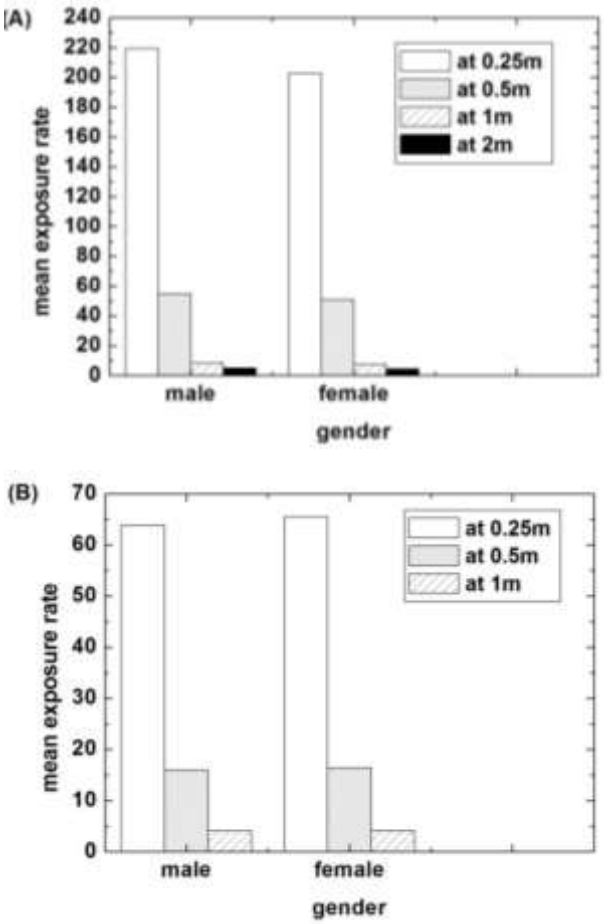

Fig. 3: The gender-wise mean exposure rate (μSv/h) at different distance: (A) immediate scan and (B) delayed scan

After the injection of radiopharmaceutical into the patients of age group 0-20 years, an average exposure of (8.5 ± 1.5) μSv/h is received immediately by individual at 1m distance. Similarly the average exposure rate at a distance of 2m from patients of this age group is (4.9 ± 0.9) μSv/h (Fig. 2A). After 3 hours of injection, the average exposure rate from such patients at a distance of 1m is (4.6 ± 0.9) μSv/h (Fig. 2B). The patients of age group 20-40 years emit an average exposure of (7.2 ± 2.1) μSv/h at 1m immediately after injection. At a distance of 2m, individual receives an average exposure of (4.5 ± 1.3) μSv/h from these patients (Fig. 2A). Delayed exposure rate to individual at a distance of 1m is (3.7 ± 1.7) μSv/h (Fig. 2B). The age group of 40-60 years (including one 63 year patient) patients give an average exposure of (9.2 ± 4.2) μSv/h and (5.0 ± 1.3) μSv/h at a distance of 1m and 2m immediately after injection (Fig. 2A). The delayed average exposure from these patients at a distance of 1m is (4.7 ± 1.9) μSv/h (figuure 2B). Individual receives more exposure from male patients than female. The average exposures from male and female patients at a distance of 1m, 2m immediately after injection are (8.3 ± 3.1) μSv/h, (4.8 ± 1.1) μSv/h and (7.5 ± 2.6) μSv/h, (4.4 ± 1.3) μSv/h respectively (Fig. 3A). The delayed 1m average exposure from male and female patients to individual are (3.9 ± 1.9) μSv/h and (4.1 ± 1.6) μSv/h respectively (Fig. 3B).

Verification of Inverse square law

Using inverse square law and exposures at 1m and 2m distances, the exposure rates at 0.5 m and 0.25m have been computed. The exposure rate at 0.5 m and 0.25 m from 0-20 age group patients is calculated to be (56.2 ± 9.2) μSv/h and (224.8 ± 36.9) μSv/h repectively immediately after injection. The immediate exposure rates from 20-40 age group patients at 0.5 m and 0.25 m distance are calculated as (49.3 ± 14.5) μSv/h and (197.3 ± 58.2) μSv/h. Similarly, (58.6 ± 18.7) μSv/h and (234.4 ± 74.8) μSv/h are the calculated immediate exposure rates received at 0.5m and 0.25m from the patients of 40-60 age groups (Fig. 2A). The delayed exposure rates calculated at 0.5m from the age groups of 0-20, 20-40 and 40-60 years are (18.4 ± 3.9) μSv/h, (14.6 ± 6.9) μSv/h and (18.9 ± 7.5) μSv/h respectively. Similarly at 0.25m these exposure rates are calculated to be (73.6 ± 15.8) μSv/h, (58.5 ± 27.7) μSv/h and (75.7 ± 29.9) μSv/h (Fig. 2B). The average calculated exposures from male and female patients at 0.5m and 0.25m immediately after injection are (54.8 ± 15.2) μSv/h, (219.4 ± 60.8) μSv/h and (50.7 ± 15.6) μSv/h, (202.6 ± 62.5) μSv/h respectively (Fig. 3A). The delayed 0.5 and 0.25m average exposure from male and female to individual are calculated as(15.9 ± 7.7) μSv/h, (63.8 ± 30.9) μSv/h and (16.4 ± 6.4) μSv/h, (65.5 ± 25.8) μSv/h respectively (Fig. 3B).

Table 2: The exposure rate of 50 patients eluted with radiopharmaceutical ^{99m}Tc, DTPA.

S.N.	Age (yrs)	Sex	Dose (mCi)	Survey Meter Reading (μSv)			
				Immediate (25min)		Delayed (3hrs)	
				1m	2m	1m	2m
1	19	M	10.0	11.3	5.0	4.6	4.1
2	36	F	9.0	7.9	3.2	3.7	0.0
3	30	F	12.0	8.3	3.3	3.0	0.0
4	34	M	10.3	8.1	3.3	3.1	0.0
5	59	M	14.0	20.1	8.2	9.1	4.0
6	04	M	4.0	7.3	4.1	3.4	0.0
7	55	M	12.0	11.3	4.4	4.1	3.2
8	23	M	10.8	7.9	3.0	4.2	3.7
9	40	F	14.0	9.4	5.0	4.0	0.0
10	60	F	14.0	9.0	4.7	4.4	3.0
11	28	F	10.0	6.0	4.7	3.4	0.0
12	44	F	14.0	14.7	6.4	6.8	3.2
13	26	F	12.0	14.0	6.5	6.1	3.7
14	33	F	12.0	8.3	4.0	7.1	3.4
15	48	M	14.0	7.4	4.4	6.1	3.4
16	32	F	11.0	9.1	4.6	4.3	3.1
17	24	F	9.0	9.0	6.4	7.8	5.2
18	24	M	9.0	10.4	6.3	3.5	3.0
19	38	F	9.0	4.5	3.5	4.0	3.1
20	30	F	9.0	9.2	4.8	4.0	3.2
21	63	M	6.1	5.6	4.0	3.0	0.0
22	51	F	6.3	5.6	4.0	3.0	0.0
23	22	F	6.8	5.9	4.1	3.0	0.0
24	30	F	6.9	6.5	4.3	3.1	0.0
25	28	M	5.75	5.3	3.4	0.0	0.0
26	30	F	5.0	3.6	0.0	0.0	0.0
27	29	M	6.4	8.1	4.7	0.0	0.0
28	35	F	6.7	4.8	3.6	3.1	0.0
29	23	M	6.9	4.4	3.8	3.3	0.0
30	29	M	6.8	7.2	5.2	3.4	3.0
31	43	M	9.0	9.1	4.8	4.1	3.3
32	24	F	9.0	5.0	3.5	3.2	0.0
33	18	F	7.0	8.4	4.9	3.8	3.0
34	50	M	7.0	5.4	4.2	3.6	0.0
35	44	M	9.0	8.2	5.4	3.0	0.0
36	22	M	7.0	6.5	5.0	3.1	0.0
37	40	M	5.2	7.2	5.1	6.7	4.1
38	21	M	5.4	8.6	5.7	3.2	0.0
39	36	F	6.2	8.0	4.9	3.5	0.0
40	20	F	7.0	6.3	4.6	5.1	3.6
41	22	M	8.2	7.6	5.3	4.3	3.2
42	36	F	6.0	4.9	3.4	3.1	0.0
43	40	M	7.0	6.3	4.8	3.6	3.1
44	30	F	7.0	5.7	4.4	3.2	0.0
45	11	M	4.0	8.0	4.2	4.4	3.2
46	6	F	3.0	8.2	6.3	5.3	4.0
47	15	M	7.0	7.4	5.0	6.1	4.6
48	36	M	7.0	8.4	6.0	5.3	3.7
49	27	F	7.0	6.0	4.5	3.2	0.0
50	32	F	9.2	8.0	5.3	6.0	3.4

Statistical Analysis

The data obtained is tested for goodness of fit by chi-square (χ^2) test. In calculating χ^2value, each observed frequency should be greater than 5. If any theoretical frequency is less than 5, one cannot apply chi-square test. If found less than 5, the technique of pooling is used, in which frequencies less than 5 are added with preceding or succeeding frequency/frequencies so as to get the resulting sum greater than 5 and degrees of freedom (d.f.) are adjusted accordingly. In present study the exposure rates are obtained with magnitude less than 5. So, in following χ^2 table, the observed data are pooled in order to make the frequency greater than 5 and have adjusted the d.f. accordingly (Yadav *et al.*, 2008).

For the exposure rate at 1 m distance immediate scan, 5 observed frequencies are pooled so that the degree of freedom is reduced by 5 which now become 44. The tabulated value of χ^2 for 44 d.f. and 5% level of significance is 60.4 (Fisher and Yates, 1974). The χ^2 calculated in this case is 46.7 which is less than tabulated value, hence H_o is accepted i.e. the exposure rate at 1m distance taken after immediate scan are reliable for analysis. For the exposure rate at 2 m distance immediate scan, 21 observed frequencies are pooled so that the degree of freedom is reduced by 21 which now become 28. The tabulated value of χ^2 for 28 d.f. and 5% level of significance is 41.3(Fisher and Yates, 1974). The χ^2 calculated in this case is 11.1 which is less than tabulated value, hence we accept H_o i.e. the exposure rate at 2m distance taken after immediate scan are commensurate with radiation exposure. For the exposure rate at 1 m distance delayed scan, 22 observed frequencies are syndicated so that the d.f. is reduced by 22 which now become 27. The tabulated value of χ^2 for 27 d.f. and 5% level of significance is 40.1 (Fisher and Yates, 1974). The χ^2 calculated in this case is 30.9 which is less than tabulated value, hence H_o is admited i.e. the exposure rate at 1m distance taken after immediate scan are reliable for analysis. For the exposure rate at 2 m distance delayed scan, 37 observed frequencies are pooled so that the d.f. is reduced by 37 which now becomes 12. The tabulated value of χ^2 for 12 d.f. and 5% level of significance is 21.0 (Fisher and Yates, 1974). The χ^2 calculated in this case is 23.8 which is greater than tabulated value, hence H_o is rejected. At 2m distance (delayed scan) data obtained are not good to fit. This may be due to low sensitivity of survey meter. At 2 m distance, after 3 hours of injection of ^{99m}Tc DTPA, low intensity radiations are emitted which are hardly detected by low sensitive survey meter. Also, the least count of the survey meter adds to this factor.

Conclusions

It is cleared that the individual at a distance of 1m from the patient who has been given maximum amount of dose receives a maximum exposure immediately after the injection of radiopharmaceutical. The exposure rate decreases as the distance from the patient increases. 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.

The levels of radiation due to renal scan patients have been measured. The level of radiation at 1m and 2m due to a patient who has been injected ^{99m}Tc, DTPA depends on the mass, height and biological nature of the patient's body. Hence, even though same amount of doses are administered to different patients, individuals receive different exposures from them.

The internationally acceptable annual dose limit for public is 1 mSv per year (ICRP, 2007).This is the limit expressed as the sum of total doses from all the sources for a year. Calculations for doses in the shorter distances show that exposures for more than few hours potentially places public in a position where they may exceed the public dose limit. Under these circumstances hospital must take account of the public while delivering such treatments to patients.

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