EXPOSURE RATE IN HOT WAITING AREA OF SMALL BUT BUSY NUCLEAR MEDICINE DEPARTMENT: "METER MATTERS"

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ABSTRACT

BACKGROUND: Time, distance and shielding are the 3 effective methods to keep radiation dose to radiation workers. However, in small but busy nuclear medicine department, efficacy of distance from injected patients staying in hot waiting area is questioned. The aim of this study was to find out the exposure rate in hot waiting area of a busy nuclear medicine department and measuring of radiation dose to NM technologists them during study period. **MATERIAL AND METHODS:** This was a prospective study conducted from 1st November 2015 till 31st December 2015 at Nuclear Medicine Department of Dr Ziauddin Hospital Karachi, Pakistan, having an area of 240 square meters and equipped with 01 gamma camera. Exposure rate was measured on all patients at 1 meter distance from anterior mid trunk in sitting position using digital rate meter (Radiation Alert Inspector, S.E. international, INC). Observed measurements of exposure rate were carried out first at 1 meter distance from sitting patients in hot waiting area followed by second measurements by doubling the distance at 2 meters to verify the inverse square law in injected patients. We also measured a distance (in meter) at which exposure rate 1 meter declined to 50% from initial values. In order to estimate agreements of observed measurements with expected values, the expected measurements of exposure by doubling distance and increase in distance for 50% reduction in exposure from initial values were also calculated by commercially available calculators of inverse square law (Rad Pro Calculator).During the study period we have also measured the personal dosimetry of 03 technologists using film badges. **RESULTS:** Study consisted of 150 consecutive patients referred for Nuclear Medicine procedures with mean age 50 ± 19 (0.25-87 Yr) years, F: M, 60%:40% with average body mass index (BMI) of 26.962 ± 6.861 Kg/m2. Average dose of the procedures was 434 ± 207 with a range of 37-851 MBq. The procedure distribution was 29% stress first myocardial perfusion scintigraphy, 53% skeletal, 15% thyroid and 03% renal scintigraphy respectively. The average exposure rates were 9.784 ± 5.761 (range: 1.477-27.808) and 2.329 ± 1.355 (range: 0.347-6.778) uSv/hr at 1 meter and at 2 meters by doubling the distance respectively. The distance measured at which 50% reduction in exposure rate from initial value was an average 1.321 ± 0.169 meters. Comparative analysis of expected (by Inverse Square Law; ISL) and measured values for exposure and distance were found non-significant difference (p=0.452) in exposure rates by doubling the distance with 75% reduction in exposure rates in both expected and measured values. 23% ± 10% increase in a distance was measured for 50% reduction in initial exposure rate which significantly lower than expected values i.e. 29% ± 03% (average 1.421 ± 0.082) as calculated by ISL (p <0.0001).The Bland Altman's analysis illustrated a good agreements between expected and measured values of exposure rate by doubling the distance to follow ISL and by increasing the distance to decline exposure to 50% respectively.The personal dosimetry record of 03 technologists during study period was i.e. average 0.140 ± 0.055 mSv over two months period **CONCLUSION:** We conclude that radiation exposure from injected patients in nuclear medicine follows Newton's inverse square law although patients are not point source. By practicing all cardinal rules of ALARA, including distance even in a small but busy department, radiation dose to NM technologists will remain well within statutory limits.

Key words: inverse square law; radiation exposure; waiting area; distance; nuclear medicine

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Introduction

Nuclear medicine (NM) is an established functional imaging modality in which tracer quantity of radio-isotopes are used for diagnostic (gamma emitting) and therapeutic purposes (preferably gamma plus particle mitting isotopes). Doses of administered isotopes are selected on the principle of justification and optimization. However, injected patients in NM are the mobile source of radiation exposures to NM technologists, staff and general public. For NM technologists, stochastic effects of ionizing radiations like cancer and genetic mutations are the major source of concerns. The probability of stochastic effects has a direct association with radiation dose received and is the basic theme for As Low As Reasonably Achievable (ALARA) principle.[1] NM technologists receive radiation while preparing and administering the radioisotope, positioning the patient on the scanner bed, monitoring the patient during data acquisition, removing the patient from the bed, and escorting the patientto the department.[2] According to Pakistan Nuclear Regulatory Authority (PNRA), the annual dose limit for a radiation worker is <20 milli Sievert (<20 mSv).[3] The three basic strategies to minimize radiation exposures are time, distance and shielding. However, in busy but small NM departments, using distance as an effective strategy is a matter of apprehension for technologists.

The aim of this study was to find out the exposure rate in hot waiting area of a busy nuclear medicine department and measuring of radiation dose to NM technologists them during study period.

Materials and Methods

Material and Method: This was a prospective study conducted at Nuclear Medicine Department of Dr Ziauddin Hospital Karachi, Pakistan from 1st November 2015 till 31st December 2015. The Nuclear medicine department is equipped with a single head gamma camera (ECAM, Siemens, Germany), with a hot laboratory and a hot waiting area placed diagonally to imaging room (Fig. 1). The total area of NM department is 240 square meter. We routinely perform thyroid, bone, renal, lung perfusion, MUGA, myocardial perfusion with tetrofosmin and iodine-131 (I-131) whole body diagnostic and post-ablative imaging. In addition, we also administer I-131 for toxic goiter on outpatient basis (< 30 mCi) and thyroid cancer on in-patient basis (30-200 mCi). We have 03 technologists who perform imaging and therapeutic procedures as per fixed weekly rotation in hot laboratory, imaging room and administration of I-131.

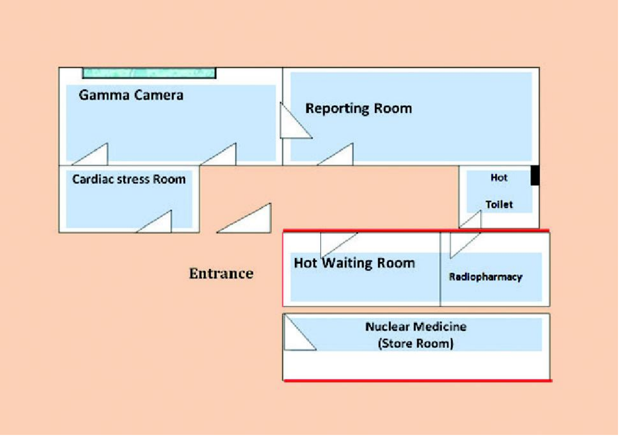

Figure 1: Nuclear Medicine Department Layout.

During study period, we measured exposure rate (in micro Sievert/hour; uSv/h) in hot waiting area at a time when it was occupied by maximum number of injected patients on that day who were waiting for their static skeletal, thyroid, MPI (after stress injection) and renal cortical imaging. Patients with resting MPI and I-131 imaging were excluded as they are used to be imaged in second half of the day.

Exposure rate was measured on all patients at 1 meter distance from anterior mid trunk in sitting position using digital rate meter (Radiation Alert® Inspector, S.E. international, INC). Observed measurements of exposure rate were carried out first at 1 meter distance from sitting patients in hot waiting area followed by second measurements by doubling the distance at 2 meters to verifythe inverse square law in injected patients. We also measured a distance (in meter) at which exposure rate 1 meter declined to 50%from initial values.

In order to estimate agreements of observed measurements with expected values, the expected measurements of exposure by doubling distance and increase in distance for 50% reduction in exposure from initial values were also calculated by commercially available calculators of inverse square law (Rad Pro Calculator). During the study period we have also measured the personal dosimetry of 03 technologists using film badges.

Statistical Analysis: Data were analyzed using commercially available packages such as the Medcalc statistical software (MedCalc® Software, Ostend, Belgium), version 11.3.10 and the statistical package for social sciences (SPSS version 17; SPSS Inc., Chicago, Illinois, USA). Comparisons between expected and measured values were made using the Student t-test for continuous variables. Continuous variables were described by mean ± SD. Scatter analysis were plotted by Bland Altman's analysis to estimate agreement between expected and measured values. P-values less than 0.05 were considered significant.

Results

Study consisted of 150 consecutive patients referred for Nuclear Medicine procedures with mean age 50 ± 19 (0.25-87 Yr) years, F: M, 60%:40% with average body mass index (BMI) of 26.962 ± 6.861 Kg/m2. Average dose of the procedures was 434 ± 207 with a range of 37-851 MBq. The procedure distribution was 29% stress first myocardial perfusion scintigraphy, 53% skeletal, 15% thyroid and 03% renal scintigraphy respectively. The average exposure rates were 9.784 ± 5.761 (range: 1.477-27.808) and 2.329 ± 1.355 (range: 0.347-6.778) uSv/hr at 1 meter and at 2 meters by doubling the distance respectively. The distance measured at which 50% reduction in exposure rate from initial value was an average 1.321 ± 0.169 meters (Tab.1).

Comparative analysis of expected (by ISL) and measured values for exposure and distance were illustrated in (Tab. 2) and found non-significant difference (p=0.452) in exposure rates by doubling the distance with 75% reduction in exposure rates in both expected and measured values. 23% ± 10% increase in a distancewas measured for 50% reduction in initial exposure rate which significantly lower than expected values i.e. 29% ± 03% (average 1.421 ± 0.082) as calculated by inverse square law (p <0.0001).

Variable	n=150
Age (Median ± SD) years	50 ± 19 (0.25-87 Yr)
BMI (mean ± SD) Kg/m2	26.962 ± 6.861
Male: Female	60:90 (40%:60%)
Dose in MBq mean ± SD (Range)	434 ± 207 (37-851)
Procedures: Skeletal scintigraphy Thyroid scintigraphy Myocardial Perfusion scintigraphy (stress First) Renal Cortical scintigraphy	 80 (53%) 22 (15%) 45 (29%) 03 (03%)
Exposure Rate at 1 meter in uSv/hr mean ± SD (Range) Within 10 minutes	9.784 ± 5.761 (1.477-27.808)
Exposure Rate at 2 meters in uSv/hr mean ± SD (Range) Within 10 minutes	2.329 ± 1.355 (0.347-6.778)
Distance at 50% reduction in Exposure rate from exposure at 1 meter mean ± SD (Range) in meters	1.321 ± 0.169 (1.071-1.778)
Two months Personal dosimetry of Technologists (mean ± SD) mSv	0.140 ± 0.055

*p<0.05
SD= Standard Deviation
BMI=Body Mass index
mCi=milli Curie
uSv/hr=micro Sieverts/hour
GI=Gastro Intestinal

Table 1: Study demographics

Variables	Expected values (by ISL calculators)	Measured values	t-test	P values
Exposure rate (uSv/h) by doubling distance (mean ± SD)	2.451 ± 1.443	2.328 ± 1.355	-0.753	0.452
%reduction in exposure rate from initial values at 1 meter by doubling distance (%mean ± SD)	75% ± 00%	75% ± 10%	0.000	1.000
Distance in meters at 50% reduction in exposure rate from initial values at 1 meter (mean ± SD)	1.421 ± 0.082 (29% ± 03%; increase in initial Distance)	1.321 ± 0.169 (23% ± 10%; increase in initial Distance)	-6.520	<0.0001

*p<0.05
SD= Standard Deviation
ISL-Inverse square law
uSv/hr= micro Sieverts/hour

Table 2: Comparative analysis of expected and measured values for exposure and distance

The Bland Altman's analysis in (Fig. 2 and 3) illustrated a good agreements between expected and measured

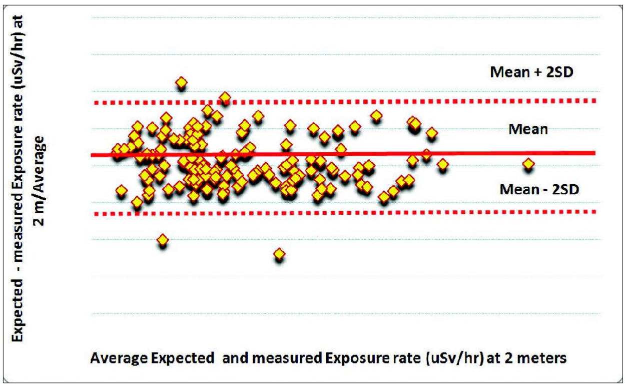

Figure 2: Bland Altman's comparative analysis for expected and measured exposure rate (uSv/hr) at 2 meters by doubling the distance to follow inverse square law.

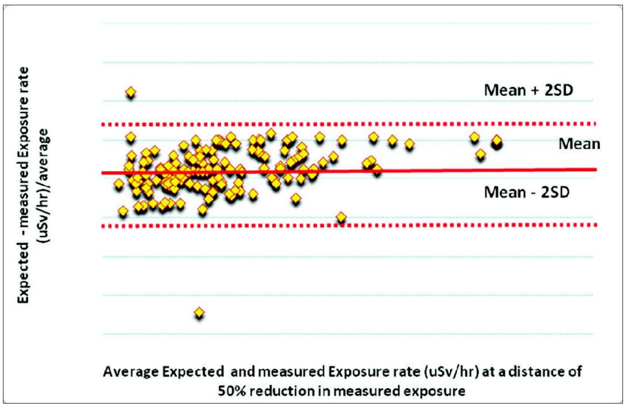

Figure 3: Bland Altman's comparative analysis for expected and measured exposure rate (uSv/hr) at a distance of 50% reduction in measured exposure rate to follow inverse square law.

values of exposure rate by doubling the distance to follow inverse square law and by increasing the distance to decline exposure to 50% respectively.

The personal dosimetry record of 03 technologists during study period was i.e. average 0.140 ± 0.055 mSv over two months period. These values also confirm the efficacy of distance, time and shielding in keeping the radiation dose to NM technologists who work in small but busy departments.

Discussion

Time, distance and shielding are the three cardinal rules to practice ALARA for radiation workers and distance is considered the most effective method. However, in small but busy nuclear medicine centers, NM technologists are at a greater risk of getting exposure from injected patients who the mobile source of radiation exposure. This issue becomes more sensitize when NM technologist is a young female with active reproductive life and relocation in a low radiation zone is not possible due to smaller area of NM department.

As mentioned above, for radiation workers distance is the most effective method as it works on Newton's Inverse Square Law (NISL) which means *doubling the distance quarter the dose*.[4] However, as a matter of fact this law is valid for point source while injected patients in nuclear medicine department are not point source. Our data shows that the mean dose rate is lower than a multicenter European trial published in 1994 which does not support the need of a second waiting room for injected patients in nuclear medicine department.[5] However our measured mean exposure rate at 1 meter is slightly higher than another study published (9.78 uSv/h vs 7.50 uSv/h).[6] This difference in mean exposure rate among these studies is due to difference in area of nuclear medicine section and number of patients staying in waiting area at the time of estimation.

In this study we also evaluated the efficacy of distance as one of cardinal steps in reducing exposure rate. As mentioned above it based on Newton ISL for a point source while injected patients are not point source. Our data shows that by doubling the distance, the exposure rate dropped to the quarter. This finding favors that distance efficacy of distance as cardinal step for reducing the exposure rate for point source as well as injected patients which are not point source. Importantly the calculated value of exposure rate (using ISL calculator) was higher than measured values and possible reason for this finding is self-shielding factor.[7] This fact also favors the notion that considering injected patients as unshielded point sources of radiation is clearly inappropriate. In reality, they are volume sources, but treatment of their exposures using a line source model with appropriate self-shielding factors produces a more realistic approach. The dosimetry record of our technologist during the study period was also well within normal acceptable limits. Worth to mention that these dosimetric values are cumulative and narrative of dose perceived during injection, positioning, escorting patients from waiting room to imaging room and passing through the corridor having hot waiting area.

We conclude that radiation exposure from injected patients in nuclear medicine follows Newton's inverse square law although patients are not point source. By practicing all cardinal rules of ALARA, including distance even in a small but busy department, radiation dose to NM technologists will remain well within statutory limits.

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