Original Research Article

Assessment of Radiation Dose in Nuclear Medicine Controlled Areas: Hot Lab, Injection and Isolated Rooms

ABSTRACT

Introduction: Observing radiation protection and safety culture in radiation practices reduce radiation exposure and the probability of radiation risk to workers, patients and the general public. This study assesses the radiation protection and safety practice at the pioneer Nuclear Medicine Centre in Nigeria, University College Hospital (UCH), Ibadan. This assessment involves measurements of dose rate and surface contamination in the hot laboratory, injection and patient's isolated rooms and compares their values with international recommended limits.

Materials and Methods: Measurements of radiation doses and surface contamination in the controlled areas were carried out using three different high-sensitive and calibrated radiation detectors namely Ultra Radiac (model MRAD 1010), Ludlum (model 2241-3/44-9) and Redeye (model PRD).

Results: The dose rate values in the controlled areas monitored ranged from 0.103 to 0.430 μGy/h while the effective doses calculated from these values ranged from 0.2 to 0.86 mSv per annum. This is far less than the recommended dose limit of 20 mSv per annum for radiation worker, who usually worked in these areas. Also, the surface contamination values obtained in these areas ranged from 0.060 to 2.867 Bq/cm^2, which is similarly less than the recommended limit of 10 Bq/cm^2.

Conclusion: These results showed that the centre has a wide range of compliance with radiation safety practice by the acceptable standards guided by the Nigerian Nuclear Regulatory Authority and International regulations.

Keywords: Nuclear Medicine, Radiation Detectors, Surface contamination, Dose Rate, Effective Dose, Controlled Areas.

INTRODUCTION

Nuclear medicine is a speciality in Medicine that uses radionuclides for diagnosis, the staging of a certain disease, therapy and monitoring of the response of a disease to treatment [1]. Since the first use of I-131 for the treatment of thyrotoxicosis by Saul Hertz in 1941, nuclear medicine procedures have served as a prerequisite in the diagnosis and treatment of various human diseases [2].

Since nuclear medicine involves exposures of patients to ionizing radiation from unsealed radioactive sources the general principles of radiation protection should be applied. Nuclear Imaging procedures are among the safest diagnostic imaging examination. The amount of radiation dose obtainable from a nuclear imaging procedure is comparable to or often less than, that from a conventional diagnostic X-rays examination [3].

The use of unsealed radionuclides in medicine is increasing as therapeutic and diagnostic radiopharmaceuticals imaging are becoming more common in the clinical settings [4]. As the code of good radiation practice demands, the fundamentals of radiation protection must be applied when undertaking nuclear medicine procedures [5]. The main objective of radiation protection is to prevent deterministic effects by keeping radiation doses below the relevant threshold doses and to reduce the probability of stochastic effects as much as is reasonably achievable [6 -7].

The radiation risk to any person working with unsealed radioactive materials should be assessed and kept under review. Hence, the need to designate radiation working environment into a controlled or supervised area based on its level of potential irradiation. In a controlled area, an individual must follow specific protective measures to control radiation exposures. Some of the rooms designated as controlled areas in Nuclear Medicine department and considered in this study are the hot laboratory (hot lab), where radiopharmaceuticals are delivered, stored and prepared for dispensing; the injection room, where radiopharmaceuticals are administered (ingested or injected) into the patient; and the isolated room, where patient to whom therapeutic amounts of radiopharmaceuticals have been given, are housed [1].

The Nuclear Medicine centre at the University College Hospital, Ibadan is the first Nuclear Medicine centre in Nigeria, hence, the need to assess the compliance of its radiation protection and safety program with globally acceptable radiation practice.

MATERIALS AND METHOD

Study Area

This study was carried out at the University College Hospital, Ibadan the first centre in Nigeria to commence clinical Nuclear Medicine services. The Nuclear Medicine centre was commissioned in the year 2006 and at its inception, the imaging room is equipped with a Single Photon Emission Computed Tomography (SPECT) unit which comprises a single head Gamma Camera and its ancillary equipment through the support (Technical Cooperation Project) of the International Atomic Energy Agency, IAEA, Vienna Austria.

Presently, the centre has added a state-of-the-art hybrid imaging facility which comprises a dual-head Gamma Camera with CT imaging capability for SPECT/CT procedures for patients' benefit. Some of the controlled areas in the Nuclear Medicine facility, where dose rate and contamination measurements were carried out for this study are the hot lab, injection and patient's isolated rooms. The Nuclear Medicine centre has a single hot lab, an injection room and two isolated rooms for I-131 patient's admission.

Data Collection and Analysis

Three different types of high-sensitive radiation detectors used for measurements were calibrated at the National Secondary Dosimetry Laboratory located at the Institute of Radiation Protection and Research, Nigerian Nuclear Regulatory Authority, Physics Department, University of Ibadan, Ibadan. These detectors are Ultra Radiac (model MRAD 1010), Ludlum probe (model 2241-3/44-9) and Radeye (model PRD). While Ultra Radiac and Radeye were used to measure radiation level in the hot lab, injection and patient's isolated rooms, the Ludlum probe was used to survey the level of contamination in these areas especially on the floor, benchtop, on top of the shielded working surface, on top of the lying-in bed, and at the door handle. Three measurements were made in each case and the average was computed. The values of the radiation level measured expressed in terms of dose rate and contamination level per unit area (Bq/cm^2)

calculated from the raw readings (counts per minute) obtained during survey are presented in Tables. The formulae used to calculate level of contamination from the raw readings, taking into consideration the diameter of the probe are as follows:

$$Area\ of\ the\ pancake\ probe\ (Circular) used = \pi r^2 \quad (1)$$

where π = 3.142; the diameter of the probe = 5 cm; and radius of the probe = 2.5 cm

Hence, from eqn. (1): Area of the pancake probe = 19.64cm^2

Readings obtained in counts per minute (cpm) were converted to Becquerel (Bq) using the formulae below:

$$Net\ Count\ (cps) = (Surface\ area\ count\ (cpm) - Background\ count, cpm)/60 \quad (2)$$

$$Contamination\ Level\ X\ (Bq) = Net\ Count\ (cps)/0.372 \quad (3)$$

where 0.372 is the conversion factor. Therefore,

$$Contamination\ per\ unit\ area, X\frac{Bq}{cm^2} = X\ (Bq)/19.64\ cm^2 \quad (4)$$

RESULTS

The surface contamination calculated from the raw readings (counts per minute) measured in the controlled areas considered in this study using equations (1) to (4) is presented in Table 1. The background dose rate measurements in the controlled areas in the absence of radionuclide generator are presented in Table 2 while the same measurements repeated during the preparation of radiopharmaceutical in the hot lab are presented in Table 3. The dose rate measurement during the administration of radiopharmaceuticals into the patient in the injection room is presented in Table 4. Presented in Tables 5, 6 and 7 are various surface contamination levels measured at different locations in the hot lab, injection room and isolated rooms A and B. In all the readings, background radiation/counts are adequately accounted for.

Table 1: Contamination levels in the controlled areas (Bq/cm^2)

Controlled Area	Hot Lab		Injection Room		Isolated Room
	Floor	Working Table	Floor	Working Table	

Background Count (cpm)	60		60		60
Surface Count (cpm)	86.3	1316.8	43.837	160.880	90.0
Net Count (cps)	0.438	20.947	0.731	2.681	0.500
Contamination (Bq)	1.178	56.308	1.964	7.208	1.344
Contamination per unit area of the probe (Bq/cm^2)	0.060	2.867	0.100	0.367	0.068

Table 2: Background dose rate measurements in the absence of radionuclide generator

Controlled Area	**Dose rate, D (µGy/h)**			**Average (µGy/h)**
	D1	**D2**	**D3**	
Hot lab	0.20	0.22	0.21	0.210
Injection room	0.20	0.20	0.20	0.200
Isolated Room	0.15	0.14	0.12	0.137

Table 3: Dose rate measurements during the preparation of radiopharmaceuticals in the hot lab

Controlled Areas	**Dose rate, D (µGy/h)**			**Average (µGy/h)**
	D1	**D2**	**D3**	
Hot lab	0.47	0.42	0.40	0.430
Injection room	0.42	0.40	0.36	0.393
Isolated room	0.20	0.22	0.20	0.207

Table 4: Dose rate measurements during the injection of patients with radiopharmaceuticals in the injection room

Controlled Area	Dose rate, D (µGy/h)			Average (µGy/h)
	D1	D2	D3	
Hot lab	0.36	0.30	0.35	0.337
Injection room	0.45	0.38	0.42	0.417
Isolated room	0.20	0.22	0.20	0.207

Table 5: Surface contamination (X) measurement in the hot Lab

Measurement Location	Reading, X (Bq/cm^2)			Average, X (Bq/cm^2)
	X1	X2	X3	
On the floor	0.06	0.06	0.06	0.060
On the benchtop	0.24	0.23	0.25	0.240
The inner part of the top of the shielded working surface	2.86	2.86	2.88	2.867
At the door of the hot lab	0.05	0.05	0.05	0.500

Table 6: Surface contamination level in the injection room

Measurement Location	Reading, X (Bq/cm^2)			Average X (Bq/cm^2)
	X1	X2	X3	
On the floor of the injection room	0.10	0.10	0.10	0.100
On the benchtop	0.36	0.37	0.37	0.367
At the handle of the door of the injection room	0.05	0.05	0.05	0.050

Table 7A: Surface contamination level in the isolated room A for I-131 patient

Measurement Location	Reading, X (Bq/cm^2)			Average X (Bq/cm^2)
	X1	**X2**	**X3**	
On the floor	0.10	0.11	0.11	0.107
On the bed sheet	0.59	0.60	0.59	0.593
Near the handle of the door	0.10	0.10	0.10	0.100

Table 7B: Surface contamination level in the isolated room B for I-131 patient

Measurement Location	**Reading, X (Bq/cm^2)**			**Average X (Bq/cm^2)**
	X1	**X2**	**X3**	
On the floor	0.10	0.11	0.11	0.107
On the bed sheet	0.48	0.47	0.48	0.477
Near the handle of the door	0.10	0.10	0.10	0.100

DISCUSSION

External radiation hazard in terms of measurement of dose rates and level of radioactive contamination in some of the controlled areas (hot lab, injection and isolated rooms) of the pioneer Nuclear Medicine centre in Nigeria has been assessed.

As seen in Table 2, the dose rates (µGy/hr) in the hot lab, injection room and isolated room in the absence of radionuclide generator are 0.12, 0.20 and 0.14 respectively. These readings (µGy/hr) increased to 0.43, 0.39 and 0.21 respectively when radiopharmaceuticals were in preparation in the hot lab as seen in Table 3. Similarly, in the injection room, as shown in Table 4, during the administration of radiopharmaceutical into the patient, the reading (µGy/hr) rose to 0.34, 0.42 and 0.21 respectively. Although in both cases, the presence of radiopharmaceuticals within the area caused an increase of about 40% in the dose rates in the respective controlled area, the mean dose rates obtained in this area are still below the recommended dose rate (10 µGy/hr) expected in the controlled areas [8 - 9]. Also, when the dose rates obtained were used to express annual radiation dose to workers, who usually work for 8 hours per day; 5 working days per week and 50 weeks per annum, it yields annual radiation dose in the range of 0.20 mSv to 0.86 mSv, which is less than recommended dose limit of 20 mSv per annum [10].

Concerning the level of radioactive contamination in the selected controlled areas, the mean contamination level (Bq/cm^2) in the hot lab, injection room and isolated room as seen in Tables

5, 6 & 7 are 0.92, 0.17 and 0.24 respectively. These values are below the recommended limit of 200 Bq, which is about 10 Bq/cm^2 based on the area of the radiation detector used for measurement of the level of contamination in this study.

CONCLUSION

The analysis of the results obtained in this study has shown that the pioneer Nuclear Medicine centre in Nigeria has an excellent compliance in the area of radiation protection and safety culture and can be concluded that their practice is safe in accordance to generally acceptable standards guided by the Regulatory Authority and International regulations.

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