Estimation of Exposure Rate to Personnel Working in Nuclear Medicine Imaging Department in Hospital Universiti Sains Malaysia: Comparison between Direct and Indirect Methods

Mohd Fahmi MY*, Norsuriani S and Abdullah Waidi I

School of Health Sciences, UniversitiSains Malaysia, 16150 Kota Bharu, Kelantan, Malaysia.

*Corresponding Author: mfahmi@usm.my

ABSTRACT: Nuclear medicine personnel are regularly exposed to radiation during imaging procedures on patients. This study focused on measurement of exposure rates to personnel in Nuclear Medicine during ^{99m}Tc-DTPA renal scans and ^{99m}Tc-MDP whole body imaging procedures, using direct and indirect methods. 3 patients undergoing ^{99m}Tc-DTPA renal scans and 3 patients undergoing ^{99m}Tc-MDP whole body scan procedures were randomly selected in this study. The direct method was conducted by measuring the exposure rate emitted from patients using Victoreen 451P-RYR survey meter at various distances (0.50 m, 1.0 m and 2.0 m) from the patients. The indirect method was conducted using mathematical model of exposure rate. The results indicated that exposure rates from indirect method were higher than direct method at all nominal distances. For ^{99m}Tc-DTPA renal scans procedure, the percentage difference between direct and indirect method for various distances were 17.16 ± 3.73 (0.50 m), 12.37 ± 9.01 (1.0 m) and 31.07 ± 8.91 (2.0 m) respectively. On the other hand, the percentage difference for ^{99m}Tc-MDP whole body scan for various distances were 166.01 ± 189.98 (0.50 m), 150.92 ± 167.38 (1.0 m) and 62.78 ± 83.74 (2.0 m). This study also showed that the exposure rates diminished with the increases in distances. Measurement of the exposure rates received from the radioactive patients is important to ensure minimal hazard to personnel in nuclear medicine department and to propose a suitable programme for radiological protection on the management of radioactive patients.

Keywords: nuclear medicine, exposure rate

Introduction

In nuclear medicine procedures, personnel working with radiopharmaceuticals are subject to radiation exposure (Kubo *et al*., 2014). The nuclear medicine personnel is responsible to perform diagnostic or therapeutic nuclear medicine procedures on patients. Members of the staff get exposed while preparing and administering radiopharmaceuticals and later-on in the vicinity of the "radioactive" patient (Ferdinand *et al.*, 2011). Besides that, most nuclear medicine laboratories do not have separate control room for technologies, which are quite close to patient during data acquisition and cause higher radiation exposure to them (Bayram*et al.*, 2011). The US' National Council of Radiation Protection and Measurement (NCRP) in 2006 established a scientific committee (SC 6-2) to review the current state on the magnitude of all sources of radiation exposure to the U.S. population with nuclear medicine personnel as one of the group specially examined (Mettler *et al*., 2008).

Methodology

Three patients undergoing ^{99m}Tc-MDP whole-body scan and three patients undergoing ^{99m}Tc-DTPA renal scan each representing low, medium and high activities of radiopharmaceuticals were selected randomly to participate in this study. The activities of radiopharmaceuticals at time administered into the patient are recorded. The patient will be quarantined for two hours to before the imaging procedures were conducted. This is to ensure that radiopharmaceuticals administered had accumulated in the organ of interest. As the decay of radionuclide is considered in this study, the activity of radiopharmaceuticals at time of imaging procedure was calculated using equation:

$$\boldsymbol{A = Ao\ e^{-\lambda t}} \qquad (1)$$

Where A and Ao is the current and initial activity respectively, λ is the decay constant of radionuclide and t is the time from A to Ao.

Table 1: Imaging procedures and activity of radiopharmaceuticals administered to the patients

Patient	Imaging Procedure	Activity, A (mCi)
1	^{99m}Tc-DTPA renal scan	2.31
2	^{99m}Tc-DTPA renal scan	5.80
3	^{99m}Tc-DTPA renal scan	6.44
4	^{99m}Tc-MDP whole body scan	11.10
5	^{99m}Tc-MDP whole body scan	15.59
6	^{99m}Tc-MDP whole body scan	20.60

External radiation exposures were measuredby direct method using Victoreen 451P-RYR survey meter at various distances (0.50, 1.0 and 2.0 m) from the midline body of patient. The distances were chosen as they represented the common distances between personnel and patients during the imaging procedures.

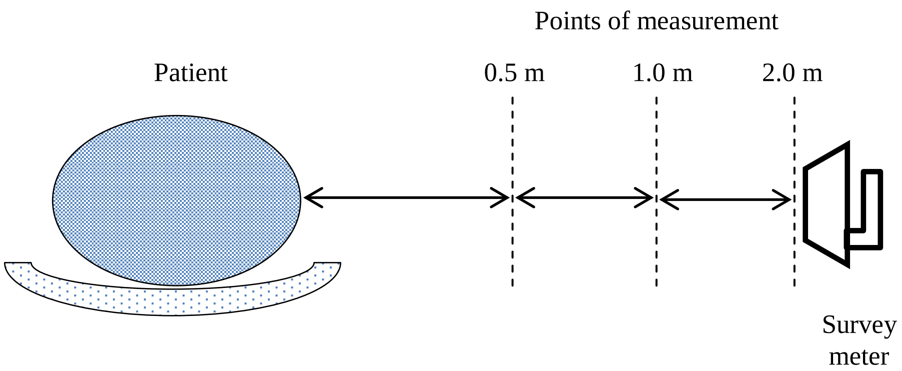

Figure 1: The distances of direct measurement using survey meter measured from the patient

The indirect method for determining the exposure rate is calculated using the equation:

$$X = \frac{n}{d^2}\ .Ao\ e^{-\mu x}\ .t \qquad (2)$$

Where n is the gamma exposure rate constant of 99mTc with value of 0.6 R.cm^2/mCi.hr, d is the distance of measurement, **μ** is linear attenuation coefficient of human body, **χ** is the thickness of human body, and t is time of measurement.

The linear attenuation coefficient of human body is determined using photon cross-section database (XCOM).Both direct and indirect readings were compared to determine the linearity of exposure rates determined using both methods.

Results and Discussion

The exposure rates were observed to be significantly varied with the activity of radiopharmaceuticals. It is noted that exposure rates from ^{99m}Tc-MDP whole body scan was higher than exposure rates from ^{99m}Tc-DTPA renal scan. This is because the average activity injected in ^{99m}Tc-MDP whole body scan (15.76 mCi) is higher compared to ^{99m}Tc-DTPA renal scan (4.85 mCi)

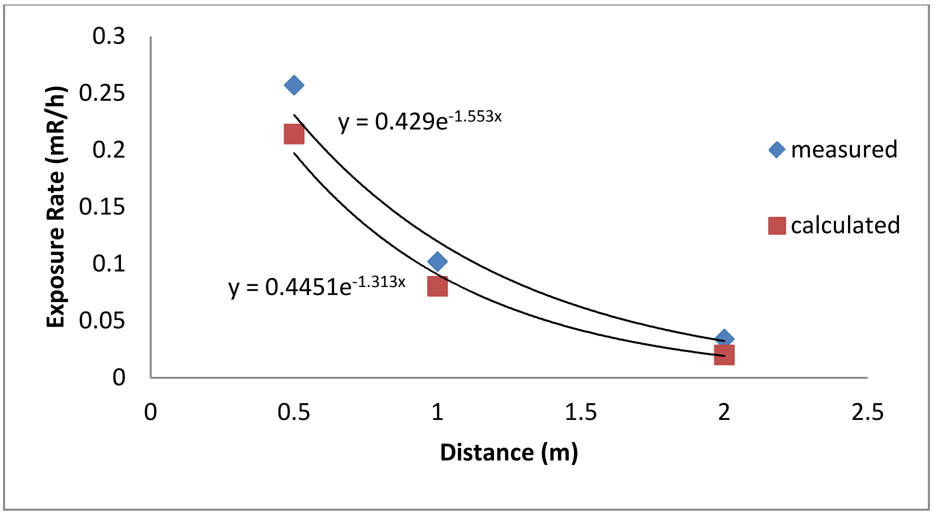

Figure 2: Exposure rate at the function of distance for patient 1

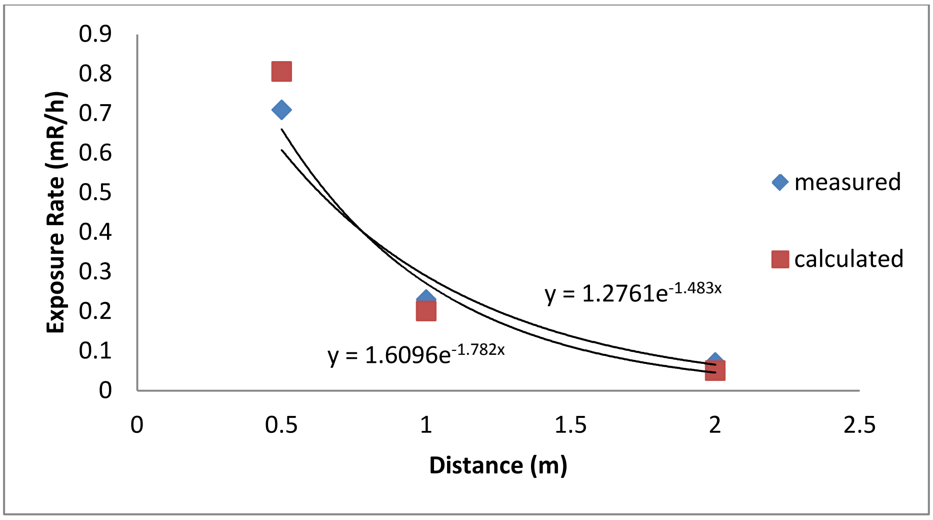

Figure 3: Exposure rate at the function of distance for patient 2

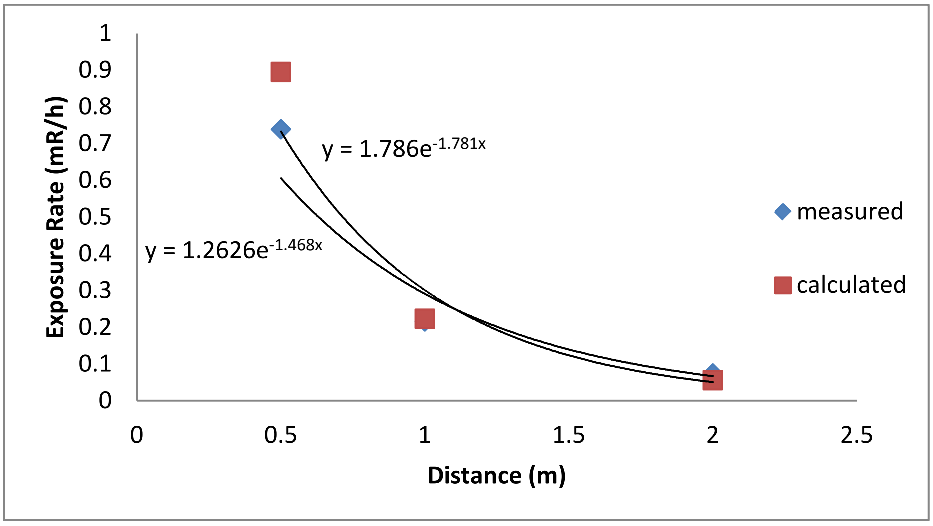

Figure 4: Exposure rate at the function of distance for patient 3

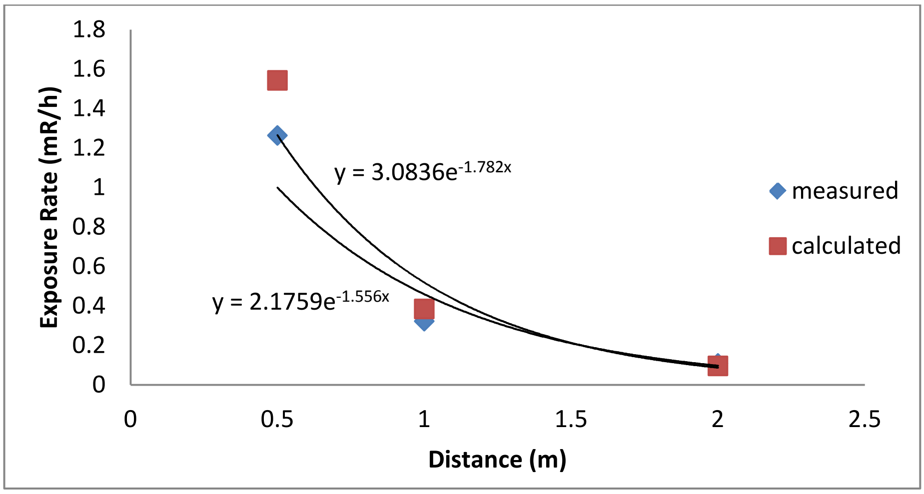

Figure 5: Exposure rate at the function of distance for patient 4

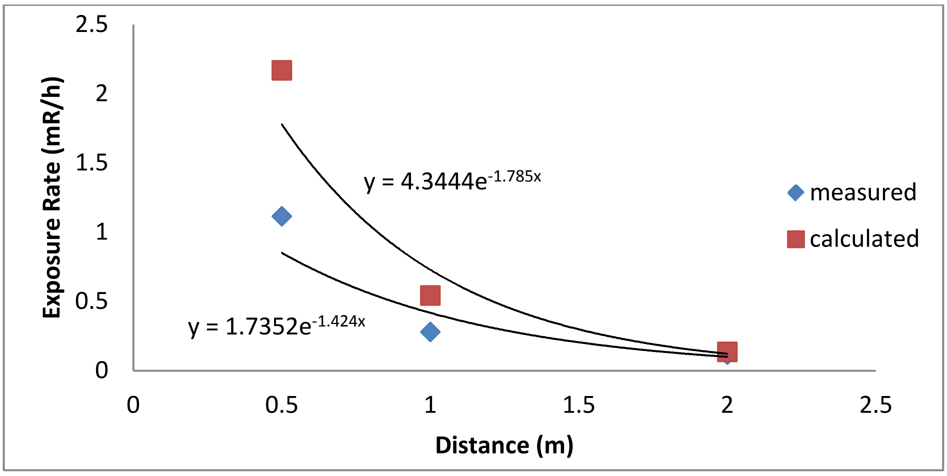

Figure 6: Exposure rate at the function of distance for patient 5

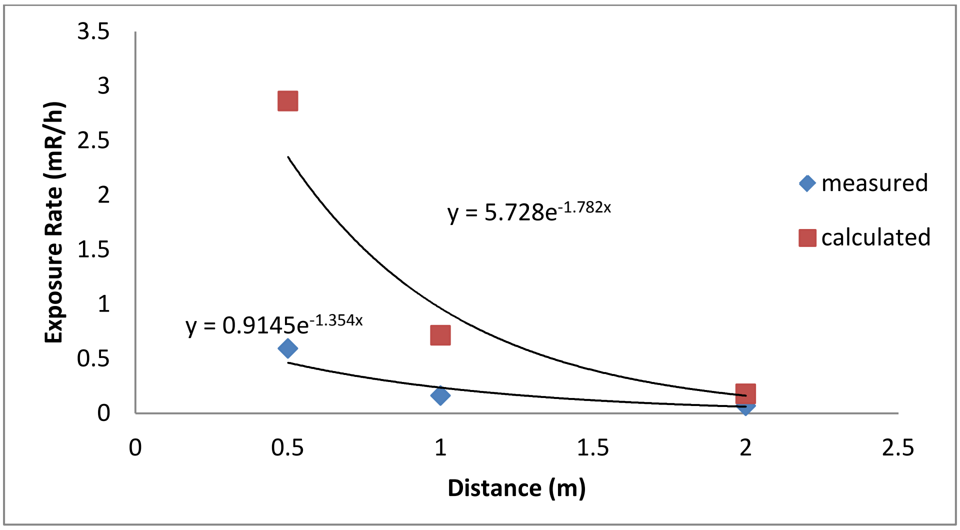

Figure 7: Exposure rate at the function of distance for patient 6

The exposure rates were found to be decreased as the distance from the patient increased for patients undergoing ^{99m}Tc-DTPA renal scan (**Figure 2, 3 and 4**) and ^{99m}Tc-MDP whole body scan (**Figure 5, 6** and **7**) at both direct and indirect methods. This agreed with the study done by Willegaignon *et al*. in 2006. Willegaignon *et al.* (2007) also showed possible overestimation of exposure rates using theoretical exposure models (indirect method), especially for distance less than 1.0 m from the patients. This is clearly shown in Figure 3 to 7 as the exposure rates using indirect method were significantly higher than the direct method at distance less than 1.0 m. The percentage differences of exposure rate between direct and indirect methods were observed to be dramatically decreased as the distance from the patient increased.

Table 2: Mean Percentage Difference ± SD between direct (measured) and indirect (calculated) methods

Imaging Procedure	Mean Percentage Difference (%) ± SD		
	0.5 m	**1.0 m**	**2.0 m**
^{99m}Tc-DTPA renal scan	17.16 ± 3.73	12.37 ± 9.01	31.07 ± 8.91
^{99m}Tc-MDP whole body scan	166.01 ± 189.98	150.92 ± 167.38	62.78 ± 83.74

The percentage difference between direct and indirect methods was noted to be lower in 99mTc-DTPA (12.37 ± 9.01% to 31.07 ± 8.91%) as compared to that in ^{99m}Tc-MDP whole body scans (62.78 ± 83.74% to 166.01 ± 189.98%) as shown in **Table 2**. This agrees with the study conducted by Yi *et al.* (20013).

Conclusion

The exposure rate was found to be decreased exponently with distance from patient undergoing nuclear medicine imaging procedures. The measured exposure rate showed an agreement between direct and indirect methods at distance 1.0m and higher. This study indicates the potential using mathematical model as an alternative method in determining exposure rate to personnel during nuclear medicine imaging procedures providing a safety working procedures for personnel.

Acknowledgements

We would like to acknowledge the Department of Oncology, Radiotherapy and Nuclear Medicine, Hospital Universiti Sains Malaysia (HUSM) for the use of their facilities for this study.

References

Bayram, T., Yilmaz, A.H., Demir, M., and Sonmez, B. (2011). Radiation dose to technologist per nuclear medicine examination and estimation of annual dose. *J Nucl Med Technol*, **39**:55-59.

Cherry, S.R., Sorenson, J.A., and& Phelps, M.E. (2012). *Physics in Nuclear Medicine* 4th Edition. Philadelphia, PA: Elsevier Saunder.

P. Covens, P., D. Berus, D., V. Caveliers, V., L. Struelens, L. and D. Verellen, D. (2011)., The Contribution of Skin Contamination Dose to the Total Extremity Dose of Nuclear Medicine Staff: First Results of an Intensive Survey, *Radiation Measurements*. **46** (2011); 1291-1294. Lundberg T.M., Gray P.J., Bartlett M.L. (2002). Measuring and Minimizing the Radiation Dose to Nuclear Medicine Technologists. *J Nucl Med Technol*. **30**: 25-30.

de Carvalho, A.B. Jr, Stabin, M.G., Siegel, J.A. and, Hunt, J. (2011). Comparison of Ppoint, Lline and volume dose calculations for exposure to nuclear medicine therapy patients. *Health Phys*. **100**: 185-190.

Ferdinand Sudbrock, KlaraUhrhan, Arndt Rimpler ,and Harald Schicha (2011). Dose and Dose Rate Measurements for Radiation Exposure Scenarios in Nuclear Medicine, *Radiation Measurements*. **46**: (2011) 1303-1306.

Fred A. Mettler, Jr, Mythreyi Bhargavan, Bruce R. Thomadsen, Debbie B. Gilley, Jill A. Lipoti, Mahadevappa Mahesh, John McCrohan, Terry T. Yoshizumi (2008)., Nuclear Medicine Exposure in the United States, 2005-2007: Preliminary Results, *Seminars in Nuclear Medicine, Elsevier Inc.* **38**:384-391.

Grigsby P.W., Siegel B.A., Baker S. (2000) . Radiation exposure from outpatient radioactive iodine (^{131}i) therapy for thyroid carcinoma. *JAMA*. **283**: 2272-2274.

International Commission on Radiological Protection (2004). Release of patients after therapy with unsealed radionuclides. Oxford: Pergamon Press; ICRP Publication 94.

A.L.S.L Kubo, A.L.S.L. and , C.L.P. Mauricio, C.L.P. (2014). TLD occupational dose distribution study in nuclear medicine. , *Radiation Measurements*.; 2014 (1-5).

Rutar, F.J., Augustine, S.C., Colcher, D., Siegel, J.A., Jacobson, D.A., Tempero, M.A., Dukat, V.J., Hohenstein, M.A., Gobar, L.S. and, Vose J.M. (2001) Outpatient treatment with ^{131}I-Anti-B1 antibody: rRadiation exposure to family members. *J Nucl Med*. **42**: 907-915.

Seierstad, T, Stranden, E, Bjering, K and, *et al*. (2007) Doses to nuclear technicians in a dedicated PET/CT centreutilising^{18}F fluorodeoxyglucose (FDG). *RadiatProt Dosimetry*. **123**:246-249.

Siegel, J.A., Kroll, S., Regan, D., Kaminski, M.S. and ,Wahl R.L. (2002a) A practical methodology for patient release after Tositumomab and ^{131}I-Tositumomab therapy. *J Nucl Med*. **43**: 354-363.

Siegel, J.A., Marcus, C.S. and, Sparks, R.B. (2002b) Calculating the absorbed dose to others from the radioactive patient: line source model versus point source model.*J Nucl Med*. **43**: 1241-1244.

Smart, R. (2004) Task specific monitoring of nuclear medicine technologists' radiation exposure. *Radiat Prot Dosimetry*. **109**:201-209

Trapp, J.V., and Kron, T. (2008). *An Introduction to Radiation Protection in Medicine*, Taylor & Francis Group, New York. Pp. 32

U.S. Nuclear Regulatory Commission (2005) Model exposure for release of patients or human research subjects administered radioactive material. Washington, DC: U.S. *Nuclear Regulatory Commission*; 10 CFR Parts 20 and **35**:62 FR 4120

Willegaignon, J. and, Guimarães, M.I.C., Sapienza, M.T., Stabin, M.G., Malvestiti, L.F., Marone, M. and, Sordi, G-M A.A. (2007). A new proposal for monitoring patients in nuclear medicine. *Health Phys*. **91**(6): 624-629.

Willegaignon, J., Guimarães, M.I.C., Stabin, M.G., Sapienza, M.T., Malvestiti, L.F., Marone M.M.S. and, Sordi G-M, A.A. (2007). Correction factors for more accurate estimates of exposure rates near radioactive patients: experimental, point, and line source models. *Health Phys*. **93**(6): 678-688.

Yi, . Y., Stabin, M.G., McKaskle, M.H., Shone, M.D. and, Johnson A.B. (2013). Comparison of measured and calculated dose rates near nuclear medicine patients. *Health Phys*. **105**(2): 187-191