ORIGINAL ARTICLE

Assessment of residual activities of Technetium-99m radiopharmaceuticals to plastic syringes in nuclear medicine scans: 1-year experience at NORIN Nawabshah, Pakistan

Muhammad Waqar[1*], Muhammad Shahban[2], Quratulain Soomro[1], Touqir Ahmad Afridi[1]

Pakistan Journal of Nuclear Medicine
Volume 12(1):31–36
https://doi.org/10.24911/PJNMed.175-1636355717

Pakistan Journal of Nuclear Medicine is the official journal of Pakistan Society of Nuclear Medicine

ABSTRACT

Background: Technetium-99m radioisotope is the backbone of any nuclear medicine institute. It is well known that various ^{99m}Tc-labeled radiopharmaceuticals may get absorbed into the plastic syringes. The consequences of this adsorption are inadequate or inconsistent absorbed dose which produces the inappropriate diagnostic response in patients. The aim of our study was to investigate the true activity administrated to patients and also compare the results of residual activities of the same dose by using different volumes of syringes.

Methods: A total 946 measurements were analyzed in which patients were injected with either 3 or 5 ml syringes and ^{99m}Tc was labeled with different pharmaceuticals, i.e., mercaptoacetyltriglycine-3, methoxy-iso-butyl isonitrile, methylenediphosphonic acid (MDP), and technetium pertechnitate. Residual activity was measured for every patient.

Results: The 3 ml syringes have less average retention rate for any radiopharmaceutical as compared to 5 ml syringes. Residual activity for MDP is lower when compared to other radiopharmaceutical for both volumes of syringes. Maximum residual activity for 5 ml syringes happens to be 3.42% of dispensed activity, while for 3 ml syringes it is 2.74% of dispensed activity. The mean effective activities were within the recommended range of EANM and PNRA guidelines.

Conclusion: For all radiopharmaceuticals and both syringes, average residual activity remained well under 1.5% of the activity drawn into syringes, which is insignificant when compared to previous reported results and may not alter the resultant image quality to a larger extent. In hospital, practices should be encouraged to reduce the residual activity as low as possible.

Keywords: ^{99m}Tc-labeled radiopharmaceutical, residual activity, nuclear medicine imaging.

Received: 08 November 2021 **Revised:** 15 February 2022 **Accepted:** 10 March 2022

Correspondence to: Muhammad Waqar
*Medical Physics Division, Nuclear Medicine Oncology & Radiotherapy Institute of Nawabshah (NORIN), Nawabshah, Pakistan.
Email: phy_waqar@yahoo.com
Full list of author information is available at the end of the article.

Introduction

The issue of retention of radiopharmaceuticals in syringes has recently seen a wide attention with varying results [1]. Although ^{99m}Tc-labeled radiopharmaceuticals are not as susceptible to adhesion as others, research on this topic is still being carried out [2]. The various reasons were reported for the retention of radioactivity in syringes, namely dead space on plunger, poor dispensing and injecting techniques used by technologist, injected volume, type of material of syringe being used, and time for which activity was kept in the syringe before injecting into the patient [3].

Residual activity may result in inconsistency and inaccuracy in the dose delivered, in case of iodine therapy, or suboptimal imaging quality, in case of ^{99m}Tc imaging [4]. Nuclear Medicine Oncology and Radiotherapy Institute Nawabshah (NORIN) is a comprehensive healthcare facility for diagnosis, treatment, and research of malignant disorders [5]. This center started their nuclear medicine facilities since 2012 with 02 SPECT Gamma camera with particular Hot Lab in the supervision of qualified medical physicists and nuclear physicians [6]. The main objective of this study is to identify the true activity administrated to the patient; investigate few factors affecting the amount of residual activity, i.e., volume of syringe and type of radiopharmaceutical; and to check whether our results are in compliance with the national and international guidelines.

Material and Methods

The current study contained the assessment of a number of commonly used radiopharmaceuticals in the nuclear medicine department of NORIN. These included ^{99m}Tc-labeled radiopharmaceuticals, such as ^{99m}Tc-pertechnetate, ^{99m}Tc-methylenediphosphonic acid (MDP), ^{99m}Tc-mercaptoacetyltriglycine (MAG-3), and ^{99m}Tc [methoxy-iso-butyl isonitrile (MIBI)]. This study also included pediatric Scan's data with 1 ml syringes.

NORIN Nawabshah uses ^{99m}Tc generators and all radiopharmaceuticals are purchased from a local vender. All data were collected prospectively within 1-year period under routine nuclear medicine practice. For adsorption measurements, two different sized syringes (3 and 5 ml) of commonly and easily available brand in Pakistan, Becton Dickinson, were used. Activity measurements were carried out by using dose calibrator CRC-25R of CAPINTEC Inc., USA [6].

Activity in the syringes was measured immediately after the manual withdrawal of the appropriate activity from the radiopharmaceuticals vial (injected activity) and immediately (within 2 minutes) injected into the patient, after which residual activity was measured. The measured parameters are (a) injected activity, (b) residual activity (%), (c) effective activity, (d) syringe volume, and (e) type of procedure. Percentage of residual activity and effective activity were calculated by using the following formulas [7]:

$$\text{Residual activity}(\%) = \left(\frac{\text{Residual activity}}{\text{Dispensed activity}}\right) \times 100$$

Effective activity = Dispensed activity – Residual activity

All the dispensing of radioactivity and their respective measurements were carried out by technologists under the supervision of nuclear physician and medical physicists in compliance with the radiation protection protocols followed [8].

Results

Overall, 946 measurements were taken during a 1-year period. There was no even distribution established among most data series of injected volumes and percentages of residual activity categorized by radiopharmaceutical. The results of individual pharmaceuticals are discussed below.

^{99m}Tc-mercaptoacetyltriglycine (MAG-3)

A total of 45 patients were injected (5,000 µCi) with 5 ml syringes. Average residual activity for these syringes was 67 µCi (1.35% of dispensed activity), with a maximum of 137 µCi (2.74% of dispensed activity) and minimum of 28 µCi (0.56% of dispensed activity).

For 3 ml syringes, 85 patients were injected with 5,000 µCi activity. Average residual activity for all patients was 63 µCi (1.27% of dispensed activity), with 25 µCi (0.5%) and 171 µCi (3.42%) as minimum and maximum residual activities, respectively. Figure 1A shows the percentages of residual activities of patients in comparison with a baseline value of average of all these percentages for both 5 and 3 ml syringes. Figure 1B is the value the effective activities for both syringes which were injected into patient.

^{99m}Tc-methylenediphosphonic acid (MDP)

A total of 207 patients were injected 20,000 µCi dispensed activity with 5 ml syringes, while 147 patients were injected with 3 ml syringes. For 5 ml syringes, 150 µCi (0.75% of dispensed activity) is average residual activity, with a standard deviation of 41 µCi for syringes dispensed with MDP with minimum value of 62 µCi (0.31%) and maximum of 341 µCi (1.73%). For 3 ml syringes, average residual activity is 118 µCi (0.59% of dispensed activity), with standard deviation of 33 µCi, and 227µCi (1.14%) and 51µCi (0.26%) as maximum and minimum values, respectively. Figure 2A shows the values of residual activities as percentage of dispensed activity for both 5 and 3 ml syringes, while Figure 2B gives the effective activity injected into the patient.

Methoxy-iso-butyl isonitrile (MIBI)

Thirty-three patients were injected with 5 ml MIBI, among which 16 were prescribed with 10,000 µCi, 2 patients with 11,000 µCi, 12 patients with 12,000 µCi, and 3 patients with 20,000 µCi. Average percentage residual activity for all these patients is 0.75% of respective

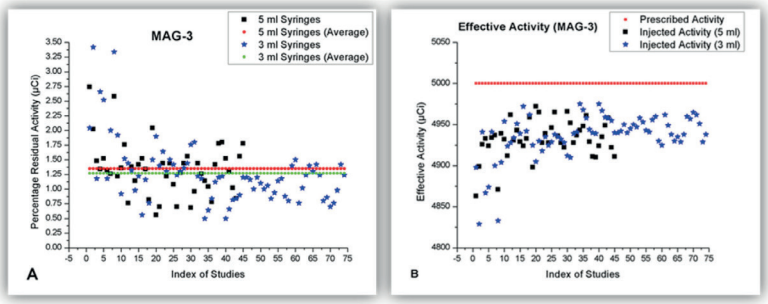

Figure 1. *Distribution of percentage residual activity and effective activity of MAG-3 in 3 and 5 ml syringes.*

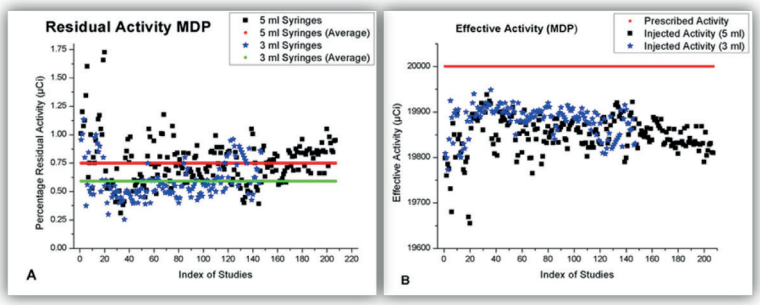

Figure 2. *The percent residual activity and effective activity for MDP in 3 and 5 ml syringes.*

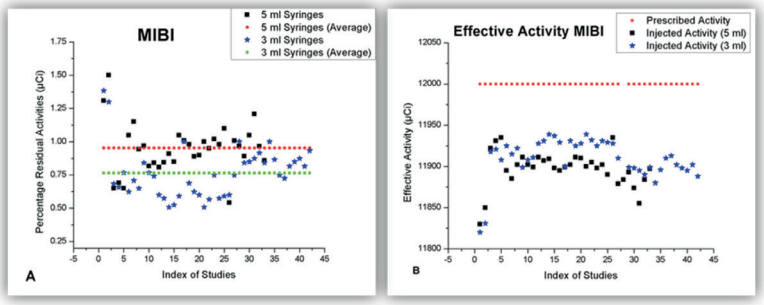

Figure 3. *The residual activity (%) and effective activity for MIBI in 3 and 5 ml syringes.*

dispensed activities with 0.69% and 1.5% as minimum and maximum values, respectively.

For 3 ml syringes, a total of 42 patients were injected with MIBI; 2 of who were injected with 13,000 μCi, 36 with 12,000 μCi, and the rest were injected with 10,000 μCi. Average residual activity for all patients was 0.76%, with 1.38% and 0.51% as maximum and minimum, respectively. Figure 3A represents percentage residual activities for both 3 and 5 ml syringes with their respective averages, while Figure 3B represents effective activity for both syringes with average effective activity.

Technetium-99m

A total of 400 patients were injected with 5,000 μCi ^{99m}Tc, among them 159 were injected with 5 ml syringes and 241 were injected with 3 ml syringes. For 3 ml syringes, average residual activity is 62 μCi (1.26% of dispensed activity), with 171 μCi (3.42%) and 16 μCi (0.32%) as maximum and minimum residual activities, respectively.

For 3 ml syringes, maximum residual activity is 119 μCi (2.38% of dispensed activity) and minimum activity is 21 μCi (0.42%), with an average of 65 μCi (1.3%). On the left of Figure 4 is a graphical representation of percentage residual activity for ^{99m}Tc with both 3 and 5 ml syringes, while on the right is a graph of effective activity along with dispensed activity for ^{99m}Tc.

Pediatric scan (1 ml syringes)

A total of 21 pediatric patients were injected with dispensed activity of 2,000 μCi of ^{99m}Tc. All patients were injected with 1 ml syringes. Percentage residual activity residing in syringe after injecting was found to be 1.34%, with minimum value is 0.63% (19 μCi) and maximum value is 1.5% (38 μCi). Mean effective activity for pediatric patients was 1973.2 μCi Data of percentage residual and effective activities with every patient are shown in Figure 5.

Discussion

There are many factors which affect the amount of activity being absorbed in syringes such as material and volume of syringes, time for which activity was remained in the syringe, and type of radiopharmaceutical being used [9]. It is evident from the data of patients for all radiopharmaceuticals that a small volume of syringe being used results in a small amount of residual activity for equal activities. For every set of data, an average value of residual activity is always higher for larger volume syringes. Studies show 1% [4] to 50% [10] variation in the residual activities due to utility of disposable material and delay factor between dispensing and injecting the activities to the patients [11]. For the analysis of type of radiopharmaceutical, we can split the above data into two groups. One group contains patients who were injected with ^{99m}Tc and MDP. The other group contains the data of patients who were injected with MAG-3 and MIBI. The number of patients for both ^{99m}Tc and MDP are quite high (more than 150 for both syringes); so, a fair conclusion can be drawn from the data. For any type of syringe (either 3 or 5 ml), average residual activity for ^{99m}Tc is high as compared to average residual activity

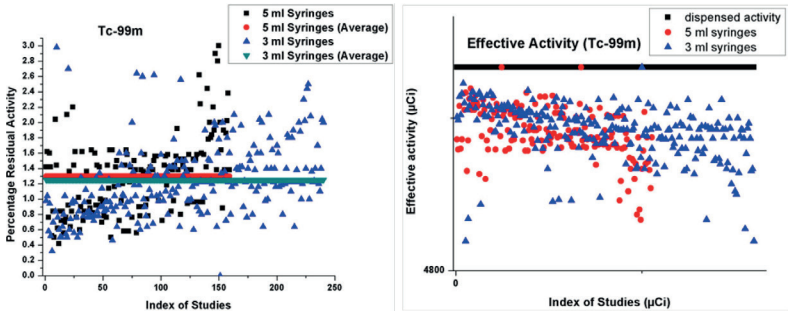

Figure 4. *Correlation of dispensed activity with residual and effective activity of two different volume syringes for ^{99m}Tc.*

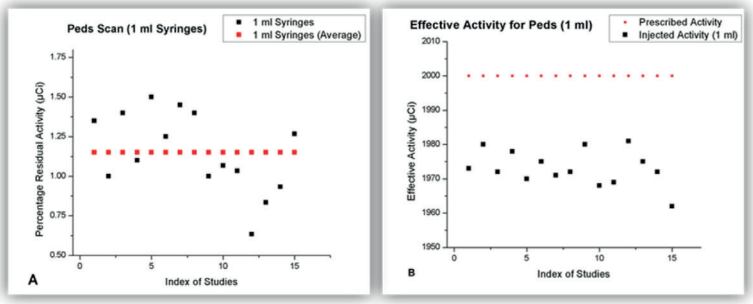

Figure 5. *Depiction of residual and effective activity for pediatric scans for 3 and 5 ml syringes.*

Table 1. *Percentage of residual activities for different injected volumes and their correlation with national and international standards.*

Parameters	^{99m}Tc-pertechnate (Thyroid Scintigraphy)		MDP (Bone Scintigraphy)		MAG-3 (Renal Scintigraphy)		MIBI		Pediatrics
	(3 ml)	**(5 ml)**	**(3 ml)**	**(5 ml)**	**(3 ml)**	**(5 ml)**	**(3 ml)**	**(5 ml)**	**(1 ml)**
No. of patients (*N*)	241	159	147	207	74	45	42	31	21
Mean dispensed activity (μCi)	5,000	5,000	20,000	20,000	5,000	5,000	(10,000-13,000)	(10,000-13,000)	2,000
Mean residual activity (μCi)	16-171	21-119	51-227	62-345	25-171	28-137	61-180	65-170	19-38
Mean effective activity (μCi)	4,937	4,934	19,881	19,878	4,936	4,932	11,766	10,832	1,973.2
Residual activity (%) minimum/ maximum	1.26% 0.32/2.38	2.38% 0.42/3.22	0.59% 0.26/1.14	0.61% 0.31/1.66	1.27% 0.50/2.74	1.35% 0.56/3.42	0.77% 0.51/1.38	0.94% 0.69/1.50	1.34% 0.63/1.50
Recommended maximum dispensed activity by PNRA	200 MBq 5,400 μCi		800 MBq 21,620 μCi		350 MBq 6,000 μCi		-		-
Recommended dispensed activity by ENMN (7)	75-370 MBq (SNMMI) 2,020-10,000 μCi		300-740 MBq 8,100-20,000 μCi		-		500-700 MBq 13,500-18,500 μCi		-

for MDP. Minimum and maximum activities for both 5 and 3 ml syringes are also higher for ^{99m}Tc. For group of patients injected with MAG-3 and MIBI, data sets with less than 50 patients for both syringes in both cases are not high to make any clear conclusion. Roughly, average residual activity is higher for MAG-3 when compared to MIBI for both types of syringes, but this result can change if a data set can be furnished. The percentage of residual activities for various volumes injected to the patients, and their relationship with national as well as international standards [12] are given in Table 1. The results consisting of mean effective activities were found well within the range recommended by EANM and PNRA. The results were in accordance with the departmental protocols.

For all radiopharmaceuticals and both syringes, average residual activity remained well under 1.5% of activity drawn into syringes. In some cases, individual residual activities exceeded 3.5%, but most of time activities in syringe after injection remained under 1.5%. Previously, residual activities as high as 13% of the dispensed activity

were also reported [7]. Another study reported that 6% of activity remained in the syringes, which is a significant amount of residual activity [13]. The results of current study have fewer variations when compared to previous reported studies due to careful observance of protocols and proper supervision in the administration of radiopharmaceutical to patients. These activities, if not compensated, may not alter the resultant image quality to a larger extent. It is the hospital's practice whether they compensate this residual activity or not [14].

Conclusion

Residual activity was measured for every patient after injection and data were collected for 1 year and analyzed. A total of 946 patients were assessed, who were injected with either 3 ml syringes or 5 ml syringes and different ^{99m}Tc-labeled radiopharmaceuticals were used. Residual activity was assessed for both syringe volume and type of radiopharmaceutical. The syringes having a volume of 3 ml had less residual activity as compared to 5 ml syringes. Similarly, residual activity for MDP is lower when compared to other radiopharmaceutical for both types of syringes. Maximum residual activity for 5 ml syringes happens to be 3.42% of dispensed activity, while for 3 ml syringes it is 2.74% of dispensed activity. For all radiopharmaceuticals and both syringes, average residual activity remained well under 1.5% of activity drawn into syringes, which is insignificant when compared to past studies, and may not alter the resultant image quality to a larger extent.

Acknowledgment

The authors are grateful to Mr. Adeel Ahmed (Hot-Lab Technetium), Mr. Junaid Farooq, and Ms. Andleeb Naz, NORIN Cancer Hospital Nawabshah, for their assistance and help.

List of Abbreviations

PNRA	Pakistan Nuclear Regulatory Authority
SNMMI	Society of nuclear medicine and molecular imaging

Conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding

None.

Consent to participate

Not applicable.

Ethical approval

For such type of retrospective/Dosimetry study, formal ethical approval is not required.

Author details

Muhammad Waqar[1], Muhammad Shahban[2], Quratulain Soomro[1], Touqir Ahmad Afridi[1]

1. Medical Physics Division, Nuclear Medicine Oncology & Radiotherapy Institute of Nawabshah (NORIN), Nawabshah, Pakistan
2. Medical Physics Division, Atomic Energy Cancer Hospital Islamabad (NORI), Pakistan

References

1. Ponto JA. Preparation and dispensing problems associated with technetium Tc-99m radiopharmaceuticals. The University of New Mexico Health Sciences Center College of Pharmacy, Albuquerque. New Mexico; 2004. 11 p. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fpharmacyce.unm.edu%2Fnuclear_program%2Ffreelessonfiles%2Fvol11lesson1.pdf&clen=456007&chunk=true
2. Mushtaq A, Ur Rehman T, Mansur MS, Jehangir M. Adsorption of 99mTc-radiopharmaceuticals onto injection vials and syringes. J Nucl Med Technol. 2008;36(2):91–4. https://doi.org/10.2967/jnmt.107.048561
3. Ozer YA, Kedkintepe D. Residual radioactivity in the syringes used in injection of radiopharmaceuticals and factors affecting the amount of residual activity. FABAD J Pharm Sci. 2005;30(January):176–80.
4. Bartosch R, Granegger S, Sinzinger H. Adsorption of technetium-99m tetrofosmin and technetium-99m furifosmin on plastic syringes. Eur J Nucl Med. 1998;25(9):1333–5. https://doi.org/10.1007/s002590050304
5. Waqar M, Shahban M, Soomro Q, Abro MN. Institution-based assessment of cancer patients treated by external beam radiotherapy in the rural area of Sindh, Pakistan: five years of data analysis. Middle East J Cancer. 2018;9(3):217–22.
6. Waqar M, Shahban M, Soomro Q, Khan ME. Performance of Tc-99m generators in terms of molybdenum contents measured in NORIN Nawabshah, Pakistan (5 years' experience). Iran J Sci Technol Trans A Sci. 2019;43(1):285–9. https://doi.org/10.1007/s40995-018-0582-0
7. Stavrou PZ, Papachristou M, Persakis E, Kouvelis K, Datseris IE. Residual activities of ^{99m}Tc-labelled radiopharmaceuticals in routine nuclear medicine practice. Nucl Med Commun. 2016;37(6):658–63. https://doi.org/10.1097/MNM.0000000000000487
8. Razaq A, Waqar M, Soomro Q, Javed MA. Evaluation of radiation workers occupational doses for newly established medical center NORIN Nawabshah in Pakistan. J Med Phys Biophys. 2016;3(1):61–5.
9. Rodrigues M, Chehne F, Sinzinger H. *In vitro* adsorption of Tc-99 (m)-MIBI, Tc-99 (m)-tetrofosmin, Tc-99 (m)-furifosmin and (TcO4-)-Tc-99-Om onto tubes. Nucl Med Commun. 2001;22(1):105–10. https://doi.org/10.1097/00006231-200101000-00015
10. Jansson BA, Göransson MB, Agren BN. Adsorption of some technetium-99m radiopharmaceuticals onto disposable plastic syringes. J Nucl Med Technol. 1998;26(3):196–9.
11. Galbraith W, Chen X, Talley K, Grantham V. Assessment of ^{99m}Tc-succimer residual activity using inert nonreactive syringes. J Nucl Med Technol. 2015;43(1):61–3. https://doi.org/10.2967/jnmt.114.147983
12. Authority PN. PNRA regulations on radiation protection (PAK/904). Islam Pakistan Nucl Regul Auth. 2004. Available from: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/viewer.html?pdfurl=https%3A%2F%2Fwww.pnra.org%2Fupload%2Flegal_basis%2FRP%2520Regulations%2520PAK-904.pdf&clen=928068&chunk=true
13. Gunasekera RD, Notghi A, Mostafa AB, Harding LK. Adsorption of radiopharmaceuticals to syringes leads to lower administered activity than intended.

Nucl Med Commun. 2001;22(5):493–7. https://doi.org/10.1097/00006231-200105000-00005

14. Stopar TG, Socan A, Peitl PK. Adsorption of radiopharmaceuticals to syringes: setting up a reliable protocol for its assessment. Nucl Med Commun. 2007;28(12):951–5. https://doi.org/10.1097/MNM.0b013e3282f1b9b7