Original article

Identification of factors affecting the retention of ^{99m}Tc-DMSA in syringes among the paediatric population in Sri Lanka

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Abstract

Background: ^{99m}Tc-DMSA is a common paediatric renal scintigraphy study, where radiopharmaceutical is introduced intravenously using disposable syringes. Radiopharmaceuticals can be retained on disposable syringes, causing under-dosing, and impacting imaging quality in paediatric patients. The study aimed to specify the factors affecting on retention of ^{99m}Tc-DMSA in disposable syringes. Furthermore, the influence of the medical staff, patient positioning, and the ascendancy of the MON.TEK ^{99m}Mo/^{99m}Tc generator were investigated.

Methods: A study of 212 paediatric patients undergoing ^{99m}Tc-DMSA renal scintigraphy was conducted using CAPINTEC-CRC-15R and CAPINTEC-CRC/15 BETA radiation dose calibrators. The ^{99m}Tc-Pertechnetate was eluted with a MON.TEK ^{99m}Mo/^{99m}Tc generator and the radiopharmaceutical volume were recorded. Six types of 1ml/1cc disposable syringes (Types 1-6) and one 1ml insulin syringe (Type 7) were used. Pre- and post-doses of these syringes were measured.he administered activity value was considered to develop DRL.

Results: Results showed a significant moderate, positive correlation between retention dose and dilution (radiopharmaceutical volume). There was no correlation between retention dose and pre-dose or patient weight. No significant difference in retention was found based on patient gender or position. Significant differences in retention dose were observed among syringe types, injection sites, labeling personnel, and administering personnel.

Conclusion: Retention of ^{99m}Tc-DMSA varies by syringe type, with Type-1 syringes showing the highest retention and Type-7 the lowest, making Type-7 the most suitable. Retention is influenced by radiopharmaceutical dilution, labeling, injecting personnel, and injection site, while pre-dose, patient gender, weight, positioning, and decay time have no significant effect. This highlights the importance of syringe selection and standardizing procedures to minimize retention, improve dosing accuracy, and enhance imaging quality.

Keywords: retention, ^{99m}Tc-DMSA, disposable syringes, paediatric population, factors affecting retention

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Introduction

^{99m}Tc-DMSA renal scintigraphy is a crucial non-invasive nuclear imaging technique for diagnosing kidney conditions, especially in children. It detects abnormalities from conditions such as Vesicoureteral reflux (VUR), urinary tract infections (UTI), pyelonephritis, renal scarring, as well as morphological issues like nephropathy[1,2]. Despite advances in other imaging methods, it remains essential for assessing renal structure and morphology[3]. The procedure involves injecting ^{99m}Tc-DMSA intravenously and using a gamma camera to capture kidney images[4,5]. It is the gold standard for detecting parenchymal damage in acute pyelonephritis and is highly sensitive for identifying renal scarring in children with VUR, aiding in early therapy decisions.

Disposable plastic syringes are used to administer the radiopharmaceutical to patients in ^{99m}Tc-DMSA renal scintigraphy procedures. However, disposable plastic syringes can retain up to 50% of the radiopharmaceutical,[6,7] leading to under-dosing and poor diagnostic imaging, particularly in paediatric patients[7,8,9]. This study aims to standardize assessments of ^{99m}Tc-DMSA retention in various syringe brands to ensure adequate dosing and improve diagnostic outcomes, addressing a significant gap in current procedures.

Methodology

Ethical statement

The approval for the research proposal for this study was obtained from the Ethical Review Committee (ERC) of the Faculty of Medicine, General Sir John Kotelawala Defence University. Permission for data collection and the continuation of the study was obtained from the Institutional Review Boards of Lady Ridgeway Hospital for Children, Borella, and Lanka Hospital, Narahenpita, Sri Lanka.

Subjects

A total of 212 paediatric patients of age ≤15 years old undergoing ^{99m}Tc-DMSA renal scintigraphy scans from the Lady Ridgeway Hospital for Children, Colombo (LRH) and the Lanka Hospital, Narahenpita, Sri Lanka (LH) were selected as the study sample by using the convenient sampling method. Detailed information is provided in Table 1.

Method of dose measurement in ^{99m}Tc-DMSA renal scintigraphy

Siemens Single Detector Gamma camera which is in the Department of Nuclear Medicine in Lady Ridgeway Hospital for Children, Borella, and Siemens- E Cam Dual Detector Gamma camera in the Department of Nuclear Medicine in Lanka Hospital, Narahenpita Sri Lanka were used to proceed ^{99m}Tc-DMSA renal scintigraphy studies. All required doses acquired at LRH were measured CAPINTEC CRC-15R 5136-30S6 radiation dose calibrator in LRH and the doses acquired at LH were measured using the CAPINTEC - CRC/15 BETA radiation dose calibrator in LH. MON.TEK 99mMo/^{99m}Tc generator which is in the Nuclear Medicine Unit of the Department of Radiology in LRH and LH was used to elute ^{99m}Tc-Pertechnetate (TcO4-).

Disposable syringes

The radiopharmaceutical is drawn into disposable syringes by the syringe needle. An IV cannula is connected to the patient's wrist or foot, and the radiopharmaceutical is injected to the patient intravenously using 1cc disposable syringes. This was done by a qualified Medical Officer or a Nursing Officer, by hand, using paralleling technique. ^{99m}Tc-DMSA radiopharmaceutical injected into the subjects at LRH was administered by 6 different types of 1ml/ 1cc disposable syringes as demonstrated in Table 2.

Table 1. Whole descriptive statistics for factors affecting retention of ^{99m}Tc-DMSA in syringes

	Retention Dose/ MBq	*Dilution/ml*	*Time duration until administration/ s*	*Pre-dose/ MBq*	*Age/ Months*	*Weight/ Kg*
Mean	11.029	0.41	1215.42	70.62	33.85	12.75
Std. Deviation	6.83	0.17	877.94	17.37	32.05	6.89
Minimum	0.75	0.13	68	36.50	2	2.40
Maximum	30.10	0.99	15097	148.50	160	55.00

In LH 1 ml [29G × ½"] disposable insulin syringe (Type 7) was used for the administration of ^{99m}Tc-DMSA. Each subject is injected with radiopharmaceutical by only one syringe.

Table 2. Information on the syringes used in the study

Syringe type	*Volume/ Gauge*
Type 1	1 ml [26G × 5/8"]
Type 2	1ml [26G × 15 mm]
Type 3	1 ml [27G × ½"]
Type 4	1ml [26G × 15mm]
Type 5	1ml [29G × ½"]
Type 6	1 ml [26G × 15mm]
Type 7	1 ml [29G × ½"]

Acquiring the retention dose

To differentiate the retention of the ^{99m}Tc-DMSA radiopharmaceutical in different syringe types, initial radiation doses (pre-patient dosages) and post-patient doses of all disposable syringes were measured using radiation dose calibrators at each facility. Each patient received the same radiation dose per kilogram (mCi/kg). The doses before administration, and after injection, the post-patient dose were measured using dose calibrators. The residual activity of the empty syringe and plunger was monitored and decay-adjusted accordingly.

Statistical analysis

All data were recorded in a customized Microsoft Excel sheet and analysed using SPSS version 26. Normality was checked using the Shapiro-Wilk test, with p>0.05 indicating normality.

A One-way ANOVA test compared retention doses across multiple groups (syringe type, labelling personnel, administering staff, and injection site), with Welch's ANOVA Test used if homogeneity was violated. The Mann-Whitney U test compared retention between two groups (patient position and gender). Spearman's Rank Order Correlation identified correlations between continuous variables (decay time, dilution, pre-dose, patient's age and gender). All tests were two-sided with a significance level of 0.05.

Results

Spearman's rank order correlation

Patient's weight: There is no statistically significant correlation between the retention dose and patient weight (p>0.05)

Pre-dose: There is no statistically significant correlation between the retention dose and pre-dose (p<0.05)

Time duration until radiopharmaceutical administration (Decay time): There is no statistically significant correlation between the retention and the time duration until radiopharmaceutical administration

Radiopharmaceutical volume (Dilution): As in Figure 1, there is a moderate, positive linear correlation between retention dose and dilution (radiopharmaceutical volume), which was statistically significant ($r_s(210) = 0.454$, ($p < 0.05$).

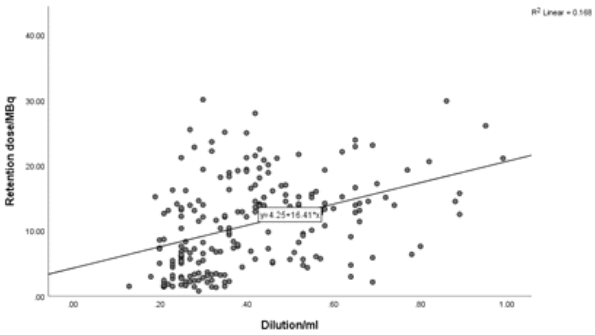

Figure 1. Scatter plot chart of dilution against retention dose.

Mann-Whitney U Test

Gender: According to the test results of Mann-Whitney U test, there was no significant difference in retention between male and female patients according to their gender.

Patient's position: Patients were either supine or erect while the radiopharmaceutical administration was done. There is no significant difference in retention dose between erect and supine patient positions.

Welch's ANOVA Test

Syringe type: Since the data set violates the homogeneity of the variance assumptions, Welch's ANOVA test was conducted to compare the retention dose

between the different syringe types. Results of the test indicated a significant difference in retention dose among disposable syringes (Fw (6,205) = 673.51, ($p < 0.05$). As in Table 3, according to Welch's ANOVA test, the retention dose values of the syringe types differed significantly from each other ($p<0.05$).

Syringe type 1 has a maximum mean value of 18.51 MBq and syringe type 7 has a minimum mean value of 2.30 MBq. Games-Howell post hoc test was conducted to identify which syringe types were different from each other in retention (Table 4).

The test results show that the retention dose of syringe Type 1 significantly differs from all other types ($p<0.05$) except type 04 ($p>0.05$). Syringe type 02 varies significantly compared to all others ($p<0.05$) except type 05 ($p>0.05$). Types 3 and 7 differ significantly from all other types. Types 04 and 05 are significantly different ($p<0.05$), but Types 5 and 6 show no significant difference ($p>0.05$).

Table 3. Descriptive statistics of retention dose with a syringe type

Syringe type	*Number of syringes*	*Mean ± SD/ MBq*	*Minimum Retention/ MBq*	*Maximum Retention/ MBq*
1	31	18.5 ± 7.15	5.65	30.10
2	32	10.63 ± 4.35	1.80	19.60
3	27	6.34 ± 2.73	1.40	13.10
4	23	16.07 ± 3.29	8.34	21.10
5	30	11.76 ± 6.53	5.00	26.10
6	32	13.92 ± 0.80	12.60	15.60
7	37	2.30 ± 0.73	0.75	3.50

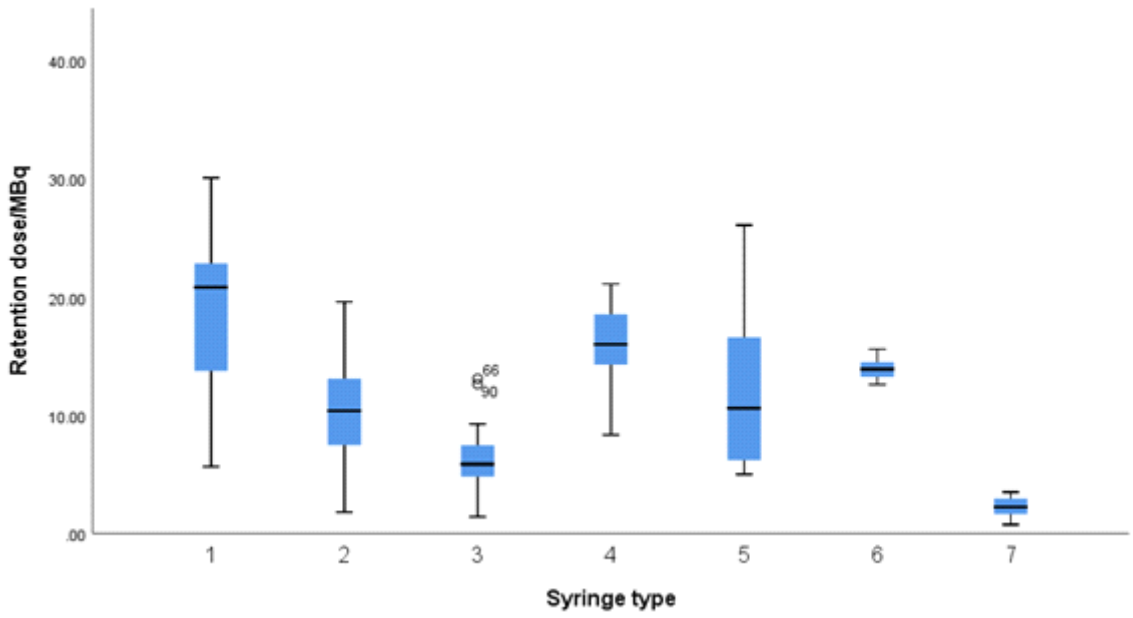

Figure 2. Simple box plot of retention dose by syringe type.

Table 4. Multiple comparison of syringe types

(I) Syringe Type	*(J) Syringe Type*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*
1	2	7.88*	1.49	0.000
	3	12.17*	1.38	0.000
	4	2.43	1.45	0.636
	5	6.75*	1.75	0.005
	6	4.58*	1.29	0.019
	7	16.20*	1.28	0.000
2	3	4.29*	0.93	0.001
	4	-5.44*	1.03	0.000
	5	-1.13	1.41	0.984
	6	-3.29*	0.78	0.003
	7	8.32*	0.77	0.000
3	4	-9.72*	0.86	0.000
	5	-5.42*	1.30	0.003
	6	-7.58*	0.54	0.000
	7	4.03*	0.53	0.000
4	5	4.31*	1.38	0.045
	6	2.15	0.70	0.069
	7	13.77*	0.70	0.000
5	6	-2.16	1.20	0.559
	7	9.46*	1.20	0.000
6	7	11.62*	0.19	0.000

Table 5. Descriptive statistics of the injected site

Injected site	*No of cases*	*Mean retention/ MBq*	*Std. Deviation MBq*	*Minimum / retention/ / MBq*	*Maximum retention*
Right Wrist	84	10.75	7.11	0.75	25.50
Left Wrist	85	9.77	6.68	1.30	30.10
Right Foot	16	13.76	2.20	8.68	19.30
Left Foot	27	14.21	7.06	3.64	29.90

Injected site: *Radiopharmaceutical injection sites were the right wrist, left wrist, right foot, and left foot. Due to variance assumptions violation, a Welch ANOVA test was conducted, revealing a significant difference in retention doses among the sites (Fw (3,208) = 8.131, p<0.05). The left foot had the highest mean retention (14.22 MBq), while the left wrist had the lowest (9.77 MBq). This is further explained in Table 5.*

Table 6. Robust tests of equality of means for radiopharmaceutical labelling personnel

Labelling personal	*No of syringes*	*Mean retention/ MBq*	*Std. Deviation*	*Std. Error*
A	26	13.10	5.52	1.08
B	66	11.68	6.22	0.77
C	6	13.10	2.09	0.85
D	16	11.36	4.23	1.06
E	17	12.59	6.74	1.63
F	19	14.49	6.85	1.57
G	17	14.96	5.66	1.37
H	8	17.14	7.20	2.55
I	37	2.30	0.73	0.12

Radiopharmaceutical labelling personnel: *There is a significant difference in retention dose with the different labelling personnel. (Fw (8,203) = 72.51, (p < 0.05) (Table 6)*

Table 7. Descriptive statistics of retention dose with administering staff

Administering Staff	*No of cases*	*Mean retention/ MBq*	*Std. Deviation*	*Std. Error*
A	4	5.64	2.57	1.28
B	28	10.69	6.02	1.14
C	9	10.39	3.93	1.31
D	11	11.30	4.86	1.47
E	3	9.74	3.57	2.06
F	6	13.95	0.48	0.20
G	26	14.57	7.18	1.41
H	22	13.88	4.62	0.99
I	16	12.45	5.20	1.30
J	28	15.04	1.05	1.33
k	22	13.44	6.34	1.35
L	37	2.30	0.73	0.12

Radiopharmaceutical administering staff: *Results of the Welch's ANOVA test indicated a significant difference among the administering staff on the retention (Fw (11,200) = 211.79, (p<0.05) (Table 7)*

Discussion

This study investigates factors affecting ^{99m}Tc-DMSA retention in disposable syringes at two NM facilities in Colombo, Sri Lanka, comparing various 1ml/1cc syringes.

This study demonstrates that the retention of ^{99m}Tc-DMSA in disposable plastic syringes is significantly influenced by syringe type. Specifically, Syringe Type 1 showed the highest retention (18.50 MBq), while Type 7 had the lowest (2.30 MBq), making Type 7 preferable for paediatric nuclear medicine.

Comparative analysis with similar studies corroborates these findings. Previous studies reported significant

variations in retention based on syringe materials and brands, affecting dosing accuracy.[10] It is emphasized that such retention impacts imaging quality, necessitating careful syringe selection to avoid under-dosing and ensure high-quality diagnostics.[4]

Present study aligns with studies which noted that administration technique and personnel experience crucially affect retention and diagnostic efficacy in paediatric ^{99m}Tc-DMSA renal scintigraphy.[8,11] The positive correlation between retention and factors like dilution volume and injection site is supported by previous studies demonstrated that optimized preparation and administration practices reduce retention and improve dose accuracy.[12,13]

However, findings of this study indicate that pre-dose, patient gender, weight, positioning, and decay time do not significantly impact retention. This divergence highlights the need for further investigation into these variables.

In summary, the practical recommendations for syringe selection and staff training derived from this study are essential for minimizing radiopharmaceutical retention and enhancing paediatric nuclear medicine procedures. These insights, consistent with and extending beyond previous research, underscore the importance of optimizing all aspects of radiopharmaceutical administration to improve patient outcomes.

Conclusion

This study highlights key factors influencing the retention of ^{99m}Tc-DMSA in disposable syringes, providing actionable insights for paediatric nuclear medicine practices in Sri Lanka. The findings indicate significant variations in retention based on syringe type, with Type 7 syringes demonstrating the lowest retention, making them the most suitable for paediatric procedures. Additionally, retention was influenced by dilution volume, personnel handling during labelling and injecting, and the injection site. In contrast, factors such as pre-dose, patient gender, weight, positioning, and radiopharmaceutical decay time showed no significant impact on retention.

These findings carry practical implications for improving clinical efficiency and patient outcomes. The identification of Type 7 syringes as the optimal choice supports a shift toward their routine use, reducing under-dosing and enhancing image quality. Moreover, the influence of human factors underscores the need for targeted staff training and standardization of procedures to minimize variability and ensure consistent dosing accuracy.

To build on these results, future studies should evaluate the cost-effectiveness of syringe types and explore other variables, such as needle gauge, to further optimize practices. These insights can guide policy changes, improve resource allocation, and elevate the quality of paediatric nuclear medicine services. In conclusion, adopting the recommended syringe selection and prioritizing staff training are crucial steps toward minimizing radiopharmaceutical retention and maximizing the diagnostic value of paediatric scintigraphy procedures.

Statements and declarations

Consent for publication

All authors read and approved the final manuscript and approved the submitted version for publication.

Availability of data and material

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Authors' contributions

Dr DDN Wimalarathne, Dr JMC Udugama and Dr N Samarasinghe substantially contributed to the conception, design and revised the manuscript critically for important intellectual content. Ms BES Jayasooriya, Ms UHV Paramee and Mr CS Wijesinghe analysed and interpreted the data and drafted the article. Further measured the pre- and post-doses. Mr Dhammika Pathirana and Mr SID Silva prepared and calibrated the ^{99m}Tc-DMSA radiopharmaceutical. All authors read and approved the final manuscript, contributed to the article, and approved the submitted version.

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