Systematic Assessment of the Adsorption of ^{99m}Tc-Radiopharmaceuticals onto Plastic Syringes

Herbert Kvaternik, Jakob Gatterer, Elisabeth Plhak, Julia F. Schwarzgruber, and Reingard M. Aigner

Division of Nuclear Medicine, Department of Radiology, Medical University of Graz, Graz, Austria

The phenomenon of adsorption of several ^{99m}Tc-radiopharmaceuticals onto disposable syringes is common knowledge and can reach a level of up to 50%, with the result being inadequate dosing. The resulting underdosing has a substantial influence on the quality of imaging, especially in pediatric patients. Therefore, we aimed to establish a standardized in vitro assessment to investigate the adsorption of several ^{99m}Tc-radiopharmaceuticals on various brands of syringes. **Methods:** The ^{99m}Tc-radiopharmaceuticals were prepared according to manufacturer instructions. For the assessment, the disposable syringes (n = 3) were filled to one third of capacity with the ^{99m}Tc preparation and incubated for 30 min at room temperature. The syringes were emptied into evacuated vials, and the radioactivity of the syringes was measured before and after they were emptied. Furthermore, the dilution effect of ^{99m}Tc preparations was studied. We used 2 different brands of syringes and systematically examined ^{99m}Tc-pertechnetate, ^{99m}Tc-butedronate, ^{99m}Tc-oxidronate, ^{99m}Tc-medronate, ^{99m}Tc-tetrofosmin, ^{99m}Tc-sestamibi, ^{99m}Tc(V)-dimercaptosuccinic acid, and ^{99m}Tc-succimer. Additionally, ^{99m}Tc-succimer was retested with 5 brands of syringes. **Results:** ^{99m}Tc-pertechnetate, ^{99m}Tc-phosphonates, and ^{99m}Tc(V)-dimercaptosuccinic acid showed no significant adsorption. The measured radioactive retention of 2%–5% was equivalent to the determined dead volume. Using ^{99m}Tc-tetrofosmin, we found a slight but significant adsorption of 4%–7%. The ^{99m}Tc-sestamibi preparation showed a nonsignificant retention of 3%–5%. However, when the ^{99m}Tc-sestamibi was diluted 1:10 with saline, the adsorption rate increased to 9%–13%. ^{99m}Tc-succimer displayed different adsorption levels depending on the brand of syringe and the preparation technique. The adsorption of ^{99m}Tc-succimer, prepared from kits according to the instructions, did not exceed 15%. The 1:10 saline dilution of a ^{99m}Tc-succimer kit preparation, as well as an in-house preparation, demonstrated a radioactive syringe adsorption rate of more than 30%. **Conclusion:** The results revealed the significance of syringe adsorption of radiopharmaceuticals in the prevention of underdosing. Therefore, a quality assurance assessment is recommended before the introduction of new brands of plastic syringes or routine application of diluted or in-house radiopharmaceuticals.

Key Words: syringe; adsorption; radiopharmaceutical; ^{99m}Tc-succimer; ^{99m}Tc-sestamibi

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In nuclear medicine for scintigraphy, ^{99m}Tc is still one of the predominant radionuclides used worldwide. A wide range of ^{99m}Tc-radiopharmaceuticals can be prepared from commercially available kits in conjunction with generator-produced ^{99m}Tc. These radioactive drugs contain a low mass of the pharmaceutically active substance and are usually administered in disposable plastic syringes (*1*). Depending on the chemical properties of the radiopharmaceutical, adsorption onto the surface of the plastic material of the disposable syringe may occur. When this phenomenon takes place, a significant part of the radioactivity intended for the patient remains in the syringe. Consequently, the dose of the radiopharmaceutical applied to the patient is reduced, leading to a decrease in image quality and an increase in the risk of possible misinterpretation of the results (*2*). Therefore, the underdosing of the radiopharmaceutical caused by adsorption affects the quality of the examination, especially in children and adolescents (*3*).

Only a few studies have been published on the adsorption and retardation effects of ^{99m}Tc-radiopharmaceuticals on disposable plastic syringes. ^{99m}Tc-sestamibi and ^{99m}Tc-tetrofosmin, both lipophilic compounds, showed increased retention in plastic syringes (*4,5*). The particularly highest adsorption of up to 50% of the radioactivity in the syringe was observed with the sulfur-containing radiopharmaceutical ^{99m}Tc-succimer (*3,6,7*). However, these studies from the literature are not directly comparable, since the individual experimental methods deviated strongly from each other.

In this study, we aimed to contrive a standard method for adsorption assessment to compare different plastic syringes with various radiopharmaceuticals under identical experimental conditions. We tested ^{99m}Tc-radiopharmaceuticals such as ^{99m}Tc-pertechnetate or ^{99m}Tc-diphosphonates, which are described as inconspicuous about adsorptions (*8*), and proved our concept with known adsorbing ^{99m}Tc-radiopharmaceuticals, such as ^{99m}Tc-sestamibi, ^{99m}Tc-tetrofosmin, and ^{99m}Tc-succimer. Furthermore, we gravimetrically determined the dead space to obtain a correlation between the actual adsorption and the residual volume remaining in the disposable syringe. Therefore, this

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For correspondence or reprints contact: Herbert Kvaternik, Division of Nuclear Medicine, Department of Radiology, Medical University of Graz, Auenbruggerplatz 9, A-8036 Graz, Austria.
E-mail: herbert.kvaternik@klinikum-graz.at
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assessment should clearly differentiate between dead space and actual radiopharmaceutical adsorption.

MATERIALS AND METHODS

As a source for ^{99m}Tc-pertechnetate, we used a 15-GBq (400 mCi) Poltechnet ^{99}Mo/^{99m}Tc-generator (Polatom). In the in vitro study, we compared ^{99m}Tc-medronate, ^{99m}Tc-oxidronate, ^{99m}Tc-butedronate, ^{99m}Tc-sestamibi, ^{99m}Tc-tetrofosmin, ^{99m}Tc-succimer, and ^{99m}Tc(V)-dimercaptosuccinic acid (DMSA(V)). All ^{99m}Tc-radiopharmaceuticals, except ^{99m}Tc-DMSA(V), were directly reconstructed from commercially available kits (Table 1). Preparation and quality control were performed according to the manufacturers' instructions. For preparation of ^{99m}Tc-DMSA(V), the lyophilized content of the commercial kit (Renocis) was dissolved in 0.5 mL of 3.5% $NaHCO_3$ solution. ^{99m}Tc-DMSA(V) was formed at pH 7–8 after the addition of 3.5 mL of ^{99m}Tc-pertechnetate (3.2 GBq, 85 mCi) (*9*). After a 15-min reaction time, the mixture was diluted with saline to 8.0 mL. The specific quality control was performed on a Silicagel 60 plastic sheet (Merck) with 4/3/1 isopropanol/water/acetic acid (v/v/v) as the mobile phase and evaluated by a thin-layer chromatography scanner (VCS-203; Veenstra Instrumenten BV). ^{99m}Tc-DMSA(V) migrates to the middle of the strip (R_f, ~0.5), whereas ^{99m}Tc-succimer remains as an impurity at the start.

We tested the ^{99m}Tc-radiopharmaceuticals (Table 1) with 2 types of 3-piece syringes: brand A (1-mL tuberculin; Codan Medical) and brand B (3-mL Luer-lock; Becton Dickinson and Co. [BD]). Both brands are routinely used at our facility. In the assessment, the syringes were filled with the ^{99m}Tc-radiopharmaceutical to approximately one third of the volume. Therefore, we filled brand A with 0.3 mL and brand B with 1.0 mL. The activity concentration of the ^{99m}Tc-radiopharmaceutical test solutions was 150–550 MBq/mL (5–15 mCi/mL), depending on the specification of the commercial kit. The syringes were incubated for 30 min at room temperature. That duration simulates the maximum time between filling of a syringe and application to a patient in our nuclear medicine division. To examine the influence of dilution on syringe adsorption, we diluted the ^{99m}Tc-preparations 1:3 and 1:10 with saline (Fresenius) and tested the dilution in the same way as described above.

The radioactivity of the syringe, including the needle, was determined using a dose calibrator (Isomed 2010). Then, the syringe was emptied into a vacuum vial (TechneVial, 11 mL; Mallinckrodt) without rinsing. The activity of the emptied syringe plus needle, the activity of the needle alone, and the activity of the vacuum vial were recorded and corrected for decay. The residual radioactivity in the syringe was calculated from the activity reading of the syringe plus needle minus the activity of the needle alone. The residual activity was expressed as a percentage. In the general study, each experiment was performed in triplicate. From each experiment, we calculated the mean and SD.

The dead space of brands A and B, as well as the used needle (Sterican 0.9 × 70 mm [20-gauge × $2^3/_4$ -in (70-mm)]; B. Braun), was determined by weight. Five syringes of brand A and brand B

TABLE 1
Formulation of ^{99m}Tc-Radiopharmaceutical Kits

Radiopharmaceutical	Kit	Ingredients	Reconstitution	
^{99m}Tc-butedronate	Teceos (CIS Bio)	13 mg of 3,3 diphospho-1,2-propanedicarboxylic acid, tetrasodium salt (butedronate), $SnCl_2 \cdot 2H_2O$, *N*-(4-aminobenzoyl)-L-glutamic acid	^{99m}Tc-TcO_4^-	2–10 mL, 0.4–11.1 GBq (10–300 mCi), 5 min of shaking, room temperature
			Butedronate	1.3–6.5 mg/mL
^{99m}Tc-oxidronate	Technescan oxidronate (Mallinckrodt)	3 mg of disodium-oxidronate, $SnCl_2 \cdot 2H_2O$, gentisinic acid, sodium chloride	^{99m}Tc-TcO_4^-	3–10 mL, 1.5–11.1 GBq (40–300 mCi), 0.5 min of shaking, room temperature
			Oxidronate	0.3–1.0 mg/mL
^{99m}Tc-medronate	Medronate Tc-IK-10 (Izotop)	5 mg of medronic acid (medronate), $SnCl_2 \cdot 2H_2O$, ascorbic acid, urea	^{99m}Tc-TcO_4^-	2–5 mL, 3–6 GBq (80–160 mCi), 15 min of incubation, room temperature
			Medronate	1–2.5 mg/mL
^{99m}Tc-tetrofosmin	Myoview (GE Healthcare)	0.23 mg of tetrofosmin, $SnCl_2 \cdot 2H_2O$, disodium sulphosalicylate, sodium D-gluconate, sodium hydrogen carbonate	^{99m}Tc-TcO_4^-	4–8 mL, <8.8 GBq (<240 mCi), 15 min of incubation, room temperature
			Tetrofosmin	0.03–0.06 mg/mL
^{99m}Tc-sestamibi	Stamicis (CIS Bio)	1 mg of tetrakis (2-methoxyisobutyl isonitrile) copper (I) tetrafluoroborate, $SnCl_2 \cdot 2H_2O$, cysteine hydrochloride monohydrate, sodium citrate, mannitol	^{99m}Tc-TcO_4^-	1–3 mL, 0.2–11 GBq (5–290 mCi), 10 min of incubation, 100°C
			Sestamibi	0.33–1 mg/mL
^{99m}Tc-DMSA (^{99m}Tc-succimer)	Renocis (CIS Bio)	1 mg of dimercaptosuccinic acid, $SnCl_2 \cdot 2H_2O$, ascorbic acid, inositol	^{99m}Tc-TcO_4^-	1–6 mL, <3.7 GBq (<100 mCi), 5–10 min of shaking, room temperature
			DMSA	0.17–1 mg/mL

including needle were filled with saline. The saline solution was emptied into a vacuum vial as described above. All components were weighed before and after the experiment. The dead space of the syringes and needles was calculated from their weight difference and expressed in microliters.

In an extension of the experiments, we evaluated 6 brands of syringes with ^{99m}Tc-succimer, which has a high adsorption tendency. Brand A contains a silicone-sealed plunger. Brands B and C (5-mL Luer-lock; BD) include an elastomer plunger seal. Brand D (1-mL tuberculin; Henke-Sass-Wolf [HSW]) includes a nonlatex rubber seal. Brand E (2-mL [3-mL] Norm-Ject; HSW) and brand F (5-mL [6-mL] Norm-Ject) are 2-piece syringes with no rubber seal at the plunger. For direct comparison, we used 1 large batch of ^{99m}Tc-succimer for all syringe tests. Therefore, 40 mL of ^{99m}Tc-succimer were chemically prepared (*10*). The ^{99m}Tc-succimer test solution should contain a DMSA concentration of more than 0.2 mg/mL, equivalent to the commercial kit. Fifty milligrams of dimercaptosuccinic acid (Sigma-Aldrich) were dissolved in water at pH 4, and the solution was then mixed with 50 mg of ascorbic acid (Sigma-Aldrich) under continuous N_2 bubbling. Finally, the DMSA reagent solution (4 mg/mL) was adjusted to pH 2.8 by addition of 1 M HCl. For radiolabeling, 3.0 mL of ^{99m}Tc-sodium pertechnetate (2.6 GBq, 70 mCi) were added to 2.4 mL of DMSA reagent solution, followed by 0.7 mL of a solution of stannous chloride dehydrate (5 mg/mL) in 0.2 M HCl. After a 15-min reaction time, the ^{99m}Tc-succimer test solution was diluted with saline to 40 mL. The radiochemical purity was determined by paper chromatography using instant thin-layer chromatography–silica gel (Agilent) and methylethylketone (Merck). In the extended study, we drew the ^{99m}Tc-succimer test solution (57 MBq/mL, 1.5 mCi/mL, 0.24 mg of DMSA/mL) into brands A–F, incubated for 30 min, and assessed as described above. Each brand was tested 5-fold.

For statistical analysis, we applied the unpaired Student *t* test to calculate differences in the percentage of residual activity in the comparison of various ^{99m}Tc-radiopharmaceuticals and various brands of syringes. A *P* value of less than 0.05 was considered to be significant.

RESULTS

The composition and labeling conditions of the tested kits are shown in Table 1. The results of the labeling efficiency and of the quality control corresponded in all cases to the manufacturer specifications and the European Pharmacopoeia. The stability of the radiopharmaceutical preparations and their dilutions were tested and agreed with the individual specifications.

By the gravimetric determination of the dead space in our assessment ($n = 5$), we found a liquid retention of 30 ± 15 μL in brand A and 41 ± 30 μL in brand B. In the needles, 23 ± 5 μL of the liquid was retained. The mean residual liquid expressed as a percentage was 2.8% with brand A and 3.4% with brand B. Therefore, in our experimental setup, a measured residual liquid of up to about 3% can be attributed to the dead space.

The radioactive adhesion of ^{99m}Tc-radiopharmaceuticals measured after 30 min of incubation is depicted in Table 2, which shows the adhesion of the undiluted ^{99m}Tc-radiopharmaceutical preparation, as well as their 1:3 and 1:10 dilutions with saline, onto 2 brands of syringes. Additionally, the adhesion of the undiluted ^{99m}Tc-radiopharmaceutical onto the needle is portrayed. We found a radioactive retention of less than 3% in both brands with the undiluted preparations of ^{99m}Tc-pertechnetate, ^{99m}Tc-oxidronate, ^{99m}Tc-medronate, and ^{99m}Tc-DMSA(V). Radioactive retention of less than 3% is in the range of our gravimetrically determined dead volume. That excludes an adsorption of these radiopharmaceuticals in the syringe and confirms published data (*8*). The undiluted preparation of ^{99m}Tc-butedronate showed a slightly higher retention rate of 3.6% in brand A, but this was considered insignificant ($P > 0.05$). The radioactive retention of various ^{99m}Tc-radiopharmaceuticals is summarized in Figure 1.

A significantly higher radioactive retention in the syringe ($P < 0.05$) was revealed with ^{99m}Tc-tetrofosmin and ^{99m}Tc-sestamibi, demonstrating actual adsorption in the syringes (*5*). Both brands showed a manifested adsorption of about 7% ^{99m}Tc-tetrofosmin for the undiluted preparation, with a tendency to decrease on dilution. In comparison, brand A has already been tested in a study (*5*) and found to result in

TABLE 2
Radioactive Retention of ^{99m}Tc-Radiopharmaceuticals in Syringes and Needles after 30 Minutes of Incubation

Radiopharmaceutical	Syringe brand	Retention in syringe (%)			Retention in needle (%) (undiluted)
		Undiluted	1:3 with saline	1:10 with saline	
^{99m}Tc-pertechnetate	A	1.3 ± 1.0	1.5 ± 0.8	4.8 ± 1.1	4.5 ± 1.1
	B	1.9 ± 0.3	1.1 ± 0.1	1.4 ± 1.0	2.9 ± 1.6
^{99m}Tc-butedronate	A	3.6 ± 0.6	2.1 ± 0.5	1.6 ± 0.8	4.3 ± 0.2
	B	2.6 ± 0.8	2.2 ± 0.3	2.1 ± 0.7	2.0 ± 0.4
^{99m}Tc-oxidronate	A	2.1 ± 1.8	2.8 ± 1.7	1.6 ± 0.8	2.9 ± 1.9
	B	1.8 ± 1.8	2.2 ± 0.2	2.3 ± 0.5	3.0 ± 1.3
^{99m}Tc-medronate	A	2.4 ± 0.3	1.4 ± 1.2	2.1 ± 2.3	3.9 ± 0.4
	B	1.7 ± 1.1	1.1 ± 0.6	1.8 ± 0.7	2.4 ± 0.5
^{99m}Tc-tetrofosmin	A	6.7 ± 0.8	5.9 ± 1.8	4.7 ± 1.8	6.7 ± 1.0
	B	6.0 ± 0.3	3.5 ± 0.8	3.8 ± 0.7	3.1 ± 0.4
^{99m}Tc-sestamibi	A	6.9 ± 3.6	7.3 ± 1.6	13.0 ± 2.5	5.2 ± 0.2
	B	3.3 ± 1.1	6.3 ± 0.8	9.0 ± 0.9	2.5 ± 0.2
^{99m}Tc-succimer	A	10.7 ± 1.4	9.8 ± 1.9	6.9 ± 0.2	13.9 ± 0.2
	B	13.9 ± 2.0	14.2 ± 1.1	19.5 ± 4.3	6.9 ± 0.2
^{99m}Tc-DMSA(V) pentavalent	A	1.8 ± 0.3	2.2 ± 0.2	2.1 ± 1.2	4.5 ± 0.9
	B	2.4 ± 0.3	2.4 ± 0.6	2.0 ± 0.5	1.7 ± 0.5

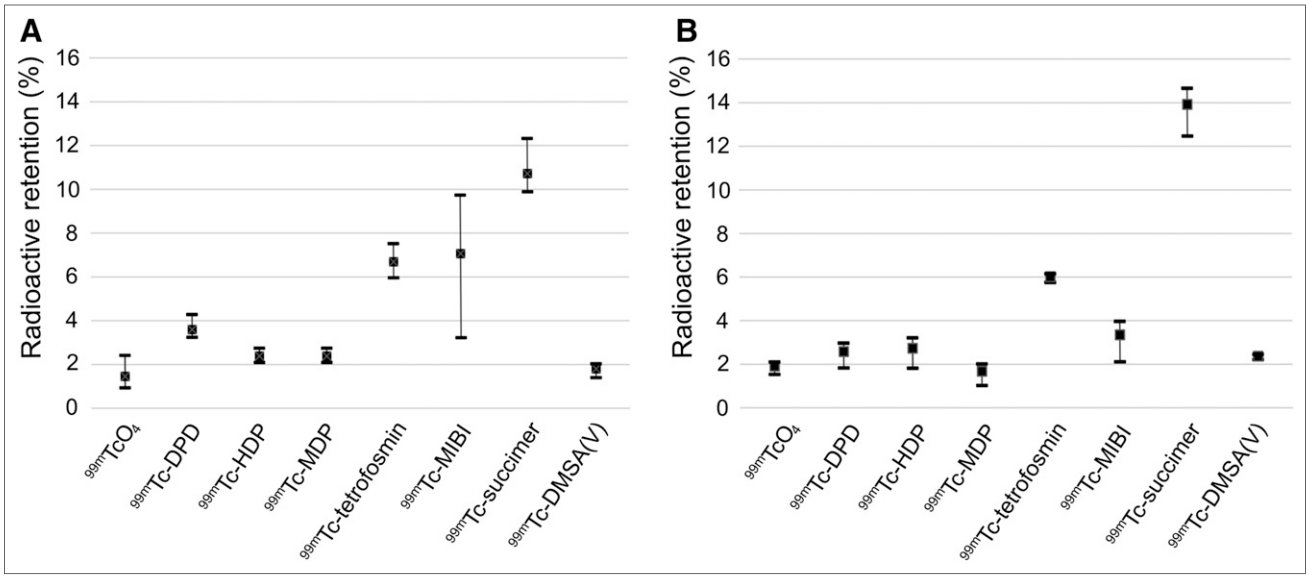

FIGURE 1. Radioactive retention of ^{99m}Tc-radiopharmaceuticals, prepared from kits according manufacturer instructions for different brands of syringes after 30 min of incubation time: brand A (A); brand B (B). DPD = butedronate; HDP = oxidronate; MDP = medronate; MIBI = sestamibi.

an adsorption of 12%. ^{99m}Tc-sestamibi is also known for potential adsorption onto syringes (*5,11*). In our assessment, the undiluted ^{99m}Tc-sestamibi showed a similar significant radioactive retention of 6.9% with brand A (silicone plunger seal), whereas for brand B (elastomer plunger seal) the retention of 3.3% was considered insignificant. Unlike ^{99m}Tc-tetrofosmin, ^{99m}Tc-sestamibi demonstrated in both brands a tendency toward rising adsorption when diluted. Compared with ^{99m}Tc-sestamibi, which was prepared according to the manufacturer's guidelines (undiluted test solution), the 1:10 dilution with saline exhibited a raised adsorption of 13.0% for brand A and 9.0% for brand B. Figure 2 shows the dependency between the concentration of sestamibi in the test solution and the adsorption of ^{99m}Tc-sestamibi in brand B as a result of our assessment.

Another ^{99m}Tc-radiopharmaceutical without a negligible adsorption effect onto syringes is ^{99m}Tc-succimer (*3,6*). Studies report radioactive syringe retention of 4% (*8*) to over 50% (*7*) for ^{99m}Tc-succimer. Using commercial kits (Renocis), our assessment revealed for brand A (silicone plunger seal) a radioactive adsorption of 10.7% and after a 1:10 dilution with saline only 6.9%. In contrast, the identical ^{99m}Tc-succimer test solution showed an adsorption of 13.9% for brand B (elastomer plunger seal), which increased to nearly 20% when the test solution was diluted 1:10 with saline. An overview of our assessment of ^{99m}Tc-radiopharmaceuticals prepared from commercially available kits testing brand A is depicted in Figure 1A. Figure 1B presents an overview of radioactive retention onto brand B.

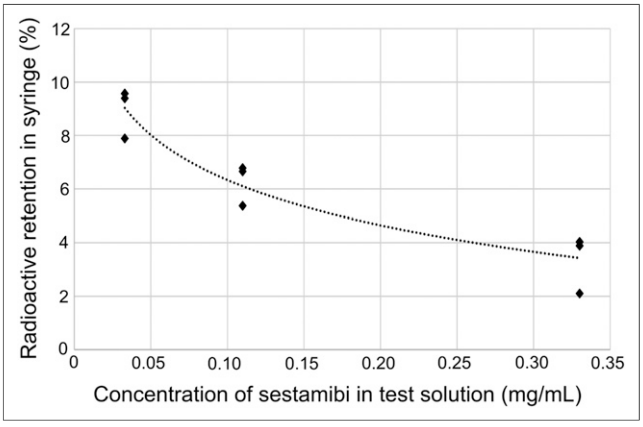

FIGURE 2. Radioactive retention: ^{99m}Tc-sestamibi in brand B syringes as function of sestamibi concentration.

In view of the results of the assessment with ^{99m}Tc-succimer, the tests were extended to other types of syringes. In addition to a retest of brands A and B, 4 further types of syringes were examined. Brand C contained an elastomer seal, and brand D (1 mL) was equipped with a rubber seal. Brands E and F (3 and 5 mL, respectively) were constructed as a 2-piece syringe and did not contain any sealing material at the plunger. All syringes were tested with an identical ^{99m}Tc-succimer solution, which was radiochemically prepared and contained—apart from ascorbic acid—no other excipient. The DMSA concentration (0.24 mg/mL) was scaled to the mass in a commercial kit. In Figure 3, the radioactive retention of ^{99m}Tc-succimer in brands A–F is depicted, demonstrating manifested differences between the syringes. Brands E and F (without plunger sealing) revealed a mean retention of less than 3%, which is about the syringe dead volume identified in our study. The retest of brand A resulted in a retention of 10.3%, corresponding to the retention of 10.7% that was determined in our assessment. Brands B–D, equipped with an elastomer or rubber plunger seal, showed a conspicuously higher radioactive adsorption (30.8%) than brand B (13.9%). This phenomenon may be related to the

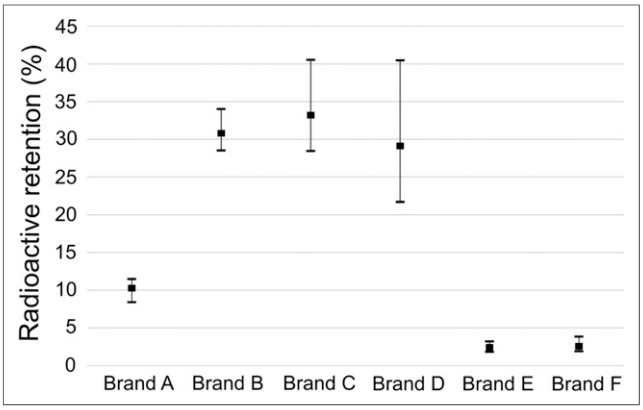

FIGURE 3. Radioactive retention of ^{99m}Tc-succimer, radiochemically prepared without inositol in different brands of syringes after 30 min of incubation time.

concentration of excipients, which are added as a supplement to a commercial kit. Figure 4 shows the radioactive retention of ^{99m}Tc-succimer in brand B (elastomer plunger seal) compared with the inositol concentration of the test solutions, which were prepared from a Renocis kit. Unexplainable differences in the syringe adsorption of ^{99m}Tc-succimer, depending on the kit composition, have already been published (*7*).

DISCUSSION

The phenomenon of adsorption of ^{99m}Tc-radiopharmaceuticals onto plastic syringes has been previously examined (*2–8*). Therefore, we established a procedure for the assessment of adsorption onto syringes under standardized conditions and tested a variety of ^{99m}Tc-radiopharmaceuticals. Compared with the specific dead volume of the syringes, we revealed that ^{99m}Tc-pertechnetate, ^{99m}Tc-phosphonates (medronate, oxidronate, and butedronate), and ^{99m}Tc-DMSA(V) have no significant syringe adsorption. We found a limited amount of radioactivity retention in the syringe (4%), where no syringe adsorption is indicated. In contrast, ^{99m}Tc-succimer, as well as the lipophilic compounds

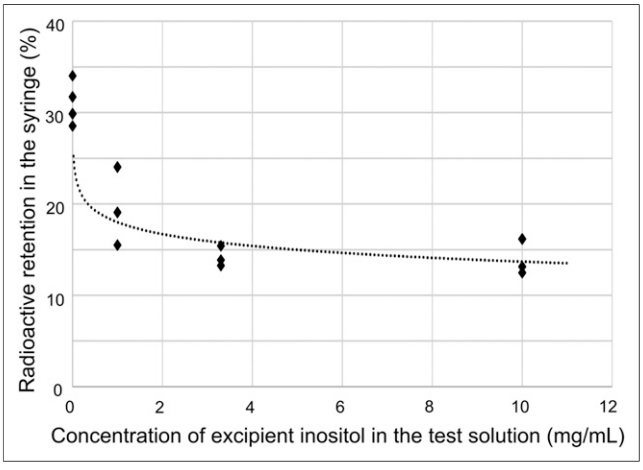

FIGURE 4. Radioactive retention: ^{99m}Tc-succimer in brand B syringes as function of concentration of excipient inositol.

^{99m}Tc-sestamibi and ^{99m}Tc-tetrofosmin, showed a trend to remain in the syringes.

Previous work defined a warning limit of 15% radioactivity retention in the syringe (*7*). For the assessment of our syringes used in routine application (brands A and B), we prepared the ^{99m}Tc-radiopharmaceuticals for the test from kits, strictly according the manufacturers' instructions, with special attention to the maximum liquid volume, to hold the specified concentration of precursor and excipients. None of the kit preparations of ^{99m}Tc-radiopharmaceuticals, performed in correspondence with the instructions, reached a mean retention of the warning limit. However, the outcome with ^{99m}Tc-succimer was nearly 15%.

Profound experiments showed the complexity of the syringe adsorption phenomenon. On the one hand, the phenomenon depends on the construction of the syringe and the sealing material of the plunger. In 2-piece syringes without plunger sealing (brands E and F) ^{99m}Tc-succimer displayed radioactive retention only within the range of the specific dead volume. Syringes with a 3-part design, with a plunger sealing, manifested mean radioactive ^{99m}Tc-succimer adsorption from 8% to 33% (Fig. 3). On the other hand, the ^{99m}Tc-succimer adsorption appeared to be dependent on the material of the seal. For brand A (silicone seal), we found adsorption of 8%, whereas for brand D (isoprene rubber seal), we determined the highest adsorption of the study to be 41%. Brands B and C (elastomer seal) also showed increased adsorption, in the range of 29%–41%. Such observations were also made in previous studies (*6,7*).

However, the dilution of the radiopharmaceutical seems to be an essential parameter in syringe retention as well. A ^{99m}Tc kit preparation contains both the precursor and the excipients. A dilution will decrease the concentration of these substances, and these may intensify the syringe adsorption. In our study, we found that ^{99m}Tc-succimer and a low concentration of the excipient inositol caused the adsorption to rapidly increase (Fig. 4). ^{99m}Tc-sestamibi presented similarly, with the adsorption increasing considerably after a saline dilution of the kit preparation (Fig. 2).

Therefore, a variety of factors influencing retention of radioactivity on a plastic syringe could be demonstrated in this work, resulting in poor image quality or the need for the study to have a prolonged exposure time. In extreme cases, the nuclear medical examination may not be suitable. On the one hand, the chemistry of the radiopharmaceutical is crucial to the adsorption. On the other hand, the materials used in the design of the syringe also have a substantial impact on this phenomenon. We found another essential parameter to be the composition of the radiopharmaceutical in terms of precursor and excipient concentration. Although ^{99m}Tc kits, prepared according to the manufacturers' instructions, consistently demonstrated a radioactive retention below the warning limit of 15%, the saline dilution of ^{99m}Tc kit preparations significantly increased syringe adsorption. Therefore, dilutions of ^{99m}Tc kits and in-house radiopharmaceuticals are to be observed.

CONCLUSION

The findings indicate that commercially available plastic syringes may be inappropriate for the administration of specific ^{99m}Tc-radiopharmaceuticals because of a high adsorption of the radiopharmaceutical onto the syringe. Under certain circumstances, the radiopharmaceuticals ^{99m}Tc-succimer, ^{99m}Tc-sestamibi, and ^{99m}Tc-tetrofosmin can reach a radioactive retention of up to 40% in the syringe. To investigate a possible adsorption effect, we introduced a protocol for a simple suitability test. The test syringe is filled one third with the radioactive test solution and incubated for 30 min at room temperature. Then, the test solution is emptied into an evacuated vial, and the retained radioactivity in the syringe is measured. This assessment protocol is recommended as a means to ensure quality before the introduction of new brands of plastic syringes for routine application or before application of a diluted radiopharmaceutical. The application of this simple adsorption test helps to ensure that the patient gets the optimal dose for a high-quality examination.

DISCLOSURE

No potential conflict of interest relevant to this article was reported.

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