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

Herbert Kvaternik[1], Jakob Gatterer[1], Elisabeth Plhak[1], Julia F. Schwarzgruber[1], Reingard M. Aigner[1]

[1]Department of Radiology, Division of Nuclear Medicine, Medical University of Graz

Corresponding author:

Herbert Kvaternik
Department of Radiology, Division of Nuclear Medicine
Medical University of Graz
Auenbruggerplatz 9
A-8036 Graz
Austria
T: +43 316 385 86348
F: +43 316 385 13266
M: herbert.kvaternik@klinikum-graz.at

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Abstract:

The phenomena of adsorption of several ^{99m}Tc-radiopharmaceuticals on disposable syringes is common knowledge and can reach a level of up to 50%, with the result of inadequate dosage. The resulting underdosage 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 instruction. For the assessment, the disposable syringes (n=3) were filled to one-third of the capacity with the ^{99m}Tc preparation and incubated for 30 min at room temperature. The syringes were withdrawn into evacuated vials. The radioactivity of the syringes was measured before and after withdrawal. Furthermore, the dilution effect of ^{99m}Tc-preparations was studied. We used two different brands of syringes and examined systematically ^{99m}Tc-pertechnetate, ^{99m}Tc-DPD, ^{99m}Tc-HDP, ^{99m}Tc-MDP, ^{99m}Tc-tetrofosmin, ^{99m}Tc-sestamibi, ^{99m}Tc-DMSA(V) and ^{99m}Tc-succimer. Additional, ^{99m}Tc-succimer was retested with five brands of syringes. **Results:** ^{99m}Tc-pertechnetate, ^{99m}Tc-phosphonates, and ^{99m}Tc-DMSA(V) showed no significant adsorption. The measured radioactive retention of 2-5% was equivalent to the determined death volume. Using ^{99m}Tc-tetrofosmin, we found a slight but significant adsorption of 4-7%. The ^{99m}Tc-sestamibi preparation showed a non-significant retention of 3-5%. However, when diluting the ^{99m}Tc-sestamibi 1:10 with saline, the adsorption rate increased to a value of 9-13%. ^{99m}Tc-succimer displayed different adsorption levels depending on the brand of the syringe and the preparation technique. The adsorption of ^{99m}Tc-succimer, prepared from kits according to the instructions, did not exceed 15%. The saline dilution 1:10 of a ^{99m}Tc-succimer kit preparation, as well as an in-house preparation, demonstrated a manifested radioactive syringe adsorption rate of more than 30%. **Conclusion:** The results revealed the significance of syringe adsorption of radiopharmaceuticals in the prevention of an under-

dosing. Therefore, an assessment is recommended as a quality assurance before the introduction of new brands of plastic syringes or routine application of diluted or in-house radiopharmaceuticals.

Introduction

Technetium-99m is still one of the predominant radionuclides used worldwide in nuclear medicine for scintigraphy. 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 plastic disposable syringes (1). Depending on the chemical properties of the radiopharmaceutical, adsorption on 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, which leads to a decrease in image quality and increases the risk of a possible misinterpretation of the results (2). Therefore, the underdosing of the radiopharmaceutical caused by adsorption effects impacts the quality of the examination, especially in children and adolescents (3).

Only a few studies have been published regarding adsorption and retardation effects of ^{99m}Tc-radiopharmaceuticals on disposable plastic syringes. Both lipophilic compounds ^{99m}Tc-sestamibi and ^{99m}Tc-tetrofosmin 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 works 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 method for a standard adsorption assessment to compare different plastic syringes with various radiopharmaceuticals under identical experimental condition. We tested ^{99m}Tc-radiopharmaceuticals like ^{99m}Tc-pertechnetate or ^{99m}Tc-diphosphonates, which are described as inconspicuous (8) and proved our concepts 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 assessment should clearly differentiate between dead space and a real 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, Otwock, Poland). In the in-vitro study we compared ^{99m}Tc-medronate (MDP), ^{99m}Tc-oxidronate (HDP), ^{99m}Tc-butedronate (DPD), ^{99m}Tc-sestamibi (MIBI), ^{99m}Tc-tetrofosmin, ^{99m}Tc-succimer (DMSA(III)) 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 manufacturer's instructions. For the preparation of ^{99m}Tc-DMSA(V), the lyophilized content of the commercial kit (RENOCIS) was dissolved with 0.5 mL 3.5% $NaHCO_3$ solution. ^{99m}Tc-DMSA(V) was formed at pH 7-8 after the addition of 3.5 ml ^{99m}Tc-pertechnetate (3.2 GBq, 85 mCi) (9). After 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 isopropanol/water/acetic acid 4/3/1 (v/v/v) as mobile the phase and evaluated by a TLC scanner (VCS-203, Veenstra Instrumenten BV, Joure, Netherlands). ^{99m}Tc-DMSA(V) migrates to the middle of the strip (R_f ~0.5) while ^{99m}Tc-DMSA(III) remains as an impurity at the start.

We tested the ^{99m}Tc-radiopharmaceuticals (Table 1) with two types of three-piece syringes: brand A (CODAN 1 mL tuberculin, CODAN Medical, Lahnsan, Germany) and brand B (3 mL Luer-

lock, Becton Dickinson & Co (BD), Heidelberg, Germany). 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 the 1 mL syringe with 0.3 mL and the 3 mL syringe with 1.0 mL test solution. The activity concentration of the ^{99m}Tc-radiopharmaceutical test solutions were 150 – 550 MBq/mL (5 – 15 mCi/mL), depending on specification of the commercial kit. The syringes were incubated for 30 min at room temperature. That simulates the maximum time between the filling of the syringe and the application to the patient at our nuclear medicine division. To examine the influence of a dilution on the syringe adsorption, we diluted the ^{99m}Tc-preparations to 1:3 and to 1:10 with saline (Fresenius, Graz, Austria) 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, Dresden, Germany). Then the syringe was emptied into a vacuum vial (TechneVial 11 mL, Mallinckrodt, Petten, NL) without rinsing. The activity of the emptied syringe including the needle, the activity of the needle 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 including the needle minus the activity reading of the needle. The residual activity was expressed in percentage. In the general study, each experiment was carried out in triplicate. From each experiment, we calculated the mean and the standard deviation (SD).

The dead space of the syringe brand A and brand B as well as the used needle (Sterican 0.9 x 70 mm (20G x 2 ¾“), B. Braun, Melsungen, Germany) was determined by weight. Five syringes of brand A and brand B including needle were filled with saline. The saline solution was withdrawn 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 six brands of syringes with ^{99m}Tc-DMSA(III), which has a high adsorption tendency. Syringe brand A contains a silicone-sealed plunger. Syringe brand B and brand C (5 mL Luer-lock, Becton Dickson & Co (BD), Heidelberg, Germany) includes an elastomer plunger seal. Syringe brand D (1 mL tuberculin, Henke-Sass-Wolf (HSW), Tuttlingen, Germany) consists of a nonlatex rubber seal. Brand E (2 mL [3 mL] NORM-JECT, HSW) and brand F (5 mL [6 mL] NORM-JECT, HSW) are two-piece syringes with no rubber seal at the plunger. For direct comparison, we used one large batch of ^{99m}Tc-DMSA(III) for all syringe tests. Therefore, 40 mL of ^{99m}Tc-DMSA(III) were chemically prepared (10). The ^{99m}Tc-DMSA(III) test solution should contain a DMSA concentration of > 0.2 mg/mL, equivalent to the commercial kit. 50 mg dimercaptosuccinic acid (Sigma-Aldrich) was dissolved in water at pH 4; then the solution was mixed with 50 mg ascorbic acid (Sigma-Aldrich) under continuous N_2 bubbling. Finally, the DMSA reagent solution (4 mg/mL) was adjusted to pH 2.8 by the addition of 1M HCl. For radiolabelling, 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 15 min reaction time the ^{99m}Tc-DMSA(III) test solution was diluted with saline to 40 mL. The radiochemical purity was determined by paper chromatography using ITLC-SG (Agilent) and MEK (Merck). In the extended study, we drew the ^{99m}Tc-DMSA(III) test solution (57 MBq/mL, 1.5 mCi/mL, 0.24 mg DMSA/mL) into the syringes brand A – F incubated for 30 min and assessed as described above. Each syringe brand was tested fivefold.

For statistical analysis, we applied the unpaired Student's *t*-test to calculate differences in the percentage of residual activity in the comparison of various ^{99m}Tc-radiopharmaceuticals and various brands of syringes. The value $P < 0.05$ was considered to be significant.

Results

The composition and the 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 to the individual specification.

By the gravimetric determination of the dead space in our assessment (n=5) we found a liquid retention in syringe brand A (1 mL CODAN) of 30 µL ± 15 µL and brand B (3 ml BD) of 41 µL ± 30 µL. In the needles 23 µL ± 5 µL of the liquid was retained. The mean residual liquid expressed in percent was with brand A 2.8% and with syringe brand B 3.4% respectively. Therefore, in our experimental setup, a measured residual liquid up to about 3% can be attributed to the dead space.

The radioactive adhesion of ^{99m}Tc-radiopharmaceuticals measured after 30 min incubation is depicted in Table 2. and shows the adhesion of the undiluted ^{99m}Tc-radiopharmaceutical preparation, as well as their 1: 3 and 1:10 dilution with saline onto two brands of syringes. Additionally, the adhesion of the undiluted ^{99m}Tc-radiopharmaceutical onto the needle is portrayed. We found a radioactive retention of < 3% in both brands with the undiluted preparations of ^{99m}Tc-pertechnetate, ^{99m}Tc-oxidronate (HDP), ^{99m}Tc-medronate (MDP) and ^{99m}Tc-DMSA(V). Radioactive retention of < 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 (DPD) showed a slightly higher retention rate of 3.6% in syringe brand A, but this was considered as not significant ($P > 0.05$). The radioactive retention of various ^{99m}Tc-radiopharmaceuticals is summarized in Figure 1.

A significant higher radioactive retention in the syringe ($P < 0.05$) was revealed with ^{99m}Tc-tetrofosmin and ^{99m}Tc-sestamibi, which demonstrates real adsorption in the syringes (5). Both syringe brands showed a manifested adsorption of about 7% ^{99m}Tc-tetrofosmin at the undiluted preparation with a tendency to decrease on dilution. In comparison, syringe brand A (CODAN) has already been tested in a study (5) resulting in an adsorption of 12%. ^{99m}Tc-sestamibi is also known for potential adsorption in syringes (5, 11). In our assessment the undiluted ^{99m}Tc-sestamibi showed a similar significant radioactive retention of 6.9% using brand A (silicone plunger seal) while in case of syringe brand B (BD, elastomer plunger seal) the retention of 3.3% was considered to be insignificant. Unlike ^{99m}Tc-tetrofosmin, ^{99m}Tc-sestamibi demonstrated in both syringe brands, a tendency of raising adsorption when diluted. Compared with ^{99m}Tc-sestamibi, which was prepared according to the kit manufacturer guideline (undiluted test solution), the 1:10 dilution with saline exhibits a raised adsorption of 13.0% (brand A, CODAN) and 9.0% (brand B, DB) respectively. Figure 2 shows the dependency between the concentration of sestamibi in the test solution and the adsorption of ^{99m}Tc-sestamibi in syringe brand B as a result of our assessment.

Another ^{99m}Tc-radiopharmaceutical with not negligible adsorption effect onto syringes is ^{99m}Tc-succimer (3,6). Studies report radioactive syringe retention with ^{99m}Tc-DMSA(III) from 4% (8) to over 50% (7). Using commercial kits (RENOCIS) our assessment revealed with syringe 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-DMSA(III) test solution showed an adsorption of 13.9% with

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 kit testing brand A (1 ml CODAN tuberculin syringe) is depicted in Figure 1A. Figure 1B presents the overview of the radioactive retention into syringe brand B (3 mL BD).

Based on the results of the assessment with ^{99m}Tc-succimer (^{99m}Tc-DMSA(III)), the tests were extended to other types of syringes. In addition to a retest of brand A and B, four further types of syringes were examined. Brand C (5 mL BD) contained, as brand D, an elastomer seal, and brand E (1 mL HSW tuberculin syringe) was equipped with a rubber seal. Brand F and G (3 mL and 5 mL HSW) were constructed as a two-piece syringe and did not contain a 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 the brands A to F is depicted, demonstrating manifested differences between the syringes. Brand E and F (without plunger sealing) revealed a mean retention of < 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 with the retention of 10.7%, which was determined in our assessment. Syringe brand B to D, equipped with elastomer or rubber plunger seal showed a conspicuous higher radioactive adsorption of 30.8% compared with the evaluation of syringe B (13.9%). The phenomenon may be related to the concentration of excipients, which are supplementary added to a commercial kit. Figure 4 shows the radioactive retention of ^{99m}Tc-succimer in syringe brand B (elastomer plunger seal) compared with the inositol concentration of the test solutions, which were prepared from a RENOCIS kit. It should be noted that unexplainable

differences in the syringe adsorption of ^{99m}Tc-succimer, depending on the kit composition has been already published (7).

Discussion

The phenomena of adsorption of ^{99m}Tc-radiopharmaceuticals into plastic syringes has been previously examined (2-8). Therefore, we established a test procedure for the assessment of the adsorption into syringes under standardized conditions and tested a variety of ^{99m}Tc-radiopharmaceuticals. Compared to the specific dead volume of the syringes, we revealed that ^{99m}Tc-pertechnetate, ^{99m}Tc-phosphonates (MDP, HDP, and DPD) but also ^{99m}Tc-DMSA(V) have no significant syringe adsorption. We found a limited amount of radioactivity retention in the syringe of < 4%, where no syringe adsorption is indicated. In contrast, ^{99m}Tc-succimer (^{99m}Tc-DMSA(III)), as well as the lipophilic compounds ^{99m}Tc-sestamibi and ^{99m}Tc-tetrofosmin showed a trend to remain in the syringes.

Previous work defined a warning limit with 15% radioactive retention into the syringe (7). For the assessment of our syringes, used in the routine application (brand A and B), we prepared the ^{99m}Tc-radiopharmaceuticals for the test from kits, strictly according the manufactures instruction, with special attention to the maximum liquid volume, to hold the specified concentration of precursor and excipients. All kit preparations of ^{99m}Tc-radiopharmaceuticals, carried out corresponding with the instructions, do not reach in mean the warning limit mentioned above. However, the outcome with ^{99m}Tc-succimer was nearly 15%.

Profound experiments showed the complexity of the syringe adsorption phenomena. On the one hand, it depends on the construction of the syringe and the sealing material of the plunger.

In two-piece syringes without plunger sealing (brand E and F) ^{99m}Tc-succimer displayed only radioactive retention in the range of the specific dead volume. Syringes with a three parts design, with a plunger sealing, manifested mean radioactive adsorption of ^{99m}Tc-succimer from 8% to 33% (Figure 3.) On the other hand, the ^{99m}Tc-succimer adsorption appears to be dependent on the material of the seal. In the tuberculin syringe brand A (CODAN, 1 mL, silicone seal) we found adsorption of 8%, while in the tuberculin syringe brand D (HSW, 1 mL, isoprene rubber seal) we determined the highest adsorption of the study with 41%. Syringes brand B and C (BD, elastomer seal) also showed increased adsorption in the range from 29% to 41%. Such observations were also made in previous studies (6,7).

However, the dilution of the radiopharmaceutical seems to be an essential parameter in the syringe retention as well. A ^{99m}Tc kit preparation contains both the precursor and 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, a rapidly increased adsorption (Figure 4). ^{99m}Tc-sestamibi presented similarly, where after a saline dilution of the kit preparation the adsorption increased considerably (Figure 2).

Therefore, a variety of factors influencing the retention of radioactivity into a plastic syringe could be demonstrated in this work; resulting in poor image quality or prolonged exposure time in the study. In extreme cases, the nuclear medical examination may be not suitable. On the one hand, the chemistry of the radiopharmaceutical is crucial for the adsorption. On the other hand, the materials used in the design of the syringe are also substantial for this phenomena. We found another essential parameter being the composition of the radiopharmaceutical in terms of precursor and excipient concentration. While ^{99m}Tc kits, prepared according to the manufactures instruction,

demonstrated a radioactive retention below the warning limit of 15% consistently, it showed 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

This study indicates that commercially available plastic syringes may be inappropriate for the administration of specific ^{99m}Tc-radiopharmaceuticals due to a high adsorption of the radiopharmaceutical into the syringe. Under certain circumstances, the radiopharmaceuticals ^{99m}Tc-succimer, ^{99m}Tc-sestamibi, and ^{99m}Tc-tetrofosmin can reach a radioactive retention into the syringe up to 40%. To investigate a possible adsorption effect, we introduced a test protocol for the assessment as a simple suitability test. The test syringe is filled to one-third with the radioactive test solution and incubated for 30 min at room temperature. Then the test solution is abandoned into an evacuated vial, and the retained radioactivity in the syringe is measured. This assessment protocol is recommended as quality assurance 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 make sure that the patient gets the optimal dose for a high-quality examination.

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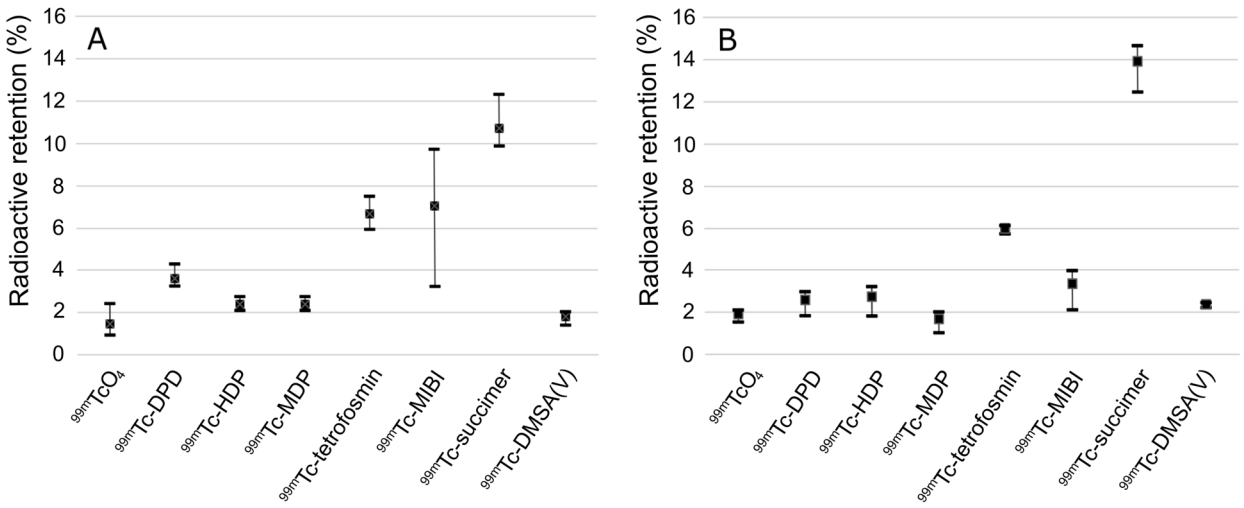

FIGURE 1. Radioactive retention of ^{99m}Tc-radiophramaceuticals, prepared from kits according manufacture instruction in different brands of syringes after 30 min incubation time; (A) 1 mL CODAN tuberculin syringe; (B) 3 mL syringe Becton Dickinson

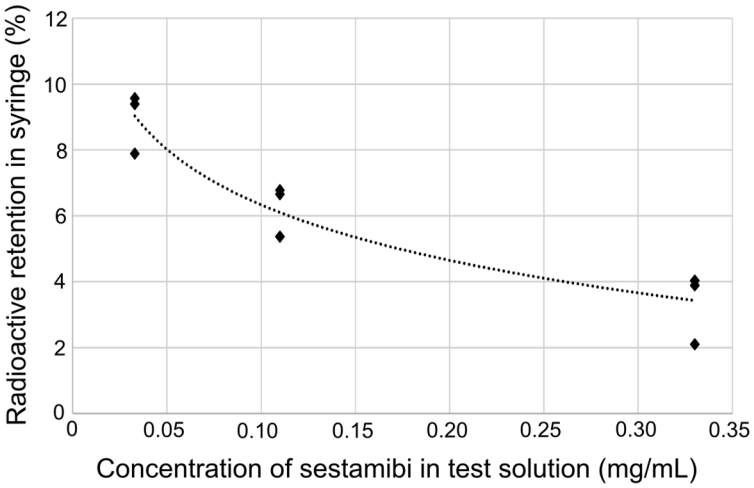

FIGURE 2. Radioactive retention: ^{99m}Tc-sestamibi in 3 mL Becton Dickinson syringes as function of the sestamibi concentration.

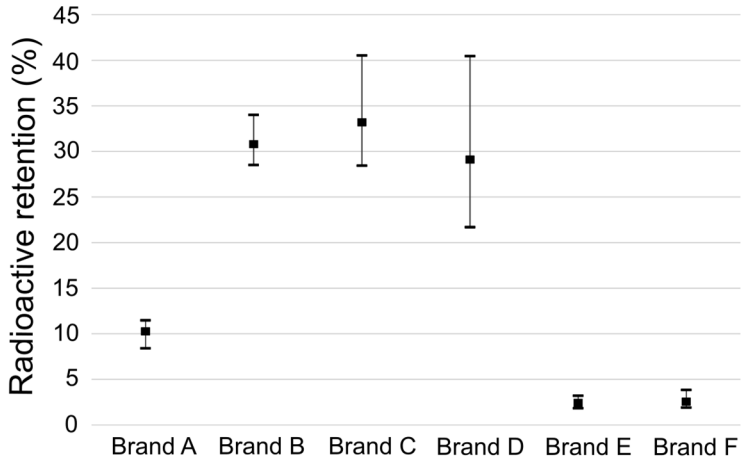

FIGURE 3. Radioactive retention of ^{99m}Tc-succimer, radiochemically prepared without inositol in different brands of syringes after 30 min incubation time; brand A: 1 mL CODAN tuberculin syringe; brand B and C: 3 mL and 5 mL syringe Becton Dickinson; brand D: 1 mL tuberculin syringe HSW; brand E and F: 3 mL and 5 mL 2-piece 'inert' syringe HSW.

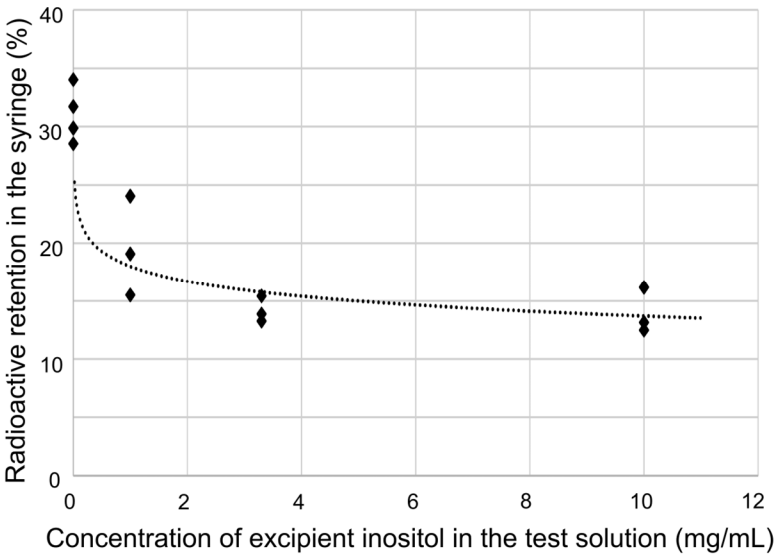

FIGURE 4. Radioactive retention: ^{99m}Tc-succimer in 3 mL Becton Dickinson syringes as function of the concentration of the excipient inositol.

TABLE 1

Formulation of the ^{99m}Tc-radiopharmaceutical kits

Radiopharmaceutical	Kit / Manufacturer	Ingredients		Reconstitution
^{99m}Tc-DPD	TECEOS	13 mg 3,3 diphospho-1,2-propanedi-	^{99m}Tc-TcO_4^-	2 - 10 mL
(^{99m}Tc-butedronate)	CIS Bio, Gif sur Yvette,	carboxylic acid, tetra sodium salt (DPD)		0.4 – 11.1 GBq (10 – 300 mCi)
	France	$SnCl_2.2H_2O$		5 min shaking, RT
		N-(4-aminobenzoyl)-L-glutamic acid	DPD	1.3 – 6.5 mg/mL
^{99m}Tc-HDP	Technescan HDP	3 mg Disodium-oxidronate (HDP)	^{99m}Tc-TcO_4^-	3 - 10 mL
(^{99m}Tc-oxidronate)	Mallinckrodt, Petten, NL	$SnCl_2.2H_2O$		1.5 – 11.1 GBq (40 – 300 mCi)
		Gentisinic acid,		0.5 min shaking, RT
		Sodium chloride	HDP	0.3 – 1.0 mg/mL
^{99m}Tc-MDP	MDP Tc-IK-10	5 mg Medronic acid (MDP)	^{99m}Tc-TcO_4^-	2 - 5 mL
(^{99m}Tc-medronate)	Izotop. Budapest,	$SnCl_2.2H_2O$		3 - 6 GBq (80 – 160 mCi)
	Hungary	Ascorbic acid		15 min incubation, RT
		Urea	MDP	1 – 2.5 mg/mL
^{99m}Tc-tetrofosmin	MYOVIEW,	0.23 mg Tetrofosmin	^{99m}Tc-TcO_4^-	4 - 8 mL
	GE Healthcare AS,	$SnCl_2.2H_2O$		< 8.8 GBq (< 240 mCi)
	Oslo, Norway	Disodium sulphosalicylate		15 min incubation, RT
		Sodium D-gluconate,	Tetrofosmin	0.03 – 0.06 mg/mL
		Sodium hydrogen carbonate		
^{99m}Tc-MIBI	STAMICIS	1 mg Tetrakis (2-methoxyisobutyl	^{99m}Tc-TcO_4^-	1 - 3 mL
(^{99m}Tc-sestamibi)	CIS Bio, Gif sur Yvette,	isonitrile) copper (I) tetrafluoroborate		0.2 - 11 GBq (5 – 290 mCi)
	France	$SnCl_2.2H_2O$		10 min incubation, 100°C
		Cysteine hydrochloride monohydrate	MIBI	0.33 – 1 mg/mL
		Sodium citrate, Mannitol		
^{99m}Tc-DMSA	RENOCIS	1 mg Dimercaptosuccinic acid	^{99m}Tc-TcO_4^-	1 - 6 mL
(^{99m}Tc-succimer)	CIS Bio, Gif sur Yvette,	$SnCl_2.2H_2O$		< 3.7 GBq (< 100 mCi)
	France	Ascorbic acid		5 – 10 min shaking, RT
		Inositol	DMSA	0.17 – 1 mg/mL

TABLE 2

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

		Retention in Syringe (%)			**Retention in Needle (%)**
Radiopharmaceutical	Syringe brand	undiluted	1:3 with Saline	1:10 with Saline	undiluted
^{99m}Tc-pertechnetat	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-DPD	A	3.6 ± 0.6	2.1 ± 0.5	1.6 ± 0.8	4.3 ± 0.2
(^{99m}Tc-butedronate)	B	2.6 ± 0.8	2.2 ± 0.3	2.1 ± 0.7	2.0 ± 0.4
^{99m}Tc-HDP	A	2.1 ± 1.8	2.8 ± 1.7	1.6 ± 0.8	2.9 ± 1.9
(^{99m}Tc-oxidronate)	B	1.8 ± 1.8	2.2 ± 0.2	2.3 ± 0.5	3.0 ± 1.3
^{99m}Tc-MDP	A	2.4 ± 0.3	1.4 ± 1.2	2.1 ± 2.3	3.9 ± 0.4
(^{99m}Tc-medronate)	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-MIBI	A	6.9 ± 3.6	7.3 ± 1.6	13.0 ± 2.5	5.2 ± 0.2
(^{99m}Tc-sestamibi)	B	3.3 ± 1.1	6.3 ± 0.8	9.0 ± 0.9	2.5 ± 0.2
^{99m}Tc-DMSA(III)	A	10.7 ± 1.4	9.8 ± 1.9	6.9 ± 0.2	13.9 ± 0.2
(^{99m}Tc-succimer)	B	13.9 ± 2.0	14.2 ± 1.1	19.5 ± 4.3	6.9 ± 0.2
^{99m}Tc-DMSA(V)	A	1.8 ± 0.3	2.2 ± 0.2	2.1 ± 1.2	4.5 ± 0.9
pentavalent	B	2.4 ± 0.3	2.4 ± 0.6	2.0 ± 0.5	1.7 ± 0.5