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COMPARATIVE STUDY OF THE ELUTION EFFICIENCY AND ELUTION PROFILE OF ^{99m}Tc IN GEL AND ALUMINA-BASED CHROMATOGRAPHIC ^{99}Mo/^{99m}Tc GENERATORS

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ABSTRACT

Fission ^{99}Mo is now routinely produced only in a few large production centers in the world and the short half-life of ^{99}Mo poses transportation and production problems. Adding to this point is the actual worldwide crisis of ^{99}Mo supply, so there is a strong need for developing alternative technologies for the production of ^{99}Mo/^{99m}Tc generators using ^{99}Mo produced by non-fission routes or for developing a suitable method for extending the life of the generator. The Radiopharmacy Center (CR) of the IPEN-CNEN/SP developed a gel type chromatographic generator of MoZr with ^{99}Mo produced by the ^{98}Mo(n, γ)^{99}Mo reaction that occurs at the IEA-R1m Nuclear Reactor. Systems of post-elution concentration were developed for the attainment of a high enough radioactive concentration for the gel generator. These systems of concentration are based in the technique of solid phase extraction (SPE) using commercial cartridges of extraction, and the saline solution (0.9% and 0.1%) or deionized water as eluents of the generators. The main objective of this work is to compare the efficiency of elution and the elution profile of both generators using the following solvents for the elutions: NaCl 0.9%, NaCl 0.1% and deionized water. The eluates will be further employed in the studies concerning the use of the systems of post-concentration of ^{99m}Tc developed for both the gel and the alumina-based chromatographic ^{99}Mo/^{99m}Tc generators.

1. INTRODUCTION

At the Radiopharmacy Center (RC) of IPEN-CNEN/SP there are two ways of producing ^{99}Mo/^{99m}Tc generators: from ^{99}Mo produced by the fission of uranium and imported from Canada and through the reaction ^{98}Mo(n, γ)^{99}Mo that occurs in IEA-R1 Nuclear Reactor (IPEN-CNEN/SP).

Fission ^{99}Mo is now routinely produced only in a few large production centers in the world and the short half-life of ^{99}Mo poses transportation and production problems. Adding to this point is the actual worldwide crisis of ^{99}Mo supply, so there is a strong need for developing alternative technologies for the production of ^{99}Mo/^{99m}Tc generators using ^{99}Mo produced by non-fission routes or for developing a suitable method for extending the life of the generator[1].

The latter employs the technique of gel elution of molybdate of zirconium to produce a gel type chromatographic generator of MoZr. Despite all efforts in the study of optimization of conditions for preparation of the MoZr gel, the radioactive concentration is lower compared to that of fission ^{99}Mo and the volume of elution is greater (12 mL) than the fission (6 mL). One way to increase the concentration of radioactive concentration is to use the post elution concentration of the initially low concentration ^{99m}Tc that provides sufficiently high concentration activity solutions for labeling procedures in radiopharmacy[2].

These systems of concentration are based in the technique of solid phase extraction (SPE) using commercial cartridges of extraction, and the saline solution (0.9% and 0.1%) or deionized water as eluents of the generators. The main objective of this work is to compare the efficiency of ^{99m}Tc and show the elution profile of both generators using the following solvents for the elutions: NaCl 0.9%, NaCl 0.1% and deionized water. The eluates will be further employed in the studies concerning the use of the systems of post-concentration of ^{99m}Tc developed for both the gel and the alumina-based chromatographic ^{99}Mo/^{99m}Tc generators.

2. MATERIAL AND METHODS

2.1. Preparation and Elution of Generators

The Zr^{99}Mo gel column generator [^{98}Mo(n,γ)^{99}Mo] was prepared using the pre-formed gel technology developed at IPEN. This pre-formed gel was then irradiated in the IEA-R1 Nuclear Reactor at a flux of 0.8~1.2 x 10^{13} n.cm^{-2}.s^{-1} for 2 hours. About 2g of gel of MoZr was placed into a glass column and then conditioned by washing with 50 mL of 0,9 % NaCl. At the beginning the ^{99}Mo activity in the column was measured using a HPGE detector and then calculated for the subsequent days using decay corrections. ^{99m}Tc was eluted with 12 mL of 0.9 % NaCl , 0.1 % NaCl and deionized water (DIW). The elution profile of ^{99m}Tc was determined by collecting 2 mL fractions of the eluate, the ^{99m}Tc and ^{99}Mo activities were measured using a HPGE detector and the elution efficiency calculated. The elution efficiency, defined as the fraction of the of ^{99m}Tc eluted and the theoretical amount available at the time of elution, expressed as percentage.

The alumina column chromatographic generator [^{235}U(n,f)^{99}Mo] of 74 GBq at reference time was obtained from the Radiopharmacy Center at IPEN-CNEN/SP. The useful life-time of a ^{99}Mo/^{99m}Tc generator made at IPEN is generally one week. ^{99m}Tc was eluted with 13 mL of 0.1 % NaCl, deionized water (DIW) and 6 mL of 0.9 % NaCl. The elution profile of ^{99m}Tc was determined by collecting 1 mL fractions of the eluate and the ^{99m}Tc and ^{99}Mo activities were measured in a pre-calibrated ion chamber dose calibrator. The elution efficiency was calculated in the same way as the gel.

2.2. Radionuclide Analyses and Quality Control of the Final Eluate

2.2.1. Radionuclide analyses

Radionuclide measurements were made using a calibrated Germanium hyperpure detector model GX1518 (HPGe) coupled to a multichannel analyzer system (Canberra Inc., USA). The radioisotope levels in all the samples were determined by the quantification of the following photopeaks: 140 keV (85%) for ^{99m}Tc and 740 keV (13%) for ^{99}Mo. The high activities of ^{99m}Tc and ^{99}Mo activity were also measured in a dose calibrator (CRC-10BC, CAPINTEC Inc., USA).

2.2.2. Radiochemical purity

The radiochemical purity of the ^{99m}Tc eluate was determined by paper chromatography using 1 CHR (Whatman International Ltd, UK) paper as solid phase and 0.9% saline as mobile phase. The Rf of $^{99m}TcO_4^-$ was 0.7~0.8 whereas $^{99m}TcO_2$ remained at the origin (Rf~0).

2.2.3. Chemical impurities

Zirconium, molybdenum and aluminum concentrations in ^{99m}Tc eluates were determined by Inductively Coupled Plasma – Optical Emission Spectrometry (ICP-OES).

2.2.4. ^{99}Mo breakthrough

^{99}Mo breakthrough was directly measured in the HPGe detector, as described in 2.2.1. Usually, a ^{99}Mo assay lead canister was used in these measurements using the dose calibrator.

2.2.5. Clarity and pH

The clarity was verified by visual inspection. The pH was measured through the color indicator pH paper (Merck KGaA, Germany).

3. RESULTS AND DISCUSSION

3.1. The Elution Profile and Efficiency

The elution radioactivity profile of the gel generator for the 3 solvents is shown in Fig. 1. The volume required to elute the ^{99m}Tc using 0.9 % NaCl and DIW was 10 mL and for 0.1 % NaCl near 12 mL.

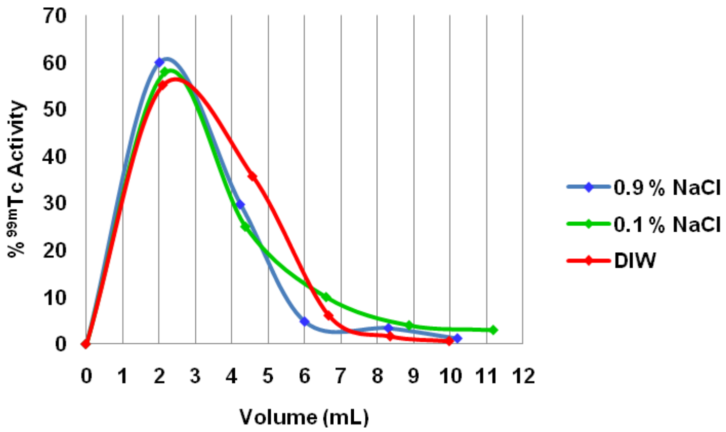

Figure 1. The elution profile of ^{99m}Tc from gel generator

Fig. 2 shows the elution profile of ^{99m}Tc from the alumina based generator eluted with 0.9% NaCl and 0.1% NaCl. The ^{99m}Tc could not be eluted from the generator by DIW. The volume required to elute ^{99m}Tc for the 0.9 % NaCl was 6 mL and for 0.1% NaCl was 13 mL.

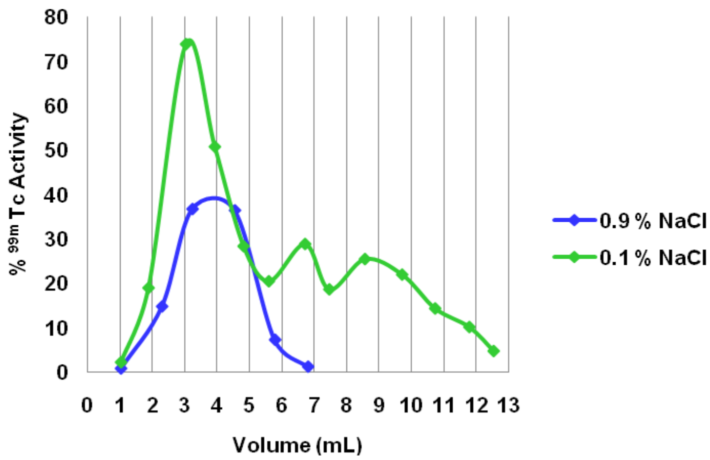

Figure 2. The elution profile of ^{99m}Tc from alumina generator

The elution efficiency for the gel generator is shown in Table 1 together with the ^{99}Mo breakthrough. The elution efficiency is low due to the radiolysis and temperature effects during the irradiation in the reactor. These conditions can lead to changes in the gel structure and also to a high number and level of impurities [3].

Table 1. Elution characteristics of gel generator

Eluent	Elution	Volume (mL)	Elution Efficiency (%)	^{99}Mo breakthrough (%)
0.9 %	I	10	19	4.1
0.1 %	I	12	21	3.2
DIW	I	10	22	8.1

The results of the elution efficiency for the alumina generator is shown in Table 2 together with the ^{99}Mo breakthrough. The elution efficiencies, measured daily on the second week of use, ranged between 98~100 % for the generator eluted with 0.1 % NaCl and higher than 103 % with 0.9% NaCl.

Table 2. Elution characteristics of the alumina generator (second week generator)

Eluent	Elution	Volume (mL)	Elution Efficiency (%)	^{99}Mo breakthrough (%)
0.9 %	I	6.0	103	$2 X 10^{-4}$
	II	6.0	107	$2 X 10^{-4}$
	III	6.0	111	<dl
	IV	6.0	108	$4 X 10^{-4}$
	V	6.8	107	<dl
0.1 %	I	12.6	99	<dl
	II	13.4	100	$2 X 10^{-4}$
	III	13.3	99	$5 X 10^{-4}$
	IV	12.9	100	$1 X 10^{-4}$
	V	13.7	98	$8 X 10^{-4}$

<dl – lower than detection limit

3.2. Quality Control of Pertechnetate

All ^{99m}Tc eluates were found clear and with pH between 4 and 6, as expected. The radiochemical purity of $^{99m}TcO_4^-$ was > 95% for all the samples. Table 3 shows the results of the chemical purity of ^{99m}Tc eluted from both generators.

Table 3. Chemical purity of ^{99m}Tc eluate

Generator Type	Eluent	Mo (ppm)	Al (ppm)	Zr (ppm)
Alumina Generator	0.9 % NaCl	0.27	<dl	<dl
	0.1 % NaCl	<dl	<dl	<dl
	DIW	<dl	<dl	<dl
$Zr^{99}Mo$ Gel	0.9 % NaCl	136	<dl	0.46
	0.1 % NaCl	440	<dl	4.17
	DIW	450	<dl	4.08
Limits[4,5]	0.9 % NaCl	*	< 10	< 5

<dl – lower than detection limit
*No limit stated literature

The chemical purity of ^{99m}Tc was according to the limits for the alumina generator, but the high levels of Mo for the gel generator is due to the irradiation conditions and also to the fact that the gel had no size uniformity so that fine particles could be eluted with ^{99m}Tc.

4. CONCLUSIONS

The results from this work show that the gel generator can be eluted with all 3 solvents whereas the alumina generator can only be eluted with saline solutions. These conditions open up the way to develop concentration systems for the gel generator and for the second week use of the alumina generator.

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