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Comparison of the Absorbed Dose for ^{99m}Tc-Diethylenetriaminepentaacetic Acid and ^{99m}Tc-Ethylenedicysteine Radiopharmaceuticals using Medical Internal Radiation Dosimetry

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ABSTRACT

The aim of this study was the investigation of absorbed dose to the kidneys, spleen, and liver during technetium-99 m ethylene dicysteine and technetium-99 m diethylenetriaminepentaacetic acid (^{99m}Tc-EC and ^{99m}Tc-DTPA) kidney scan. Patients who had been prepared for the kidney scan, were divided into two groups (Groups 1 and 2). The first group (Group 1) and the second group (Group 2) received intravenous injection of ^{99m}Tc-EC and ^{99m}Tc-DTP, respectively. A certain amount of radiopharmaceuticals was injected into each patient and was immediately imaged with dual-head gamma camera to calculate the activity through the conjugated view method. Then, the doses of kidney, liver, and spleen were measured using medical internal radiation dosimetry method. Finally, absorbed dose of these organs was compared. Based on these different results ($P < 0.05$), organs absorbed dose was significantly less with radiopharmaceutical ^{99m}Tc-EC as compared with ^{99m}Tc-DTPA.

Key words: *Absorbed dose, conjugate view method, cumulated activity, medical internal radiation dosimetry*

INTRODUCTION

Radionuclide imaging relies on tracer principles. In such images, the amount of radiopharmaceutical measured during the *in vivo* condition that is used to assess physiological performances of the body.[1] The nuclear medicine is important because helps physicians diagnose the disease earlier to make the treatment. The image is created by entrance of radionuclide into the body, emission of radiation inside the body, and detection of radiation outside the body.[2,3] Studies to investigate the appropriate radiopharmaceutical for kidney scan have been started since 1996. The role of technetium-99 m (^{99m}Tc) has well-established in nuclear medicine. Due to the emission of gamma rays with energy of 140 keV and half-life of 6 h, technetium is widely used in nuclear medicine centers. Technetium is also used with the different radiopharmaceutical for imaging the kidneys. Therefore, the given widespread use of radioactive substances and their possible risks, measurement of the absorbed dose of organs is a useful approach for the assessment of profit and risk of any method.[4] It should be noted that absorbed dose to organs after injection of the radiopharmaceutical is critical. Studies with these radiopharmaceuticals in nuclear medicine showed significant challenges. In this study, we investigated into two radiopharmaceuticals (^{99m}Tc ethylene dicysteine [^{99m}Tc-EC] and ^{99m}Tc-diethylen etriaminepentaacetic acid [^{99m}Tc-DTPA]) used for kidney scan in nuclear medicine. They play an important role in diagnosis and treatment of renal diseases. ^{99m}Tc-EC is an ethylene cysteine dimer metabolite whose carbon glycine chain plays a critical role in legating to kidney proteins.[5] ^{99m}Tc-DTPA is another radiopharmaceutical used in this study. This is used for examining kidneys and urinal system perfusion and imaging.[6] It should be noted that several problems are associated with the use of radioactive substances, including contamination of human and the environment.[7] Therefore, in this study absorbed a dose of kidneys, spleen, and liver during kidney scan was calculated for both ^{99m}Tc-EC and ^{99m}Tc-DTPA radiopharmaceuticals using medical internal radiation dosimetry (MIRD) method. The MIRD method is one of the most reliable dosimetry techniques used in the nuclear medicine.[8]

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MATERIALS AND METHODS

Patient Population

This study was carried out on 30 patients that they have been referred to the Department of Nuclear Medicine, Chamran Hospital, Isfahan, Iran. They had to be at least 18 years old. All of them were informed of the experiment and signed a form to reveal their agreement. They were divided into two groups (Groups 1 and 2), and underwent kidney scan using ^{99m}Tc-EC and ^{99m}Tc-DTPA radiopharmaceuticals. The first group (Group 1) and the second group (Group 2) received an intravenous injection of ^{99m}Tc-EC and ^{99m}Tc-DTPA, respectively.

Radiopharmaceutical Preparation

In this study, the radiopharmaceutical dose was measured using a dose calibrator, to ensure dose validity. EC and DTPA were labeled with the ^{99m}Tc.[9]

Study Design

In preparation for kidney scan, a dual-head γ-camera was calibrated on 140 keV photo peak with ±20% window width for ^{99m}Tc which was used.[10] Gamma camera was calibrated for both of the radiopharmaceuticals used in this study. A calibration procedure was performed by an expert technician at the department to reassure validity of gamma photo peak and window width. The scanning is carried out for both groups in the same way. To this end, collimators were placed in a proper distance from the patient, and imaging was started after the injection. A kidney scan from each patient was acquired using γ-camera at various times after injection of the radiopharmaceutical.

Absorbed Dose Calculation

Scintigraphy, serial planar images of patients were obtained using a dual-head γ-camera equipped with a low energy high resolution (LEHR) collimator. Organ absorbed dose was obtained conjugate (anterior and posterior) counts of organs in these images. Each imaging was obtained using a photo peak of 140 keV, a ±20% window and a 64 × 64 × 16 matrix. All images were reviewed by one physician and nuclear medicine expert that was aware of patients, considering the conjugate view method. The following equation was used for calculating organ activity (Eq. 1):[11-13]

$$A = \sqrt{\frac{I_A \times I_P}{e^{-\mu_e \times t}}} \times \frac{f}{C} \quad (1)$$

Where I_A and I_p are the number of counts for anterior and posterior views, respectively. They are count's organs (kidneys, spleen, and liver) region of interest for the anterior and posterior views. I_A and I_p are background corrected count rate, that are obtained through the following equation (Eq. 2):[14]

$$I_A = I_{ROI\ source} - I_{ROI\ background} \times S_{source}$$

$$I_P = I_{ROI\ source} - I_{ROI\ background} \times S_{source} \quad (2)$$

Where t is body thickness across each organ (kidneys, spleen and liver). It is obtained using γ-camera software and lateral image, body thickness is computed for each organ in anatomic area.[15,16] The following image was indicated [Figure 1]:

Where μ_e is called the linear attenuation coefficient that values of the linear attenuation coefficient is 0.12 cm^{-1}[17-20] based on the MIRD committee recommendation, dispersion correction is not required. This is due to reduced dispersed ray using LEHR collimator that no correction is needed.[21] Where C is the camera calibration factor that was obtained by a certain amount of radiopharmaceutical activity for the fixed period with the same imaging condition in the air with the same camera,[22-25] and f was (μ_j t/2)/sinh (μ_j t/2), and represents a correction factor for source attenuation coefficient (μ_j) and source thickness (t).[22,26,27]

Absorbed Dose

After the computation of activity for organs (kidneys, spleen, and liver) at various times (2, 30, 60, 180 min) activity curve was drawn for each organ and also for each patient. Then, using the curve-fitting method, cumulated activity value was computed. Based on the MIRD scheme, organs (kidneys, spleen, and liver) absorbed dose was obtained through the following equation (Eq. 3):

$$D \approx A_0 \times \tau_h \times \frac{\Delta}{m} \quad (3)$$

Where A_0 is administration of radiopharmaceuticals (Group 1 is 10 mCi and Group 2 is 15 mCi), Δ is the

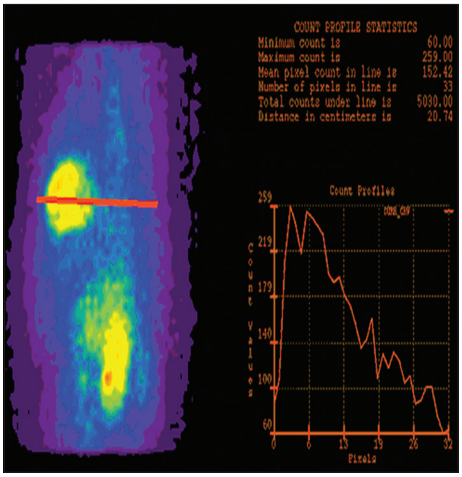

Figure 1: Body thickness is computed in anatomic area

equilibrium dose constant with the amount of 0.0332 (rad.g/μCi.h),[28] m is the organ mass, and τ is organ residence time which was calculated through the following equation (Eq. 4):

$$\tau_h = \frac{A_h}{A_0} \quad (4)$$

Where A_h is cumulated activity and A_0 is administration of radiopharmaceuticals.

Statistical Analysis

At the end, the dose was computed for each individual in each group using the above mentioned formula. Results were analyzed using SPSS version 14 software (SPSS, Inc., Chicago, IL, USA). The normality of data distribution was examined using one-sample Kolmogorov–Smirnov test. Moreover, two groups were compared using *t*-test in terms of the calculated dose. And the whole results were described as the mean ± standard deviation (SD).

RESULT

Time-Activity Curve

Group 1

Figure 2 shows a box plot of mean organ activity for each organ at various times (2, 30, 60, 180 min) after injection of the ^{99m}Tc-EC.

Table 1 shows values of mean activity ± SD in kidney, spleen, and liver at various times (2, 30, 60, 180 min).

Group 2

Figure 3 shows a box plot of mean organ activity for each organ at various times (2, 30, 60, 180 min) after injection of the ^{99m}Tc-DTPA.

Table 2 shows values of mean activity ± SD in kidney, spleen, and liver at various times (2, 30, 60, 180 min).

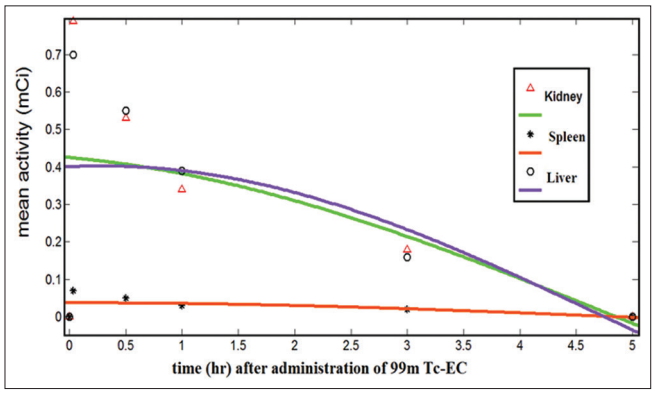

Figure 2: Organ time-activity curve at various times after injection of 10 mCi ^{99m}Tc-ethylenedicysteine

Organ Cumulated Activity

Table 3 gives the calculated cumulated activity and comparison of the results using a *t*-test for both ^{99m}tc-ec and ^{99m}Tc-DTPA radiopharmaceuticals. There was a significant difference cumulated activity in the organ during the 3 h after injection of the radiopharmaceuticals between the two groups (Group 1 and Group 2). The results indicate that ^{99m}Tc-EC is useful as radiopharmaceuticals for kidney scan. Because the amount of cumulated activity is lower than Group 2.

Organ Absorbed Dose

Table 4 gives absorbed dose and the results of comparison using a *t*-test for both radiopharmaceuticals. There was a significant difference is organ absorbed dose during 3 h after injection of the radiopharmaceuticals between two groups.

DISCUSSION

The cumulated activity ± SD of the organs (kidneys, spleen, and liver) in Group 1 were (1.17 ± 0.06, 0.12 ± 0.021

Table 1: Results are mean activity after administration of ^{99m}Tc-EC

Time (min)	Kidney	Spleen	Liver
2	0.79±0.09	0.07±0.00	0.7±0.05
30	0.53±0.06	0.05±0.02	0.55±0.08
60	0.34±0.04	0.03±0.01	0.39±0.03
180	0.18±0.02	0.02±0.00	0.16±0.03

Results are mean mCi±SD. SD – Standard deviation; ^{99m}Tc-EC – ^{99m}Tc-Ethylenedicysteine

Table 2: Results are mean activity after administration of ^{99m}Tc-DTPA

Time (min)	Kidney	Spleen	Liver
2	3.04±0.34	0.40±0.05	3.68±0.28
30	2.03±0.23	0.30±0.04	2.90±0.38
60	1.15±0.21	0.18±0.05	1.58±0.27
180	0.68±0.08	0.09±0.02	0.92±0.16

Results are mean mCi±SD. SD – Standard deviation; ^{99m}Tc-DTPA – ^{99m}Tc-Diethylenetriaminepentaacetic Acid

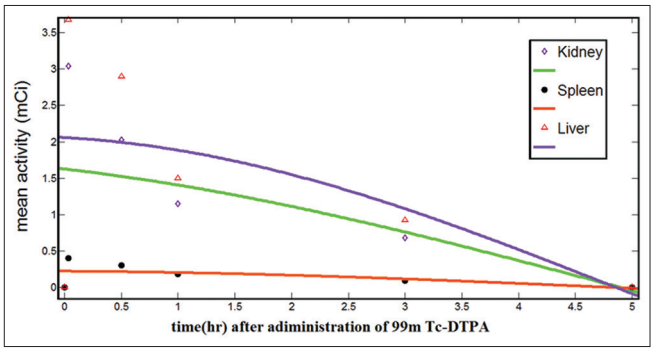

Figure 3: Organ the time-activity curve at various times after injection of 10 mCi ^{99m}Tc-Diethylenetriaminepentaacetic Acid

Table 3: The cumulated activity and the results of comparison using *t*-test

	Group 1	Group 2	*P*
Kidneys	1.17±0.06	4.12±0.50	0.000
Spleen	0.12±0.02	0.63±0.12	0.000
Liver	1.21±0.13	5.65±0.96	0.001

Results are mean mCi.h±SD. SD – Standard deviation

Table 4: The calculated absorbed doses and comparison of the results using *t*-test

	Group 1	Group 2	*P*
Kidneys	13±0.66	31±3.35	0.000
Spleen	2.2±0.38	7.7±1.53	0.002
Liver	2.1±0.24	6.8±0.85	0.003

Results are mean mrad/mCi ±SD. SD – Standard deviation

and 1.21 ± 0.13 mCi.h, respectively) and in Group 2 (4.12 ± 0.50, 0.63 ± 0.12 and 5.65 ± 0.96 mCi.h, respectively). The results of the present study indicated that the accumulation of activity in the organs was significantly lower in Group 1 than Group 2. Since, the manufacturer of radiopharmaceuticals ^{99m}Tc-EC and ^{99m}Tc-DTPA reported that the maximum accumulation of the radiopharmaceuticals to be occurred in the first few minutes after injection. Their activities were studied at the various times for each organ (kidney, spleen, and liver). In both Groups 1 and 2, the activity decreased with time and the maximum accumulation of the radiopharmaceuticals was seen in the first few minutes after their administration. The results of this study had a good consistency with the data reported in the radiopharmaceutical brochure. The absorbed dose in Group 1 for the prescribed ^{99m}Tc-EC radiopharmaceutical in mGy/MBq for people of all ages was reported in ICRP-106 in October 2007 as the absorbed dose per unit of administered activity. In this report, the doses reached to the organs (kidney, spleen, and liver) were (3.40×10^{-3}, 5.00×10^{-4} and 4.50×10^{-4} μGy/MBq, respectively),[29] the values obtained in our study in Group 1 were (3.51×10^{-3}, 5.90×10^{-4} and 5.60×10^{-4} μGy/MBq, respectively). About Group 2, Stabin *et al*. reported the amount of absorbed dose per unit of administered activity. According to this report, the doses reached to organs (kidneys, liver, and spleen) in mGy/MBq were (5.70×10^{-3}, 1.90×10^{-3} and 1.80×10^{-3}, respectively).[30] The values obtained in our study were (8.37×10^{-3}, 1.83×10^{-3} and 2.08×10^{-3}, respectively). The difference in this result obtained in Groups 1 and 2 in the present study with those reported by ICRP and Stabin may be arisen from possible error in calculation of calibration factor, calculation of linear attenuation coefficient, and the thickness of the organ. In general, since the dose of the administrated radiopharmaceutical reached to the patients' organ was lower in Group 1 than in Group 2, there were statistical differences between the two groups in organs (kidneys, spleen, and liver). Finally, given the lower doses received by the patients in Group 1, and negligible liver uptake in comparison with Group 2. For performing kidney scan in nuclear medicine centers, radiopharmaceuticals ^{99m}Tc-EC and ^{99m}Tc-DTPA can replace each other except when the measurement of glomerular filtration is required. In this study, we concluded that the absorbed dose of the organ studied was significantly less in radiopharmaceuticals ^{99m}Tc-EC than ^{99m}Tc-DTPA. The reports by Stabin and ICRP are consistent with our study and shows a lower dose for radiopharmaceuticals ^{99m}Tc-EC.[29,30] This can be concluded according to the lower dose of organs in scanning with radiopharmaceuticals ^{99m}Tc-EC, and therefore it is more appropriate for use in nuclear medicine centers.

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