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A Dosimetrist Performance Analysis on the Dosimetry of 177Lu-DOTATATE Radionuclide Treatment

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ABSTRACT

Purpose: The accuracy of the peptide receptor radionuclide therapy (PRRT) dosimetric procedure depends on the dosimetrist's personal skills in the step of determining the accumulated activity in the relevant organ. The detection of activity involvement is done manually by the dosimetrist using a mouse on SPECT images. Creating custom ROIs may create differences in dosimetric calculations. The purpose of this study is to investigate the effect of dosimetrist performance on critical organ dose calculations in PRRT.

Methodology: To assess the biodistribution of the radiopharmaceutical and calculate organ-specific activity, serial SPECT/CT imaging was performed at 4, 24, 48, and 96 hours post-administration. Bu using SPECT images, VOIs counts were separately determined by using ROIs on the relevant organ created by 3 independent dosimetrist. Statistical tests were applied to the counts to determine whether there was a significant difference between the counts detected by the 3 independent dosimetrists. The ANOVA test is an analysis of variance method used to determine whether there is a statistically significant difference between the means of three or more groups.

Findings and Conclusion: In the Anova test, if $p < 0.05$, there is a statistically significant difference between the groups. If $p \geq 0.05$, there is no significant difference between the groups, the observed differences may be due to chance criteria were taken into account. We conducted a statistical evaluation (ANOVA Test) between the counts determined by three different dosimetrists, and no significant difference was observed between their results.

Keywords: *Lu-177, Dosimetry, Dosimetrist Performance, Radionuclide Treatment*

INTRODUCTION

Neuroendocrine tumors (NETs) are rare but heterogeneous neoplasms that most commonly arise in the stomach, pancreas, lungs, and intestines, although they may also originate in organs such as the ovaries and testes. Their incidence is higher in men and tends to increase with age. While NETs often display an indolent course, some cases may present with aggressive clinical behavior. In recent years, peptide receptor radionuclide therapy (PRRT) has become an effective option for patients with metastatic NETs, providing both prolonged survival and improved quality of life. The primary goal of radionuclide therapy is to maximize the absorbed dose to tumor tissue while minimizing radiation exposure to normal organs. Optimal therapeutic efficacy is achieved when critical organs receive radiation doses below their established tolerance limits [1].

Lutetium-177 (Lu-177) is a medium-energy beta emitter (maximum energy 498 keV) with a physical half-life of 6,7 days. It also emits two gamma photons at 208 keV (11%) and 113 keV (6.4%), making it suitable for both therapy and imaging within the same treatment protocol, thereby facilitating patient-specific dosimetry. Among radiopharmaceuticals, Lu-177-DOTATATE is the most widely used agent in PRRT, owing to its high affinity for somatostatin receptor subtype 2 expressed in both primary and metastatic NET lesions. However, due to its pharmacokinetics, Lu-177-DOTATATE also accumulates in non-target tissues, with kidneys and bone marrow considered the main dose-limiting organs [2].

The absorbed doses of these critical organs are decisive for determining the number of treatment cycles, the interval between them, and the amount of administered radiopharmaceutical in each session. Typically, PRRT is delivered in four cycles at intervals of 6–8 weeks. Since interpatient variability can significantly influence organ kinetics, the integration of individualized dosimetric approaches into treatment planning has become increasingly important. Such personalization allows for optimization of therapeutic efficacy while avoiding unnecessary toxicities [3].

Due to the side effects of radiation, accurate dosimetric calculation is extremely important. The accuracy of the PRRT dosimetric procedure also depends on the dosimetrist's personal skills in the step of determining the accumulated activity in the relevant organ. The detection of activity involvement is done manually by the dosimetrist using a mouse on SPECT images. Creating custom ROIs may create differences in dosimetric calculations. Although there are studies in the literature on the consistency of different software platforms [4], there is no study examining the differences between dosimetrists' ROI drawings. The purpose of this study is to investigate the effect of dosimetrist performance on critical organ dose calculations in PRRT.

MATERIAL AND METHODS

Patient Population

This study included 20 NET patients (6 female and 14 male) who were treated in our clinic with Lu-177-DOTATATE between 2017 and 2021. Patient data were evaluated retrospectively. The average age of the patients are 58. Ethical Approval Ethics committee approval was obtained from the Ethics Committee of Istanbul University, Istanbul Medical Faculty (permission no. 2023/2219.

Treatment Procedure

Eligibility for PRRT was determined based on clinical evaluation, laboratory tests, and Ga-68-DOTATATE PET/CT imaging. Patients showing high tracer uptake in tumor lesions were considered suitable candidates. To reduce renal radiation exposure, amino acid infusion was started 3 hours prior to radionuclide administration and continued for 30 minutes after completion. Each patient received an initial dose of approximately 200 mCi (7,4 GBq) of Lu-177-DOTATATE intravenously, infused over 30 minutes.

Dosimetric Method (MIRD)

In this study, dosimetric calculations were made using the medical internal radionuclide dose (MIRD) method. Whole body and SPECT-CT images of patients were performed with a gamma camera, equipped with a CT scanner (GE Discovery NM670; General Electric Healthcare, Waukesha, WI) after each treatment to calculate the radiation dose absorbed by the critical organs. With the help of the gamma camera images obtained, the amount of activity accumulated in the organs was calculated. Counts collected in organs were converted to Activity using the Count-to-Activity conversion factor [3]. The activity accumulated in organs over 96 hours was then converted to Absorbed Dose (Gray) using the MIRD formalism [5].

Determination of Organ Activity Using SPECT images

The primary objective of this study was to evaluate the impact of the dosimetrist on organ activity quantification. To assess the biodistribution of the radiopharmaceutical and calculate organ-specific activity, serial SPECT/CT imaging was performed at 4, 24, 48, and 96 hours post-administration, following the protocol described by Sandström et al. [6]. All acquisitions were carried out using a medium-energy general-purpose collimator, with a 20% energy window centered on the 208 keV photopeak. SPECT data were obtained in a 128 × 128 matrix with 360° rotation, six angular steps, and 20 seconds per projection. Simultaneously, low-dose CT scans were acquired for anatomical localization. Attenuation correction was applied to the SPECT data using the CT images, and volumes of interest (VOIs) for relevant organs were delineated manually.VOIs counts were separately determined by using ROIs on the relevant organ created by 3 independent dosimetrist. As an example, for Right Kidney ROIs drawn by 3 Dosimetrist, Figure 1 was given. In addition, as an example of organ activity counts obtained from SPECT images, the Right Kidney, Left Kidney and Liver counts obtained from the SPECT images of Day 1 (4. Hours) were given separately in Tables 1, 2, 3 in the Results Section.

Statistical Analysis

Statistical tests were applied to the counts to determine whether there was a significant difference between the counts detected by the 3 independent dosimetrists. The ANOVA test is an analysis of variance method used to determine whether there is a statistically significant difference between the means of three or more groups. In the Anova test, if $p < 0.05$, there is a statistically significant difference between the groups. If $p \geq 0.05$, there is no significant difference between the groups, the observed differences may be due to chance criteria were taken into account.

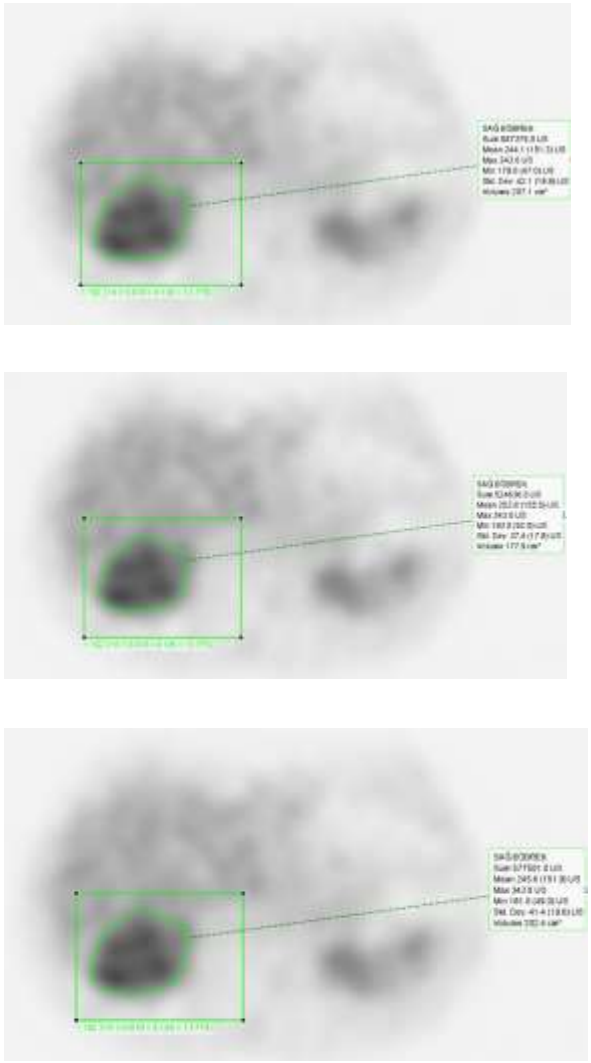

Figure 1: Right Kidney ROI drawn by independent 3 dosimetrists on Day 1 (4. Hours) images.

RESULTS

As an example for critical organ activity counts found with VOIs drawn for Right kidney, left Kidney, Liver and Total Body by 3 different dosimetrists were given Table 1 and 2, and 3.

Table 1. Right kidney activity count values determined by 3 different dosimetrists from SPECT images taken on the first day (Day 1 / 4. hours).

	Right Kidney Day 1 (4. Hours)		
Patient No	Dosimetrist 1	Dosimetrist 2	Dosimetrist 3
1	1043770	880799	860243
2	1360136	1360123	1360115
3	1149560	1266652	1231633
4	1099778	1099778	1013892
5	3166028	3166017	3166025
6	1080955	1268134	1208243
7	333872	433319	435811
8	880317	880827	852722
9	706711	603170	629580
10	920129	842107	816620
11	1291989	1180451	1197289
12	906195	945517	908145
13	2544239	2544189	2544197
14	1193027	1251510	1215163
15	1105563	1069595	1127242
16	1429686	1307555	1286866
17	734753	578171	558101
18	803707	687326	688657
19	1141506	1142356	1142156
20	630743	622026	610522
Average	1176133,20	1156481,10	1142661,10
SD	639456,37	650427,58	652230,16

Table 2. Left kidney activity count values determined by 3 different dosimetrists from SPECT images taken on the first day (Day 1 / 4. hours).

	Left Kidney Day 1 (4. Hours)		
Patient No	Dosimetrist 1	Dosimetrist 2	Dosimetrist 3
1	1208757	1256107	1199290
2	1058233	1750086	1923425
3	1515341	1642559	1588845
4	1490601	1490601	1608430
5	683361	748836	776760
6	961152	1137017	1060647
7	182029	202604	209769
8	315723	335681	320472
9	691456	617143	631695
10	1095465	1011892	968842
11	1408312	1139116	1095687
12	824857	908353	864218
13	1600823	1600823	1528781
14	1430298	1464073	1377831
15	653161	610463	591730
16	1837804	1694412	1568472
17	1130730	874782	811641
18	932042	798869	803030
19	1107259	1107259	1013441
20	577932	471188	494322
Average	1035266,80	1043093,20	1021866,40
SD	438229,75	466550,62	467136,86

Table 3. Liver activity count values determined by 3 different dosimetrists from SPECT images taken on the first day (Day 1 /4. hours).

	Liver Day 1 (4. Hours)		
Patient No	Dosimetrist 1	Dosimetrist 2	Dosimetrist 3
1	2387802	2941429	2436636
2	5026673	5672455	5795504
3	1991723	2053966	2106443
4	9881907	9881907	16034920
5	2403045	2460925	2462372
6	1774963	1992095	2086495
7	19629096	19952860	19940940
8	1188730	1113039	1121385
9	1971456	1851166	1922082
10	1780765	1559586	1408190
11	2617896	3278184	3090760
12	3143048	4093595	4147524
13	5799262	5799262	5646879
14	4319734	4515092	4262764
15	1808323	1727512	1774838
16	35803588	35017332	36109956
17	1634669	1476765	1573947
18	2013924	1955443	1954530
19	2224902	2224902	2198955
20	1970492	2052050	2207129
Average	5468599,90	5580978,25	5914112,45
SD	8283704,09	8146285,81	8634189,91

Table 4. Anova test results for the 3 Dosimetrist counts. If $p < 0,05$ there is a statistically significant difference between the groups. If $p \geq 0,05$ there is no significant difference between the groups.

ANOVA	Right Kidney	Left Kidney	Liver
Day 1 (4. Hours)	0,987	0,963	0,985
Day 2 (24. Hours)	0,891	0,890	0,991
Day 3 (48. Hours)	0,982	0,815	0,998
Day 4 (96. Hours)	0,993	0,818	0,995

For this study, the results of the statistical evaluation performed for the counts obtained by 3 different dosimetrists for the right kidney, left kidney, liver and total body for Day 1, Day 2, Day 3 and Day 4 are given in Table 4.

DISCUSSION

Radionuclide therapy stands out as a targeted, effective, and relatively low-toxic approach to treating various diseases, such as cancer. In this treatment method, administered systemically or locally, radioisotopes selectively bind to tumor cells or pathological tissues, causing minimal damage to surrounding healthy tissues. However, as with all radiation treatments, it is crucial to precisely know the doses received by critical organs and to ensure that limit doses are not exceeded. As with all radiation treatments, it is crucial to precisely know the doses received by critical organs and to avoid exceeding limit doses. While in the early years of radionuclide therapy, the number of treatments was determined through clinical experience, critical organ doses are now determined using patient-specific dosimetric approaches, and treatment numbers and doses are determined accordingly [7,8].

One of the most critical steps in radionuclide therapies is the determination of organ counts. This count is used directly to calculate the absorbed dose in the organ [9]. These counts are obtained from SPECT images. Although computer software is being developed to automatically determine organ counts, organ counts are currently determined by the dosimetrist using ROIs drawn on SPECT images. Naturally, this process is directly dependent on the dosimetrist's experience.

In this study, we examined the effect of the dosimetrist in determining activity counts in organs. As shown in Table 4, we conducted a statistical evaluation (ANOVA Test) between the counts determined by three different dosimetrists, and no significant difference was observed between their results. (All p values in the tables are $p \geq 0.05$). Although no statistically significant difference was observed, there were patients for whom all three dosimetrists disagreed. For example, in the right kidney counts for Patient 1, Dosimetrist 1 determined a count of 1043770, Dosimetrist 2 determined a count of 880799, and Dosimetrist 3 determined a count of 860243. As can be seen, Dosimetrist 1 determined approximately 20% more counts than the other two.

Points to consider when determining organ activity via on SPECT images;

1- CT images should be used as reference for organ drawings, and SPECT margins should be slightly wider than CT margins. This way, scattered radiation from the organs can be included in the counts.

2- In cases where two organs are adjacent (e.g., kidney-liver), the margins should be drawn so that they do not overlap.

3- A standard threshold should not be applied to Day 1, Day 2, Day 3, and Day 4 images. (i.e., a generally standart accepted threshold of 40%). Instead, CT images should be used as reference. For example, in this study, for % 55 threshold , 207 cm3 volume on Day 1, for % 45 threshold, 208 cm3 volume on Day 2, for % 42 threshold, 20,5 cm3 volume on Day 3, and for %33 threshold, 207,4 cm3 volume on Day 4 were obtained.

CONCLUSION

Ensuring the accuracy and reliability of dosimetric results depends on the accurate acquisition and analysis of dosimetric images. First, selecting the correct data acquisition parameters for SPECT images [10] and then applying the correct reconstruction parameters (High Iteration value and High Subset value should be applied to the images) will ensure that organ boundaries and areas of activity in the images can be visually distinguished. Furthermore, the dosimetrist's personal skills and training are also important parameters affecting organ activity counts. Therefore, before clinics begin using Radionuclide Therapy dosimetry, it is crucial for the

medical physicist who will serve as a dosimetrist to receive dosimetry training from competent institutions.

Conflict of Interest

There are no conflicts of interest and no acknowledgements.

References

1-Strosberg J, Wolin E, Chasen B, et al. Health-related quality of life in patients with progressive midgut neuro endocrine tumors treated with Lu-DOTATATE in the phase III NETTER-1 trial. J Clin Oncol 2018;36:2578-2584.

2-Ramonaheng K, Qebetu M, Ndlovu H, et al. Activity quantification and dosimetry in radiopharmaceutical therapy with reference to 177Lutetium. Front. Nucl. Med., Sec. Dosimetry and Radiation Safety. 2024;4:1355912.

3-Kovan B, Özkan Z G, Demir B, et al. An Analysis for Therapeutic Doses of Patients with Neuroendocrine Tumor Treated with Lutetium-177-DOTATATE. Cancer Biotherapy & Radiopharmaceuticals. 2022;37(1):17-22.

4-Mora-Ramirez E, Santoro L, Cassol E et al. Comparison of commercial dosimetric software platforms in patients treated with 177 Lu-DOTATATE for peptide receptor radionuclide therapy. Med Phys. 2020;47(9):4602-4615.

5-Kovan B, Demir B, Işık EG, et al. An anthropomorphic body phantom for the determination of calibration factor in radionuclide treatment dosimetry. Radiation Protection Dosimetry. 2023:199(12);1274-1283.

6-Sandstro¨m M, Garske-Roma´n U, Granberg D, et al. In dividualized dosimetry of kidney and bone marrow in pa tients undergoing 177 Lu-DOTA-octreotate treatment. J Nucl Med. 2013;54:33-41.

7-Zanzonico P. The MIRD Schema for Radiopharmaceutical Dosimetry: A Review. Journal of Nuclear Medicine Technology.2024;52(2):74-85.

8-Gillespie T, Swinson A, Fu Y, et al. Impact of Post-Therapy Imaging and Dosimetry on Patient Management in Radionuclide Therapy: A Case Study Review. Journal of Nuclear Medicine. 2025;66 (supplement 1):25140.

9-Vergnaud L, Dewaraja Y K., Giraudet A L, Badel J N, Sarrut D. A review of 177Lu dosimetry workflows: how to reduce the imaging workloads? EJNMMI Physics. 2024;11:65.

10-Kratochwil C, Fendler W P, Eiber M et al. EANM procedure guidelines for radionuclide therapy with 177Lu-labelled PSMA-ligands (177Lu-PSMA-RLT): Eur J Nucl Med Mol Imaging. 2019;46(12):2536-2544.