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Size-dependent dose estimation applied to ^{177}Lu and ^{90}Y-DOTATATE using ICRP Phantoms

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Abstract – Purpose: Radiolabeled peptide has attracted growing interests for neuroendocrine cancer therapy. We aim to calculate S-values of Lu-177, nd Y-90 in different size of International commission of radiation protection (ICRP) male and female phantoms for pre-estimation of absorbed dose in critical target organs using Monte Carlo simulation to see the extent of difference. **Materials and methods**: We employed the most advanced hybrid ICRP phantom and used its different male MIs to resemble reality. Six different size of ICRP malephantoms were generated. GATE code was used to perform dosimetry calculations. Spline, bladder, kidneys, and liver were chosen as the source organs and the S- values were calculated in interested target organs for twenty different body mass indexes (BMIs). **Results:** The S-values in both self-absorptions and target organs were statistically ower for ^{177}Lu-DOTATATE compared to ^{90}Y-DOTATATE. The highest difference between the absorption in kidneys is for BMI of 24.3. The highest S-value in bladder from bladder is 0.01 mGy/MBq.s in BMI of 34.4 for ^{177}Lu-DOTATATE, whereas it is 0.0049 mGy/MBq.s in BMIs of 34.4 for 90Y-DOTATATE. It was found that dose per unit cumulated activity had a tendency to decrease with BMI. **Conclusion**: Variability in ^{177}Lu-DOTATATE and ^{90}Y-DOTATATE dosimetry across morphometrically different patients are important in optimizing therapy protocols and research studies. Using size-dependent phantoms for dosimetry, more accurate dose estimations per cumulated activity relative to standard reference dosimetry are obtained. To prevent excessive dosage to patients, it is important to consider the relationship between body size and dose.

Keywords: Internal dosimetry / Phantom / Monte Carlo

1 Introduction

Peptide receptor radionuclide therapy (PRRT) is an important class of systemic treatment of patients with unrespectable or metastasized neuro-endocrine tumors (NETs). Radiolabeled somatostatin analogs such ^{177}Lu-DOTATATE (DOTA is 1,4,7,10-tetraazadodecane-*N,N_,N_,N_*-tetraacetic acid) and ^{90} Y-DOTATATE are most successful in detecting, imaging and therapy of tumors expressing somatostatin receptors (Mittra, 2018; Delpassand *et al.*, 2014). Localization of these radiopharmaceuticals after ligand binding makes them a favorable target for therapy (Sandström *et al.*, 2018; Lassmann *et al.*, 2021). Radiolabeled peptides are excreted mainly *via* the kidneys and are partly reabsorbed in the proximal tubular cells. Therefore retention and excretion of these molecules from urine pathway may cause toxicity due to highbsorbed dose to critical organs such as kidney, liver and bladder. This toxicity precludes the use of higher doses, thus limiting the efficacy of therapy.

Internal dosimetry is an outstanding procedure in nuclear medicine to optimize both diagnostic and therapeutic procedures (Carneiro *et al.*, 2015; Potter, 2024) and the resulting dose to the patient (Bertho and Bourguignon, 2024). Pre-estimation of absorbed dose in critical target organs can be performed by atlas-based simulations using advanced anthropomorphic phantoms and Monte Carlo codes (Panta, *et al.* 2012). The ICRP developed reference computational phantoms in mesh format to provide anatomically more realistic representations of the human body. These advanced phantoms define numerous source and target regions with different size (mass and height) providing more similarity to real conditions. Furthermore, the results obtained from dosimetry simulations may help to extract approximate values of absorbed dose in different organs and optimize the selection of radionuclide.

^{90}Y and ^{177}Lu are two commonly used radionuclides in therapy of neuro-endocrine tumors (Seregni *et al.*, 2014; Zemczak *et al.*, 2021). Based on the previous literature, ^{177}Lu and ^{90}Y have low and high energy beta particles, respectively. According to the range of beta particles emitted from each of these two radionuclides, they are widely used for treating

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smaller and larger tumors (Zweit, 1996; Ljungberg *et al.*, 2016). It is recommended to use the appropriate cocktail of these radionuclides due to different size of metastatic tumors. Another important problem in radionuclide therapy is the prevention of critical organ radiotoxicity. Although a radionuclide may have a high efficacy but high absorbed dose in critical organs close to the target organ makes it an unsuitable selection for therapy (Kunikowska *et al.*, 2011; Huizing *et al.*, 2018). An important factor affecting critical organ dose is the size of that organ, which isdepended on BMI.

There are a few studies that compare the differences between the absorbed doses between ^{90}Y-DOTATATE and ^{177}Lu-DOTATAE (Segars *et al.*, 2017). Most study in this field use simple stylized phantom such as MIRD and do not consider anatomical details of organs (Mattsson, 2015). Human-simulating computational phantoms have become an important tool for dosimetric calculations in medical imaging and radiation therapy. Using these phantom in Monte Carlo simulation can lead to more convenient and also yield reliable results. In this study we used male CRP phantom to perform an accurate estimation of absorbed dose in organs of interest. A primary aim of this work was to assess differences in ^{177}Lu and ^{90}Y- DOTATATE dose coefficient (dose per unit cumulated activity) named S-values estimations using various patient morphologies. S-values of ^{177}Lu and ^{90}Y- DOTATATE in different body mass indexes (BMIs) of ICRP (Pinto *et al.*, 2020) male phantoms were calculated for pre-estimation of absorbed dose in critical target organs using GATE (GEANT4 Application to Tomographic Emission). We then investigated differences due to phantom format by comparing dose coefficients.

2 Materials and methods

All simulations in this study were performed using GATE version 8.2 based on the Geant4 (Geometry And Tracking, version 10.4).

We used the method developed by Segars *et al.* (2017) to produce six total body ICRP male hantoms with different BMIs. Some parameters of phantom such as BMI are changeable. The reference mass and height are 60 kg and 163 cm respectively (BMI = 22.6 kg/cm^2). The adult mesh reference phantoms were reshaped and scaled to culminating in an additional 6 male phantomphantoms representing the 10th, 50th, and 90th percentiles of standing height and weight corresponding to BMI of 23, 24.9, 27.1, 28.4, 29.3, 34.5. The matrix size of each phantom was 128 × 128 × 300 with a voxel size of 3.125 mm × 3.125 mm × 3.125 mm to cover the desired region of the body (Fig. 1). Dosimetry calculations were performed for 20 MBq activity of ^{177}Lu-DOTATATE and ^{90}Y- DOTATATE that were distributed uniformly in each voxels of the source organs.

The detailed decay data and emission spectra of selected radionuclides were taken from MIRD: radionuclide data and decay schemes (Goddu, 1997). For each radionuclide, the emitted energy spectra (gamma, X-ray, beta, internal conversion, Auger electrons and alpha) were considered independently to estimate the relative contribution of each radiation independently. The transitions for each radionuclide are summarized in Table 1.

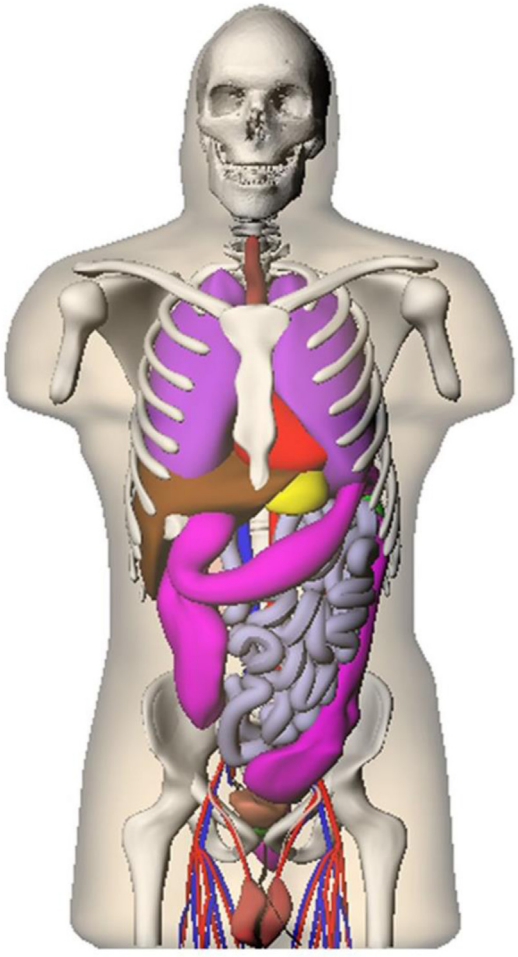

Fig. 1. ICRP phantom that covers the interested organs.

Simulations were performed by Intel® Core™ i5 Processors with 6 GB RAM. In total, 10^7 histories were simulated for each phantom. After dosimetry simulations with GATE, the output is two binary files containing the absorbed dose in voxels (in cGy) and the corresponding uncertainties respectively. Using MATLAB (version R2017b), results were converted to numeric values. We chose spine, bladder, kidneys, and salivary glands as the source organs according to the biodistribution of selected radiopharmaceuticals and we calculated the S-value (in units of mGy/MBq.s) based on Medical International Radiation Dose (MIRD) committee guideline [13] in kidneys, spleen, liver, and bladder as the target organs. several target regions are defined in the ICRP phantom that comprise multiple sub regions (*e.g.* kidneys, comprising left and right renal pelvis, cortex, and medulla). The mass weighted combination of absorbed doses (in unit of mGy per MBq.s) were calculated as the mean dose to such regions according to the equation (1).

$$S_{mreg} = \sum_{rT \in mreg} \frac{M(rT \in mreg)}{M(mreg)} S(rT \in mreg) \qquad (1)$$

where S_{mreg} is the S-value for a multiregional target; $M(rT \in mreg)$ is the mass of a region rT comprising the multiregional target; M(mreg) is the total mass of the

Table 1. Summery of the decay transition of the radionuclides investigated in this study. The third column to fifth column shows respectively the number of emitted rays, sum of the yield of each ray ($\sum Yi$) and sum of the product of yield and energy divided by total yield $\frac{\sum Yi.Ei}{\sum Yi}$ named mean energy.

Radionuclide	**Radiation**	**Number**	**Total yield per disintegration**	**Mean energy (MeV)**
Lutetium 177	Gamma	6	1.803E–01	1.750E–01
	X-ray	60	1.374E+00	2.576E–03
	Beta	4	1.000E+00	1.333E–01
	Int. Conv.	36	1.548E_01	8.737E–02
	Auger	15	1.117E+00	1.014E–03
Yttrium 90	Gamma	1	1.400E–08	2.186E+00
	x-ray	40	1.466E–03	8.193E–04
	Int. Conv.	10	1.150E–04	1.745E+00
	Beta	3	1.000E+00	9.329E–01
	Auger	11	1.273E–03	5.144E–04

Table 2. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 23.0 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	1.010e-05	1.715e-06	1.342e-05	2.451e-03	1.761e-05
		±1.23e-06	±1.32e-07	±0.65e-06	±1.12e-04	±1.02e-06
	^{177}Lu-DOTATATE	3.410e-08	5.904e-08	7.698e-08	7.381e-04	1.165e-07
		±2.28e-9	±2.21e-08	±5.31e-09	±3.21e-09	±1.12e-09
Kidney	^{90}Y-DOTATATE	2.312e-03	2.341e-04	2.654e-05	9.923e-06	3.123e-04
		±1.13e-05	±1.32e-05	±2.11e-06	±2,43e-09	±1.21e-05
	^{177}Lu-DOTATATE	3.260e-04	3.165e06	1.132e-07	4.114e-08	4.673e-06
		±1.67e-05	±2.21e-07	±1.01e-08	±1.87e-08	±1.21e-06
Spleen	^{90}Y-DOTATATE	3.204e-05	2.204e-05	1.745e-05	1.637e-06	2.523e-05
	^{177}Lu-DOTATATE	2.829e-07	1.013e-07	2.282e-07	2.345e-09	9.113e-08
		±1.31e-08	±1.07e-08	±1.21e-08	±1.45e-09	±2.21e-08
Liver	^{90}Y-DOTATATE	1.331e-04	8.421e-05	9.543e-05	1.056e-04	1.321e-04
		±1.10e-05	±2.21e-05	±3.21e-05	±2.21e-05	±2.30e-05
	^{177}Lu-DOTATATE	2.012e-06	1.111e-06	1.110e-03	1.845e-06	1.532e-06
		±4.21e-07	±3.02e-07	±2.94e-04	±1.1e-06	±2.11e-07

multiregional target; and $S(rT \in mreg)$ is the S-value for a subregion.

In this study, paired t-test and linear regression were used to evaluate the correlation of the interested organ absorbed dose per unit cumulated activity as S-values and BMI. All statistical tests and comparisons were done using SPSS version 18 and SYSTAT 13 software.

3 Results

Results are presented in Tables 2–7. The S values in both self-absorptions and target organs were lower for ^{177}Lu-DOTATATE as compared to ^{90}Y-DOTATATE. Differences of S- values were not significant ($P < 0.005$). The highest difference between the absorption is in kidneys ($P = 0.0032$) when source is in kidney. When the source organ is the kidneys, the greatest S value is 0.0025 from ^{90}Y-DOTATATE and 3.55e-04 from ^{177}Lu-DOTATATE in BMI of 28.3. The highest S-value in BMI of 34.5 in bladder from bladder is 0.01 from^{90}Y-DOTATATE, whereas it is 0.0049 from ^{177}Lu-DOTATAE. The most self-absorption (when source and target are the same) in spine is in BMI of 28.3 and is 7.04e-04 from ^{90}Y-DOTATATE and 1.12e-04 from ^{177}Lu-DOTATAE. For the spleen as source organs' self-absorption have the S-value (in mGy/MBq.s) of 0.0035 from the source of 90Y-DOTATATE and about 7.5e-04 from 177Lu-DOTATAE in all BMI. Moreover, when liver is considered as the source organ(source is distributed in liver), the absorption in kidneys and bladder is approximately 100 times lower in ^{177}Lu-DOTATAE.. In the case of organs such as liver and pancreas, all the trend lines varied inversely with S-values and they demonstrated a strong or weak tendency to decrease with BMI. Also, plots in Figure 2 illustrate that for ^{177}Lu-DOTATAE, the self-absorption is dramatically lower than that of ^{90}Y-DOTATATE. The dependence of the dose to the morphology of the patient is

Table 3. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 24.9 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	2.010e-05 ±1.31e-06	1.616e-06 ±3.21e-07	1.342e-05 ±4.21e-06	3.521e-03 ±2.21e-04	1.761e-05 ±1.31e-05
	^{177}Lu-DOTATATE	3.231e-08 ±2.21e-09	7.845e-08 ±4.21e-09	7.698e-08 ±2.21e-08	7.381e-04 ±3.21e-04	1.165e-07 ±1.21e-08
Kidney	^{90}Y-DOTATATE	3.323e-03 ±2.11e-03	1.432e-04 ±5.24e-05	2.654e-05 ±1.10e-05	9.923e-06 ±1.21e-06	3.123e-04 ±4.11e-05
	^{177}Lu-DOTATATE	3.656e-04 ±2.11e-04	2.280e06 ±6.21e-07	1.132e-07 ±2.56e-08	4.114e-08 ±7.11e-09	4.673e-06 ±1.01e-06
Spleen	^{90}Y-DOTATATE	3.204e-05 ±1.21e-05	3.223e-05 ±1.10e-05	1.745e-05 ±1.11e-06	1.637e-06 ±	2.523e-05 ±1.45e-06
	^{177}Lu-DOTATATE	2.829e-07 ±1.21e-07	5.341e-07 ±3.21e-08	2.282e-07 ±5.50e-08	2.345e-09 ±1.22e-09	9.113e-08 ±1.11e-09
Liver	^{90}Y-DOTATATE	1.113e-04 ±8.21e-05	9.623e-05 ±1.21e-05	9.543e-05 ±1.10e-05	1.056e-04 ±2.37e-05	1.321e-04 ±6.21e-05
	^{177}Lu-DOTATATE	3.331e-06 ±1.11e-06	8.431e-06 ±4.41e-07	1.651e-06 ±3.26e-07	1.845e-06 ±3.21e-07	1.532e-06 ±1.1e-07

Table 4. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 27.1 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	1.010e-05 ±1.10e-06	2.544-06 ±2.76e-07	1.442e-05 ±3.21e-06	3.521e-03 ±1.21e-03	1.761e-05 ±1.10e-05
	^{177}Lu-DOTATATE	3.561e-08 ±1.10e-08	5.666e-08 ±3.19e-08	6.643e-08 ±2.21e-08	7.381e-04 ±1.90e-05	1.165e-07 ±1.10e-08
Kidney	^{90}Y-DOTATATE	2.323e-03 ±1.98e-03	3.566e-04 ±1.05e-04	2.344e-05 ±1.10e-05	9.923e-06 ±1.45e-06	4.443e-04 ±1.10e-04
	^{177}Lu-DOTATATE	2.656e-04 ±1.10e-04	4.216e06 ±1.66e-06	2.222e-07 ±8.21e-08	4.114e-08 ±5.46e-09	6.622e-06 ±2.41e-06
Spleen	^{90}Y-DOTATATE	4.234e-05 ±1.78e-05	2.113e-05 ±1.10e-05	2.234e-05 ±1.23e-05	1.637e-06 ±1.10e-06	3.334e-05 ±1.15e-05
	^{177}Lu-DOTATATE	1.829e-07 ±8.10e-08	2.321e-07 ±1.20e-07	2.112e-07 ±6.45e-08	2.345e-09 ±0.23e-09	3.334e-08 ±1.11e-08
Liver	^{90}Y-DOTATATE	1.113e-04 ±6.5e-05	7.453e-05 ±2.67e-06	4.513e-05 ±3.21e-06	1.056e-04 ±1.10e-05	1.761e-04 ±1.19e-05
	^{177}Lu-DOTATATE	2.331e-06 ±7.10e-07	6.391e-06 ±8.18e-07	1.541e-06 ±5.10e-07	1.845e-06 ±1.10e-07	1.332e-06 ±5.10e-07

shown in these figures for the percentile-specific phantoms.. More specifically, all the R2 values were greater than 0.7. For all these results, organ doses decreased with increasing BMI. The S values negatively correlates strongly with body mass index (Spearman $r = 0.9505$; $P < 0.0001$).

4 Discussion

The high interest for dosimetry of ^{90}Y-DOTATATE in clinical researches, necessitate a knowledge on the absorbed dose of organs (Cwikla *et al.*, 2010; Kunikowska *et al.*, 2011; Sowa-Staszczak *et al.*, 2011). But, to the best of our knowledge, there are very few studies that compare the differences between the absorbed doses between ^{90}Y-DOTATATE and ^{177}Lu-DOTATAE. Capala *et al.* evaluated the dosimetry methods for radiopharmaceutical therapy and stated that the main different feature between ^{177}Lu-DOTATAE and ^{90}Y-DOTATATE is the particles and energy emitted by each disintegration (Capala *et al.*, 2021). Beside this factor, patient specifics such as height, weight, sex, and underlying physical factors (such as linear energy transfer, attenuation) affect S-values. Due to lower energy of beta particles emitted from ^{90}Y as compared to ^{177}Lu and consequently due to the lower range of these particles, the absorbed dose to the organs would be lower. Alnaaimi *et al.* calculated S-Values (in mGy/MBq s) in some of the critical

Table 5. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 28.4 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	1.340e-05 ±1.10e-05	1.616e-06 ±7.10e-07	1.342e-05 ±6.10e-06	6.521e-03 ±1.10e-03	2.761e-05 ±1.10e-05
	^{177}Lu-DOTATATE	2.571e-08 ±6.16e-09	7.845e-08 ±1.43e-08	7.698e-08 ±3.21e-08	6.381e-04 ±2.41e-04	3.165e-07 ±7.21e-08
Kidney	^{90}Y-DOTATATE	6.689e-03 ±1.10e-03	1.432e-04 ±1.54e-05	2.654e-05 ±1.10e-05	5.923e-06 ±9.15e-07	1.123e-04 ±7.17e-05
	^{177}Lu-DOTATATE	7.124-04 ±1.32e-04	2.280e06 ±9.21e-07	1.132e-07 ±8.56e-08	4.114e-08 ±1.10e-08	2.673e-06 ±7.31e-07
Spleen	^{90}Y-DOTATATE	1.245e-05 ±0.51e-05	3.223e-05 ±6.41e-06	1.745e-05 ±8.12e-06	3.637e-06 ±1.10e-06	5.523e-05 ±1.10e-05
	^{177}Lu-DOTATATE	1.239e-07 ±6.56e-08	5.341e-07 ±7.34e-08	2.282e-07 ±3.54e-08	3.345e-09 ±1.10e-09	7.113e-08 ±1.78e-08
Liver	^{90}Y-DOTATATE	2.573e-04 ±1.10e-04	9.623e-05 ±1.39e-05	9.543e-05 ±1.72e-05	4.056e-04 ±8.10e-05	1.331e-04 ±3.21e-05
	^{177}Lu-DOTATATE	2.781e-06 ±0.10e-06	8.431e-06 ±1.67e-06	1.651e-06 ±3.56e-07	5.845e-06 ±0.41e-06	1.652e-06 ±5.04e-07

Table 6. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 29.3 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	1.012e-05 ±5.51e-06	5.666e-06 ±1.03e-05	3.112e-05 ±7.23e-06	6.261e-03 ±1.01e-03	2.761e-05 ±6.45e-06
	^{177}Lu-DOTATATE	2.221e-08 ±3.45e-09	4.365e-08 ±7.23e-09	6.228e-08 ±4.21e-09	6.261e-04 ±5.98e-05	2.165e-07 ±6.78e-08
Kidney	^{90}Y-DOTATATE	1.113e-03 ±5.50e-04	3.752e-04 ±7.21e-05	2.224e-05 ±6.12e-06	5.323e-06 ±0.34e-06	7.123e-04 ±0.23e-04
	^{177}Lu-DOTATATE	1.346e-04 ±5.67e-05	3.110e06 ±3.89e-07	2.332e-07 ±6.57e-08	5.321e-08 ±1.01e-08	5.673e-06 ±1/04e-06
Spleen	^{90}Y-DOTATATE	3.212e-05 ±5.78e-06	4.523e-05 ±6.34e-06	1.335e-05 ±7.34e-06	4.354e-06 ±6.35e-07	1.523e-05 ±5.21e-06
	^{177}Lu-DOTATATE	4.011e-07 ±8.21e-08	4.361e-07 ±7.98e-08	1.233e-07 ±4.67e-08	4.213e-09 ±0.10e-09	3.113e-08 ±5.86e-09
Liver	^{90}Y-DOTATATE	2.111 −04 ±6.79e-05	4.623e-05 ±6.98e-06	6.663e-05 ±1.01e05	2.113e-04 ±7.21e-05	1.671e-04 ±6.81e-05
	^{177}Lu-DOTATATE	2.771e-06	7.465e-06	4.451e-06	2.215e-06	1.122e-06

organs according MIRD formalism and ^{90}Y-DOTATATE and ^{177}Lu-DOTATATE biodistribution (Alnaaimi *et al.*, 2021). They showed that for both target and self-absorption, S-values are notably reduced when ^{90}Y-DOTATATE is substituted by ^{177}Lu-DOTATATE. Their results are in agreement with the trend of our results. Having effective half-life of ^{177}Lu and ^{90}Y, rough estimation of absorbed dose (in Gy) in target organs can be provided for physicians and this also help them to decide how much of activity should be injected according to the patient's BMI (Veress *et al.*, 2010) and the therapeutic or imaging objectives. Ahmadzadehfar *et al.* emphasized that DOTATATE-based radiopharmaceuticals is a molecular target with diagnostic and therapeutic agent simultaneously (Ahmadzadehfar *et al.*, 2015), and reported that clinical study with ^{177}Lu-DOTATATE has demonstrated very effective results and was well tolerated. This point comes to more attention in our study when deciding for assessment of absorbed dose ratio for Lu-177 therapy – as a promising new therapeutic agent. The results for different BMIs, demonstrate that using ^{177}Lu-DOTATATE has less hazards compared to ^{90}Y-DOTATATE. Because ^{177}Lu-DOTATATE can detect lesions even more precisely, its lower S-values in target organs pose another reason for bias towards ^{90}Y-DOTATATE. The major drawback of the current study is the lack of simulation with real patient's data. There are subtle variations between biodistribution of different derivatives of DOTATATE-based ligands. The small differences between various derivatives of DOTATAE-based agents cannot be assessed in phantom studies. This will be of more focus in our future work on real patients. For instance, there is a slight difference

Table 7. S-values (mGy/MBq.s) for ^{177}Lu-DOTATATE & ^{90}Y-DOTATATE for BMI 34.5 of male ICRP phantom

Source organs		Target organs				
		Kidney	Spleen	Liver	Bladder	Prostate
Bladder	^{90}Y-DOTATATE	2.010e-05	1.616e-06	1.342e-05	3.521e-03	1.761e-05
		±6.54e-06	±5.61e-07	±5.34e-06	±7.12e-04	±5.24e-06
	^{177}Lu-DOTATATE	3.231e-08	7.845e-08	7.698e-08	7.381e-04	1.165e-07
		±4.35e-09	±1.73e-08	±1.02e-08	±3.12e-04	±5.86e-08
Kidney	^{90}Y-DOTATATE	3.323e-03	1.432e-04	2.654e-05	9.923e-06	3.123e-04
		±7.31e-04	±7.23e-05	±6.83e-06	±1,54e-06	±6.42e-05
	^{177}Lu-DOTATATE	3.656e-04	2.280e06	1.132e-07	4.114e-08	4.673e-06
		±5.75e-05	±7.34e-07	±7.23e-08	±5.21e-09	±7.34e-07
Spleen	^{90}Y-DOTATATE	3.204e-05	3.223e-05	1.745e-05	1.637e-06	2.523e-05
		±6.31e-06	±5.21e-06	±5.45e-06	±7.12e-07	±4.54e-06
	^{177}Lu-DOTATATE	2.829e-07	5.341e-07	2.282e-07	2.345e-09	9.113e-08
		±6.40e-08	±6.75e-08	±8.21e-08	±1.12e-09	±1.31e-08
Liver	^{90}Y-DOTATATE	1.113e-04	9.623e-05	9.543e-05	1.056e-04	1.321e-04
		±6.76e-05	±1.04e-06	±1.01e-05	±5.89e-05	±5.87e-05
	^{177}Lu-DOTATATE	3.331e-06	8.431e-06	1.651e-06	1.845e-06	1.532e-06
		±5.82e-07	±1.02e-06	±7.39e-07	±5.98e-07	±6.12e-07

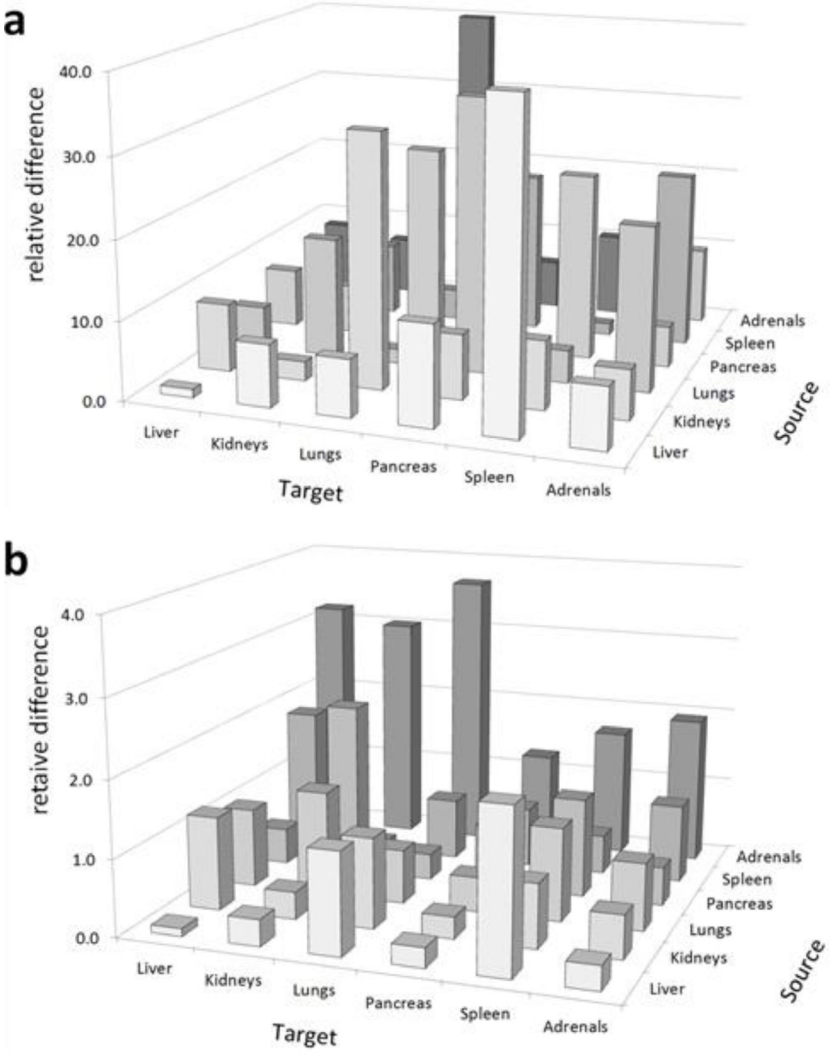

Fig. 2. Relative differences between Lu-177(a) and Y-90(b) absorbed dose in different organs.

between the biodistribution of ^{177}Lu-DOTATATE and ^{90}Y-DOTATATE. The differences include renal clearance of ^{90}Y-DOTATATE that is less than ^{177}Lu-DOTATATE which leads to less accumulation of radiopharmaceutical in bladder, resulting in better capacity of the surrounding bladder and bladder tissue. Also, liver absorption is higher in ^{90}Y-DOTATATE compared to ^{177}Lu-DOTATATE. This high absorption is considered a weakness in detecting liver metastases. Patient-specific dosimetry definitely will help to determine accurately amount of differences between these two tracers. Data gained from real patients imaging may lead also to determine how much total received dose is different for these two agents as well as organ doses.

5 Conclusion

Our results show that the absorbed dose falls down dramatically when ^{177}Lu-DOTATATE is employed instead of ^{90}Y-DOTATATE. The lower absorbed dose in patient body may be another reason to put ^{177}Lu-DOTATATE in superiority for neuroendocrine tumor therapy. As a consequence, patients with a high BMI were exposed to more radiation than those with a low BMI. To prevent excessive dosage to patients, it is important to consider the relationship between body size and dose.

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Conflicts of interests

The authors report no conflict of interest.

Data availability statement

The author confirms that the data supporting the findings of this study are available within the article.

Ethics approval

Research does not involve human participants or animals Informed consent.

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