STM JOURNALS

Journal of
Nuclear Engineering & Technology

ISSN: 2277-6184 (Online)
ISSN: 2321-6514 (Print)
Volume 15, Issue 2, 2025
May–August
DOI (Journal): 10.37591/JoNET

https://journals.stmjournals.com/jonet

Review JoNET

MIRDcalc and OLINDA/EXM Dosimetry Software Analysis by SPECT/CT Scan Data of Lu-177 DOTATATE Radionuclide Therapy of NET Patients

Madhulika Mehrotra[1,*], Prashant Mishra[2], Saurabh Sharma[3], Preethi Deenadayalan[4]

Abstract

Accurate dosimetry is essential in nuclear medicine for optimizing radionuclide therapies and ensuring patient safety. In radiopharmaceutical dosimetry, the Medical Internal Radiation Dosimetry (MIRD) Committee of the Society of Nuclear Medicine is the pioneer in organ-level dosimetry providing the fundamental basis for commonly used clinical and research dosimetry software like MIRDOSE and OLINDA/EXM. Recently, in the MIRD Pamphlet No. 28, Part 1, the MIRD Committee of the Society of Nuclear Medicine and Medical Imaging presented a new Software Tool, MIRDcalc, for organ-level and sub-organ tissue dosimetry, based on a standard Excel Spreadsheet Platform to enhance the personalized internal dosimetry. This study evaluates and compares the internal dosimetry software MIRDcalc and OLINDA/EXM for calculating absorbed and effective doses in neuroendocrine tumor (NET) patients treated with Lutetium-177 DOTATATE, based on quantitative SPECT/CT imaging data. MIRDcalc, a freely accessible Excel-based dosimetry tool, integrates updated anatomical models, user-friendly interfaces, and quality control utilities. Its performance was assessed against OLINDA/EXM, a widely used commercial software, and benchmarked using the standardized absorbed radiation dose calculation equations, described in the MIRD primer 2022. Dose estimates for key organs were derived using both platforms, and results demonstrated a high level of concordance between the two methodologies. Minor discrepancies in absorbed dose values were attributed to differences in underlying phantom models, organ definitions, and dose calculation algorithms. The analysis underscores MIRDcalc's viability as a research-grade tool for personalized dosimetry, offering comparable accuracy to established systems like OLINDA/EXM. Future work should focus on expanding personalized dosimetry, especially for Lu-177 DOTATATE, NET patients, for radionuclide therapy capabilities, and validating models across broader clinical datasets.

***Author for Correspondence**
Madhulika Mehrotra
E-mail: madhulika_mehrotra@aiims.edu

[1]Women Scientist Fellow, Department of Nuclear Medicine, All India Institute of Medical Sciences, New Delhi, India
[2,3]M.Sc. Nuclear Medicine, Department of Nuclear Medicine, All India Institute of Medical Sciences, New Delhi, India
[4]Clinical Application Specialist, Mediso, Nuclear Medsystems India Pvt. Ltd., Delhi, India

Received Date: May 15, 2025
Accepted Date: May 19, 2025
Published Date: May 19, 2025

Citation: Madhulika Mehrotra, Prashant Mishra, Saurabh Sharma, Preethi Deenadayalan. MIRDcalc and OLINDA/EXM Dosimetry Software Analysis by SPECT/CT Scan Data of Lu-177 DOTATATE Radionuclide Therapy of NET Patients. Journal of Nuclear Engineering & Technology. 2025; 15(2): 48–63p.

Keywords: MIRDcalc, OLINDA/EXM, Lu-177 DOTATATE, absorbed dose, effective dose, internal dosimetry, SPECT/CT, radionuclide therapy

INTRODUCTION

Radiopharmaceutical dosimetry has undergone significant evolution since its inception in the 1960s [1], becoming an integral component in nuclear medicine to ensure both therapeutic efficacy and patient safety. The Medical Internal Radiation Dosimetry (MIRD) [2] schema remains the foundational approach for calculating absorbed

radiation doses based on the radiopharmaceutical distribution in the human body. This method enables dose assessments at various biological scales, from the whole body to organ, sub-organ, voxel, and cellular levels, facilitating both personalized and population-based dosimetry [3]. Organ-level dosimetry is commonly used in clinical settings because of the balance between computational efficiency and anatomical accuracy [4].

The most prominent software tools built on the MIRD framework are MIRDOSE [5] and its successors [6], OLINDA/EXM [7], and MIRDcalc [8, 9]. OLINDA/EXM is a licensed Java-based application that relies on RADAR phantoms and includes modules for kinetic modeling and effective dose calculation based on ICRP Publications 103 and 128, [10, 11] tissue-weighting factors. In contrast, MIRDcalc is a freely accessible Microsoft Excel-based software developed by the MIRD Committee. It offers updated phantom models, including those from ICRP Publications 110 and 143 [12, 13] and is designed to be both user-friendly, single-screen interface, and transparent, with an emphasis on educational and research applications. MIRDcalc is a robust computational tool for absorbed dose calculation in the dosimetry protocol workflows, by initially providing an input of time-integrated activity coefficients (TIACs) [14, 15] (also known as *'residence time'*) of the radiopharmaceutical in organs and tissues. Comparative studies of different dosimetry platforms are essential because of the differences in anatomical modeling, computational algorithms, and assumptions about radiopharmaceutical kinetics. In the context of Lu-177 DOTATATE therapy [16, 17] for neuroendocrine tumors (NETs) [18], precise calculation of absorbed radiation dose is crucial, given the heterogeneity in organ uptake and tumor burden. Despite the availability of multiple tools, variability in dose estimates remains a concern, particularly when reference phantoms do not match the patient-specific anatomy [19]. This study focused on a comparative analysis of absorbed and effective dose outcomes between MIRDcalc and OLINDA/EXM using SPECT/CT imaging data from NET patients undergoing Lu-177 DOTATATE radionuclide therapy [20]. This study aimed to assess the validity, limitations, and potential of MIRDcalc as a practical dosimetry tool for clinical research.

METHODOLOGY

Overview of MIRDcalc Software

MIRDcalc is freely accessible dosimetry software developed to facilitate organ-level radiation dose estimation using the established MIRD schema. Implemented in Microsoft Excel, the software integrates Visual Basic modules to support user interaction and automate calculations. It utilizes updated anatomical models based on ICRP Publications 110 and 143, offering both adult and pediatric phantoms. MIRDcalc, which is based on a standard Excel Spreadsheet Platform, provides enhanced capabilities to facilitate radiopharmaceutical internal dosimetry. The program is designed for educational and research purposes, enabling users to compute absorbed doses using TIACs for radiopharmaceuticals. It supports up to 333 radionuclides and provides a streamlined single-screen interface, making it accessible to users with basic dosimetric knowledge [8, 9].

Organ-Level Dosimetry Calculations

The core principle behind the absorbed dose estimation of MIRDcalc is the MIRD equation [21], which is defined as

$$D(r_T) = \Sigma\, \tilde{A}(r_S).\, S\,(r_T \leftarrow r_S) \tag{1}$$

Where, $D(r_T)$ is the mean absorbed dose to the target region from activity in the source region (in the unit, *Gray (Gy) or1 J/kg = 1 Gy)*, $\tilde{A}(r_S)$ is the time-integrated activity in the source region (in the unit, *Becquerel second*), and $S(r_T \leftarrow r_S)$ is the S-value indicating the absorbed dose per unit activity from the source to target (in units, $Gy\cdot(Bq\cdot s)^{-1}$ *or* $mGy\cdot(MBq\cdot s)^{-1}$).

TIACs [22] represent cumulative activity over time and are calculated from the biodistribution data defined as

$$\tilde{a}(r_S) = \frac{\tilde{A}(rs)}{A0} \tag{2}$$

Where, $\tilde{a}(r_S)$ is the Time-Integrated Activity Coefficient (TIAC), and A_0 is the administered activity. MIRDcalc enables global scaling of S-values [23] according to patient-specific total-body mass, thereby improving personalization.

Tumor Dosimetry Implementation

MIRDcalc supports the definition of up to five spherical tumor regions for dosimetric evaluation [24, 25]. Users input TIACs and specify radionuclides for each sphere. The absorbed dose was calculated using the interpolated S-values based on the tumor volume. The cross-dose between the tumors and organs was not considered in the current version [8, 9].

Biodistribution Data Input and Processing

Biodistribution data from SPECT/CT imaging were used to derive TIACs representing cumulative radiopharmaceutical activity. These are input into MIRDcalc in hours, along with administration activity in *MBq*, and the software outputs absorbed doses per injection and per organ [26].

Effective Dose Estimation

In MIRDcalc, the effective dose [27], a measure of stochastic radiation risk, is computed as a weighted sum of organ doses using tissue-weighting factors from ICRP Publication 103. This calculation allows for comparisons across software tools and facilitates the assessment of the potential biological effects of radionuclide therapy [22, 23].

Comparative Software: OLINDA/EXM

OLINDA/EXM [28] is a commercially licensed software (Hermes Medical Solutions) for organ-level dosimetry that implements a Java-based interface and employs RADAR phantoms [29]. It calculates the absorbed and effective doses using a biokinetic modeling module that fits exponential retention curves to time-activity data. For this study, only adult male and female RADAR phantoms were considered. Notably, OLINDA/EXM differs from MIRDcalc in its anatomical models and handling of source regions.

Dosimetric Comparison Metrics

To compare the Lu-177 DOTATATE radiopharmaceutical and absorbed dose estimates from both MIRDcalc and OLINDA/EXM, two statistical approaches were used [9]:

Logarithmic relative difference $(\Delta_{MIRDcalc}^{OLINDA})$;

$$\Delta_{MIRDcalc}^{OLINDA} = 100 \times \ln \frac{D(OLINDA)}{D(MIRDcalc)} \tag{3}$$

Where, *D(MIRDcalc)* is the absorbed dose for the target organ r_T computed by MIRDcalc, and *D(OLINDA)* is the absorbed dose computed by the OLINDA software. This metric is reference-independent and symmetrical.

Percentage Error $(PE_{MIRDcalc}^{OLINDA})$, taken as the gold standard reference [9];

$$PE_{MIRDcalc}^{OLINDA} = \frac{D(OLINDA) - D(MIRDcalc)}{D(MIRDcalc)} \times 100\ (\%) \tag{4}$$

These metrics were applied across datasets of seven neuroendocrine tumor (NET) patients treated with Lu-177 DOTATATE based on SPECT/CT-derived dosimetric inputs. The flowchart for the clinical dosimetry workflow using two software (OLINDA/EXM and MIRDcalc) is shown in Figure 1.

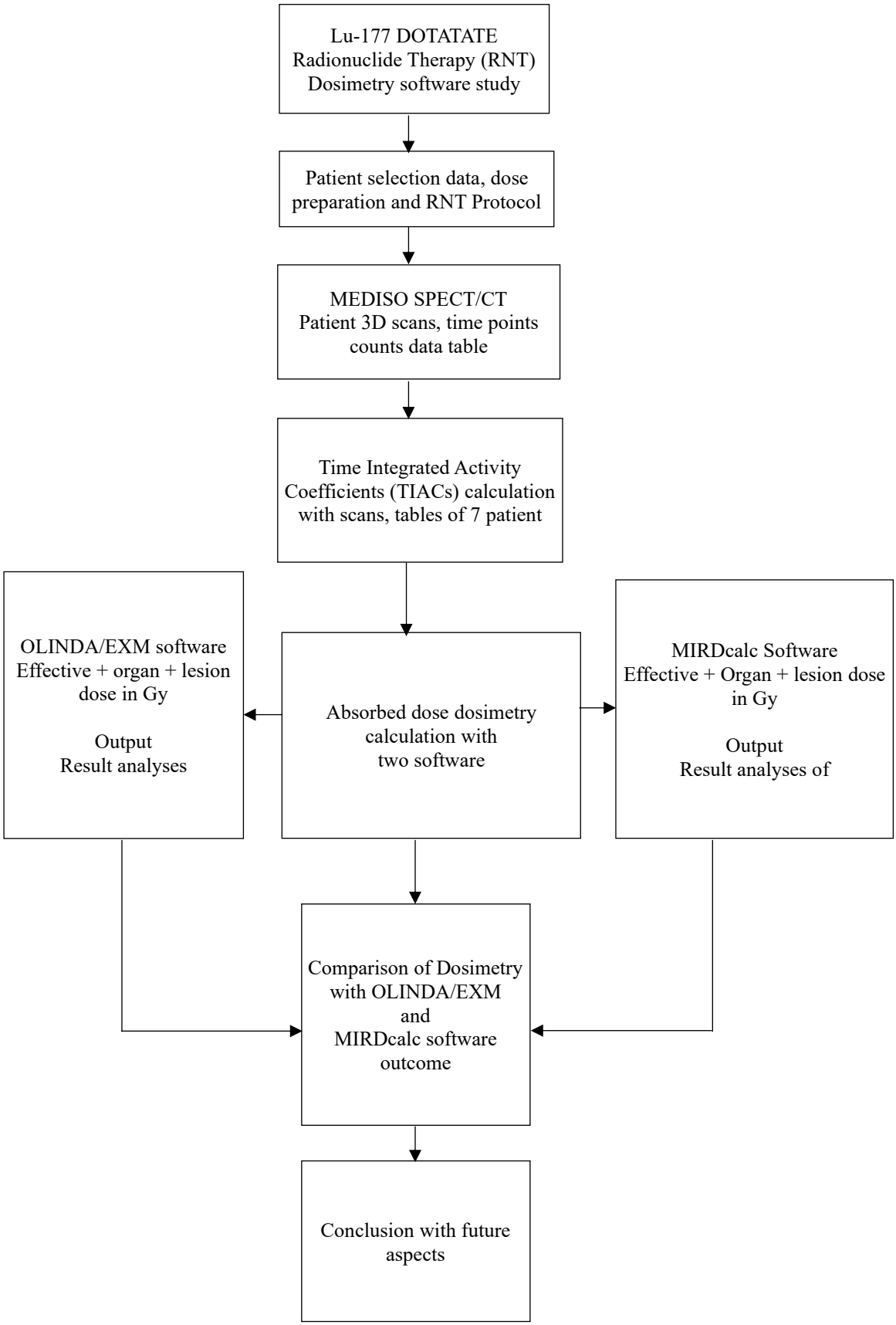


Figure 1. Flowchart for clinical dosimetry workflow using two software (OLINDA/EXM and MIRDcalc).

RESULT

Patient P1, OLINDA/EXM software, and absorbed dose report are shown in Table 1, and Patient P1, MIRcalc software, and absorbed dose spreadsheet are shown in Figure 2.

Table 1. Patient P1, OLINDA/EXM software, absorbed dose report.

OLINDA - Organ Level INternal Dose Assessment Code (Version 2.1 - copyright Vanderbilt University - 2012)								
P1 3D OLINDA REPORT								
NOTE: This code gives doses for stylized models of average individuals –results should be applied with caution to specific human subjects.								
NOTE: Users should always carefully check input data (shown below) and critically review the reported results.								
Organ Doses [mSv/MBq] - Nuclide:Lu-177 (); ICRP 89 Adult Male								
Calculated 07.16.2024 at 06:39:53 IST								
Target Organ	**Alpha**	**Beta**	**Gamma**	**Total**	**ICRP-103 ED**	**Source Organ Name**	**Mass [g]**	**Kinetics Value [MBq-h/MBq]**
Adrenals	0.00E+00	1.98E-01	9.09E-02	2.89E-01	2.66E-03	Adrenals	14	0.00E+00
Brain	0.00E+00	1.79E-01	1.42E-02	1.93E-01	1.93E-03	Brain	1450	0.00E+00
Esophagus	0.00E+00	1.79E-01	3.99E-02	2.19E-01	8.75E-03	Esophagus	40	0.00E+00
Eyes	0.00E+00	1.79E-01	1.42E-02	1.93E-01	0.00E+00	Eyes	15	0.00E+00
Gallbladder Wall	0.00E+00	1.85E-01	8.78E-02	2.73E-01	2.52E-03	Gallbladder Contents	58	0.00E+00
Left colon	0.00E+00	1.81E-01	5.22E-02	2.34E-01	1.13E-02	Left colon	75	0.00E+00
Small Intestine	0.00E+00	1.80E-01	4.16E-02	2.22E-01	2.05E-03	Small Intestine	350	0.00E+00
Stomach Wall	0.00E+00	1.84E-01	6.71E-02	2.51E-01	3.01E-02	Stomach Contents	250	0.00E+00
Right colon	0.00E+00	1.79E-01	4.55E-02	2.24E-01	1.09E-02	Right colon	150	0.00E+00
Rectum	0.00E+00	1.79E-01	2.40E-02	2.03E-01	4.66E-03	Rectum	75	0.00E+00
Heart Wall	0.00E+00	1.79E-01	4.42E-02	2.23E-01	2.06E-03	Heart Contents	510	0.00E+00
Kidneys	**0.00E+00**	**2.25E+00**	**8.42E-02**	**2.33E+00**	**2.15E-02**	Heart Wall	330	0.00E+00
Liver	**0.00E+00**	**2.15E+00**	**1.14E-01**	**2.27E+00**	**9.06E-02**	**Kidneys**	**310**	**8.20E+00**
Lungs	0.00E+00	1.80E-01	3.26E-02	2.13E-01	2.56E-02	**Liver**	**1800**	**4.55E+01**
Pancreas	0.00E+00	9.21E+00	2.07E-01	9.41E+00	8.69E-02	Lungs	1200	0.00E+00
Prostate	0.00E+00	1.79E-01	2.39E-02	2.03E-01	9.37E-04	**Pancreas**	**140**	**1.52E+01**
Salivary Glands	0.00E+00	1.79E-01	1.81E-02	1.97E-01	1.97E-03	Prostate	17	0.00E+00
Red Marrow	0.00E+00	1.34E-01	2.44E-02	1.59E-01	1.90E-02	Salivary Glands	85	0.00E+00
Osteogenic Cells	0.00E+00	1.89E-01	4.16E-02	2.31E-01	2.31E-03	Red Marrow	1170	0.00E+00
Spleen	**0.00E+00**	**1.81E+00**	**6.59E-02**	**1.88E+00**	**1.73E-02**	Cortical Bone	4400	0.00E+00
Testes	0.00E+00	1.79E-01	1.54E-02	1.94E-01	7.77E-03	Trabecular Bone	1100	0.00E+00
Thymus	0.00E+00	1.79E-01	2.53E-02	2.04E-01	1.88E-03	**Spleen**	**150**	**3.20E+00**
Thyroid	0.00E+00	1.79E-01	2.05E-02	1.99E-01	7.97E-03	Testes	35	0.00E+00
Urinary Bladder Wall	0.00E+00	1.79E-01	2.23E-02	2.01E-01	8.04E-03	Thymus	25	0.00E+00
Total Body	**0.00E+00**	**2.63E-01**	**2.08E-02**	**2.84E-01**	**0.00E+00**	Thyroid	20	0.00E+00
						Urinary Bladder Contents	211	0.00E+00
Effective Dose	**3.69E-01**					**Total Body**	**73000**	**1.53E+02**

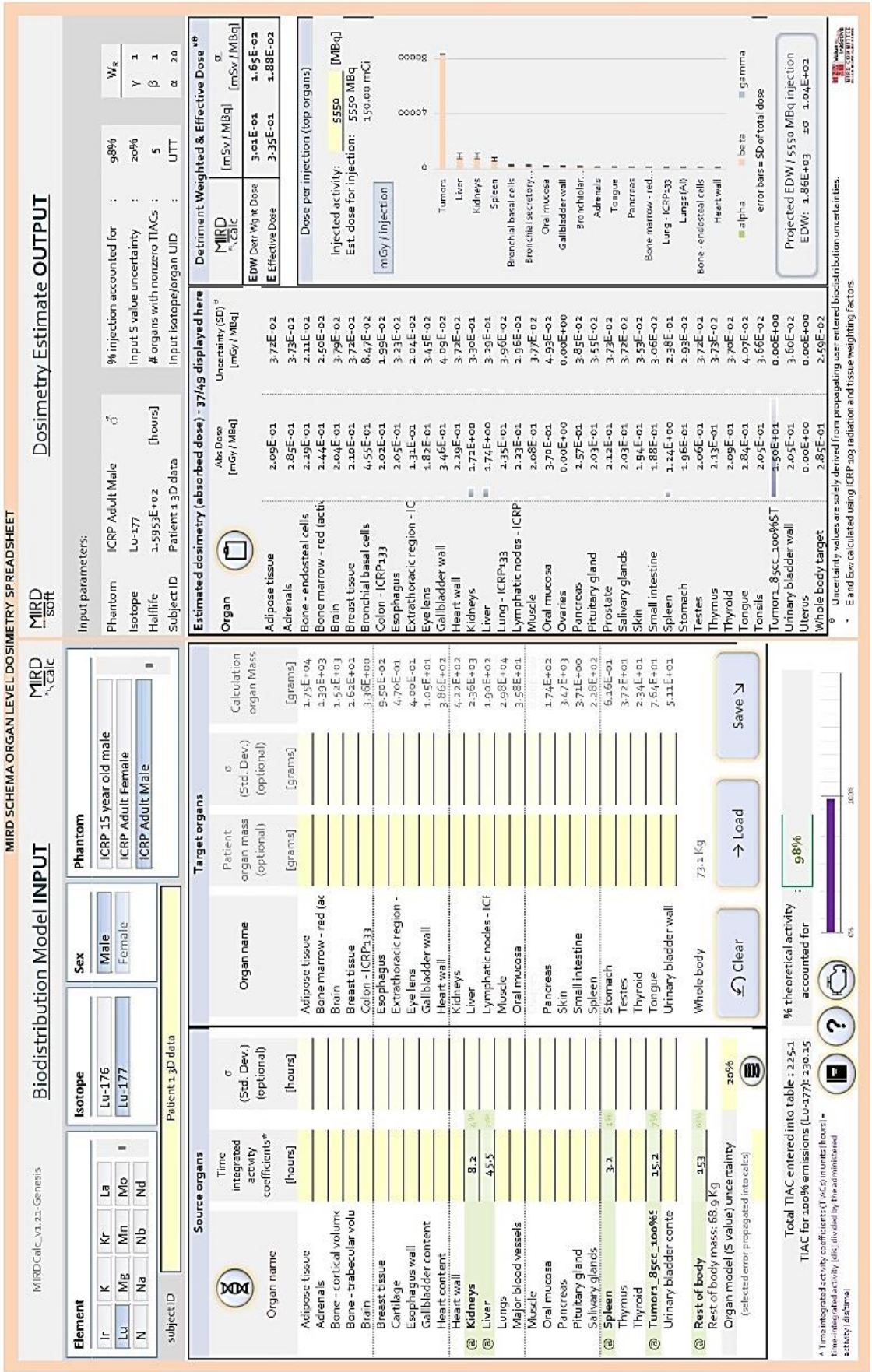


Figure 2. Patient P1, MIRcalc software, absorbed dose spreadsheet.

The estimates of % Injected Dose(%ID) or TIAC for the liver, kidney, spleen, and lesion/tumor varied by <9% between the two OLINDA/EXM and MIRDcalc dosimetric software. The highest variability for TIAC results was observed for the kidneys and liver (approximately 10%) in the seven patients in the first cycle of post-therapy scans. We also noted that in all seven patient cases, the relative error ($PE_{[\frac{OLINDA-}{MIRDcalc}]}$ (the gold standard relative percentage error)) approaches the log relative difference ($\Delta_{[\frac{OLINDA-}{MIRDcalc}]}$ (the logarithmic relative difference metric)) for minimal differences. Relative standard deviations in mean absorbed doses were slightly higher than those observed for TIAC but remained of the same order of magnitude in both software packages. When applying a similar processing approach, the results obtained were of the same order of magnitude regardless of the dosimetric software used. The overall estimated absorbed doses in our study showed a good correlation, but other factors, such as camera calibration and lesion delineation, also played an important role. However, comparing the performances of the OLINDA/EXM and MIRDcalc software is still difficult, as they do not address the same dosimetric analysis system.

Comparative Analysis of MIRDcalc and OLINDA/EXM Dosimetry Software

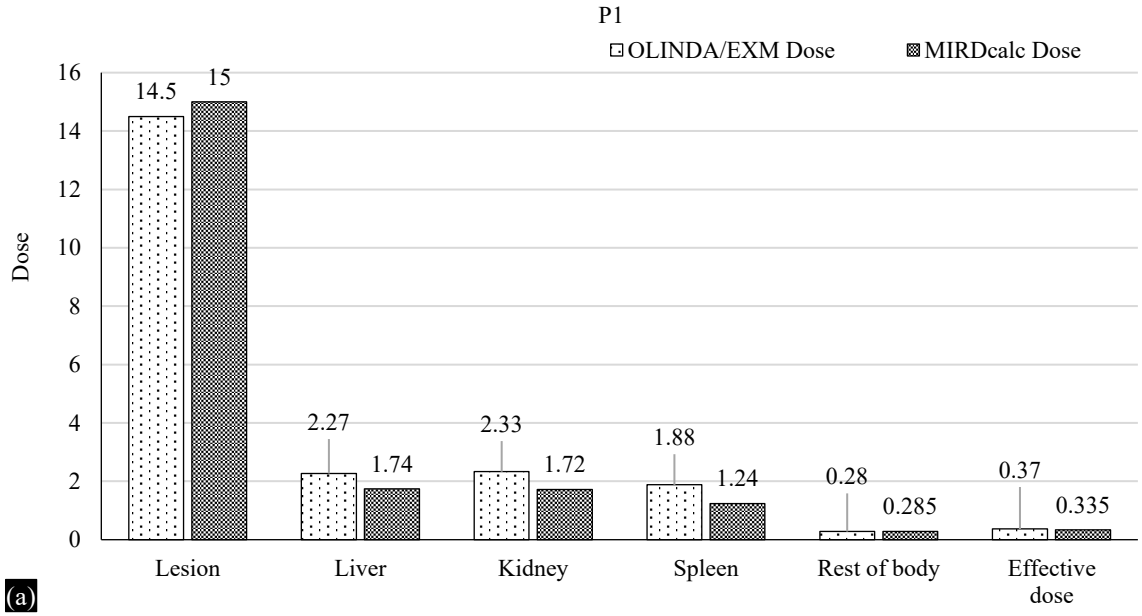
The TIAC (in units of MBq-h/MBq) in the Organs and OLINDA_MIRDcalc software comparative analysis of absorbed dose (in units of mGy/MBq) data of seven patients is shown in Table 2.

Table 2. TIAC (MBq-h/MBq) in organs and 3D OLINDA_MIRDcalc absorbed dose (mGy/MBq) data of seven patients.

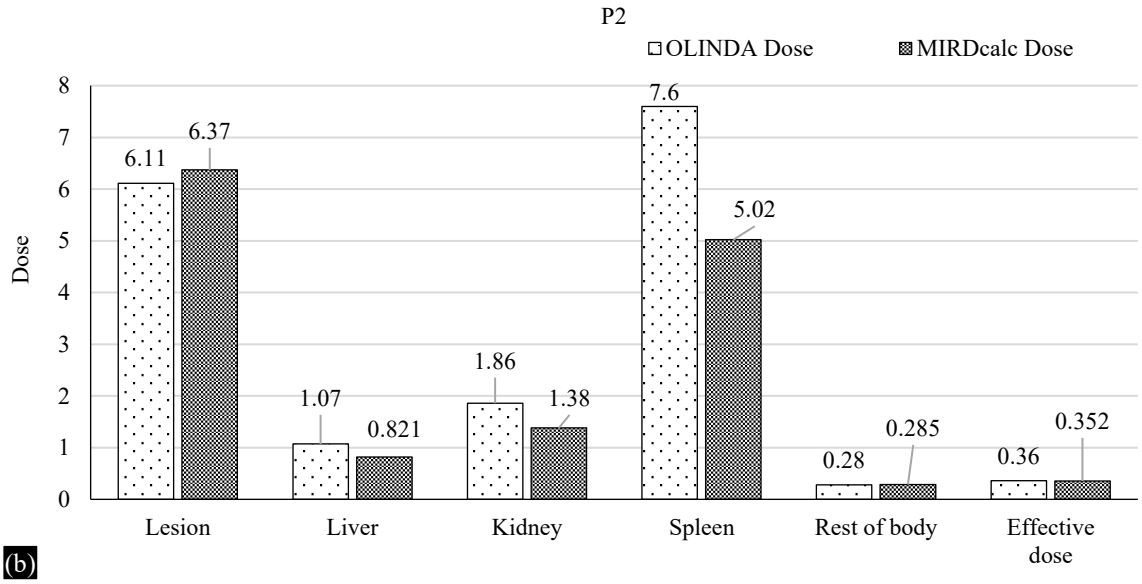
Pl					
Organ	**TIAC (h)**	**OLINDA/EXM Dose**	**MIRD Cale Dose**	**$\Delta_{[OLINDA\_MIRDcalc]}$**	**$PE_{[OLINDA\_MIRDcalc]}$**
Lesion	15.2	14.5	15	-3.39	-3.33
Liver	45.5	2.27	1.74	26.59	30.46
Kidney	8.2	2.33	1.72	30.35	35.47
Spleen	3.2	1.88	1.24	41.62	51.61
Rest of body	153	0.28	0.285	-1.77	-1.75
Effective dose	--	0.37	0.335	9.94	10.45
P2					
Organ	**TIAC (h)**	**OLINDA Dose**	**MIRDcalc**	**$\Delta_{[OLINDA\_MIRDcalc]}$**	**$PE_{[OLINDA\_MIRDcalc]}$**
Lesion	10.4	6.11	6.37	-4.17	-4.08
Liver	21.2	1.07	0.821	26.49	30.33
Kidney	6.52	1.86	1.38	29.85	34.78
Spleen	13.2	7.6	5.02	41.47	51.39
Rest of body	173	0.28	0.285	-1.77	-1.75
Effective dose	--	0.36	0.352	2.25	2.27
P3					
Lesion	16.2	7.16	7.46	-4.1	-4.02
Liver	66.6	4.22	3.27	25.2	29.05
Kidney	1.37	0.49	0.395	21.55	24.05
Spleen	11.4	7.6	5.27	36.61	44.21
Rest of body	59	0.24	0.24	0	0
Effective dose	--	0.71	0.267	97.8	165.92
P4					
Lesion	25.7	8.92	9.28	-3.96	-3.88
Liver	123	7.98	6.18	25.56	29.13
Kidney	0.56	0.26	0.232	11.39	12.07
Spleen	1.24	0.86	0.615	33.53	39.84
Rest of body	76.3	0.36	0.357	0.84	0.84
Effective dose	--	0.49	0.365	29.45	34.25

P5					
Organ	**TIAC (h)**	**OLINDA Dose**	**MIRDcalc**	**$\Delta_{[OLINDA\_MIRDcalc]}$**	**$PE_{[OLINDA\_MIRDcalc]}$**
Lesion	6.35	22.1	23	-3.99	-3.91
Liver	86.6	5.49	4.25	25.6	29.18
Kidney	3.69	1.23	0.971	23.64	26.67
Spleen	5.67	3.79	2.65	35.78	43.02
Rest of body	105	0.32	0.342	-6.65	-6.43
Effective dose	--	0.47	0.351	29.19	33.9
P6					
Lesion	16.7	6.27	6.53	-4.06	-3.98
Liver	73.9	3.66	2.8	26.78	30.71
Kidney	2.37	0.71	0.541	27.18	31.24
Spleen	2.49	1.47	0.97	41.57	51.55
Rest of body	136	0.29	0.297	-2.39	-2.36
Effective dose	--	0.66	0.352	62.86	87.5
P7					
Lesion	3.79	4.78	4.97	-3.9	-3.82
Liver	18.4	0.92	0.712	25.63	29.21
Kidney	1.43	0.43	0.325	28	32.31
Spleen	1.34	0.79	0.532	39.54	48.5
Rest of body	189	0.27	0.274	-1.47	-1.46
Effective dose	--	0.33	0.306	7.55	7.84

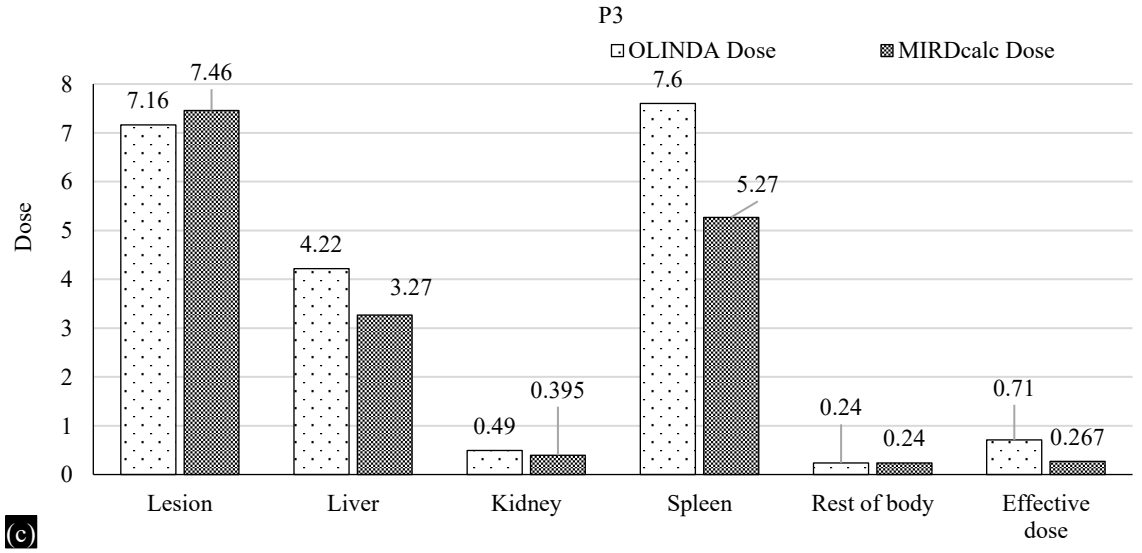
For the radiopharmaceutical Lu-177 DOTATATE, the absorbed dose estimates obtained from MIRDcalc were compared with those calculated using OLINDA/EXM. Two metrics were used for this comparison: the logarithmic relative difference and traditional percentage error. The logarithmic approach was selected owing to its neutrality regarding the reference method, allowing a consistent magnitude of difference, irrespective of which software was used as the baseline. Overall, the results demonstrated a close agreement between MIRDcalc and OLINDA/EXM. Minor variations in the absorbed dose estimates were observed, as reflected by both calculation methods. The effective dose values derived from MIRDcalc differed slightly from those computed using OLINDA/EXM, with a reported mean difference of approximately -10% and a standard deviation of 45% for adult patients (Figures 3 and 4). It was noted that OLINDA/EXM tended to produce slightly higher dose estimates for critical organs, which may be attributed to its reliance on conservative assumptions used in reference phantoms and biokinetic models, especially for organs with rapid clearance and higher radiopharmaceutical uptake. This comparative analysis revealed that both software platforms yielded consistent dosimetric outcomes for most of the target organs. However, discrepancies in dose values for certain organs were found, likely due to differences in phantom geometry, organ segmentation, and interpolation methods used to derive the S-values. MIRDcalc's use of updated ICRP-based phantom models and flexible input interfaces appeared to align more closely with patient-specific anatomical variations, particularly when organ mass, shape, and spacing were considered. Moreover, the variation in absorbed dose estimates was observed to range from 15% to 49% across the seven patients' scanned dataset. This variability is expected because of individual anatomical differences and biokinetic behaviors that are not fully captured by reference phantoms. Nevertheless, both tools showed improved concordance when the comparison focused solely on organs that contributed the most to the effective dose or received the highest radiation exposure. These findings suggest that, while both MIRDcalc and OLINDA/EXM software are robust and clinically useful tools for dosimetry calculations, attention must be paid to the specific modeling assumptions and phantom selection in each software. Personalized dosimetry, supported by imaging-based organ definitions and biodistribution inputs, is likely to benefit from the adaptable architecture of MIRDcalc.



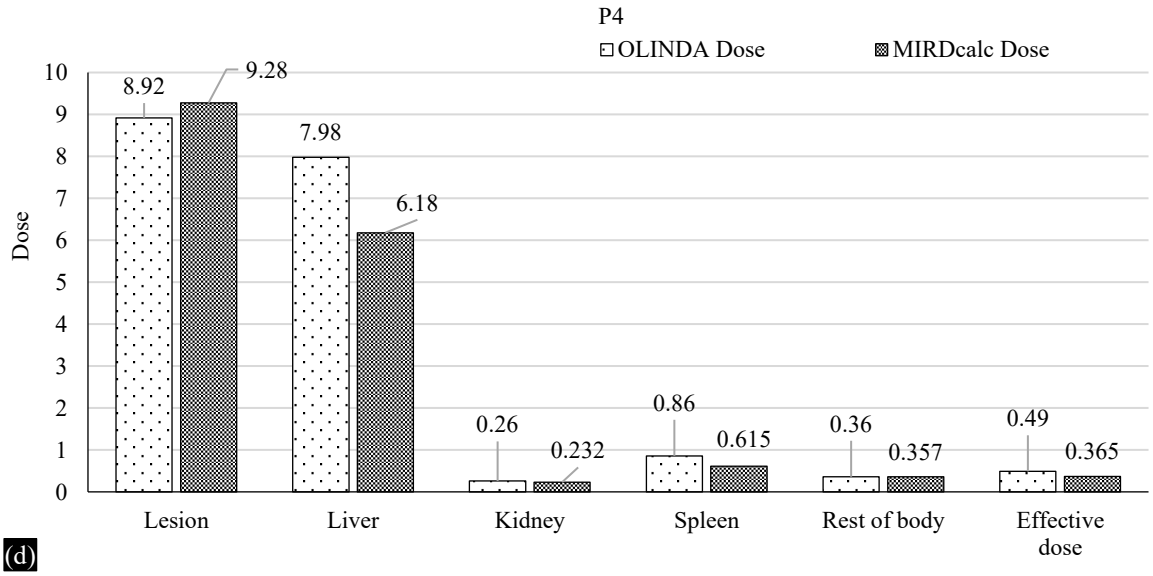
(a)



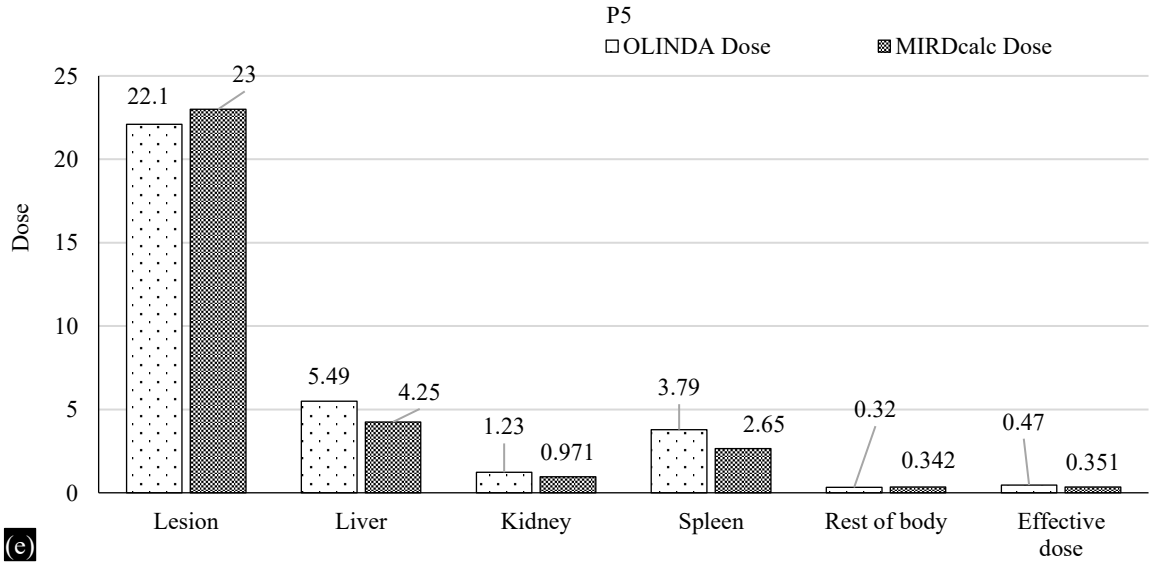
(b)



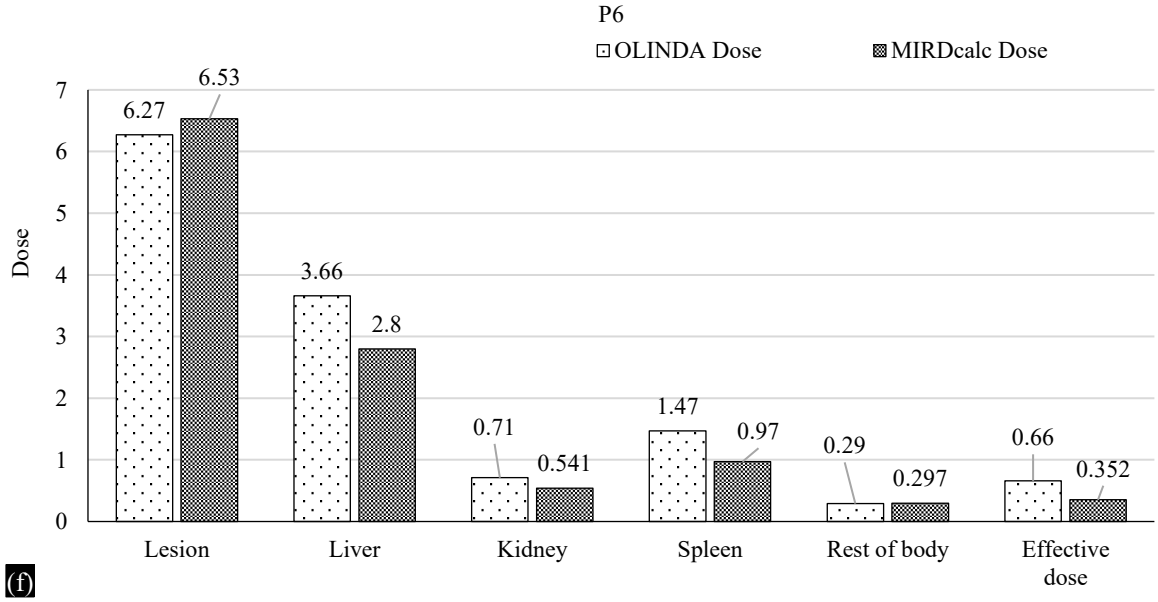
(c)



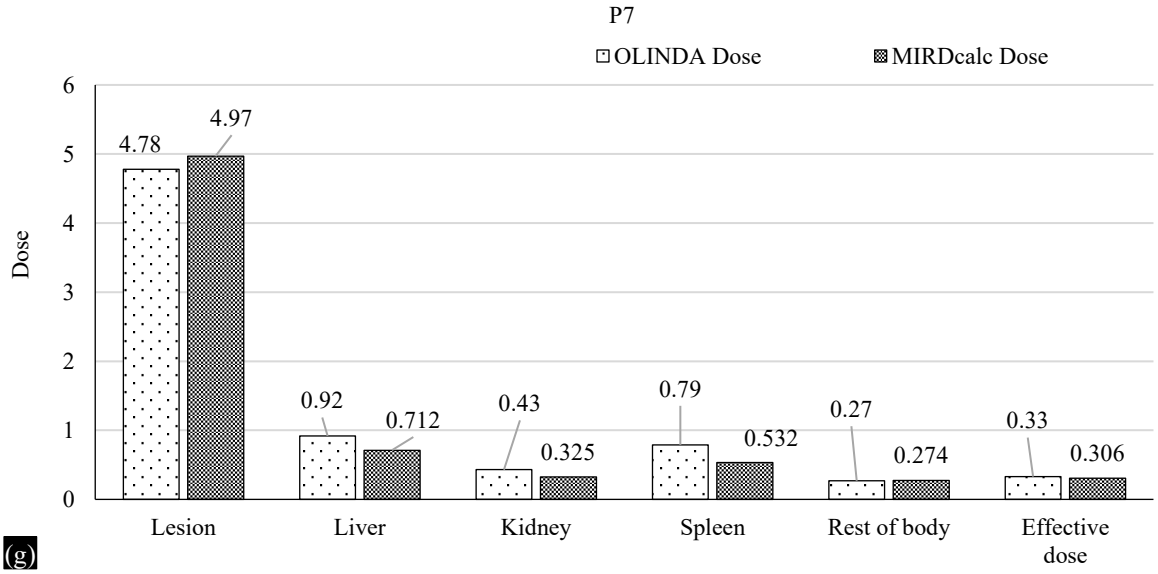
(d)



(e)

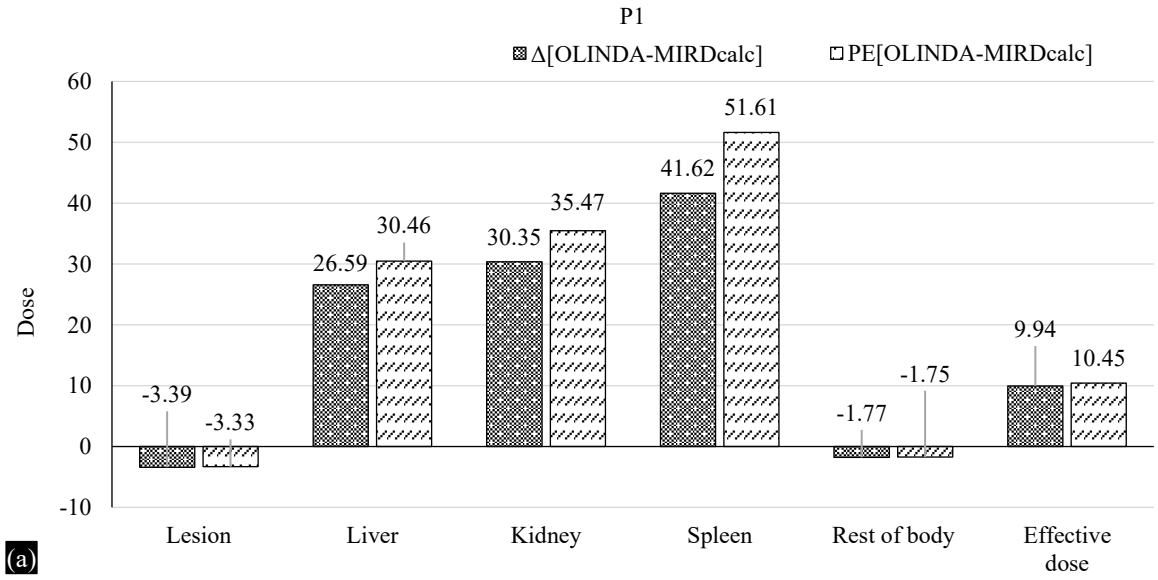


(f)

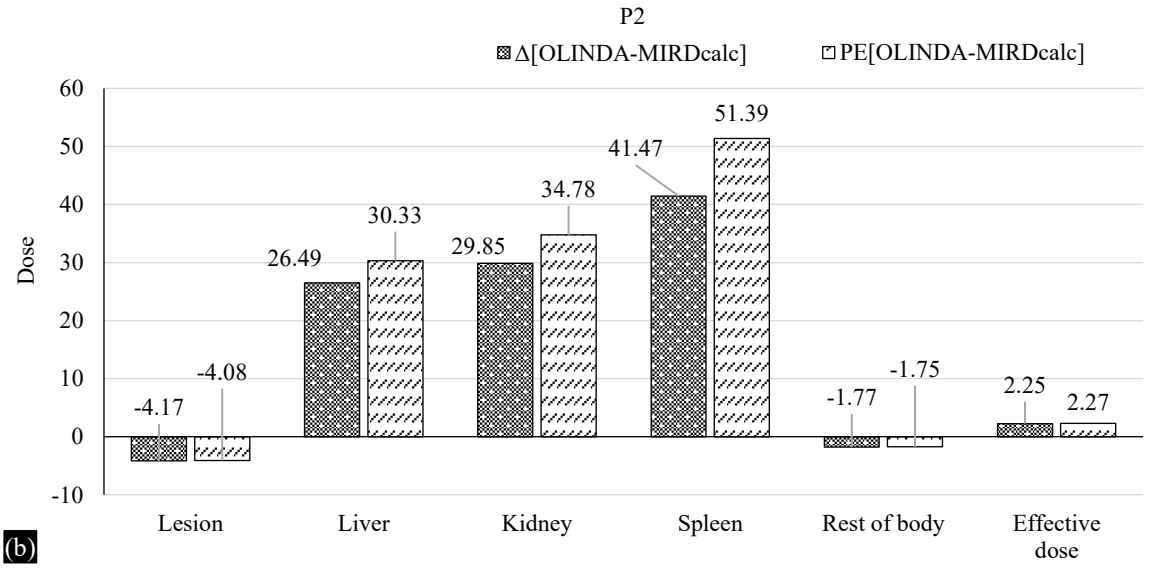


(g)

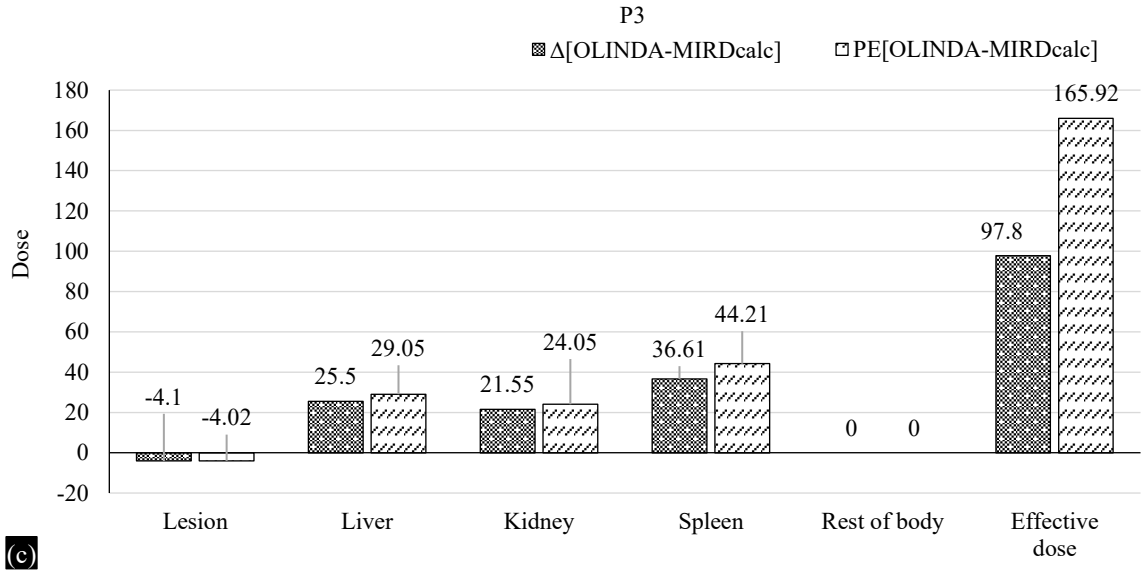
Figure 3. (a to g) 3D OLINDA_MIRDcalc absorbed dose (mGy/MBq) data.



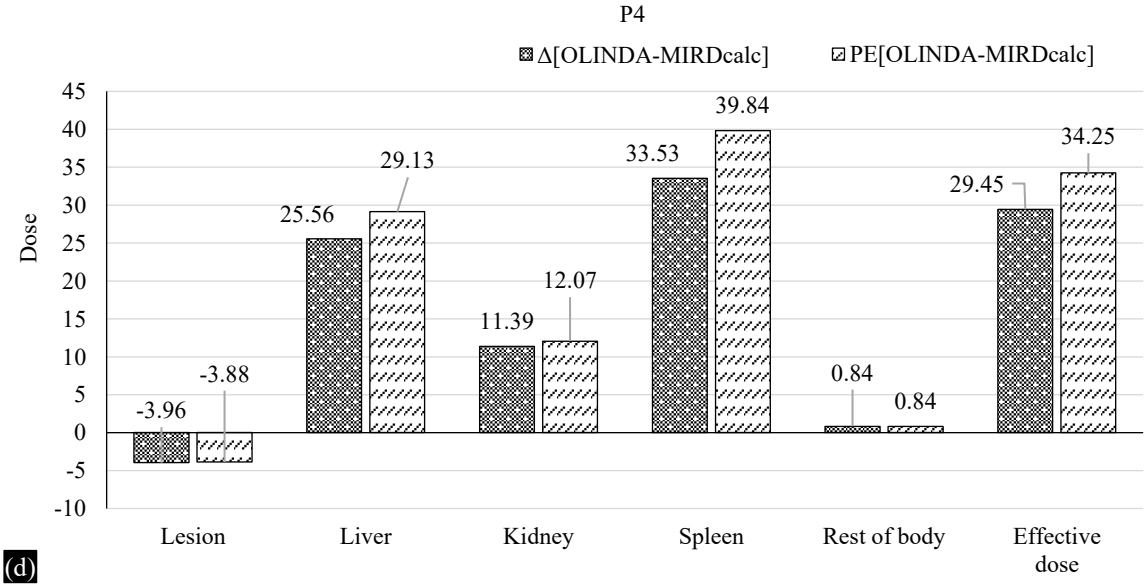
(a)



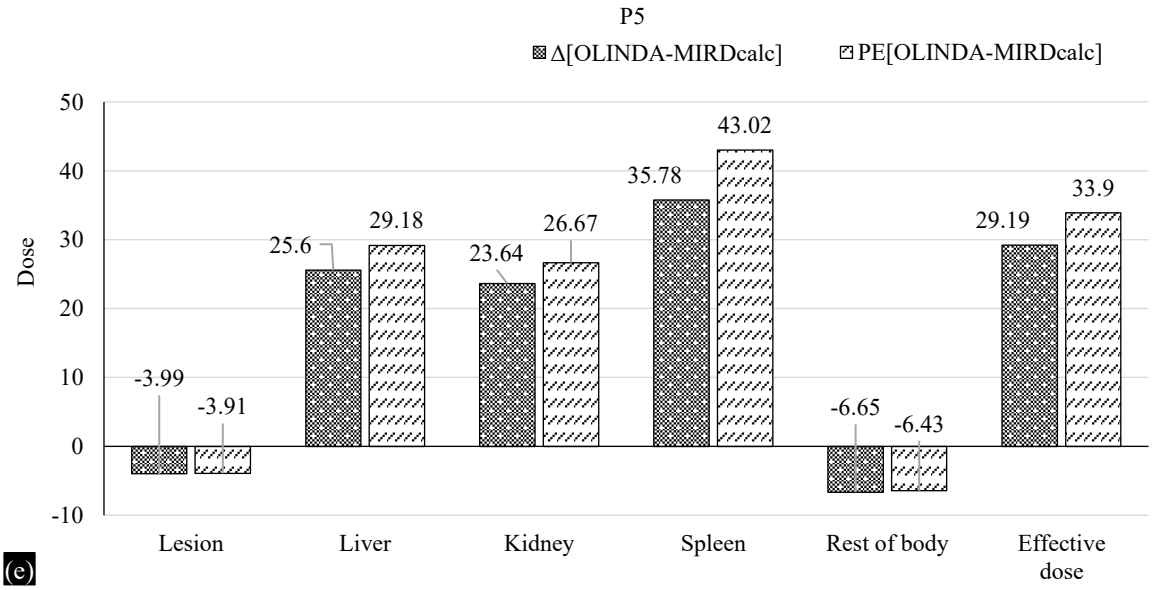
(b)



(c)



(d)



(e)

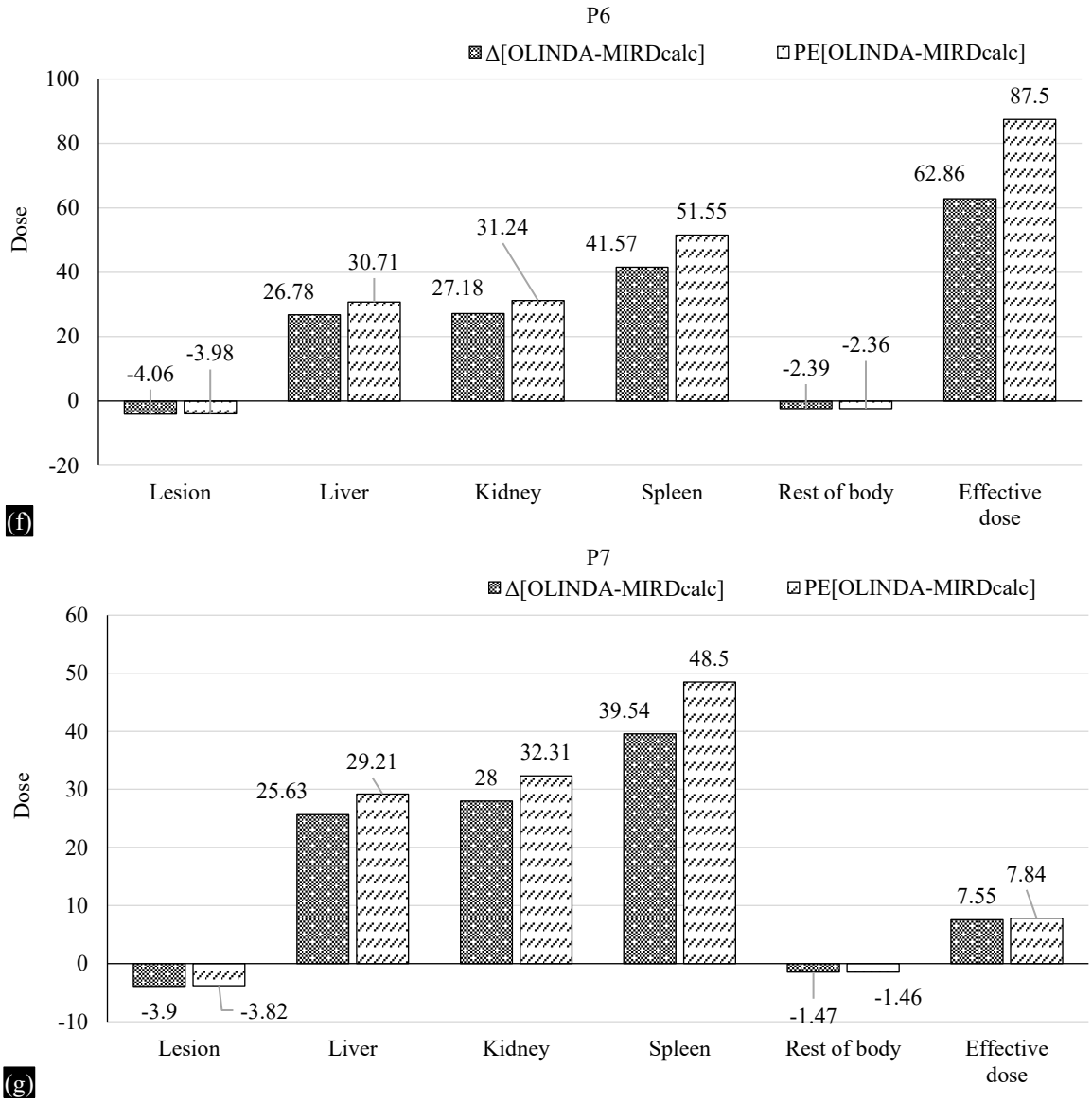


Figure 4. (a to g) 3D OLINDA_MIRDcalc software, comparison of absorbed dose coefficients analysis (Δ[OLINDA-MIRDcalc] and PE[OLINDA-MIRDcalc]) (mGy/MBq) data.

DISCUSSION

This study presents absorbed dose estimates specifically for Lu-177 DOTATATE administered to neuroendocrine tumor (NET) radionuclide therapy patients, using data acquired through SPECT/CT imaging. A key limitation of internal dosimetry lies in the uncertainty surrounding TIACs, which often results from the scarcity of accurate biodistribution data for Lu-177 and similar radiopharmaceuticals. Furthermore, in our evaluation, the TIACs were generated using earlier compartmental pharmacokinetic models and exponential retention functions, initially designed for use with stylized Cristy-Eckerman phantoms [30]. Therefore, the dose values provided should primarily be interpreted in a comparative context, useful for validating software tools, rather than as definitive clinical measures. Recalculation using contemporary models and updated software tools, such as MIRDcalc, is recommended. Looking ahead, dosimetric evaluations should be extended to include a wider array of patient-specific organ and tumor doses, enabling deeper comparisons between MIRDcalc and other dosimetry platforms that support individualized therapy and theranostic applications. As the field of internal dosimetry continues to evolve, the availability and sophistication of dosimetry software tools are increasing. However, the variability among these platforms, often driven by differences in phantom models and dose calculation

methods, necessitates rigorous comparisons and critical analyses. Most of the discrepancies observed between software tools stem from how they define and implement the anatomical reference phantoms. MIRDcalc, for instance, utilizes adult voxel phantoms from ICRP Publication 133 and specific absorbed fractions (SAFs) derived from ICRP 143, whereas OLINDA/EXM version 2.0 is based on the RADAR phantom series. These differences can significantly influence dose outcomes. MIRDcalc was developed to address the growing demand for validated, open-source, and flexible dosimetry solutions that are freely accessible to the global research and clinical community. MIRDcalc significantly reduces the complexity and time required for dosimetry calculations and offers a collaborative platform for ongoing developments. Future enhancements to MIRDcalc are expected to include advanced features, such as curve-fitting tools, pregnant/fetal phantom modeling, and sub-organ dosimetry. The integration of updated nuclear decay data with patient-specific imaging makes it a powerful and accessible tool for personalized dose planning in nuclear medicine.

A comparative study of ^{177}Lu-DOTATATA radionuclide therapy on NET patients using OLIND/EXM and MIRDcalc software provided a piece of wide information in standardizing and automating internal dose calculations for the existing dosimetry workflow practiced worldwide. The mathematical and physical methods implemented in the software program algorithm increase the accuracy of activity quantification and absorbed dose calculations in radionuclide therapies.

CONCLUSION

This study presents a detailed comparison of organ and tumor absorbed radiation doses, as well as effective doses, estimated using MIRDcalc and OLINDA/EXM software for Lu-177 DOTATATE radionuclide therapy in NET patients, based on SPECT/CT imaging data. The analysis indicated that MIRDcalc yields dose estimates that closely align with those from OLINDA/EXM and other dosimetry tools built on ICRP reference voxel phantoms. In most cases, the dose coefficients calculated using MIRDcalc were consistent with values derived using alternative reference models. These findings underscore the growing demand for advanced and updated nuclear emission databases to support the evolving applications of new radiopharmaceuticals. Although integrating additional features can enhance software capability, the design of next-generation dosimetry platforms should aim to address existing gaps, particularly those related to individualization, standardization, and improved biokinetic modeling. There is also a need for systems that allow user-specific anatomical inputs based on medical imaging, enabling interpolation between standardized models and refining dose estimation. Going forward, the MIRDcalc initiative is well-positioned to contribute to this progress by offering open-access, user-friendly tools tailored for research and educational use. Future developments are expected to expand its capabilities further, including functionalities such as curve fitting, fetal dosimetry, and sub-organ level dose calculations. As the field of nuclear medicine advances, incorporating detailed quantitative imaging with anatomically accurate models is essential for precise patient-specific internal dosimetry and therapy planning.

Acknowledgment

The present study is part of a research project (AIIMS project Fellowship Code No. D-616/202s2/RS), which was supported by the Department of Nuclear Medicine, All India Institute of Medical Sciences (AIIMS), Sri Aurobindo Marg, Ansari Nagar East, New Delhi, India.

Funding

This research was funded by the Women Scientist Scheme-A (WOS-A) under the Department of Science and Technology (DST), Ministry of Science and Technology, Government of India. (Grant Reference No. SR/WOS-A/PM-14/2019), for the Research project titled "Quantitative Analysis of Patient-Specific Internal Dosimetry Using Molecular Imaging Tools and Softwares for Radionuclide Therapy," to Dr. Madhulika Mehrotra, as Women Scientist Fellow, under the mentorship of Dr. C.S. Bal, Professor and Head, as Project Investigator (PI), Department of Nuclear Medicine, AIIMS, New Delhi.

Conflict of Interest Statement

The authors declare no conflicts of interest.

Author Contributions Statement

Conceptualization: Madhulika Mehrotra (MM); Literature Search: MM; Experimental Studies: MM, Prashant Mishra (PM), Saurabh Sharma (SS); Data Acquisition: MM, PM, SS; Data Analysis: MM; Manuscript Preparation and Editing: MM, PM, SS; Manuscript Review: All authors have read and approved the final version of the manuscript.

Ethical Approval/or Institutional Review Board (IRB) Approval

The study protocol was approved by the Institutional Ethics Committee of All India Institute of Medical Sciences, New Delhi, India (Ref No. IEC-11/14.01.2022), approved on 17.01.2022.

REFERENCES

1. Schlafke-Stelson AT, Watson EE, Cloutier RJ. A history of medical internal dosimetry. Health Phys. 1995;69:766–782. doi:10.1097/00004032-199511000-00011. PubMed: 7558867.
2. Loeevinger R, Berman M. A schema for absorbed-dose calculations for biologically-distributed radionuclides. J Nucl Med. 1968 Feb:Suppl 1:9-14. PMID: 5646656.
3. Loevinger R, Budinger TF, Watson EE, Society of Nuclear Medicine. Medical Internal Radiation Dose Committee. MIRD Primer for Absorbed Dose Calculations. Rev ed. New York: Society of Nuclear Medicine; 1991.
4. Bolch WE, Eckerman KF, Sgouros G, Thomas SR. MIRD Pamphlet No. 21: A generalized schema for radiopharmaceutical dosimetry—standardization of nomenclature. J Nucl Med. 2009;50:477–484. doi:10.2967/jnumed.108.056036. PubMed: 19258258.
5. Stabin MG. MIRDOSE: Personal computer software for internal dose assessment in nuclear medicine. J Nucl Med. 1996;37:538–546. PubMed: 8772664.
6. Stabin MG, Siegel JA. Physical models and dose factors for use in internal dose assessment. Health Phys. 2003;85:294–310. doi:10.1097/00004032-200309000-00006. PubMed: 12938720.
7. Stabin MG, Sparks RB, Crowe E. OLINDA/EXM: The second-generation personal computer software for internal dose assessment in nuclear medicine. J Nucl Med. 2005;46:1023–1027. PubMed: 15937315.
8. Kesner AL, Carter LM, Ramos JC, Lafontaine D, Olguin EA, Brown JL, et al. MIRD pamphlet no. 28, part 1: MIRDcalc—a software tool for medical internal radiation dosimetry. J Nucl Med. 2023;64(7):1117–1124.
9. Carter LM, Ocampo Ramos JC, Olguin EA, Brown JL, Lafontaine D, Jokisch DW, Bolch WE, Kesner AL. MIRD Pamphlet No. 28, Part 2: Comparative evaluation of MIRDcalc Dosimetry Software across a compendium of diagnostic radiopharmaceuticals. J Nucl Med. 2023 Aug;64(8):1295-1303. doi: 10.2967/jnumed.122.264230.
10. International Commission on Radiological Protection (ICRP). The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP. 2007;37(2-4):1-332. doi: 10.1016/j.icrp.2007.10.003. PMID: 18082557.
11. Mattsson S, Johansson L, Leide Svegborn S, Liniecki J, Noßke D, Riklund KÅ, et al. Radiation dose to patients from radiopharmaceuticals: a compendium of current information related to frequently used substances. Ann ICRP. 2015 Jul;44(2 Suppl):7–321. doi: 10.1177/0146645314558019.
12. Grosswendt B. ICRP Publication 110. Radiat Prot Dosimetry. 2012 Jun;150(1):124–6. doi: 10.1093/rpd/ncs059.
13. Bolch WE, Eckerman K, Endo A, Hunt JGS, Jokisch DW, Kim CH, et al. ICRP Publication 143: Paediatric reference computational phantoms. Ann ICRP. 2020;49:5–297. doi:10.1177/01466453 20915031. PubMed: 33000625.
14. Bolch WE, Jokisch D, Zankl M, Eckerman KF, Fell T, Manger R, et al. ICRP Publication 133: The ICRP computational framework for internal dose assessment for reference adults: Specific absorbed fractions. Ann ICRP. 2016;45(2):1–74.

15. Gear JI, Cox MG, Gustafsson J, Gleisner KS, Murray I, Glatting G, et al. EANM practical guidance on uncertainty analysis for molecular radiotherapy absorbed dose calculations. Eur J Nucl Med Mol Imaging. 2018;45:2456–2474. doi:10.1007/s00259-018-4136-7. PubMed: 30218316.
16. Loevinger R, Budinger TF, Watson EE. MIRD primer for absorbed dose calculations. Rev ed. New York: Society of Nuclear Medicine; 1991.
17. Bartlett RM, Bolch WE, Brill AB, Dewaraja YK, Fahey FH, Fisher DR, Hobbs RF, Howell RW, Meredith RF, Rajendran JG, Sgouros G, Zanzonico P. MIRD primer 2022: Complete Guide to Radiopharmaceutical Dosimetry. Reston, VA: Society of Nuclear Medicine & Molecular Imaging; 2022.
18. Dewaraja YK, Frey EC, Sgouros G, Brill AB, Roberson P, Zanzonico PB, et al. MIRD Pamphlet No. 23: Quantitative SPECT for patient-specific 3-dimensional dosimetry in internal radionuclide therapy. J Nucl Med. 2012;53:1310–1325. doi:10.2967/jnumed.111.100123. PubMed: 22743252.
19. Ljungberg M, Celler A, Konijnenberg MW, Eckerman KF, Dewaraja YK, Sjögreen-Gleisner K, et al. MIRD Pamphlet No. 26: Joint EANM/MIRD Guidelines for Quantitative 177Lu SPECT Applied for Dosimetry of Radiopharmaceutical Therapy. J Nucl Med. 2016;57:151–162. doi:10.2967/jnumed.115.159012. PubMed: 26471692.
20. Sgouros G, Bolch WE, Chiti A, Dewaraja YK, Emetzoglou D, Hobbs RF, et al. ICRU Report 96: Dosimetry-guided radiopharmaceutical therapy. J ICRU. 2021;21:1–212. doi:10.1177/14736691211060117.
21. Hindorf C. Internal dosimetry. In: Bailey DL, Humm JL, Todd-Pokropek A, van Aswegen A, editors. Nuclear Medicine Physics: A Handbook for Teachers and Students. Vienna: International Atomic Energy Agency; 2015.
22. Snyder WS, Ford MR, Warner GG, Watson SB. "S" absorbed dose per unit cumulated activity for selected radionuclides and organs. MIRD Pamphlet No. 11. New York: Society of Nuclear Medicine; 1975.
23. Olguin E, President B, Ghaly M, Frey E, Sgouros G, Bolch WE. Specific absorbed fractions and radionuclide S-values for tumors of varying size and composition. Phys Med Biol. 2020;65:235015. doi:10.1088/1361-6560/abbc7e. PubMed: 32992308.
24. Capala J, Graves SA, Scott A, Sgouros G, James SS, Zanzonico P, Zimmerman BE. Dosimetry for radiopharmaceutical therapy: Current practices and commercial resources. J Nucl Med. 2021;62(Suppl 3):3S–11S. doi:10.2967/jnumed.121.262749. PubMed: 34857621.
25. Katugampola S, Wang J, Rosen A, Howell RW, SNMMI MIRD committee. MIRD Pamphlet No. 27: MIRDcell V3, a revised software tool for multicellular dosimetry and bioeffect modeling. J Nucl Med. 2022;63:1441–1449. doi:10.2967/jnumed.121.263253. PubMed: 35145016.
26. Roedler HD. Accuracy of internal dose calculations with special consideration of radiopharmaceutical biokinetics. In: Watson EE, Schlafke-Stelson AT, Coffey JL, Cloutier RJ, editors. Third International Radiopharmaceutical Dosimetry Symposium (HHS Publication FDA 81-8166). Oak Ridge (TN): Oak Ridge Associated Universities; 1981. p. 1–20.
27. Andersson M, Johansson L, Minarik D, Leide-Svegborn S, Mattsson S. Effective dose to adult patients from 338 radiopharmaceuticals estimated using ICRP biokinetic data, ICRP/ICRU computational reference phantoms and ICRP 2007 tissue weighting factors. EJNMMI Phys. 2014;1:9. doi:10.1186/2197-7364-1-9. PubMed: 26501451.
28. Stabin M, Adam Farmer. OLINDA/EXM 2.0: The new generation dosimetry modeling code. Nucl Med. 2012;53(Suppl 1):585.
29. Stabin MG, Siegel JA. RADAR dose estimate report: A compendium of radiopharmaceutical dose estimates based on OLINDA/EXM version 2.0. J Nucl Med. 2018;59:154–160. doi:10.2967/jnumed.117.196261. PubMed: 28887400.
30. Subramanian S, He B, Frey E, Jokisch DW, Bolch W, Sgouros G. Improved accuracy of S-value-based dosimetry: A guide to transition from Cristy–Eckerman to ICRP adult phantoms. EJNMMI Phys. 2022;9:57. doi:10.1186/s40658-022-00485-9. PMID: 36018453.

