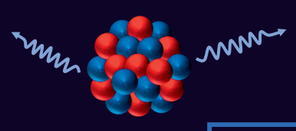
MIRD Synopsis for Dosimetry in Radiopharmaceutical Therapies With ^{177}Lu

By Carlos Uribe, PhD,[1] on behalf of the MIRD Committee 2023

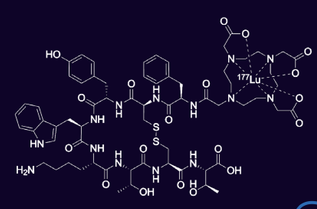
[1]BC Cancer and The University of British Columbia, Vancouver, Canada

Recent FDA approval of radiopharmaceuticals for diagnosis and treatment of neuroendocrine tumors and metastatic prostate cancer has increased the awareness of and enthusiasm for theranostics; in particular those labeled with ^{177}Lu. However, in the era of personalized medicine, radiopharmaceutical therapies may be improved by tailoring them to each patient's physiology and biology. Routine dosimetry includes quality and standardized workflows that can be integrated with patient management standards of care. Here, we present the key points in ^{177}Lu dosimetry, to "de-mystify" the steps of the dosimetry workflow.



^{177}Lu

- β^- emitter
- Maximum energy[1] = 497 keV
- Half life[1] = 6.647 days
- Decay emits gammas with most intense energies being 208 keV (10%) and 113 keV (6%)



FDA Approved ^{177}Lu-labeled radiopharmaceuticals

^{177}Lu-DOTATATE

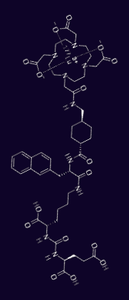
For gastroenteropancreatic neuroendocrine tumors.
Every 8 weeks for 4 cycles.

Organs at risk: kidneys and bone marrow.

^{177}Lu-PSMA-617

For metastatic castration-resistant prostate cancer.
Every 6 weeks for up to 6 cycles.

Organs at risk: kidneys, salivary glands, and bone marrow.

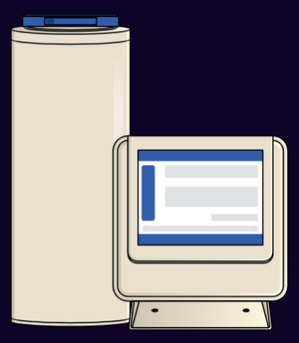


Dosimetry should be performed or overseen by a qualified medical physicist

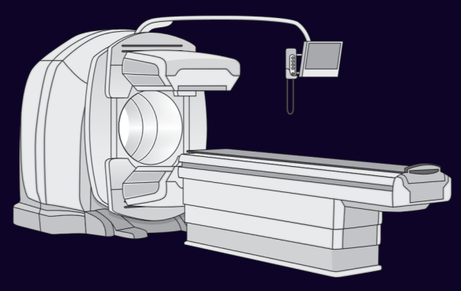
Calibration

Radionuclide Activity Calibrator

1. Order source traceable to standard from radiopharmaceutical manufacturer.
2. Take note of reference activity, date and time.
3. Perform decay calculations to obtain activity of reference source at measurement date and time.
4. Place standard source in the radionuclide activity calibrator.
5. Change the dial setting until you read the calculated activity from step 3.
6. Use calibrated setting to measure activity administered to patients.



SPECT Camera[2,3]



1. Use a Medium Energy Collimator.
2. Configure the following energy windows.

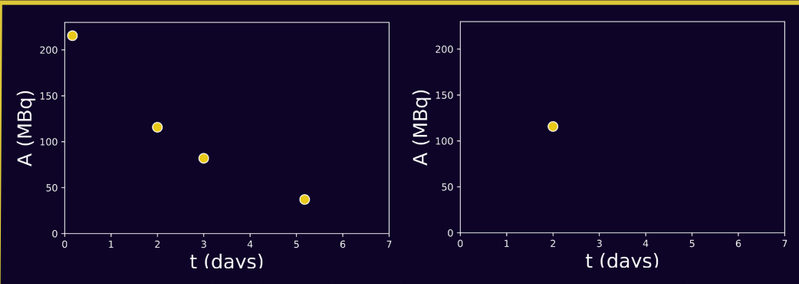
Photopeak window	208 keV @20% [187.2 – 228.8] keV
Low scatter window	10% [166.4 – 187.2] keV
Upper scatter window	10% [228.8 – 249.6] keV

3a. Planar acquisition method: If corrections applied in image reconstruction are accurate, perform a planar acquisition of a small point-like source placed in air. Perform triple energy window scatter correction to the image.

3b. Water cylinder method: Scan a cylinder containing a known amount of ^{177}Lu using the same acquisition and reconstruction protocol as used in patients.

4. Determine the total counts in the image and divide it by the acquisition time (time/view × # of views). Knowing the reference activity of the source, calculate the calibration factor in units of MBq/cps.

Imaging Timepoints to measure the time-activity curve (TAC)[2,4,5]



Option 1 : Multiple and single time point approach.
Acquire at least 3 time points for first cycle (prior information) within one week of injection.
Acquire a single time point for subsequent cycles:

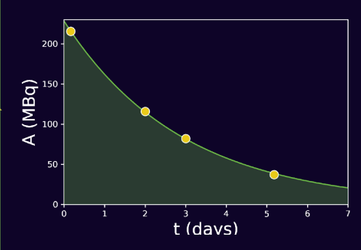
- ^{177}Lu-DOTATATE scan close to 72 hours post-injection.
- ^{177}Lu-PSMA-617 scan close to 48 hours post-injection.

Option 2 (preferred): Multiple time points for all cycles.
Acquire at least 3 time points within one week of injection.

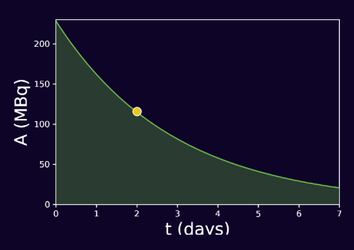
Perform quantitative image reconstruction (i.e. applying scatter and attenuation correction) and segmentation of the organs at risk from the quantitative images to determine the activity for each at each measured time point.

Time-integrated activity (TIA)

Determine the total number of disintegrations of ^{177}Lu in each of the organs by integrating the TAC. The integration can be done at the organ level or at a voxel level to generate a 3D absorbed dose maps.

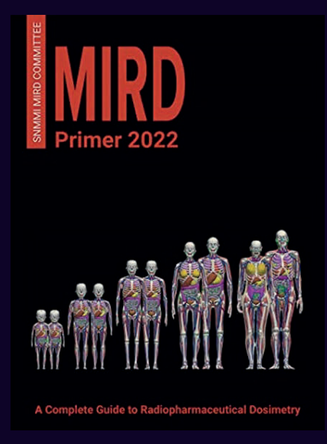


Fit with exponentials: Fit the data to exponential equations and calculate the time integrated activity.



Based on Prior information: Use effective half-time from cycle 1 and apply to subsequent cycles of the same patient.

More Resources



MIRDsoft.org
Radiation Dosimetry Community Platform

Absorbed Doses

Organ Level

Use a validated dosimetry software like MIRDCalc[6] and enter the time-integrated activity values, normalized by injected activity (i.e. MBq*h/MBq), for each organ you have segmented as well as the rest of the body.

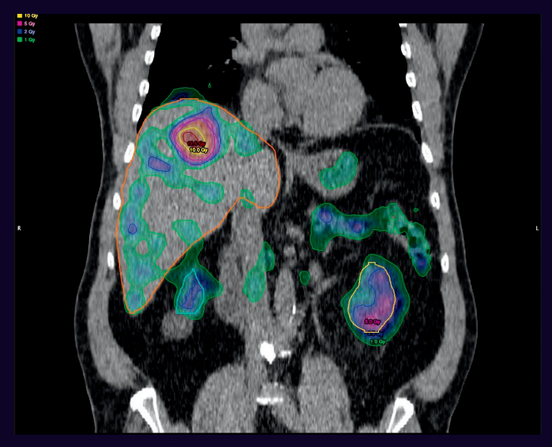
Estimate and enter the true mass of each organ from the volume of the region of interest of the segmentation.

The software will apply the correct S-values to the data and a value for the absorbed dose of each organ will be presented.

Voxel Level

If a voxelized TIA image was generated, the image can be convolved with a dose kernel to generate a 3D dose map.

The regions of interest drawn in the segmentation can be used to obtain statistics from the dose map (e.g. mean absorbed dose).



Dose map fused with a CT scan on a patient treated with 177Lu-DOTATATE.[9]

References

[1]. *Brookhaven National Laboratory, NuDat 2.8. –* ***[2].*** *Ljungberg, et al. 2016. JNM 57 (1): 151–62. –* ***[3].*** *Uribe, et al. 2017. EJNMMI Physics 4 (1): 2. –* ***[4].*** *Hou et al. 2021. JNM 62 (7): 1006–11.* ***[5].*** *Brosch-Lenz et al. 2023. JNM 64 (5): 767–74. –* ***[6].*** *Kesner et. al., MIRD Pamphlet No. 28, JNM, 2023, In press. –* ***[7]*** *Bolch, et al. 2009. JNM 50 (3): 477–84. -* ***[8]*** *MIRD committee, MIRD Primer 2022* ***[9]*** *Dewaraja, Y. K. (2021). Lu-177 DOTATATE Anonymized Patient Datasets: Multi-Time Point Lu-177 SPECT/CT Scans 2021. https://doi.org/10.7302/0n8e-rz46*

SNMMI SOCIETY OF NUCLEAR MEDICINE & MOLECULAR IMAGING
MIRD COMMITTEE
MEDICAL INTERNAL RADIATION DOSE