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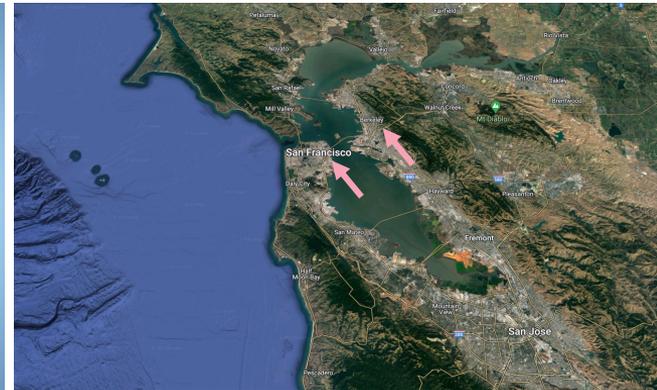


Practical Session for Radiopharmaceutical Dosimetry

IEEE NPSS School on Advanced Topics in Medical Imaging

Youngho Seo, PhD

UCSF Physics Research Laboratory



Whole-Body Counting to Bone Marrow (^{131}I -NaI for Thyroid Cancer)

Total Number of Disintegrations (Time-Integrated Activity Coefficients or Residence Times)

Total number of disintegrations	Organ Mass	Energy absorbed disintegration
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$$D = \left[\int_{t=0}^{\infty} A(t) dt \right] \left[\frac{1}{M} \sum_i n_i E_i \phi_i \right] = \tilde{A} S$$

Area under time-activity curve	S-value (tabulated)
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S-Value and Dose Computation: Data To Extract

TABLE 1. Mean Whole Body Counts After Radioiodine Administration

Mean Whole Body Counts

Administered Activity, GBq	No of Patients	Time Points					
		2 hours	6 hours	12 hours	24 hours	48 hours	96 hours
3.7	8	595,355 ± 19,042	476,672 ± 40,731	351,524 ± 37,856	203,052 ± 70,673	98,670 ± 96,714	40,453 ± 64,475
4.62	5	637,759 ± 40,618	522,328 ± 27,194	361,438 ± 22,981	182,159 ± 27,175	82,663 ± 29,719	18,074 ± 22,614
5.55	10	788,381 ± 94,883	599,361 ± 90,943	434,541 ± 142,638	220,179 ± 132,040	90,284 ± 54,225	33,814 ± 40,995

TABLE 2. Mean the Blood Sampling Activity After Radioiodine Administration

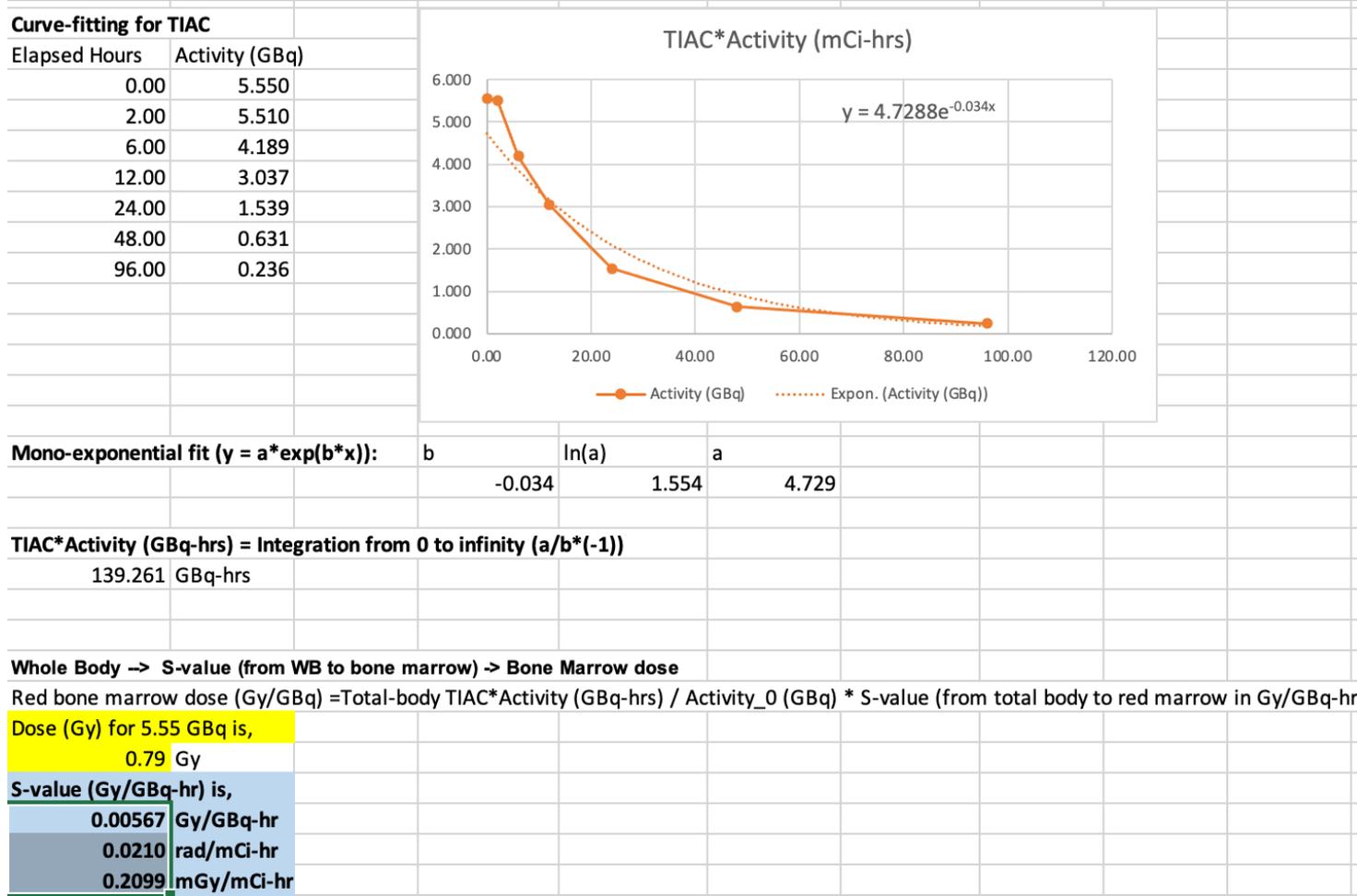
Mean the Blood Sampling Activity, µCi

Administered Activity, GBq	No of Patients	Time Points					
		2 hours	6 hours	12 hours	24 hours	48 hours	96 hours
3.7	8	4.49 ± 1.15	2.62 ± 0.89	1.46 ± 0.29	0.85 ± 0.28	0.37 ± 0.12	0.17 ± 0.06
4.62	5	5.30 ± 0.80	2.72 ± 0.55	1.39 ± 0.31	0.78 ± 0.13	0.35 ± 0.08	0.14 ± 0.16
5.55	10	6.21 ± 1.51	3.48 ± 0.79	1.73 ± 0.97	0.79 ± 0.53	0.29 ± 0.20	0.13 ± 0.12

TABLE 3. Mean Values of Absorbed Dose to the Blood 96 hours After Radioiodine Administration

	Administered Activity, GBq		
	3.7	4.62	5.55
Absorbed dose to the blood, Gy	0.65 ± 0.19	0.67 ± 0.18	0.79 ± 0.51

S-Value from Whole-Body Counts to Bone Marrow



Reconstituting Absorbed Dose from TIAC*Activity and S-Value

S-value (Gy/GBq-hr) is,
0.00579 Gy/GBq-hr
0.0214 rad/mCi-hr
0.2142 mGy/mCi-hr
bone marrow dose rate (Gy/GBq)
0.1757
bone marrow dose (Gy)
0.6500

S-value (Gy/GBq-hr) is,
0.00594 Gy/GBq-hr
0.0220 rad/mCi-hr
0.2198 mGy/mCi-hr
bone marrow dose rate (Gy/GBq)
0.1450
bone marrow dose (Gy)
0.6700

S-value (Gy/GBq-hr) is,
0.00567 Gy/GBq-hr
0.0210 rad/mCi-hr
0.2099 mGy/mCi-hr
bone marrow dose rate (Gy/GBq)
0.1423
bone marrow dose (Gy)
0.7900

Mean S-value calculated from these datasets in three different units:

5.80E-03 Gy/GBq-hr			
2.15E-02 rad/mCi-hr			
2.15E-01 mGy/mCi-hr			

Tumor Dosimetry using a Sphere Model (Lesional Dosimetry)

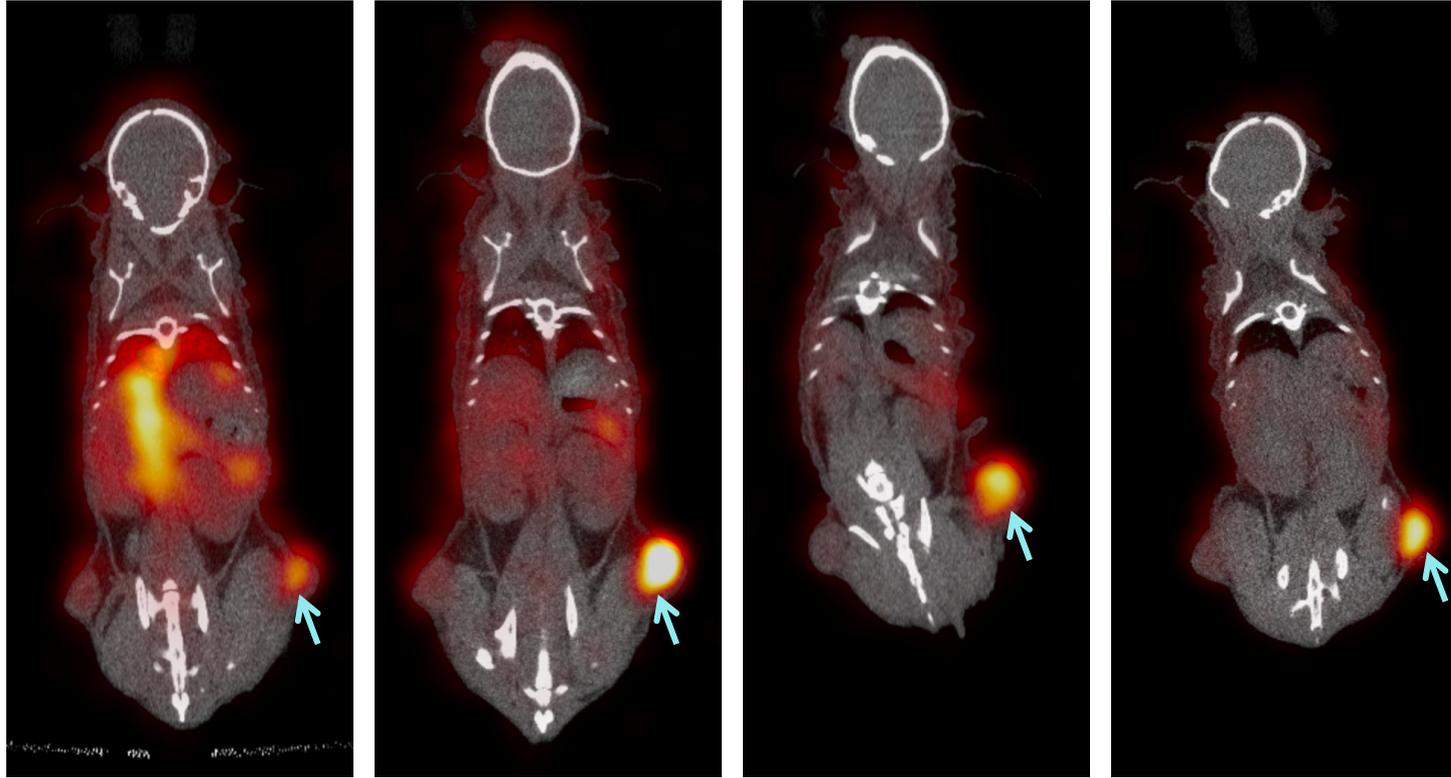
Total Number of Disintegrations (Time-Integrated Activity Coefficients or Residence Times)

Total number of disintegrations	Organ Mass	Energy absorbed disintegration
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Area under time-activity curve	S-value (tabulated)
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Data to Extract: Quantitative SPECT/CT Imaging



Over 8 days

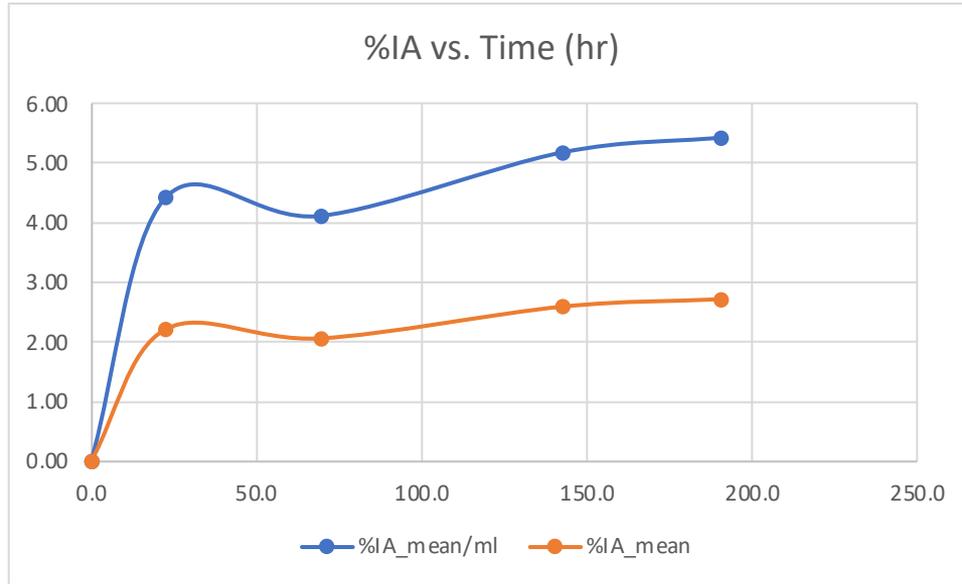
Data to Extract: Time and %Injected_Activity(IA)/mL

From SPECT/CT Imaging	
Time (hr)	%IA/mL_mean
0.00	0.00
22.53	4.42
69.53	4.11
142.53	5.18
190.53	5.43

%IA Calculation

%IA Calculation		
%IA/tumor calculation for 0.5 ml tumor volume		
Time (hr)	%IA_mean/ml	%IA_mean
0.0	0.00	0.00
22.5	4.42	2.21
69.5	4.11	2.06
142.5	5.18	2.59
190.5	5.43	2.71

Time-Integrated Activity Coefficient Calculation



177Lu-TIAC (hr)

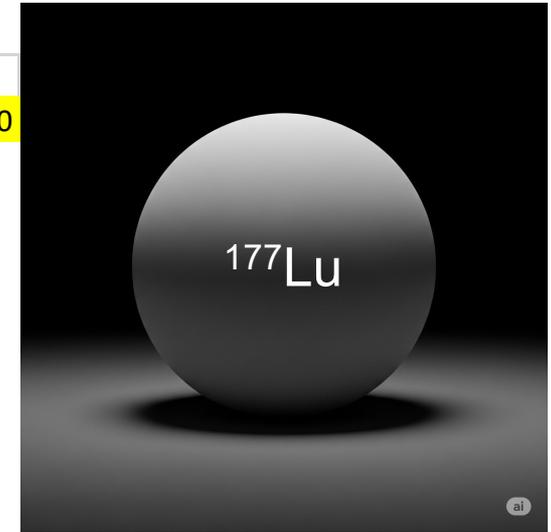
5.51E+00

Dose Calculation using a Sphere Model

mass (g)	Dose (mGy/MBq)	LN(mass(g))	LN(Dose(mGy/MBq))
0.01	43200.00	-4.61	10.67
0.10	4500.00	-2.30	8.41
0.50	914.00	-0.69	6.82
1.00	462.00	0.00	6.14
2.00	232.00	0.69	5.45
4.00	116.00	1.39	4.75
6.00	77.80	1.79	4.35
8.00	58.30	2.08	4.07
10.00	46.80	2.30	3.85
20.00	23.40	3.00	3.15
40.00	11.80	3.69	2.47
60.00	7.87	4.09	2.06
80.00	5.91	4.38	1.78
100.00	4.74	4.61	1.56
300.00	1.59	5.70	0.46
400.00	1.20	5.99	0.18
500.00	0.96	6.21	-0.04
600.00	0.80	6.40	-0.22
1000.00	0.49	6.91	-0.72
2000.00	0.25	7.60	-1.40
3000.00	0.17	8.01	-1.80
4000.00	0.12	8.29	-2.09
5000.00	0.10	8.52	-2.30
6000.00	0.08	8.70	-2.48

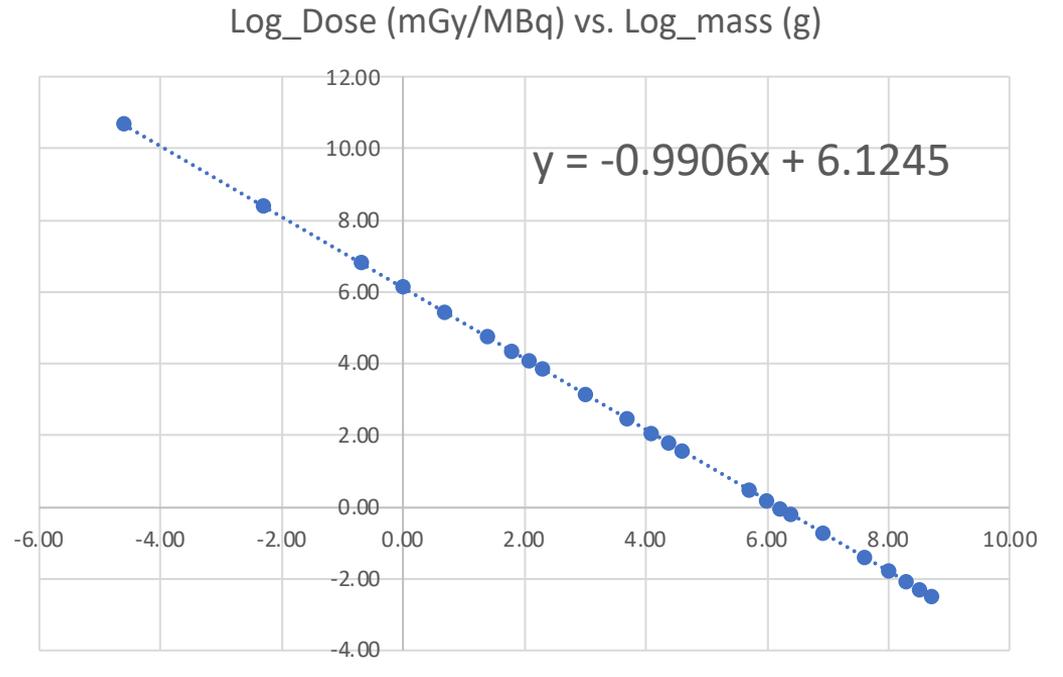
^{177}Lu -TIAC (hr)

5.51E+00



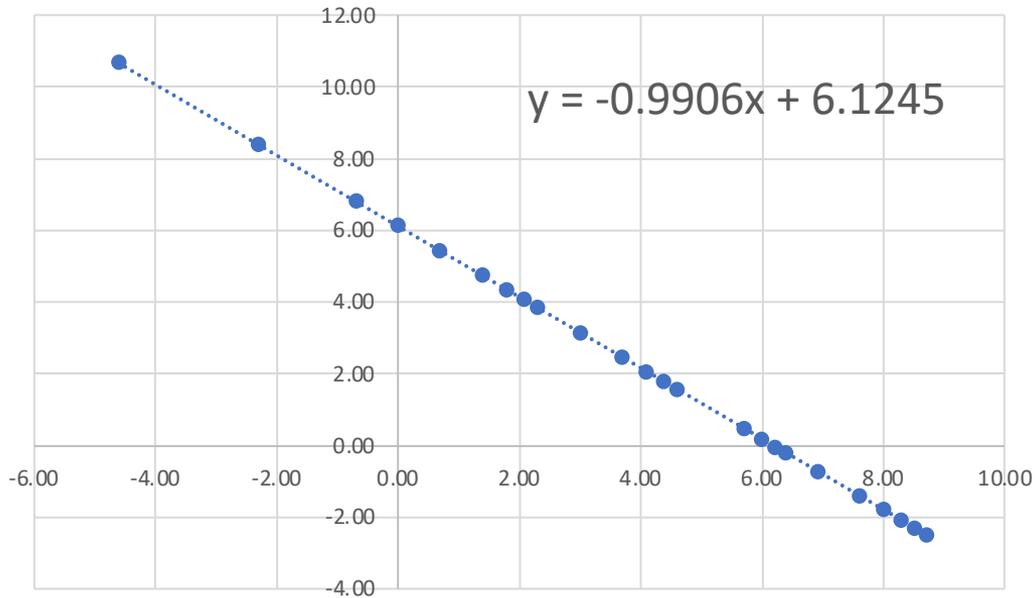
Dose Value Extrapolation for Any Mass/Volume

mass (g)	Dose (mGy/MBq)	LN(mass(g))	LN(Dose(mGy/MBq))
0.01	43200.00	-4.61	10.67
0.10	4500.00	-2.30	8.41
0.50	914.00	-0.69	6.82
1.00	462.00	0.00	6.14
2.00	232.00	0.69	5.45
4.00	116.00	1.39	4.75
6.00	77.80	1.79	4.35
8.00	58.30	2.08	4.07
10.00	46.80	2.30	3.85
20.00	23.40	3.00	3.15
40.00	11.80	3.69	2.47
60.00	7.87	4.09	2.06
80.00	5.91	4.38	1.78
100.00	4.74	4.61	1.56
300.00	1.59	5.70	0.46
400.00	1.20	5.99	0.18
500.00	0.96	6.21	-0.04
600.00	0.80	6.40	-0.22
1000.00	0.49	6.91	-0.72
2000.00	0.25	7.60	-1.40
3000.00	0.17	8.01	-1.80
4000.00	0.12	8.29	-2.09
5000.00	0.10	8.52	-2.30
6000.00	0.08	8.70	-2.48



Tumor Dose Interpretation

Log_Dose (mGy/MBq) vs. Log_mass (g)



Tumor volume (ml)	0.5	
Tumor mass (g)	0.5	
LN(tumor_mass)	-0.69	
LN(tumor_dose)	6.81	
tumor_dose (mGy/MBq)	907.90	
Tumor dose from 177Lu		
	908	in mGy/MBq
	33.6	in Gy/mCi
	0.034	in Gy/uCi

Further Reading and Exercise (e.g., `OpenDose3D`)



SlicerOpenDose3D

☆ Star 14

deveLop opendose3d

Find file Code



Merge branch 'Users-manual-update' into 'develop' Jose Alejandro Fragoso Negrin authored 1 month ago



66048630 History

Name	Last commit	Last update
OpenDose3D	Merge branch 'fix-missing-elastix-in-ni...	1 month ago
images	Compress manual images	5 months ago
.gitignore	Nukfit manual mode	1 month ago
.gitlab-ci.yml	allowing kernels from different sources	1 year ago
CMakeLists.txt	changing all obsolete nomenclature	4 years ago
CODE_OF_CONDUCT.md	Refactor Completed	5 years ago
Developers.md	Users manual update	1 month ago
Dosimetry.png	first working commit	6 years ago
LICENSE	Add LICENSE	6 years ago
OpenDose3D.s4ext	Compress manual images	5 months ago
README.md	Users manual update	1 month ago
User_Manual.md	Users manual update	1 month ago

Project information

This project implements a Slicer3D module aiming for molecular radiotherapy dosimetry

3d-slicer-ex...

- pipeline passed
- opensef best practices passing
- coverage 22.00%

833 Commits

9 Branches

11 Tags

README

Apache License 2.0

Auto DevOps enabled

Created on

November 18, 2019

Good Readings

- Stabin M, Wendt III RE, Flux GD. RADAR Guide: Standard Methods for Calculating Radiation Doses for Radiopharmaceuticals, Part 1 – Collection of Data for Radiopharmaceutical Dosimetry
- Stabin M, Wendt III RE, Flux GD. RADAR Guide: Standard Methods for Calculating Radiation Doses for Radiopharmaceuticals, Part 2 – Data Analysis and Dosimetry

RADAR Guide: Standard Methods for Calculating Radiation Doses for Radiopharmaceuticals, Part 1—Collection of Data for Radiopharmaceutical Dosimetry

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¹Radiation Dose Assessment Resource (RADAR) Task Force, Society of Nuclear Medicine and Molecular Imaging, Nashville, Tennessee; ²Department of Imaging Physics, University of Texas M.D. Anderson Cancer Center, Houston, Texas; and ³Department of Physics, Royal Marsden NHS Foundation Trust, Sutton, United Kingdom

This paper presents standardized methods for collecting data to be used in performing dose calculations for radiopharmaceuticals. Various steps in the process are outlined, with some specific examples given. This document can be used as a template for designing and executing kinetic studies for calculating radiation dose estimates, from animal or human data.

Key Words: image reconstruction; radiation physics; radiobiology/dosimetry; radiopharmaceuticals; clinical imaging; radiation dosimetry

J Nucl Med 2022; 63:316–322
DOI: 10.2967/jnumed.120.259200

Currently, there is renewed interest in performing radiation dosimetry for radiopharmaceuticals, particularly in therapy applications. To have any new radiopharmaceutical approved by the U.S. Food and Drug Administration (FDA), whether for diagnostic or therapeutic applications, human radiation doses must be estimated. In 1999, Siegel et al. (1) published a guide for obtaining quantitative data for use in radiopharmaceutical dosimetry. The current article, and a companion article to it (2), updates that information with practical guidance and worked examples.

requirements for dose calculations to support these submissions (3). Applicants should provide a description of which organs have a significant accumulation of activity over time, what activity levels were observed at different times (with at least 2 time points obtained per phase of radionuclide uptake or clearance), an evaluation of time integrals of activity, descriptions of how they were obtained, and a description of how they were combined with dose conversion factors to obtain doses (if not done by software). Any significant radiation hazards to other patients and health-care workers should also be assessed.

FDA requirements (4) require a preclinical phase, in which studies are done on an animal species, and phase 1, 2, and 3 clinical studies, in which dosimetry data are gathered from human subjects, to establish and refine the radiation dose estimates and establish the safety and efficacy of any new drug.

First-in-humans studies can establish the safety and tolerability and preliminary efficacy of a new drug before entering into full-fledged clinical trials, but all 4 phases of study are needed to establish the radiation dosimetry of any candidate for a new drug application (5).

PLANNING A STUDY TO OBTAIN BIOKINETIC DATA

In either animal or human studies, one must collect sufficient data to fully characterize the radiation dose (Gy) to all relevant organs and tissues in the body. Siegel et al. (1) noted that there are

RADAR Guide: Standard Methods for Calculating Radiation Doses for Radiopharmaceuticals, Part 2—Data Analysis and Dosimetry

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This paper presents standardized methods for performing dose calculations for radiopharmaceuticals. Various steps in the process are outlined, with some specific examples given. Special models for calculating time-activity integrals (urinary bladder, intestines) are also reviewed. This article can be used as a template for designing and executing kinetic studies for calculating radiation dose estimates from animal or human data.

Key Words: image reconstruction; radiation physics; radiobiology/dosimetry; radiopharmaceuticals; clinical imaging; radiation dosimetry

J Nucl Med 2022; 63:485–492
DOI: 10.2967/jnumed.121.262034

Currently, there is renewed interest in performing radiation dosimetry for radiopharmaceuticals, particularly in therapy applications. To have any new radiopharmaceutical approved by the U.S. Food and Drug Administration, whether for diagnostic or therapeutic applications, human radiation doses must be estimated. In 1999, Siegel et al. (1) published a guide for obtaining quantitative data for use in radiopharmaceutical dosimetry. The current article, and the companion article to it (2), updates that information with practical guidance and worked examples.

Direct Integration

One can directly integrate under the actual measured values by several methods. This does not give much information about the biokinetic system, but it does allow calculation of the number of disintegrations rather easily. The most common method is the trapezoidal method, which uses linear interpolation between the measured data points and approximates the area under the time-activity curve as a series of trapezoids. An important concern with this method is calculation of the integrated area under the curve after the last datum. If activity is clearing slowly near the end of the dataset, a significant portion of the total decays may occur after the last time point and be represented by the area under the curve after that point. Several approaches may be used to estimate this area. The most conservative is to assume that activity is removed only by physical decay after the last point; another approach is to calculate the slope of the line using the last 2 or 3 points and assume that this slope continues until the retention curve crosses the time axis. No single approach is necessarily right or wrong—several approaches may be acceptable under different circumstances. It is generally preferable to overestimate the cumulated activity rather than to underestimate it, as long as the overestimation is not too severe. The important point is to calculate this area by an appropriate method and to clearly document what was done.

Least-Squares Analysis

An alternative to simple, direct integration of a dataset is to