Nuclear Medicine Physics

Lecture 9
Internal Dosimetry

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References :
- Physics in Nuclear medicine, 4th ed. by Cherry et al
- Essentials of Nuclear Medicine Physics and Instrumentation, 3rd ed. by Powsner.
- SNMMI, MIRD Pamphlet No.16.

How much radiation dose for NM scans

Nuclear Medicine Radiation Dose Tool

http://www.snmmi.org/ClinicalPractice/doseTool.aspx?ItemNumber=11216&navItemNumber=11218

- The site provides broad estimates for effective dose and absorbed dose to the critical organ
- These dose estimates are for standard models and should not be considered patient-specific under any circumstance.

Nuclear Medicine Radiation Dose Tool

Click Here to View Disclaimer

Select Nuclear Medicine Exam:

---Common Exams---
F-18 FDG
Tc-99m DMSA
Tc-99m Pertechnetate
Tc-99m MAA
Tc-99m MDP
Tc-99m MIBI (exercise)
Tc-99m Tetrofosmin (exercise)
---List of all exams---
H-3 Water

Input Injected Activity:

10 mCi or 370 MBq

Select patient model:

No Selection
Adult (gender average)
15-yr-old
10-yr-old
5-yr-old
1-yr-old
early pregnant woman

Dosimetry Table:

RADAR 2017

Recommended Adult Injected Activity:

Minimum	10	mCi	370.00	MBq
Maximum	20	mCi	740.00	MBq

Reference for adult injected activity:

Radiation Dose Estimate:

According to RADAR 2017 dosimetry estimates, a 370 MBq injection for a F-18 FDG study would impart to a Adult (gender average) an approximate effective dose of **7.1 mSv** (**0.71 rem**). The critical organ for this study is the bladder wall, which would receive 54.0 mGy (5.40 rad).

VERSION: 4.10; 23-Apr-2018

Nuclear Medicine Radiation Dose Tool

Click Here to View Disclaimer

Select Nuclear Medicine Exam:

---Common Exams---
F-18 FDG
Tc-99m DMSA
Tc-99m Pertechnetate
Tc-99m MAA
Tc-99m MDP
Tc-99m MIBI (exercise)
Tc-99m Tetrofosmin (exercise)
---List of all exams---
H-3 Water

Input Injected Activity:

25 mCi or 925 MBq

Select patient model:

No Selection
Adult (gender average)
15-yr-old
10-yr-old
5-yr-old
1-yr-old
early pregnant woman

Dosimetry Table:

RADAR 2017

VERSION: 4.10; 23-Apr-2018

Recommended Adult Injected Activity:

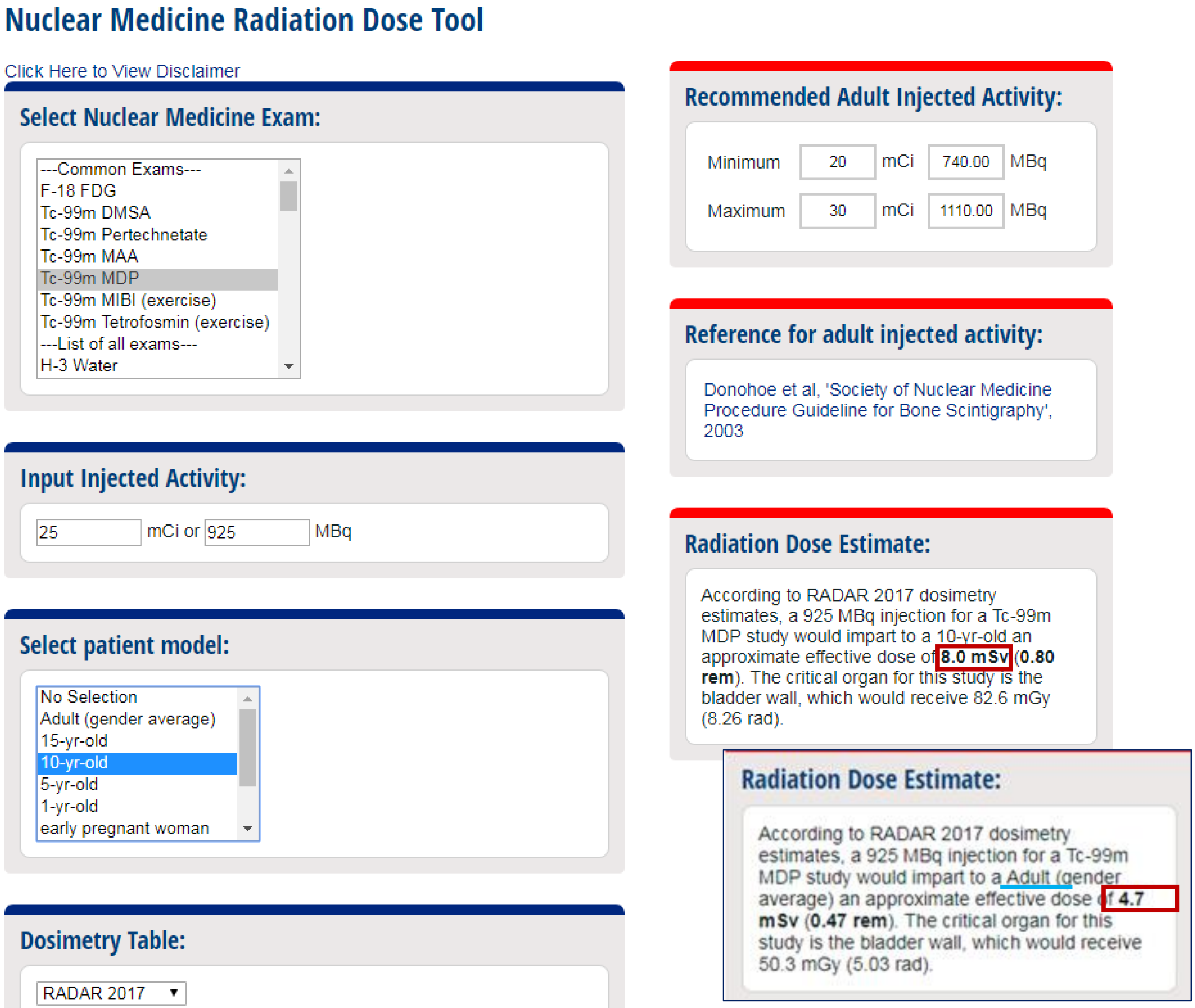
Minimum	20	mCi	740.00	MBq
Maximum	30	mCi	1110.00	MBq

Reference for adult injected activity:

Donohoe et al, 'Society of Nuclear Medicine Procedure Guideline for Bone Scintigraphy', 2003

Radiation Dose Estimate:

According to RADAR 2017 dosimetry estimates, a 925 MBq injection for a Tc-99m MDP study would impart to a Adult (gender average) an approximate effective dose of $\boxed{\textbf{4.7}}$ **mSv** (**0.47 rem**). The critical organ for this study is the bladder wall, which would receive 50.3 mGy (5.03 rad).


Nuclear Medicine Radiation Dose Tool
Click Here to View Disclaimer
Select Nuclear Medicine Exam:
---Common Exams---
F-18 FDG
Tc-99m DMSA
Tc-99m Pertechnetate
Tc-99m MAA
Tc-99m MDP
Tc-99m MIBI (exercise)
Tc-99m Tetrofosmin (exercise)
---List of all exams---
H-3 Water
Input Injected Activity:
25 mCi or 925 MBq
Select patient model:
No Selection
Adult (gender average)
15-yr-old
10-yr-old
5-yr-old
1-yr-old
early pregnant woman
Dosimetry Table:
RADAR 2017
Recommended Adult Injected Activity:
Minimum 20 mCi 740.00 MBq
Maximum 30 mCi 1110.00 MBq
Reference for adult injected activity:
Donohoe et al, 'Society of Nuclear Medicine Procedure Guideline for Bone Scintigraphy', 2003
Radiation Dose Estimate:
According to RADAR 2017 dosimetry estimates, a 925 MBq injection for a Tc-99m MDP study would impart to a 10-yr-old an approximate effective dose of 8.0 mSv (0.80 rem). The critical organ for this study is the bladder wall, which would receive 82.6 mGy (8.26 rad).
Radiation Dose Estimate:
According to RADAR 2017 dosimetry estimates, a 925 MBq injection for a Tc-99m MDP study would impart to a Adult (gender average) an approximate effective dose of 4.7 mSv (0.47 rem). The critical organ for this study is the bladder wall, which would receive 50.3 mGy (5.03 rad).

Radiation Doses from Common Diagnostic Nuclear Medicine Procedures*

Radionuclide	Agent	Typical administered** activities (mCi)	Highest dose (organ)** (rad)	EDE (rem)
^{18}F	FDG	10	5.9 (bladder)	0.7
^{67}Ga	Citrate	5	11.8 (bone surfaces)	1.9
^{99m}Tc	HIDA	5	2.0 (gallbladder)	0.3
	HMPAO	20	2.5 (kidneys)	0.7
	MAA	4	1.0 (lungs)	0.2
	MDP	20	4.7 (bone surfaces)	0.4
	MAG3 (normal function)	20	8.1 (bladder wall)	0.5
	DTPA	10	2.3 (bladder wall)	0.2
	Sestamibi			
	Rest	20	2.9 (gallbladder)	0.7
	Stress	20	2.4 (gallbladder)	0.6
	Sulfur colloid	8	2.2 (spleen)	0.3
	Tetrofosmin			
	Rest	20	2.7 (gallbladder)	0.6
	Stress	20	2.0 (gallbladder)	0.5
^{111}In	White blood cells	0.5	10.9 (spleen)	1.2
^{123}I	NaI (25% uptake)	0.4	2.8 (thyroid)	0.2
	MIBG	0.4	0.1 (liver)	0.02
^{131}I	NaI (25% uptake)	0.02	26.6 (thyroid)	0.8
	MIBG	0.02	0.06 (liver)	0.01
^{133}Xe	Gas	15	0.06 (lungs)	0.04
^{201}Tl	Chloride	2	4.6 (thyroid)	1.2

* Adapted from Bushberg JT, Seibert JA, Leidholdt EM, Boone JM. *The Essential Physics of Medical Imaging.* 2d ed. Philadelphia, PA: Lippincott Williams & Wilkins; in press; 2002; available on-line at www.doseinfo-radar.com.)

** SI conversion: 1 rem = 0.01 Sv; 1 mCi = 37 MBq.

https://www.nrc.gov/materials/miau/miau-reg-initiatives/guide_2002.pdf

Biokinetics of the radiopharmaceutical & Organ Dose

- **Spatial and temporal distribution** in the body for each tracer, depends
    - radiotracer delivery,
    - uptake,
    - metabolism,
    - clearance and excretion,
    - And physical decay of the radionuclide.

    - may differ from one patient to the next because of pathophysiologic effects on uptake, clearance, and excretion of the radiopharmaceutical

- **Organ dose** depends on
    - Amount of radioactivity cumulated in the organ
    - Size, shape, and density of the organ
    - Energy and type of radiation it contains

Purpose of dosimetry in Nuclear Medicine

- In NM, radiation is used in diagnostic and therapeutic procedures
- **For an evaluation of the risks and benefits of a procedure, dose information to targeted and normal organs are useful**

- In diagnostic procedures, the biokinetics of the radiopharmaceutical is determined for a number of representative patients.
- In therapy, the patient's individual biokinetics of the radiopharmaceutical is essential in order to calculate the absorbed doses to critical normal organs/tissues

Quantities and Units

Quantity	Units	definition
Activity	Bq or Ci (1Bq = 2.7 x 10 $^{-11}$ Ci)	Number of disintegrations per second
Exposure	Coulombs per kg (C/kg) or Roentgen (R) 1C/kg=3.9 x 10^3 R	Amount of charge liberated per unit mass of air
Absorbed dose	Gray (Gy) or rad (1Gy = 100 rad)	Energy absorbed per unit mass of absorber
Dose Equivalent	Sievert (Sv) or rem (1 Sv =100rem)	Absorbed dose times the quality factor

Quality Factor (QF) : Relative damage for each type of radiation
Alpha → 20
Proton neutron → 10
Gamma-ray, x-ray, beta particles → 1
(electrons and positrons)

One **roentgen** deposits 0.00877 Gy of absorbed dose in dry air, or 0.0096 Gy (0.96 **rad**) in soft tissue.

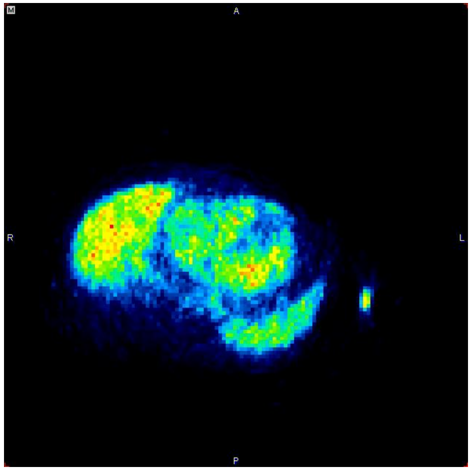
Dose Calculation

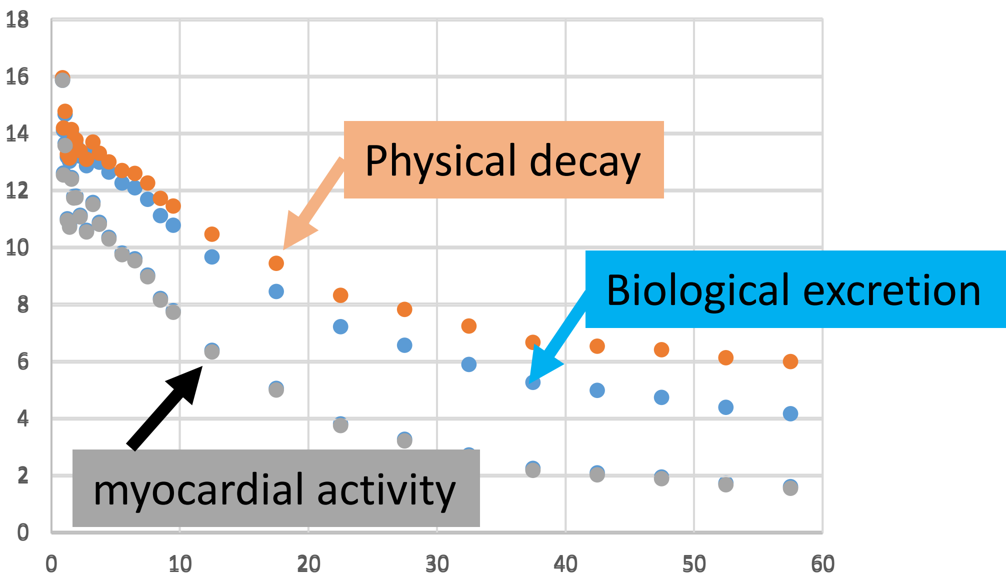
Dose delivered to an organ $D = \tilde{A} \times S$

$\tilde{A}$: Total activity (or cumulated activity) within the organ

S : factor based on characteristics of the administered radiotracer and the organ of interest.

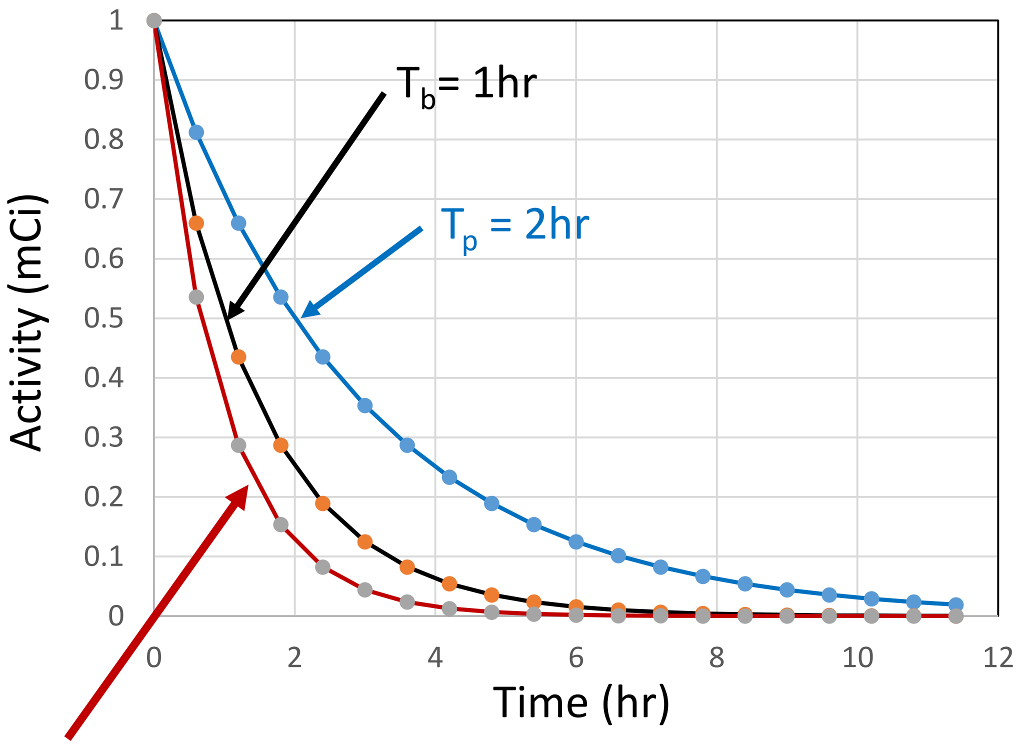
What is $\tilde{A}$?





Effective Half-life

Physical half-life (T_p) : time it takes for half of radionuclide to become stable
Biological half-life (T_b) : time for half of the tracer to be excreted by an organ



Decay Eq : $e^{-\ln(2)*t/T_{1/2}}$

$$\frac{1}{T_e} = \frac{1}{T_b} + \frac{1}{T_p}$$

$$T_e = \frac{T_b \times T_p}{T_b + T_p}$$

Effective half-life (T_e)
Measurement that combines two effects – time required for one half of the initial radiotracer to disappear from an organ by exception and physical decay.

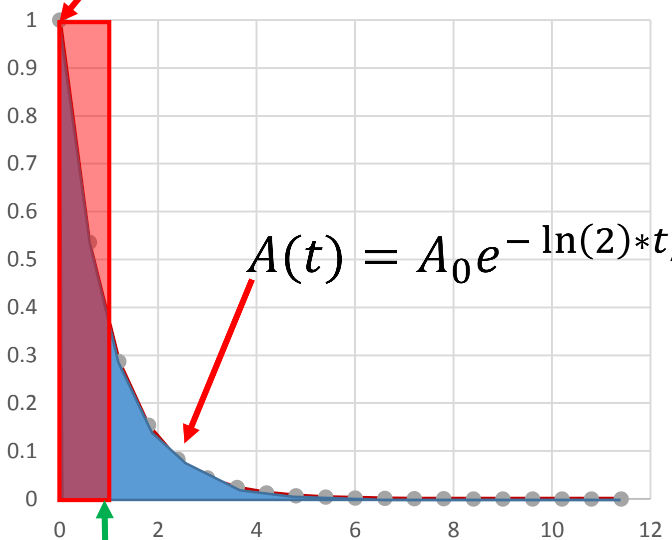
$$T_e = \frac{1 \times 2}{1 + 2}$$

= 2/3 = 0.67 hr

Cumulated Activity (total activity)

summed activity within the organ over the entire time
→ Area under the time-activity curve

A_0 : activity in organ at time=0



$$A(t) = A_0 e^{-\ln(2) * t/T_e}$$

0.96 hr

$$\tilde{A} = A_0 \int_0^{\infty} e^{-\ln(2) \times t/T_e}\, dt$$

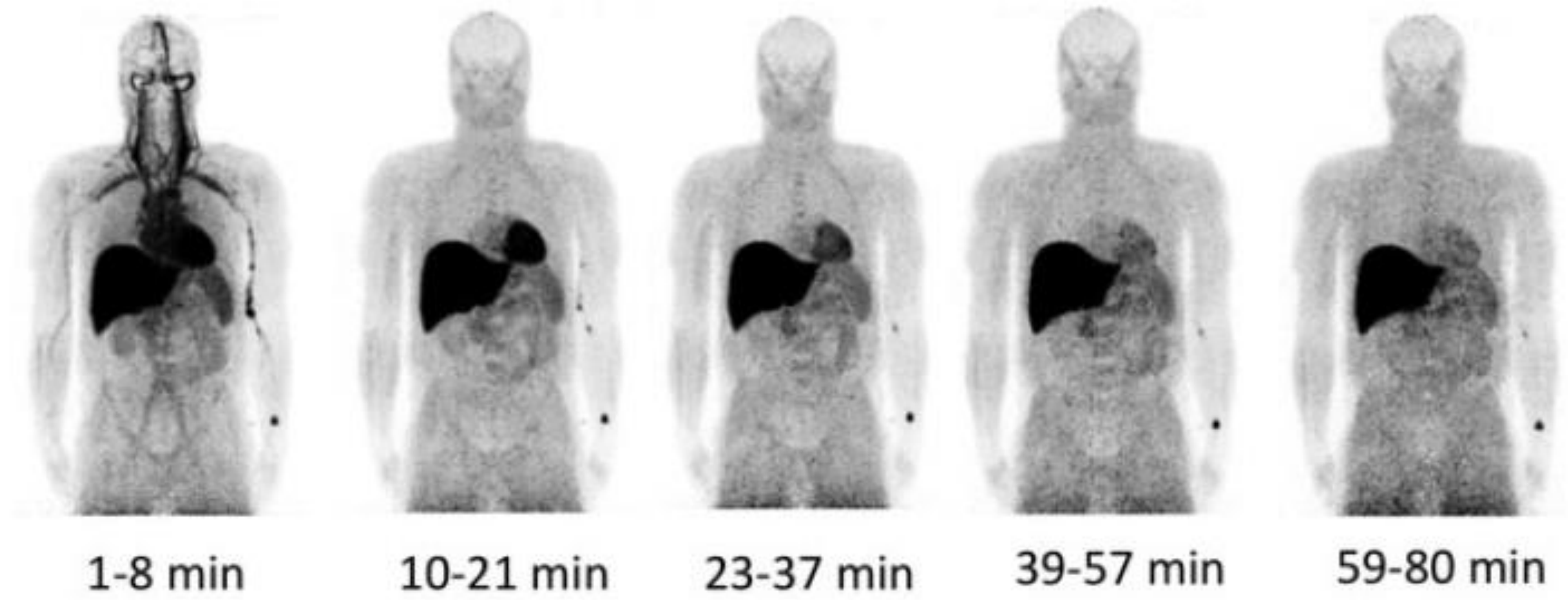
$$\tilde{A} = 1.44 \times T_e \times A_0$$

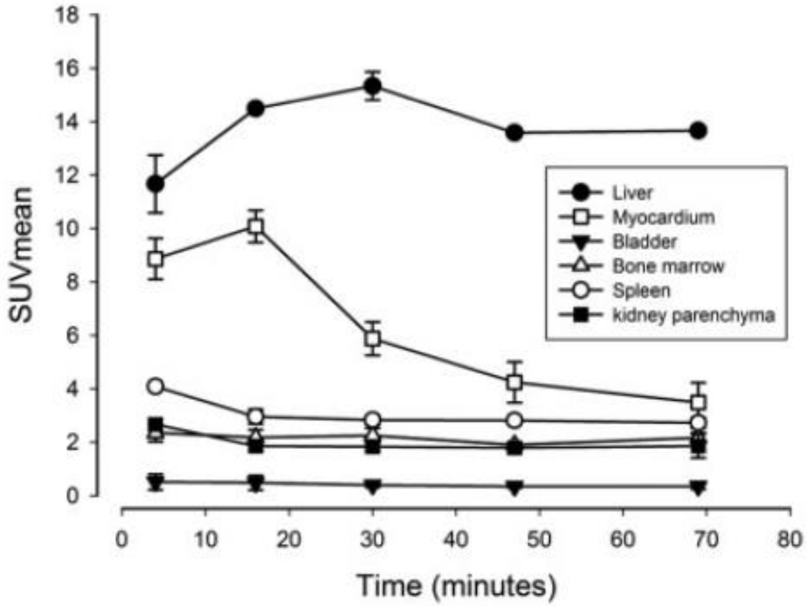
$$\tilde{A} = \tau \times A_0$$

Residence time

T_e = 0.67 hr
→ τ = 1.44 x 0.67 = 0.96 hr

Time-Activity curve of radiotracer in patient





Christensen et al, Molecular Imaging Volume 16: 1-9

fatty acid metabolism in the myocardium, brain, and liver using C11-Palmitate

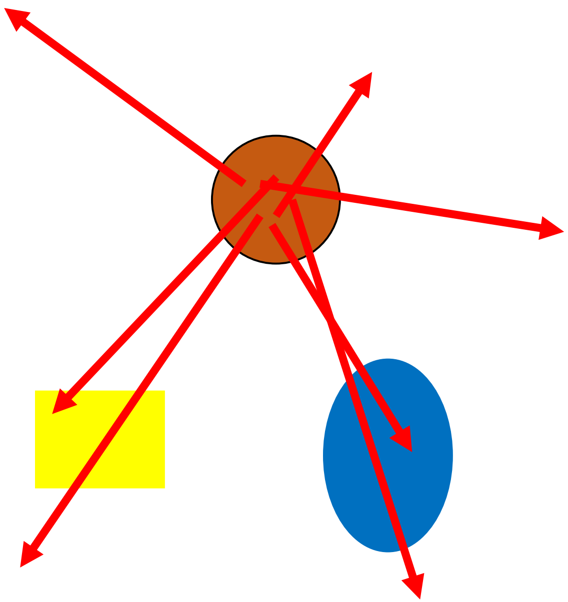
Using dynamic PET/SPECT/planar imaging, estimate A_0 and T_e for various organs, and calculate cumulated activity

$$\tilde{A} = 1.44 \times T_e \times A_0$$

Dose delivered to an organ $D = \tilde{A} \times S$

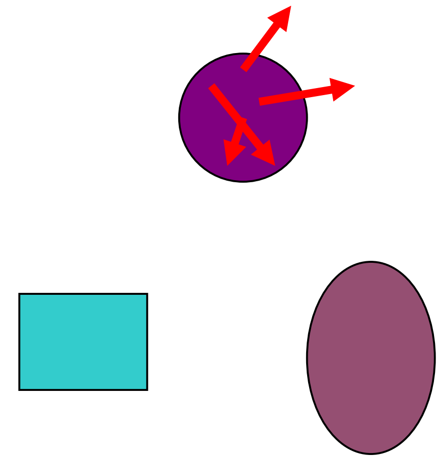
Different absorption properties

X-ray and gamma-ray



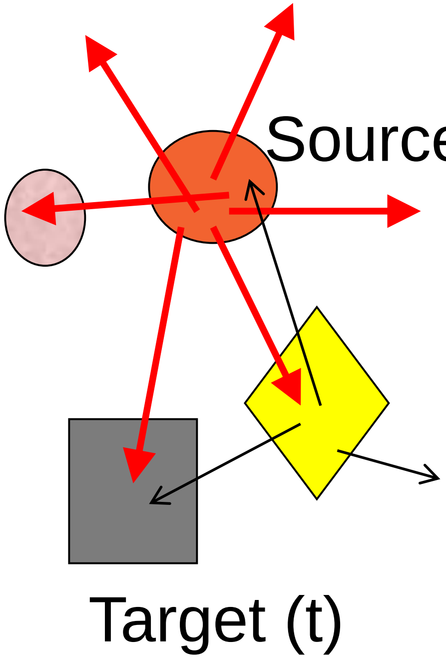
Deposit energy in both source and other close and distant targets

Beta and alpha particles



Generally, absorbed within or very close to the source

Dosimetry of internal emitters



- <u>Source</u> : organs with radionuclide
- <u>Target</u> : objects that are receiving radiation

Absorbed organ/tumor dose : radiation energy delivered from the source to the target organ divided by the mass of the target organ

$$D_{\text{target}} = \frac{E}{M_{\text{target}}}$$

1 Gy = 1 J/kg
1 rad=0.01Gy=1 cGy

Dosimetry of internal emitters

Absorbed fraction (f) : the fraction of the energy emitted by radioactivity in the source organ that is absorbed in the target organ

$0 \leq \phi \leq 1$

- f=1 : locally absorbed in the source organ.
  for non-penetrating radiations (alpha particles or low-energy beta particles)
- 0<f<1 : penetrating radiations (high-energy betas and photons)
- f →0 : for distant targets

Cumulated activity in source region

Energy emitted per unit of cumulated activity

Absorbed dose to the target (t) by the source (s)

$$D_{t \leftarrow s} = \frac{\tilde{A}_s \, \Delta \, \phi_{t \leftarrow s}}{M_t}$$

Absorbed fraction

Mass of the target region

MIRD : S-value (target vs source)

$$D_{target} = \widetilde{A_s} \times S$$

S-value : mean absorbed dose per unit cumulated activity
(quantity based on characteristics of the administered radiotracer and the organ of interest)

Absorbed dose in the target organ, t, from activity in the multiple source organs, s

$$D_t = \sum_s \tilde{A}_s S(t \leftarrow s)$$

Organ dose is estimated.

Emitted Energy

Cumulated activity in source region

Energy emitted per unit of cumulated activity

$$D_{t\leftarrow s} = \frac{\tilde{A}_s \, \Delta \, \phi_{t\leftarrow s}}{M_t}$$

Absorbed fraction

Mass of the target region

Equilibrium absorbed dose constant (Δ) :

- Energy emitted per unit of cumulated activity
- Calculated for each type of emission for the radionuclide.

$$\Delta = 1.6 \times 10^{-13} N_i E_i \text{ (Gy. kg /Bq .sec)}$$

N_i : relative frequency of the emission I, (0 – 1)

E_i : average energy of the emission I in MeV

Medical Internal Radiation Dose (MIRD) Schema

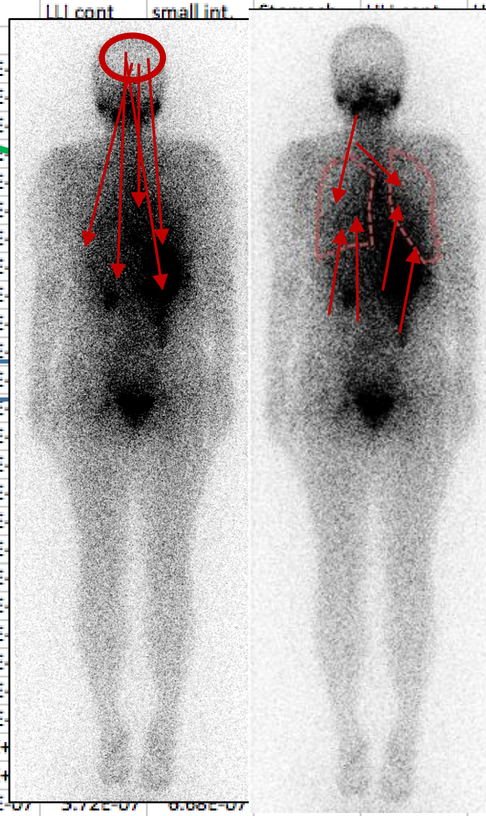
Internal doses are calculated from standardized assumptions and procedures recommended by **MIRD** committee of the Society of Nuclear Medicine and Molecular Imaging.

- Compiled & tabulated absorbed dose for individual radionuclide according to source-target regions.
- Use standard models : average adult male and female, newborn, 1,5,10,15-year old child, and pregnant woman.
- Assumed the activity is distributed uniformly within each source organ.
- Source and target regions were homogeneous in composition
- Simple and general

Example of S-value (I-131)

S-values for the Adult (70kg) for 131 I 53 (mGy/MBq-s)
(PENETRAT + NON-PENETRATING)
SOURCE ORGANS

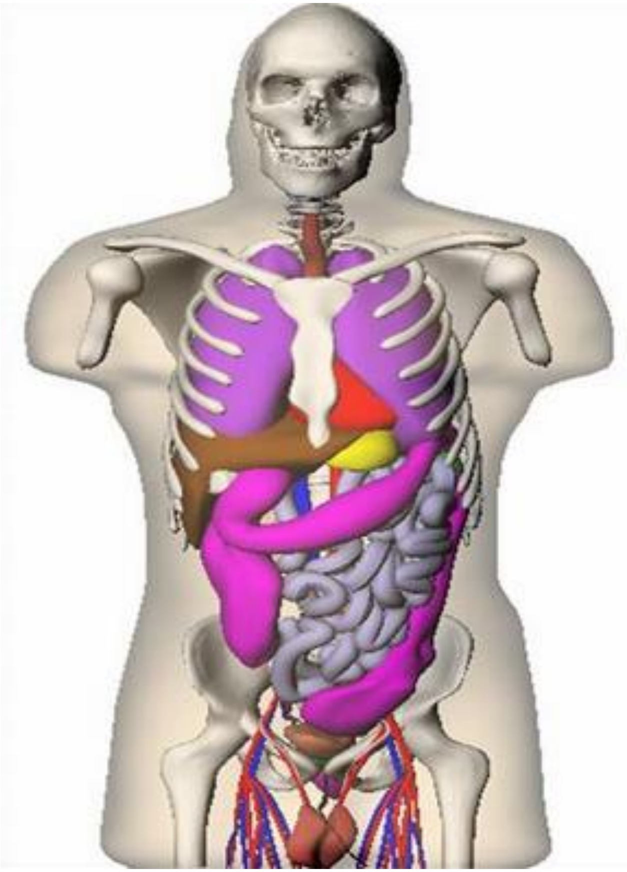
TARGET	Adrenals	Brain	Breasts	GallBl	Heart co	heart wall	Kidneys	Liver	Lungs	Muscle	Ovaries	Pancreas	Red Mar.
Adrenals	1.95E-03	6.19E-09	1.80E-07	7.50E-	6.33E-07	7.15E-07	1.93E-06	1.12E-06	6.12E-07	3.13E-07	9.92E-08	2.55E-06	6.94E-07
Brain	6.19E-09	2.83E-05	1.90E-08	3.09E-	2.30E-08	2.12E-08	2.84E-09	8.55E-09	4.16E-08	7.27E-08	6.74E-10	6.93E-09	2.59E-07
Breasts	1.80E-07	1.90E-08	9.97E-05	1.19E-	6.94E-07	7.89E-07	9.02E-08	2.17E-07	6.33E-07	1.40E-07	2.11E-08	2.04E-07	1.88E-07
Gallbladder	8.14E-07	2.86E-09	1.21E-07	3.06E-	2.75E-07								
LLI	7.88E-08	5.68E-10	1.86E-08	1.67E-	2.39E-08								
Small	2.19E-07	1.11E-09	4.09E-08	1.05E-	6.43E-08								
Stomach	6.68E-07	5.08E-09	2.08E-07	6.95E-	4.37E-07								
ULI	2.64E-07	1.40E-09	4.06E-08	1.86E-	7.89E-08								
Heart	7.15E-07	2.12E-08	7.89E-07	2.79E-	4.10E-05	1.08E-04	2.28E-07	5.97E-07	1.08E-06	2.54E-07	3.74E-08	8.75E-07	3.07E-07
Kidneys	1.93E-06	2.84E-09	9.02E-08	9.23E-	2.10E-07	2.28E-07	1.16E-04	7.53E-07	2.05E-07	2.78E-07	2.14E-07	1.32E-06	4.94E-07
Liver	1.12E-06	8.55E-09	2.17E-07	2.02E-	5.30E-07	5.97E-07	7.53E-07	2.10E-05	5.07E-07	2.11E-07	1.25E-07	9.00E-07	2.56E-07
Lungs	6.12E-07	4.15E-08	6.33E-07	1.85E-	1.14E-06	1.08E-06	2.05E-07	5.07E-07	3.33E-05	2.54E-07	3.06E-08	4.37E-07	3.21E-07
Muscle	3.13E-07	7.27E-08	1.40E-07	3.07E-	2.36E-07	2.54E-07	2.78E-07	2.11E-07	2.54E-07	1.39E-06	3.83E-07	3.35E-07	2.69E-07
Ovaries	9.92E-08	6.74E-10	2.11E-08	2.86E-	3.46E-08	3.74E-08	2.14E-07	1.25E-07	3.06E-08	3.83E-07	3.62E-03	1.22E-07	5.52E-07
Pancreas	2.55E-06	6.93E-09	2.04E-07	1.61E-	6.26E-07	8.75E-07	1.32E-06	9.00E-07	4.37E-07	3.35E-07	1.22E-07	3.55E-04	4.10E-07
Red	6.94E-07	2.60E-07	1.88E-07	2.92E-	3.18E-07	3.18E-07	4.90E-07	2.56E-07	3.21E-07	2.69E-07	5.51E-07	4.10E-07	2.84E-05
Bone	3.91E-07	4.51E-07	1.39E-07	1.46E-	2.13E-07	2.13E-07	2.30E-07	1.74E-07	2.44E-07	2.73E-07	2.17E-07	2.31E-07	5.76E-06
Skin	1.21E-07	1.49E-07	2.48E-07	1.10E-	1.22E-07	1.25E-07	1.43E-07	1.29E-07	1.34E-07	1.90E-07	1.07E-07	1.07E-07	1.48E-07
Spleen	1.14E-06	8.78E-09	1.54E-07	3.27E-	3.03E-07	4.29E-07	1.75E-06	2.09E-07	4.30E-07	2.87E-07	9.99E-08	3.23E-06	2.68E-07
Testes	1.44E-08	1.65E-10	0.00E+00	4.04E-	6.93E-09	7.92E-09	2.47E-08	1.52E-08	5.22E-09	2.96E-07	0.00E+00	2.02E-08	9.93E-08
Thymus	1.81E-07	4.47E-08	7.78E-07	6.46E-	2.27E-06	1.85E-06	7.28E-08	1.80E-07	7.53E-07	2.99E-07	1.66E-08	1.59E-07	2.51E-07
Thyroid	3.88E-08	4.07E-07	1.17E-07	2.02E-	1.36E-07	1.40E-07	2.39E-08	3.81E-08	2.48E-07	3.20E-07	4.20E-09	3.73E-08	2.26E-07
Urin	4.32E-08	3.89E-10	1.32E-08	1.62E-	1.78E-08	1.23E-08	8.25E-08	5.85E-08	1.26E-08	3.74E-07	1.25E-06	6.02E-08	2.27E-07
Uterus	8.12E-08	6.26E-10	2.30E-08	3.09E-	3.22E-08	3.59E-08	2.07E-07	1.07E-07	2.47E-08	3.80E-07	3.58E-06	1.21E-07	3.74E-07
Fetus	0.00E+00	0.00E+00	0.00E+00	0.00E+	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Placenta	0.00E+00	0.00E+00	0.00E+00	0.00E+	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Total	7.72E-07	6.50E-07	6.27E-07	3.77E-07	4.12E-07	7.59E-07	7.47E-07	7.47E-07	6.99E-07	6.96E-07	8.01E-07	7.98E-07	7.26E-07

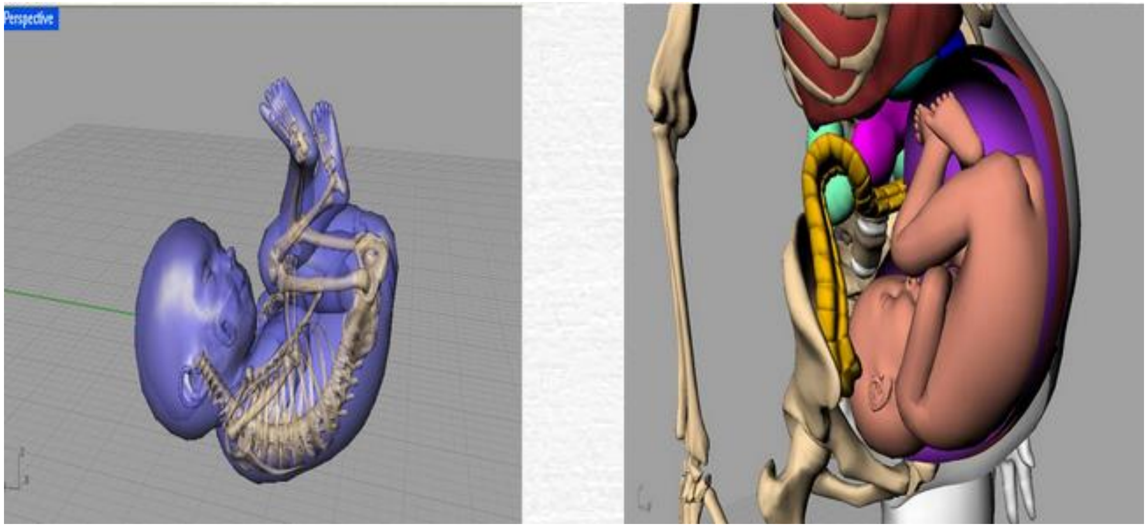


Self-dose : radiation dose to an organ from the radiation within it

$$D_{lung} = \sum_{s} \tilde{A}_s S(lung \leftarrow s)$$

MIRD phantoms





http://www.doseinfo-radar.com/RADARphan.html

MIRD ≠ patient specific

- Individual patients rarely meet the MIRD assumptions.
- MIRD is not suitable for non-standard organ geometries (e.g., with tumors).

→ The ultimate goal of internal dosimetry is to develop a method for individual patient, rather than that for a standard phantom.

Personalized dosimetry requires two major pieces of information

- A – biology related: Time-varying distribution of activity in individual patients – using planar or SPECT/PET images and blood/urine measurements
- S – physics related: Three dimensional voxel phantom conforming to the individual patient to derive S-values from MC approach or convolution – using CT or MRI

Challenges in NM imaging and internal dosimetry

- The goal of radionuclide therapy is to deliver radiation selectively to lesions/organs while minimizing radiation absorbed to normal tissues.
- Good dose prediction is very important.

- Internal doses can never be directly measured.
- Every patient is different
- Every radiotracers works differently
- Distribution of the tracer within the body and within organs are inhomogeneous

- Several Monte Carlo simulation dosimetry tools are being developed

Administered activity of I-131

- ✓ Radioactive iodine treatment may be given
  - To clear all potentially cancerous thyroid cells that may not have been removed during surgery (remnant ablation)
  - <u>To treat thyroid cancer that has spread (metastasis)</u>
  - <u>To treat recurrent thyroid cancer</u>

<u>Fixed empirical dose – “best guess”</u>

- most common and simplest method
- regardless of the amount of I-131 that accumulates in tumors

e.g., 30 - 100 mCi for remnant ablation

~ 150 mCi for cervical lymph node metastasis

~ 200 mCi for distant metastasis

I-131

- Half-life ($T_{1/2}$) : 8.04 days
- Beta emitter (90%)
  - E_{max}= 610 keV
  - **E_{mean} = 193 keV**
  - tissue range ~ 0.8mm (local deposit)
- Gamma emitter : imaging
  - E = 365 keV (81%)

- 94% of absorbed dose is from beta particles

$$\Delta = 1.6 \times 10^{-13} N_i E_i \text{ (Gy. kg /Bq .sec)}$$

$$\Delta_\beta = 1.6 \times 10^{-13} \text{ x } 0.9 \text{ x } 0.193 \text{ (Gy. kg /Bq .sec)} = 0.28 \times 10^{-13} \text{ (Gy. kg /Bq.sec)}$$

$$\Delta_\gamma = 1.6 \times 10^{-13} \text{ x } 0.81 \text{ x } 0.365 \text{ (Gy. kg /Bq .sec)} = 0.47 \times 10^{-13} \text{ (Gy. kg /Bq.sec)}$$

Organ dose limits : How much I-131 to give?

- whole body dose limit : 120mCi at 48 hr

  (or 80mCi with lung mets)

- Lung dose limit : 20 Gy
- Bone marrow dose limit : 2Gy

- Maximum safe (or tolerable) dose (MSD or MTD) determined by a dosimetry
- Allows a higher radiation to tumors while minimizing side effects.

- For pre-therapeutic imaging for dosimery, low activity of I-131 Is administered.
- Image-based dosmetry is useful in patients likely to have high lung uptake or prolonged blood or whole-body clearance

Dosimetry procedure

Whole Body transmission and blank

Administration of I131 (~ 2-4mCi)

Blood sample (d1, d2, d2, d4)

WB planar (d1, d2, d2, d4)

process the blood samples (d1,d2,d3,d4)

process the images (d1,d2,d3,d4)

Estimate WB retention at 48 hours (<80 or 120 mCi?)
Estimate lung dose (<20Gy?)
Estimate marrow dose (2Gy?)

Determine the MSD for therapy

Image-based dosimetry procedure

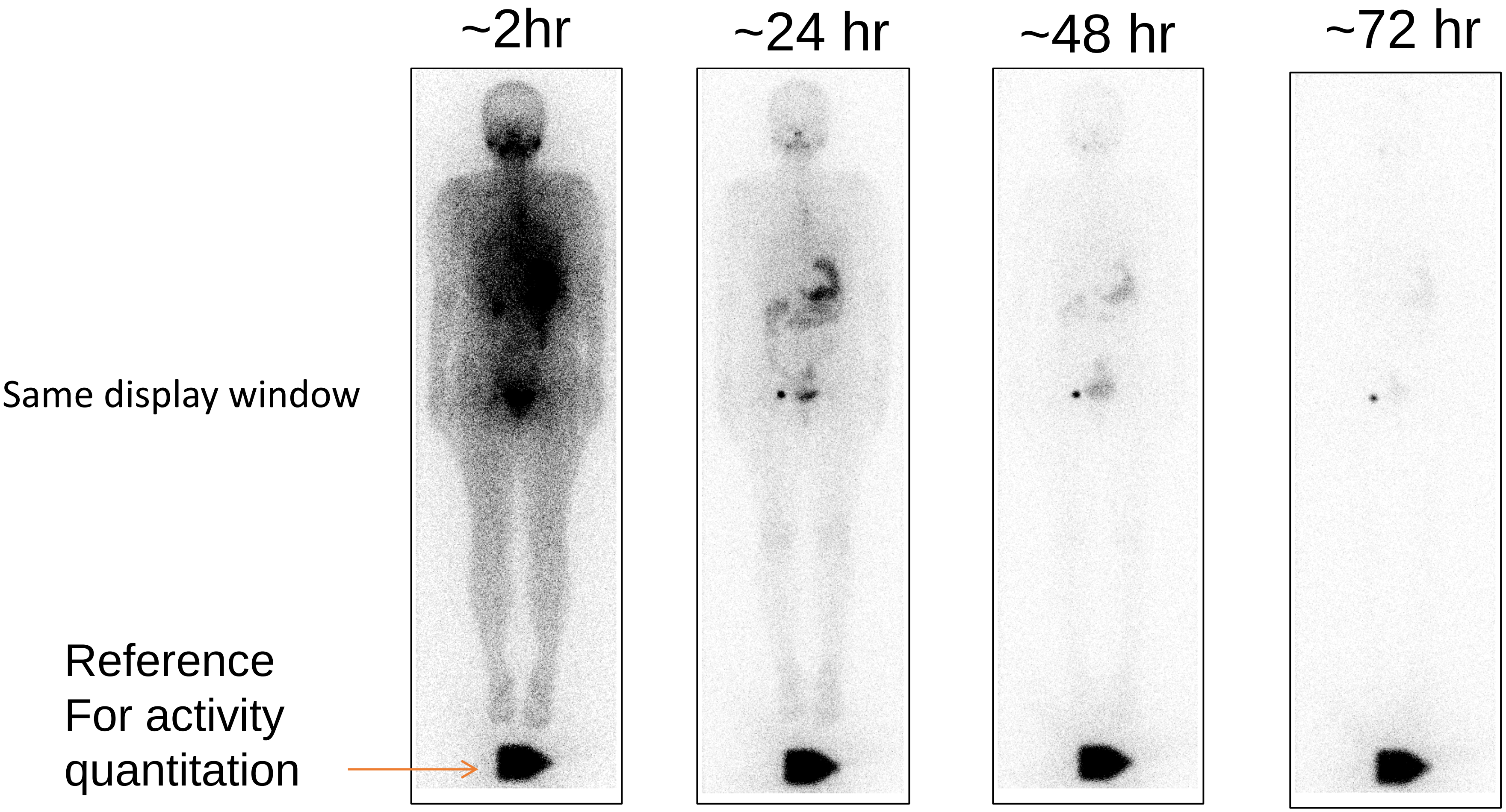
- Transmission scan using a Co-57 sheet

blank transmission

- To calculate the attenuation factor for every pixels
- Mark patient position for later use

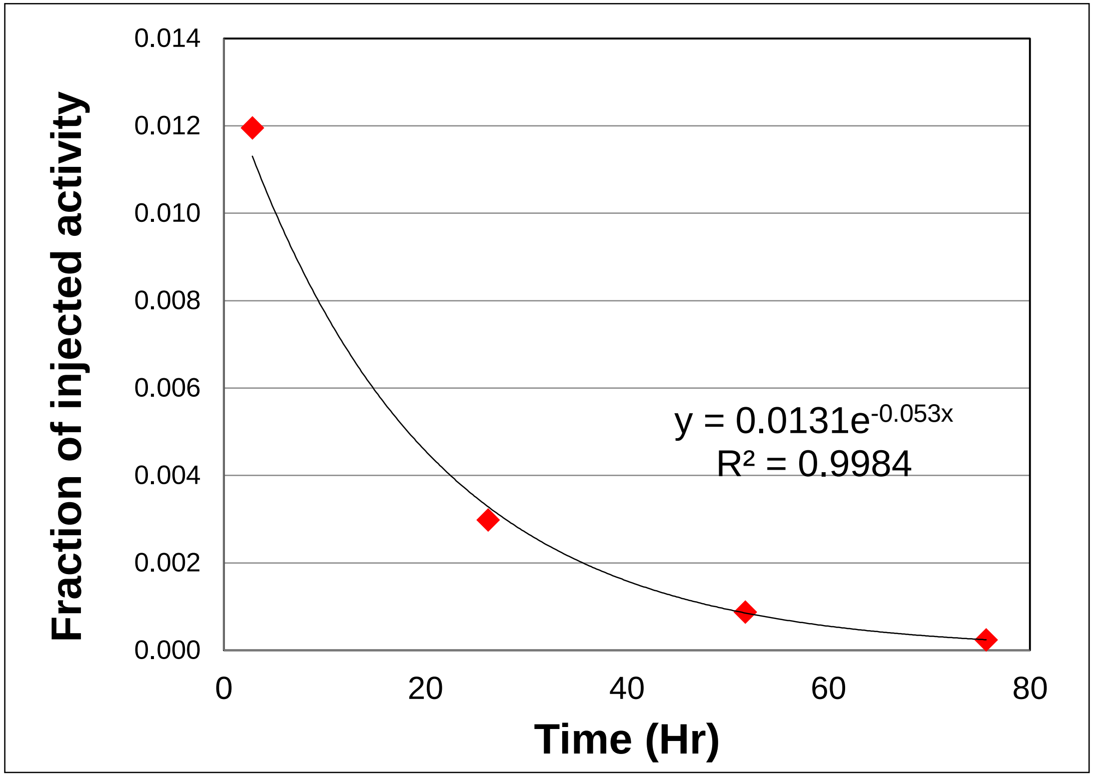
Serial whole body scans for personalized dosimetry

- 2-4 mCi administration,
- Blood sampling after each scan (~2mL)
- Obtain geometric mean image = sqrt (A*P)
- Attenuation & Decay correction



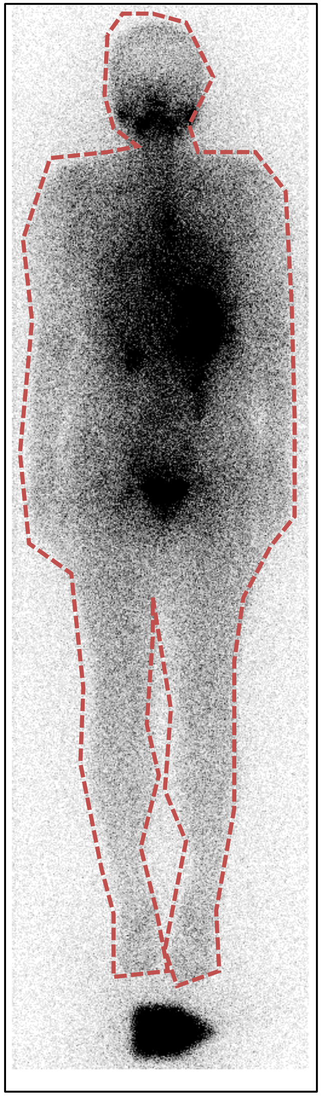
I-131 amount in the blood and Time-activity curve

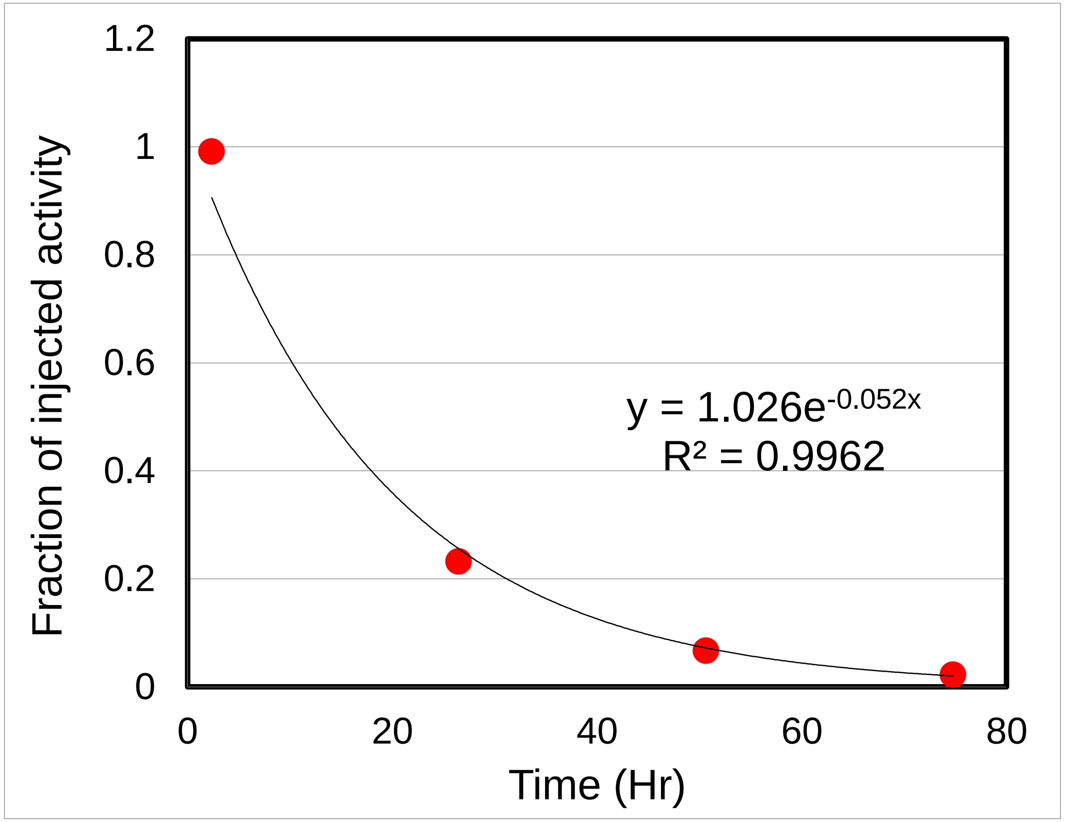
I-131 activity in 4 blood samples were measured in a Gamma well-counter



- 1.3 % of the administered I-131 activity was in the blood in 2hr
- I-131 washed out fast from the blood (T_{bio} ~ 13 hours)
- Blood weight : Assumed 4.3% of WB weight

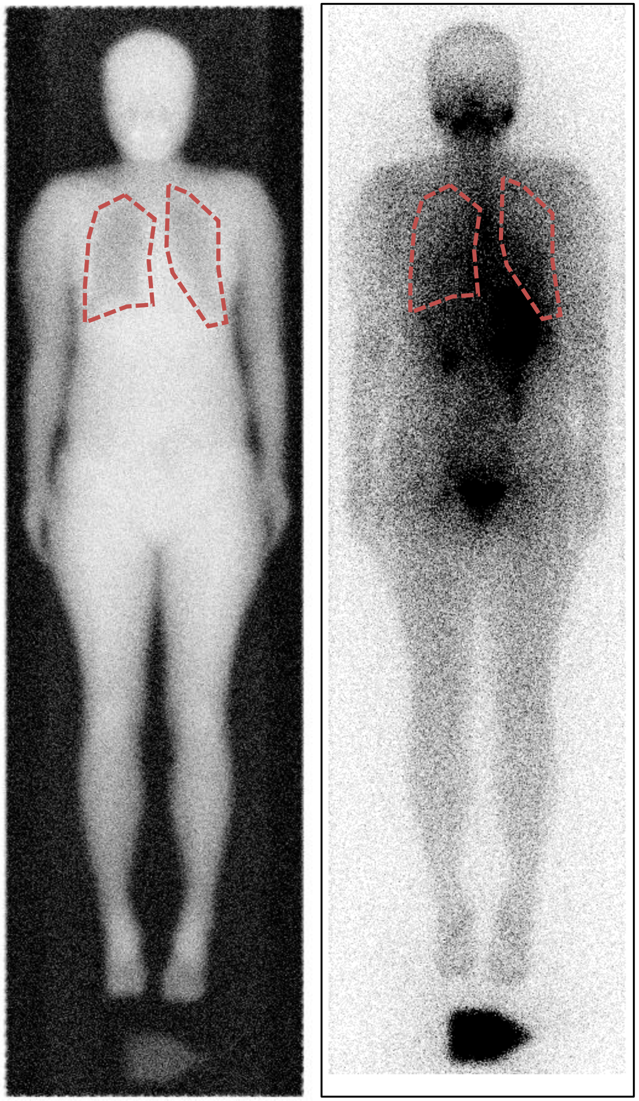
Whole Body ROI and Time-activity curve

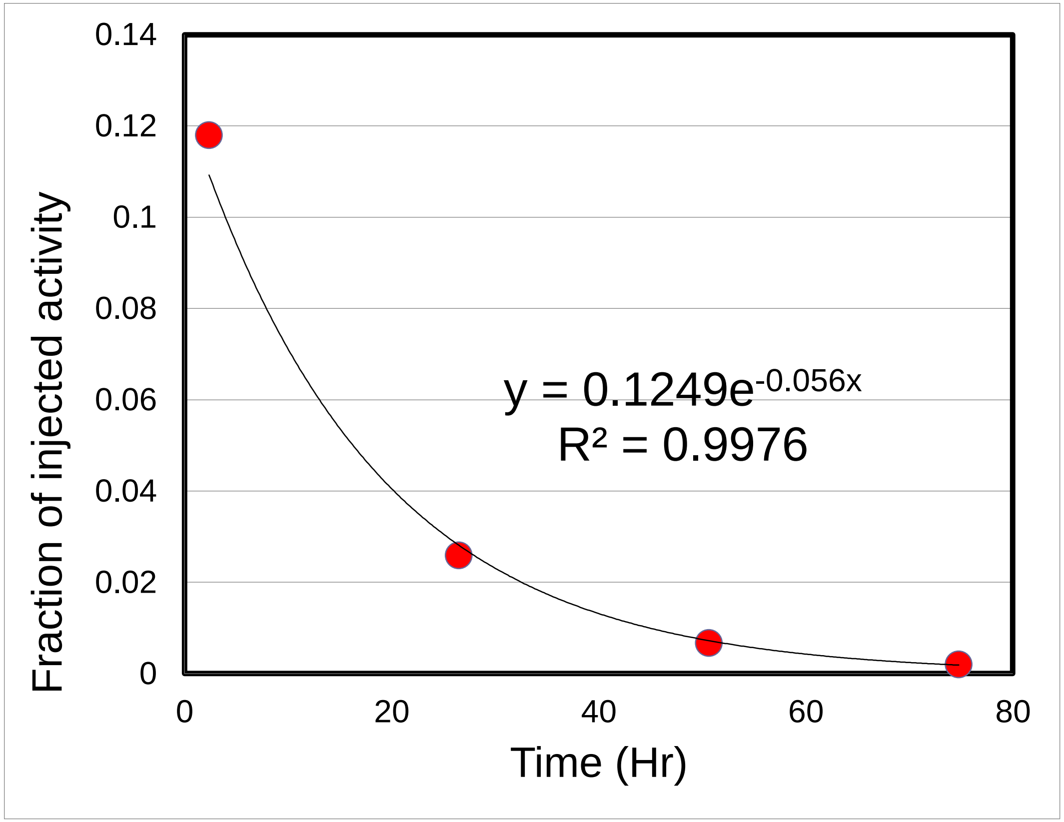




- T (WB) ~ 13 hours
- I-131 amount at 48 hours = 7% of the administered activity (e.g., 7mCi with 100mCi administration)

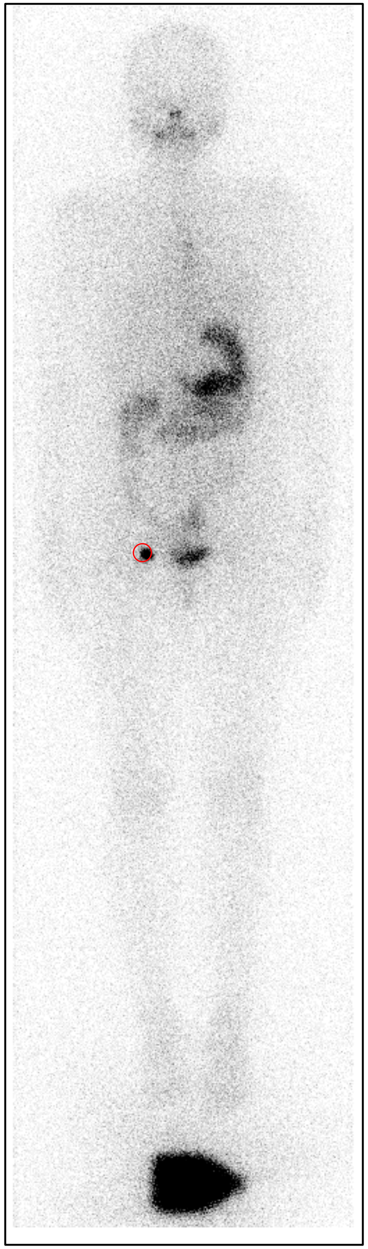
Lung ROI and Time-activity curve

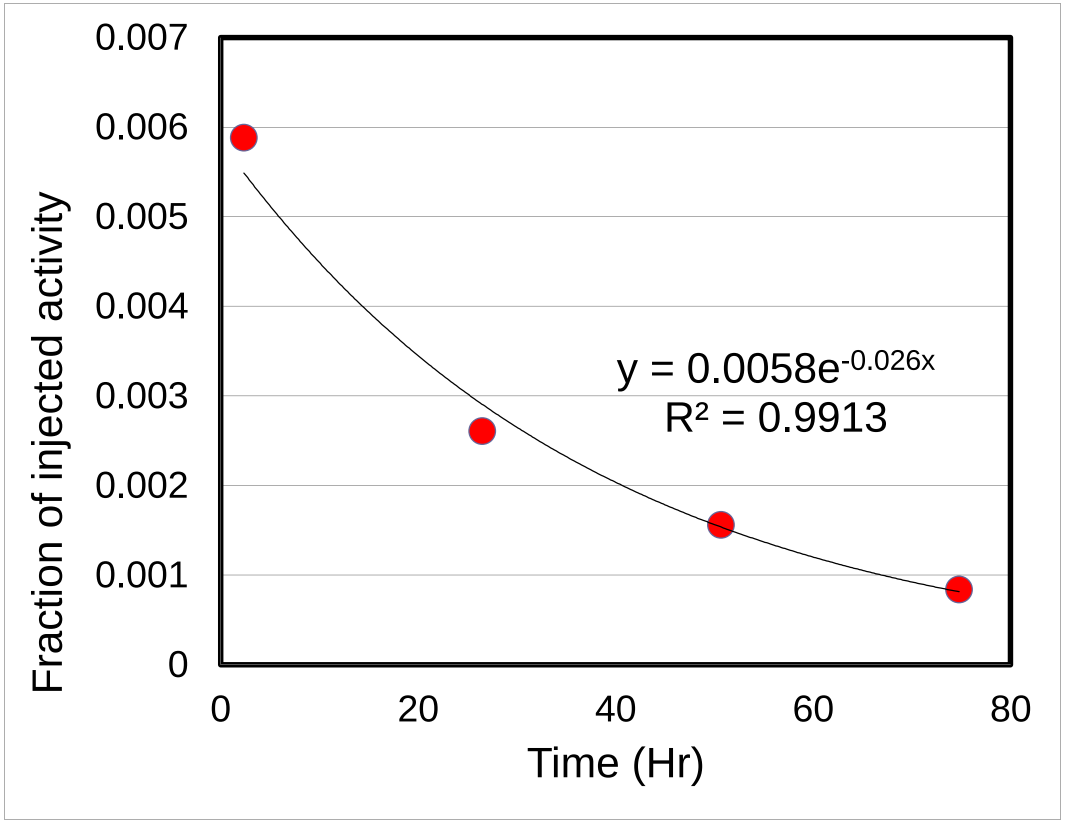




T (lung) ~ 12.4 hours

Dose to the tumor





- T (tumor) ~ 26 hours
- Tumor dose ~ 4 mGy/ MBq (0.15 Gy/mCi)
- ~ 30 Gy with 200mCi administration

Medical Internal Radiation Dose (MIRD) for organ dose

- Use TACs & blood information to estimate S-values of organ of interests.
- Utilize a MIRD-based software, e.g., NUCLIDOSE, OLINDA/EXM
- Estimate the MSD for each patient

  - For lung dose : dose from the lungs + from WB

  - For red marrow dose : dose from the blood + from WB

MIRD results using TACs & standard phantom

Radiation Dose Estimates for the Adult Female - Nonpregnant
for 131 I 53

	TARGET ORGAN	TOTAL DOSE mGy/MBq	TOTAL DOSE rad/mCi	PRIMARY CONTRIBUTOR	%	SECONDARY CONTRIBUTOR	%
1)	Adrenals	3.78E-02	1.40E-01	Rem. Body	80.5%	Stomach Co	8.0%
2)	Brain	2.59E-02	9.57E-02	Rem. Body	99.1%	Lungs	0.5%
3)	Breasts	2.84E-02	1.05E-01	Rem. Body	87.0%	Lungs	8.3%
4)	Gallbladder Wall	4.20E-02	1.55E-01	Rem. Body	71.0%	ULI Conten	12.3%
5)	LLI Wall	5.17E-01	1.91E+00	LLI Conten	91.4%	Rem. Body	5.9%
6)	Small Intestine	8.55E-02	3.16E-01	Sm Int Con	38.3%	Rem. Body	34.2%
7)	Stomach	3.18E-01	1.18E+00	Stomach Co	88.7%	Rem. Body	9.4%
8)	ULI Wall	2.28E-01	8.45E-01	ULI Conten	80.6%	Rem. Body	13.5%
9)	Heart Wall	3.80E-02	1.41E-01	Rem. Body	78.8%	Lungs	11.8%
10)	Kidneys	3.65E-02	1.35E-01	Rem. Body	80.1%	Stomach Co	7.6%
11)	Liver	3.61E-02	1.34E-01	Rem. Body	81.5%	Lungs	6.0%
12)	Lungs	1.45E-01	5.38E-01	Lungs	91.2%	Rem. Body	7.4%
13)	Muscle	3.43E-02	1.27E-01	Rem. Body	78.7%	Urin Bl Co	6.9%
14)	Ovaries	6.52E-02	2.41E-01	Rem. Body	47.3%	LLI Conten	25.8%
15)	Pancreas	4.88E-02	1.80E-01	Rem. Body	64.1%	Stomach Co	26.3%
16)	Red Marrow	4.32E-02	1.60E-01	Rem. Body	73.9%	Red Marrow	8.0%
17)	Bone Surfaces	3.51E-02	1.30E-01	Rem. Body	84.4%	LLI Conten	3.3%
18)	Skin	2.65E-02	9.81E-02	Rem. Body	89.2%	Urin Bl Co	3.2%
19)	Spleen	4.05E-02	1.50E-01	Rem. Body	72.6%	Stomach Co	17.2%
21)	Thymus	3.24E-02	1.20E-01	Rem. Body	88.3%	Lungs	8.8%
22)	Thyroid	2.80E-02	1.04E-01	Rem. Body	95.6%	Lungs	3.5%
23)	Urin Bladder Wall	6.78E-01	2.51E+00	Urin Bl Co	96.6%	Rem. Body	2.4%
24)	Uterus	6.14E-02	2.27E-01	Rem. Body	49.8%	Urin Bl Co	31.4%

How to determine the maximum safe dose

1. Dose factor (lung) = 0.145 mGy/MBq (=0.538 rad /mCi)
   → For 20Gy limit, more than **<u>3000 mCi</u>** can be given to the patient

2. Dose factor (red marrow) = 0.0432 mGy/MBq (=0.16 rad /mCi)
   → For 2 Gy limit, ~**<u>1250 mCi</u>** can be given to the patient

3. Whole-body retention at 48hr : 120 mCi (no lung mets)
   This patient : 7% of administered activity in WB
   → **<u>1700mCi</u>** can be given

- ✓ Should be less than the lowest estimated value
- ✓ Consider other clinical & lab findings

Critical Organs

Administered activity is often limited by the dose to one or more **critical organs**, part of the body that is most susceptible to radiation damage

- renal clearance can affect dose to kidney, urinary bladder, and/or whole body
- GI clearance of activity can increase dose to other abdominal organs and GI tract

Occupational dose limit :
Any individual organ dose < 0.5 Sv (=50 rem)