

Bismuth-213

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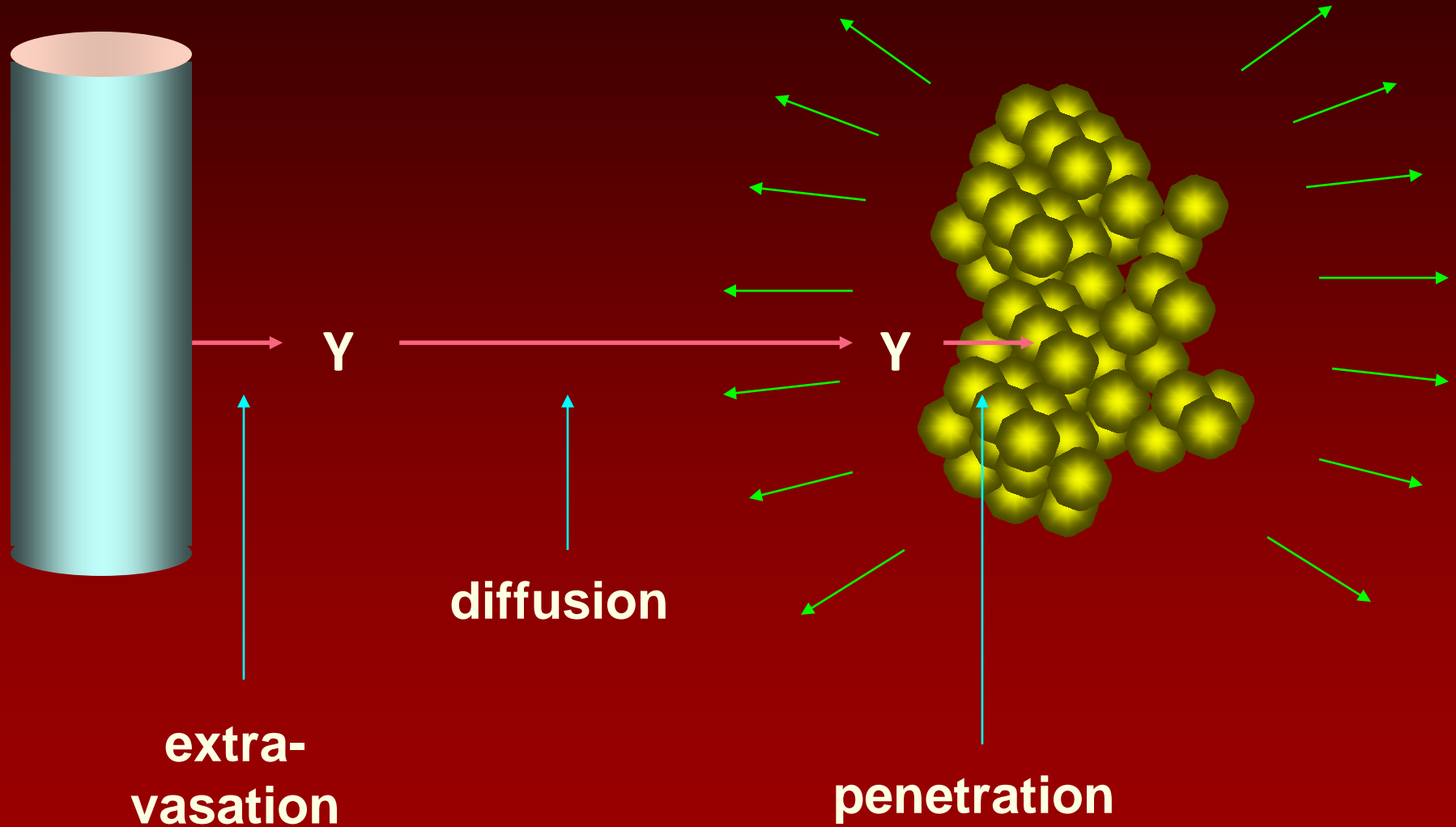
Disclosures

Consultant: Bayer, Roche, Radiomedix

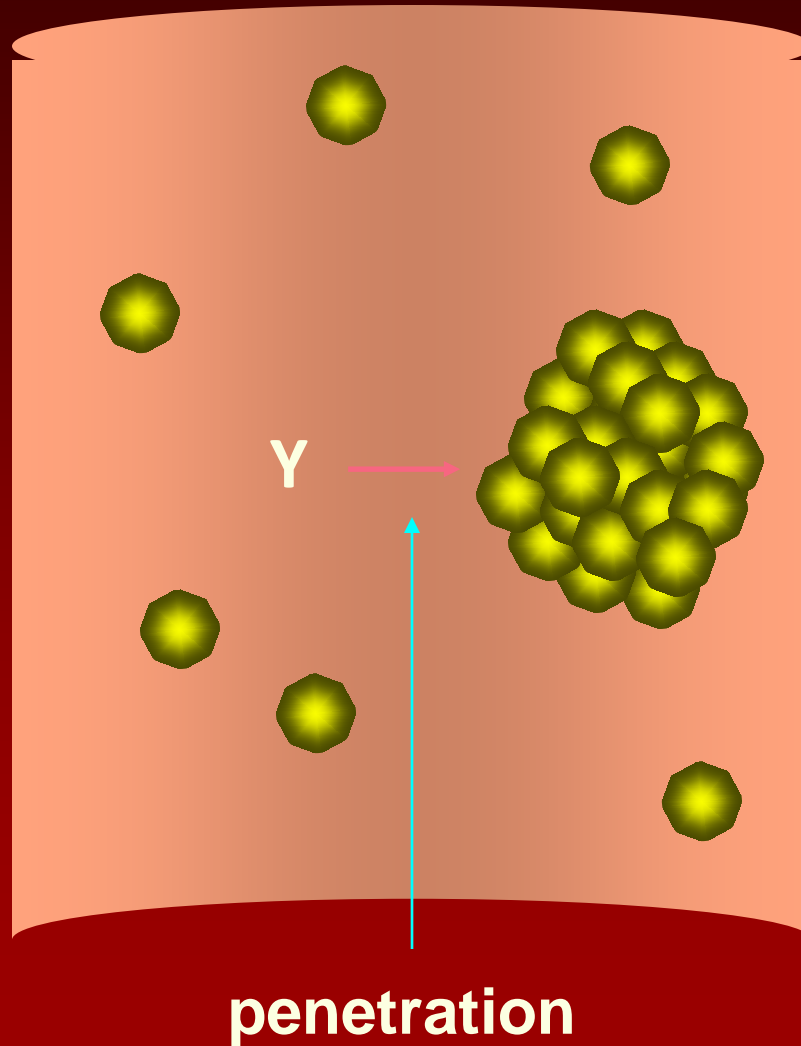
Scientific Advisory Board: Orano Med

Founder: Radiopharmaceutical Imaging and
Dosimetry (RAPID), LLC

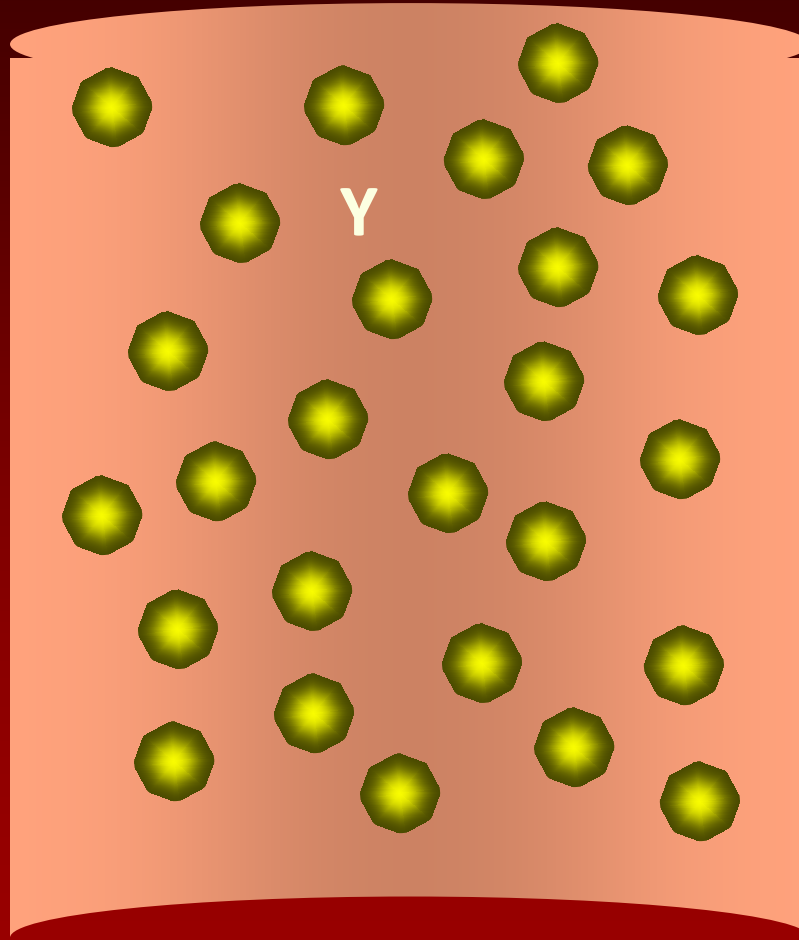
Antibody Targeting - Solid Disease



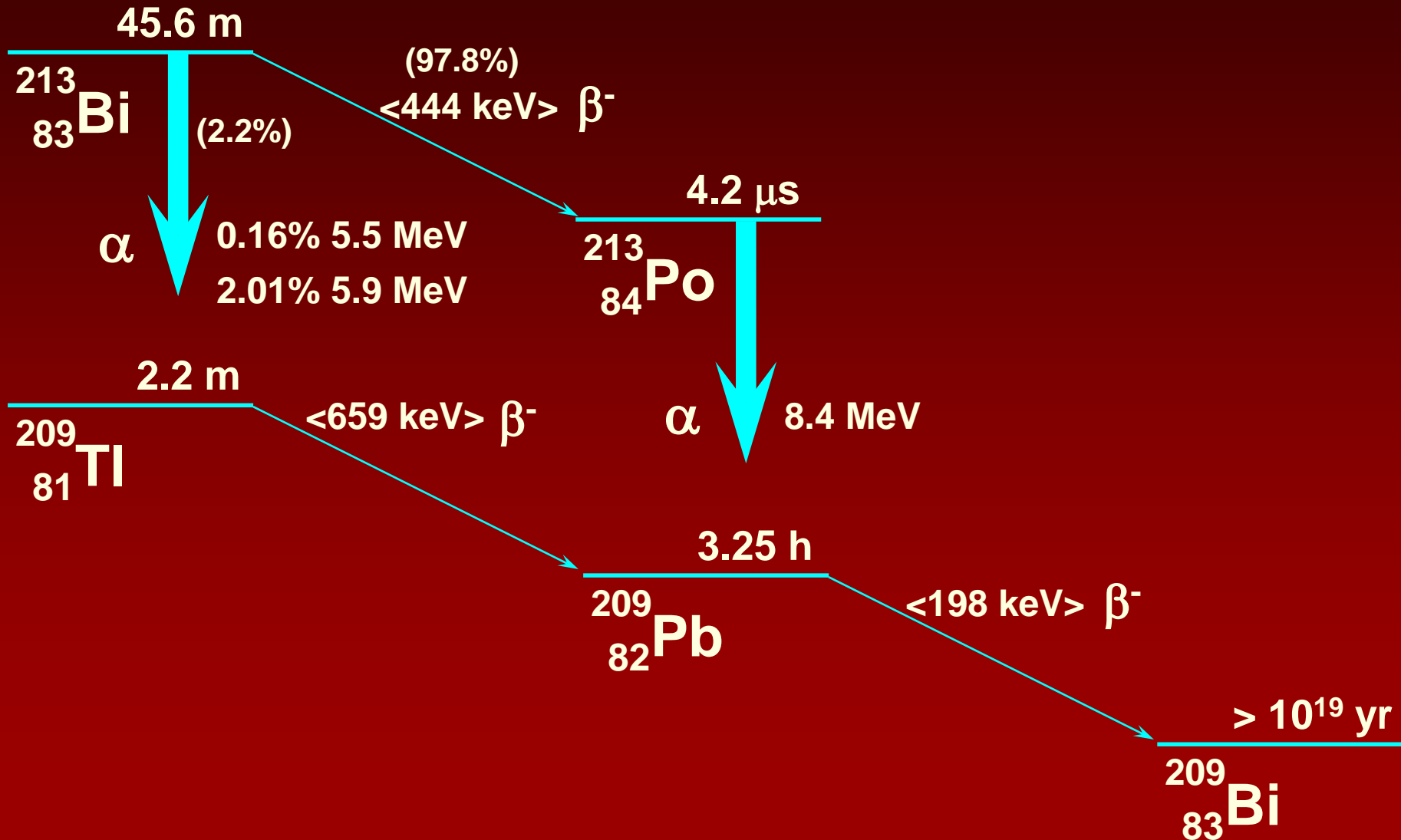
Antibody Targeting - Micrometastases



Antibody Targeting - Leukemia



Bi-213 Decay Scheme



^{213}Bi -HuM195 Leukemia Trial

- **Rapid (5-10 min) targeting of disease**
 - 45.6 min half-life is not limiting
- **Marrow toxicity (nadir duration) similar to ^{90}Y**
- **Targeting of rapidly accessible disease**
 - micrometastases

Short Time Scale

- **Inject under a gamma camera**
 - **Collect in dynamic or list mode**
 - **SPECT imaging may not be feasible**
 - **Image over critical tissues**
- **Feasibility of biopsy, tissue sampling**
- **Relevance of biological clearance**

Bi-213 Decay Characteristics

ISOTOPE	ALPHA PARTICLES					
	energy (keV)	isotope % per disin.	effective % per disin.	<kev> (kev/dis)	delta (Gy-kg/ Bq-s)	delta (g-rad/ μCi-hr)
Bi-213	5549	0.16	0.16	8.88	1.42E-15	.019
Bi-213	5869	2.01	2.01	117.97	1.89E-14	.252
Po-213	7614	0.00	0.00	0.22	3.58E-17	.000
Po-213	8375	100.00	97.80	8190.75	1.31E-12	17.472
SUM				8318	1.33E-12	17.743

Bi-213 Decay Characteristics

TABLE 1
Electron Emissions Considered in Absorbed Dose Calculations

Isotope	Electrons					
	Energy (keV)	Isotope % per disintegration	Effective % per disintegration	Mean energy (keV/disintegration)	Δ_e (Gy·kg/Bq·s)	Electron range (mm)
²¹³ Bi	200	0.20	0.20	0.40	6.41E-17	0.5
²¹³ Bi	347	2.55	2.55	8.85	1.42E-15	1.4
²¹³ Bi	423	0.40	0.40	1.69	2.71E-16	1.9
²¹³ Bi (beta)	444	97.80	97.80	434.23	6.96E-14	2.1
²⁰⁹ Tl (beta)	659	100.00	2.20	14.50	2.32E-15	4.2
²⁰⁹ Pb (beta)	198	100.00	100.00	198.00	3.17E-14	0.5
Total				657.67	1.05E-13	

Δ_e = electron energy emitted per nuclear transition of ²¹³Bi.

Bi-213 Decay Characteristics

TABLE 3
Individual Photon S-Factors and Summed Photon S-Factor
Used for ^{213}Bi Photon Dosimetry

Isotope	Photon energy (keV)	S-factor (Gy/MBq-s)
^{213}Bi	440	5.78E-11
^{213}Bi	79	9.84E-13
^{209}Tl	117	1.60E-12
^{209}Tl	467	6.71E-12
^{209}Tl	1566	2.37E-11
Total = $S_{\text{WB-WB}}$		9.08E-11

$S_{\text{WB-WB}}$ = whole-body to whole-body S-factor.

Distribution assumptions for normal tissues

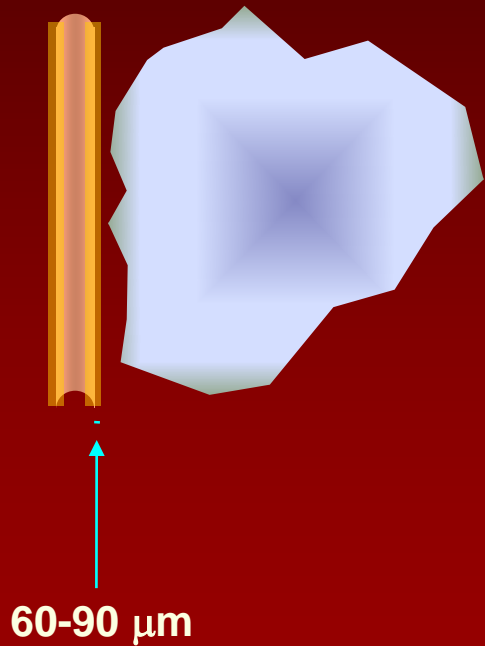
- **^{213}Bi decays are confined to blood**
 - apportion decays according to each tissues blood volume
 - alphas have a range of 60-90 microns and do not irradiate normal tissue
 - electrons have a range of 5 to 10 mm and could irradiate normal tissue even if they originate in the vasculature
- **^{209}Pb rapidly extravasates**
 - Electron range is 0.5 to 1 mm
- **^{209}Pb is confined to blood**
 - Complexed with hemoglobin and remains in red blood cell compartment

Where/how to distribute energy?

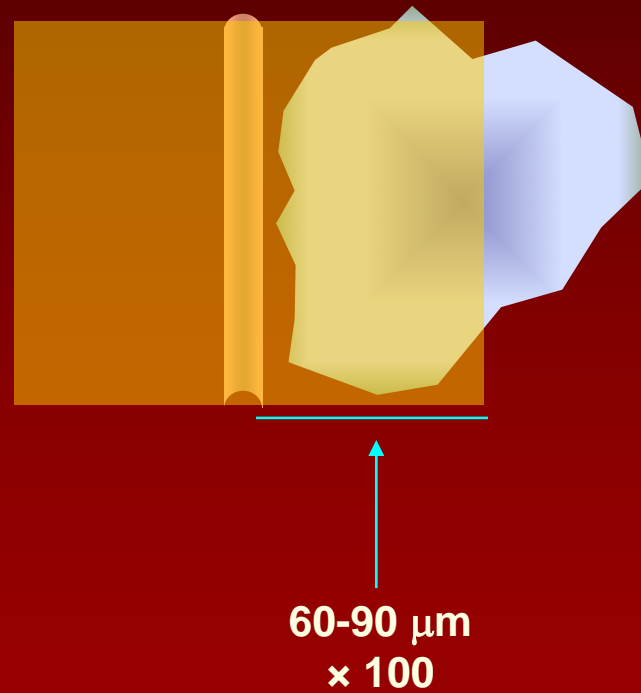
- **Absorbed dose = energy absorbed in volume/volume mass**
- **Total alpha, electron and photon energy emitted by parent and daughters**
- **Use range, half-life, likely biologic fate of daughter in deciding apportionment**

Distribution assumptions for normal tissues

alphas



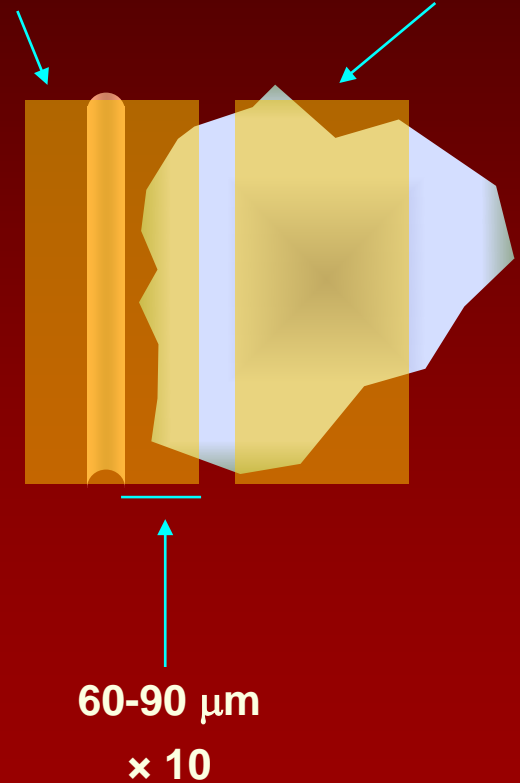
^{213}Bi -electrons



^{209}Pb -electrons

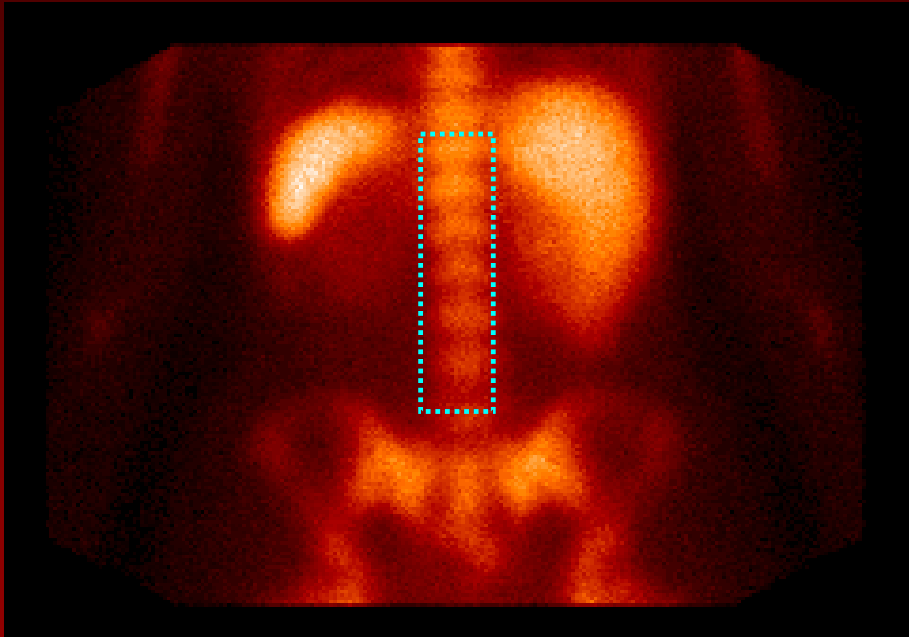
RBC-bound

free

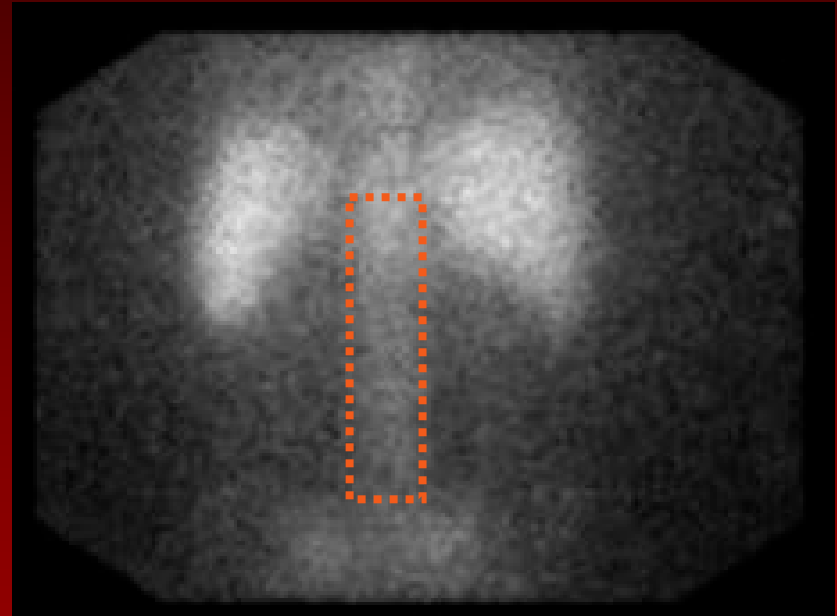


(not drawn to scale)

HuM195 (anti-CD33)



In-111 Day 4, posterior



Bi-213, 4th inj., summed posterior

HuM195 (anti-CD33)

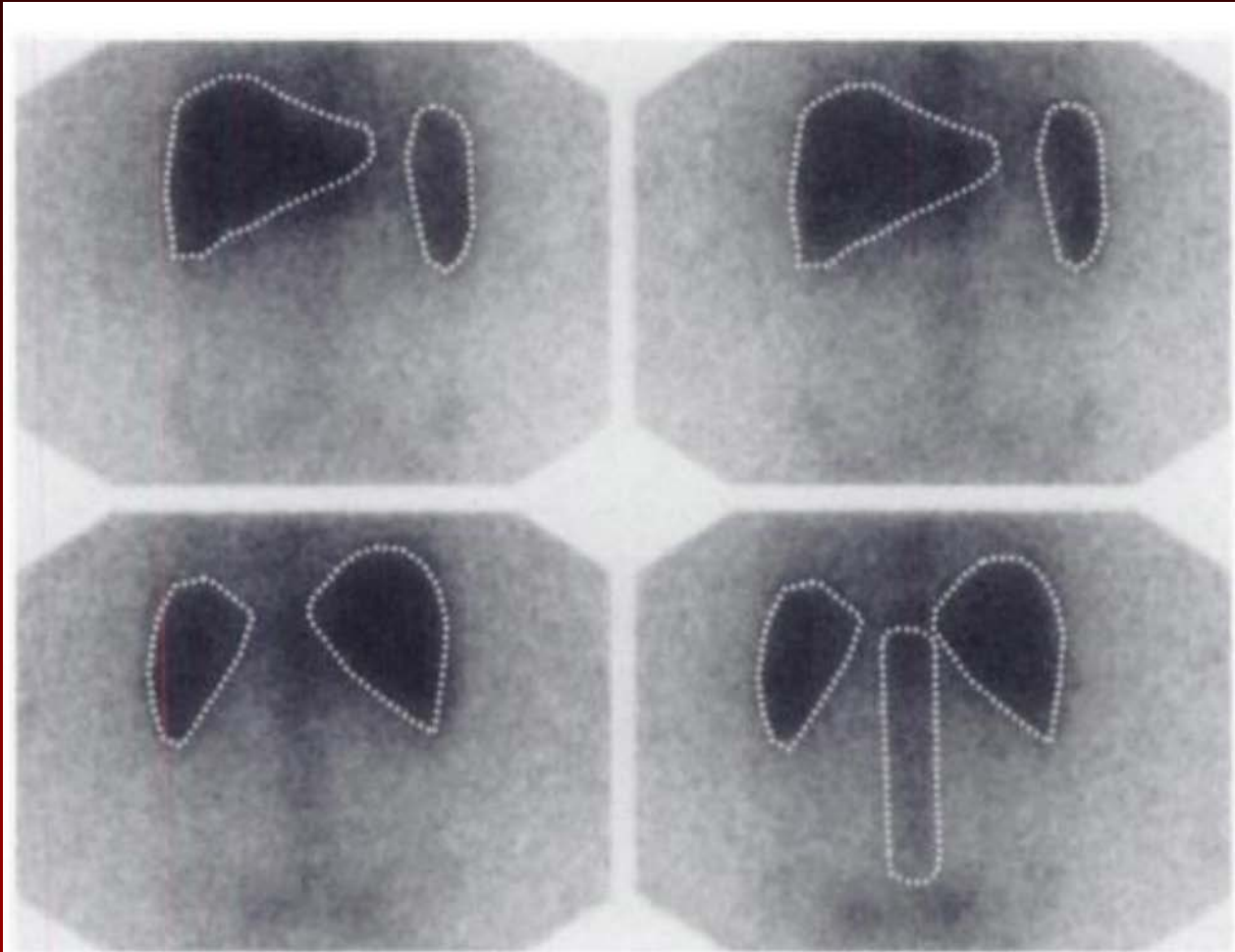


FIGURE 2. Anterior (top row) and posterior (bottom row) patient images showing contours used to identify liver, spleen and red marrow region. Images after second and fourth injection are shown.

Dosimetry - results

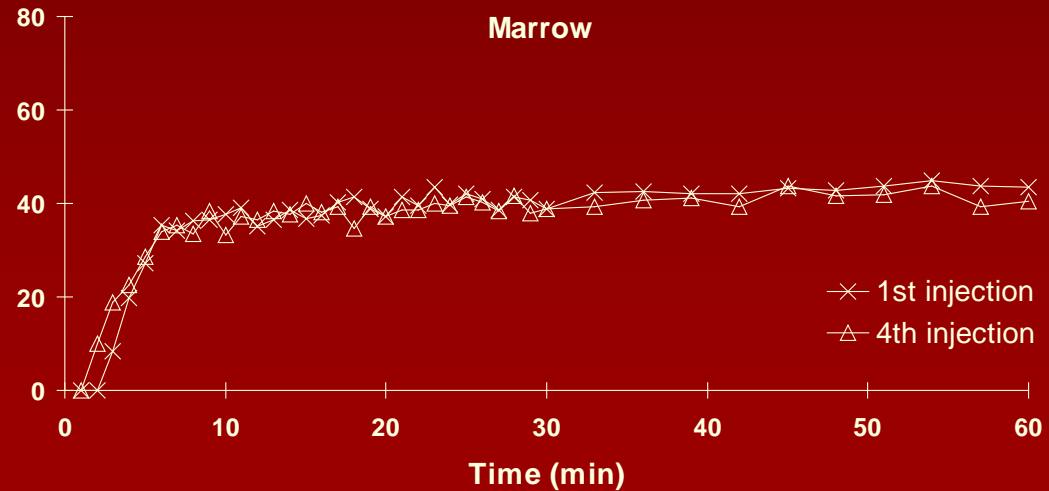
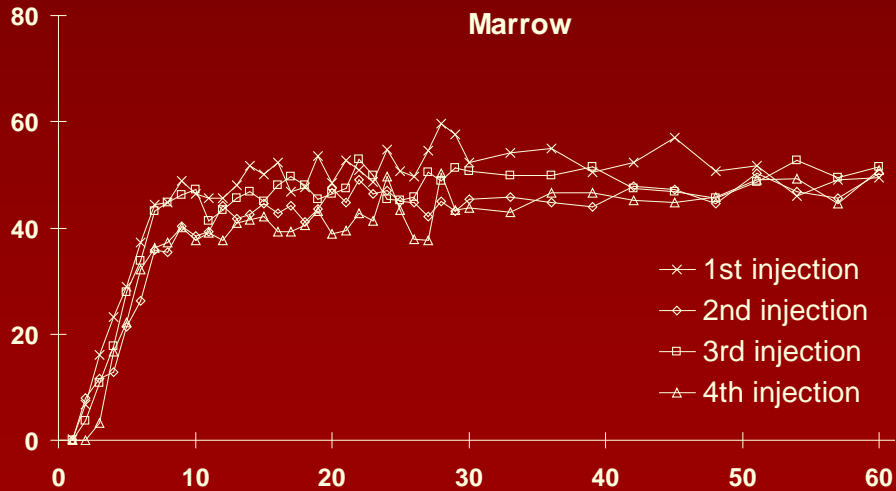
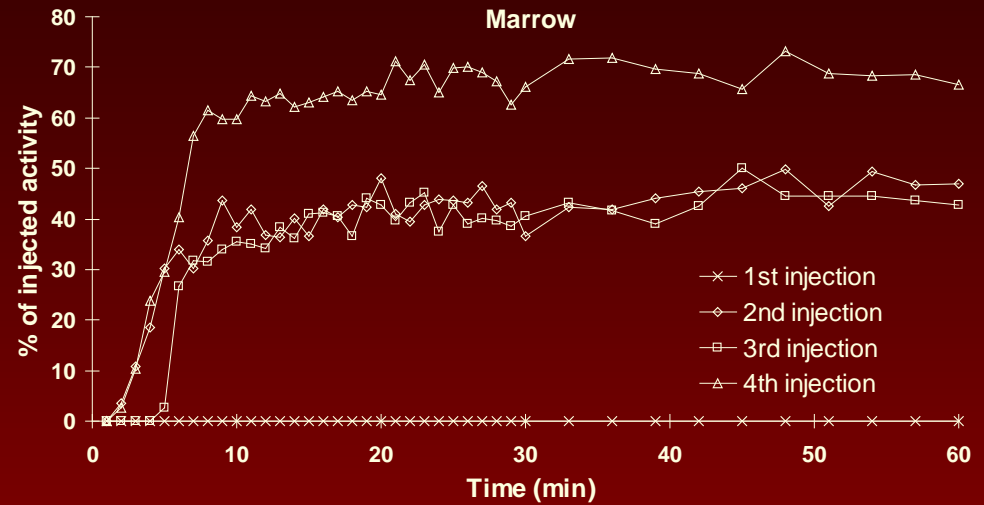
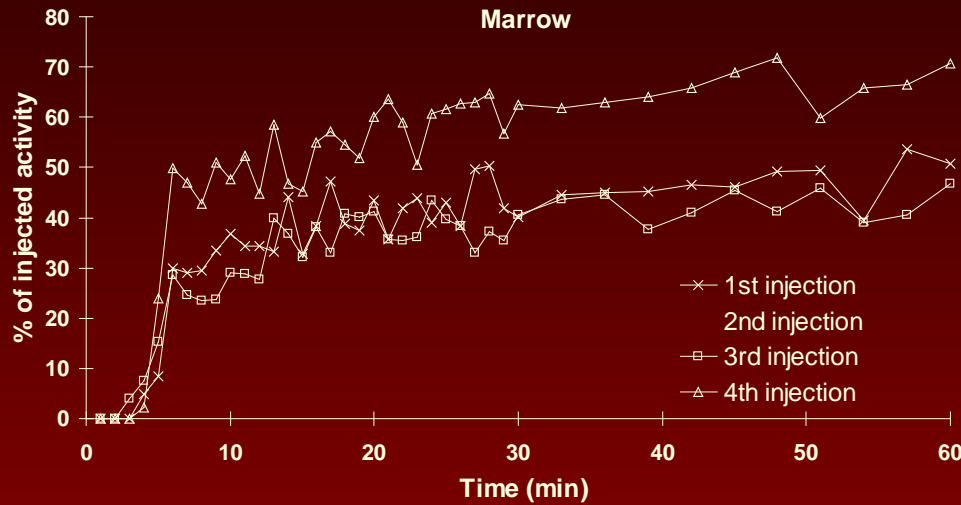
TABLE 5

Absorbed Dose Estimates for Normal Organs (Disease-Free Organs not Targeted by ^{213}Bi -HuM195)

Patient no.	Absorbed dose (mGy/MBq)								
	Heart			Kidneys			Lungs		
	^{213}Bi electrons	^{209}Pb electrons	Total*	^{213}Bi electrons	^{209}Pb electrons	Total*	^{213}Bi electrons	^{209}Pb electrons	Total*
1	2.6E-03	1.2E-03	4.1E-03	3.7E-03	1.7E-03	5.7E-03	8.6E-03	3.9E-03	1.3E-02
2	2.3E-03	1.0E-03	3.6E-03	3.2E-03	1.4E-03	5.0E-03	7.4E-03	3.4E-03	1.1E-02
3	2.8E-03	1.3E-03	4.4E-03	3.9E-03	1.8E-03	6.0E-03	9.1E-03	4.1E-03	1.4E-02
4	5.9E-03	2.7E-03	8.9E-03	8.3E-03	3.8E-03	1.2E-02	1.9E-02	8.8E-03	2.9E-02
5	8.1E-03	3.7E-03	1.2E-02	1.1E-02	5.2E-03	1.7E-02	2.7E-02	1.2E-02	3.9E-02
6	2.6E-03	1.2E-03	4.1E-03	3.6E-03	1.7E-03	5.7E-03	8.6E-03	3.9E-03	1.3E-02
7	3.2E-03	1.4E-03	5.0E-03	4.4E-03	2.0E-03	6.8E-03	1.0E-02	4.8E-03	1.6E-02
8	3.9E-03	1.8E-03	6.0E-03	5.4E-03	2.5E-03	8.2E-03	1.3E-02	5.8E-03	1.9E-02
9	3.5E-03	1.6E-03	5.5E-03	5.0E-03	2.3E-03	7.6E-03	1.2E-02	5.3E-03	1.7E-02

*Whole-body photon dose of 0.00036 mGy/MBq is included in total organ estimates.

^{213}Bi -HuM195 Leukemia Trial



ANTERIOR

POSTERIOR

1st Injection

Last Injection

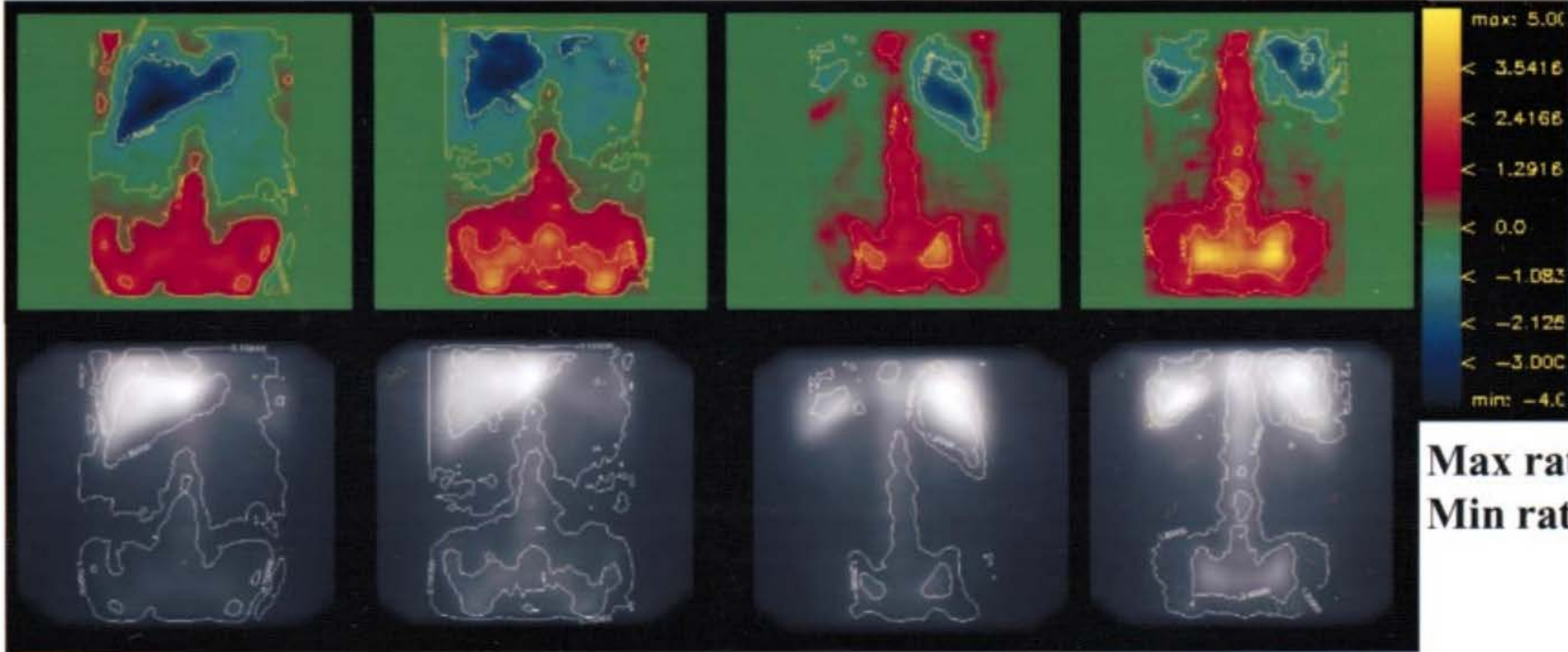
1st Injection

Last Injection

RATE (CPM)

60 MINUTE

SUMMATION



Max rate: 4.9
Min rate: -3.9

Acknowledgments

Åse Ballangrud

Wei-Hong Yang

Klaus Hamacher

Katherine Kolbert

Sherry Farzan-Kashani

Robert Den

Jessica Loh

David Scheinberg

Michael McDevitt

Dangshe Ma

Joe Jurcic

Ron Finn

C. Clifton Ling

Steven Larson

John Humm

Joseph O'Donoghue