Skin dosimetry associated with accidents involving Tc99m, Y90 and F18, I123, I131 , In111 , Lu177

(The Model is key !)

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Set the Scene – the ‘Phone call’

- **Incidents – Phone call**
  - **“X has just found Tc99m on their fingers”**
  - **“1GBq Tc99m has sprayed onto Z’s gloves in the radiopharmacy”**
  - **“Y90 was found on the doctor’s gloves after administration”**

Fortunately very low incidence , but skin doses can be very high

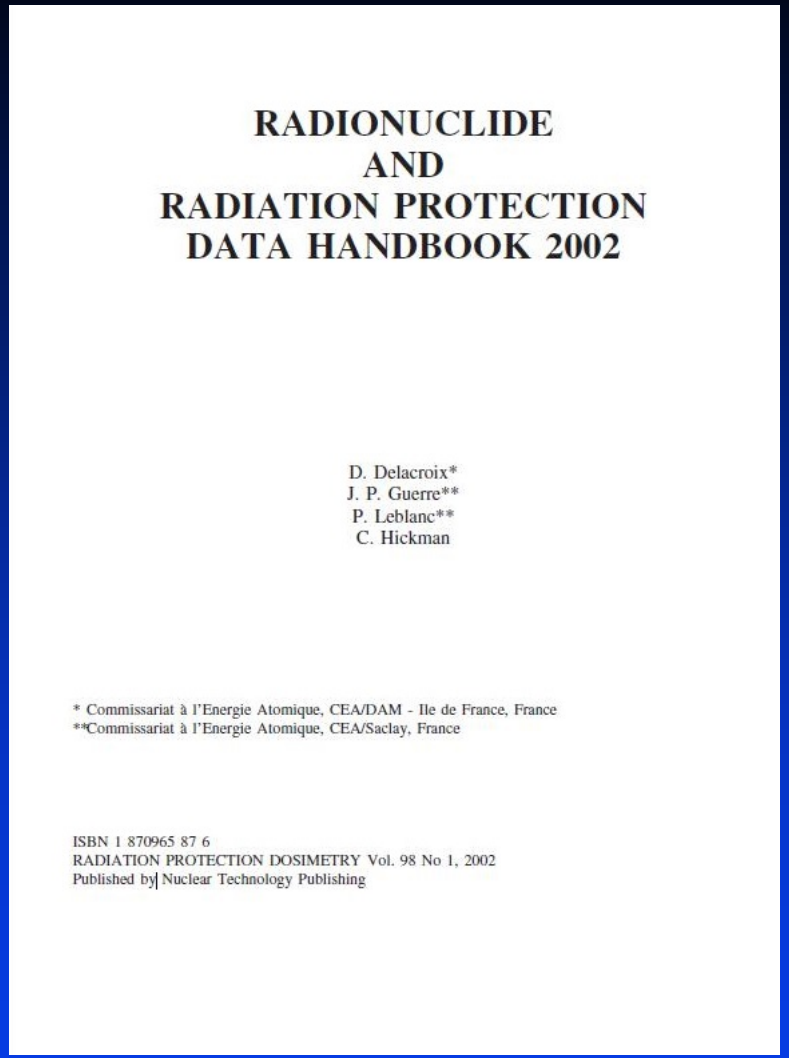
Calculation of Dose (ICRP) - Hp(0.07) averaged over 1cm^2

- **Activity ? Area ? Time?**

Data Sources?

VARSKIN v6.2 Software from RAMP

Allows protective layers, air gaps etc.



RADIONUCLIDE
AND
RADIATION PROTECTION
DATA HANDBOOK 2002

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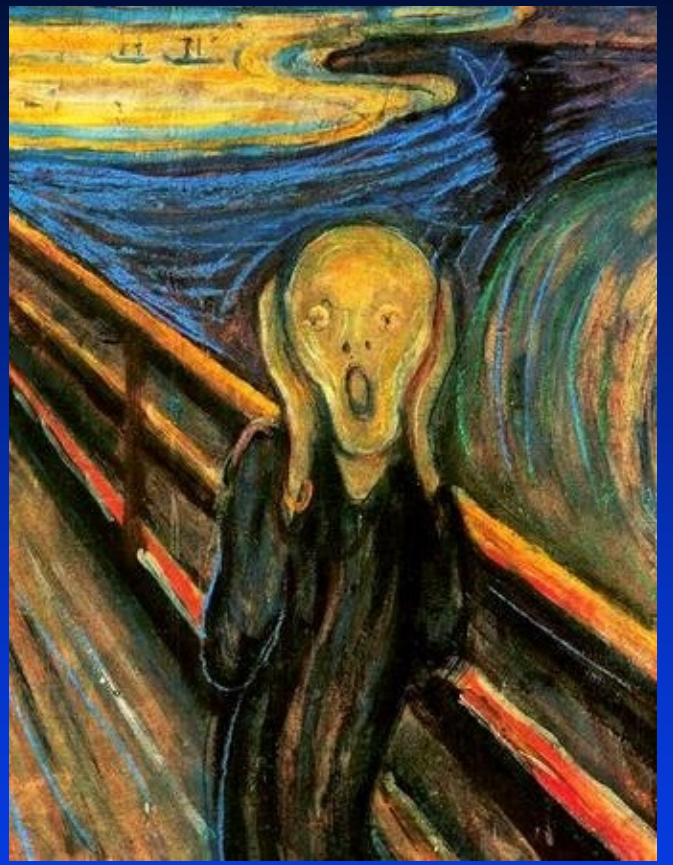
Used VARSKIN 2

Data Presented – APOLOGY!

Pearson Correlation Coefficients, N = 39845888
Prob > |r| under H0: Rho=0

	anti_nucleus	event_file	event_number	event_time	hist_file	multiplicity	n_above_lb	n_below_lb	n_lb	primary_tracks	prod_time	pt	run_number	vertex_x	vertex_y	vertex_z
anti_nucleus	1.00000	-0.05117 <.0001	-0.04428 <.0001	-0.15406 <.0001	-0.05116 <.0001	0.61390 <.0001	0.28379 <.0001	. .	0.58400 <.0001	0.63107 <.0001	-0.00927 <.0001	0.00602 <.0001	-0.16519 <.0001	0.57079 <.0001	0.57079 <.0001	0.57078 <.0001
event_file	-0.05117 <.0001	1.00000	-0.17578 <.0001	0.35877 <.0001	1.00000 <.0001	0.03786 <.0001	0.02324 <.0001	. .	-0.00421 <.0001	0.05387 <.0001	0.61721 <.0001	0.00497 <.0001	0.31135 <.0001	0.01435 <.0001	0.01435 <.0001	0.01441 <.0001
event_number	-0.04428 <.0001	-0.17578 <.0001	1.00000	0.02782 <.0001	-0.17576 <.0001	-0.06958 <.0001	-0.03303 <.0001	. .	-0.06899 <.0001	-0.07290 <.0001	-0.13817 <.0001	0.00064 <.0001	0.09952 <.0001	-0.08885 <.0001	-0.08884 <.0001	-0.08883 <.0001
event_time	-0.15406 <.0001	0.35877 <.0001	0.02782 <.0001	1.00000	0.35877 <.0001	-0.15711 <.0001	-0.07261 <.0001	. .	-0.16606 <.0001	-0.15021 <.0001	0.04217 <.0001	0.00226 <.0001	0.95529 <.0001	-0.22068 <.0001	-0.22068 <.0001	-0.22067 <.0001
hist_file	-0.05116 <.0001	1.00000 <.0001	-0.17576 <.0001	0.35877 <.0001	1.00000	0.03786 <.0001	0.02324 <.0001	. .	-0.00421 <.0001	0.05388 <.0001	0.61722 <.0001	0.00497 <.0001	0.31134 <.0001	0.01435 <.0001	0.01435 <.0001	0.01441 <.0001
multiplicity	0.61390 <.0001	0.03786 <.0001	-0.06958 <.0001	-0.15711 <.0001	0.03786 <.0001	1.00000	0.40685 <.0001	. .	0.90805 <.0001	0.97085 <.0001	0.07072 <.0001	0.00910 <.0001	-0.17419 <.0001	0.82273 <.0001	0.82274 <.0001	0.82266 <.0001
n_above_lb	0.28379 <.0001	0.02324 <.0001	-0.03303 <.0001	-0.07261 <.0001	0.02324 <.0001	0.40685 <.0001	1.00000	. .	0.43895 <.0001	0.41031 <.0001	0.04266 <.0001	0.00438 <.0001	-0.07636 <.0001	0.33529 <.0001	0.33530 <.0001	0.33527 <.0001
n_below_lb	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .	. .
n_lb	0.58400 <.0001	-0.00421 <.0001	-0.06899 <.0001	-0.16606 <.0001	-0.00421 <.0001	0.90805 <.0001	0.43895 <.0001	. .	1.00000	0.90911 <.0001	0.01140 <.0001	0.00699 <.0001	-0.18194 <.0001	0.75936 <.0001	0.75936 <.0001	0.75925 <.0001
primary_tracks	0.63107 <.0001	0.05387 <.0001	-0.07290 <.0001	-0.15021 <.0001	0.05388 <.0001	0.97085 <.0001	0.41031 <.0001	. .	0.90911 <.0001	1.00000	0.09648 <.0001	0.01009 <.0001	-0.16794 <.0001	0.84798 <.0001	0.84798 <.0001	0.84791 <.0001
prod_time	-0.00927 <.0001	0.61721 <.0001	-0.13817 <.0001	0.04217 <.0001	0.61722 <.0001	0.07072 <.0001	0.04266 <.0001	. .	0.01140 <.0001	0.09648 <.0001	1.00000	0.00753 <.0001	0.05690 <.0001	0.03509 <.0001	0.03509 <.0001	0.03516 <.0001
pt	0.00602 <.0001	0.00497 <.0001	0.00064 <.0001	0.00226 <.0001	0.00497 <.0001	0.00910 <.0001	0.00438 <.0001	. .	0.00699 <.0001	0.01009 <.0001	0.00753 <.0001	1.00000	0.00249 <.0001	0.00688 <.0001	0.00688 <.0001	0.00689 <.0001
run_number	-0.16519 <.0001	0.31135 <.0001	0.09952 <.0001	0.95529 <.0001	0.31134 <.0001	-0.17419 <.0001	-0.07636 <.0001	. .	-0.18194 <.0001	-0.16794 <.0001	0.05690 <.0001	0.00249 <.0001	1.00000	-0.23948 <.0001	-0.23948 <.0001	-0.23945 <.0001
vertex_x	0.57079 <.0001	0.01435 <.0001	-0.08885 <.0001	-0.22068 <.0001	0.01435 <.0001	0.82273 <.0001	0.33529 <.0001	. .	0.75936 <.0001	0.84798 <.0001	0.03509 <.0001	0.00688 <.0001	-0.23948 <.0001	1.00000	1.00000 <.0001	0.99998 <.0001
vertex_y	0.57079 <.0001	0.01435 <.0001	-0.08884 <.0001	-0.22068 <.0001	0.01435 <.0001	0.82274 <.0001	0.33530 <.0001	. .	0.75936 <.0001	0.84798 <.0001	0.03509 <.0001	0.00688 <.0001	-0.23948 <.0001	1.00000 <.0001	1.00000	0.99998 <.0001
vertex_z	0.57078 <.0001	0.01441 <.0001	-0.08883 <.0001	-0.22067 <.0001	0.01441 <.0001	0.82266 <.0001	0.33527 <.0001	. .	0.75925 <.0001	0.84791 <.0001	0.03516 <.0001	0.00689 <.0001	-0.23945 <.0001	0.99998 <.0001	0.99998 <.0001	1.00000



Some data tables included for later reference if needed ; not discussed

Radionuclides - Discussed

		range	
	Electron / Beta	Tissue (mm)	Use
Tc99m	120keV (11%)	0.3mm	Diag. >90% NM
F18	634keV (97%)	1.7mm	Diag. PET
Y90	2.28MeV (100%)	9.2mm	Therapy

Radionuclides – Also given

		range	
	Electron	Tissue (mm)	Use
Tc99m	120keV (11%)	0.3mm	Diag. >90% NM
F18	634keV (97%)	1.7mm	Diag. PET
Y90	2.28MeV (100%)	9.2mm	Therapy
I123	127keV (14%)	0.3mm	Diag. NM
In111	145keV (9%)+219keV (5%)	0.5mm	Diag. NM
I131	606keV(90%) + 330keV(9%)	1.6mm	Therapy (capsule)
Lu177	498keV (78%)	1.3mm	Therapy

Two Delacroix Models

- **Contamination area** – has ‘Zero’ thickness

  (use for inadvertent ‘pick-up’ contamination)

  Tc99m 1kBq/cm^2 0.25 mSv.h^{-1}

- **Droplet** 1cm^2 , 0.5mm thick , 0.05ml volume

  (use for obvious droplet)

  Tc99m 1kBq 0. 0088 mSv.h^{-1}

(disc)

(1cm^2 cylinder)

(Not to Scale!)

- Droplet model has a big effect on the dose calculation

Delacroix vs VARSKIN - contamination

Contamination area – assumes ‘Zero’ thickness

	mSv / min for 1MBq /cm2		
	Delacroix	VARSKIN	Difference
Tc99m	4.1	3.6	-11%
F18	32	25	-21%
Y90	34	24	-21%

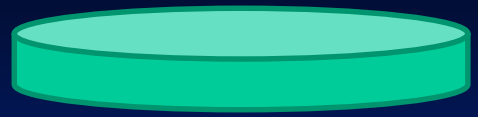
Delacroix vs VARSKIN - contamination

Contamination area – assumes ‘Zero’ thickness

	mSv / min for 1MBq /1cm2		
	Delacroix	VARSKIN	Difference
Tc99m	4.1	3.6	-12%
F18	32	25	-22%
Y90	34	24	-29%
I123	6.3	5.2	-17%
In111	6.3	5.1	-19%
I131	27	22	-18%
Lu177	-	20	

Delacroix vs VARSKIN - Droplet

Droplet 1cm^2 , 0.5mm thick , 0.05ml volume



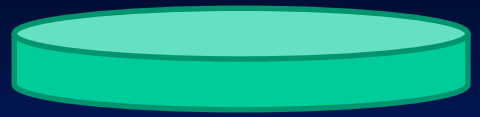
	mSv / min / MBq		
	Delacroix	VARSKIN	Difference
Tc99m	0.15	0.52	+253%
F18	13	12	-8.2%
Y90	23	17	-26%

N.B. my Units ! mSv / min for 1 MBq

Also, are instantaneous dose rates

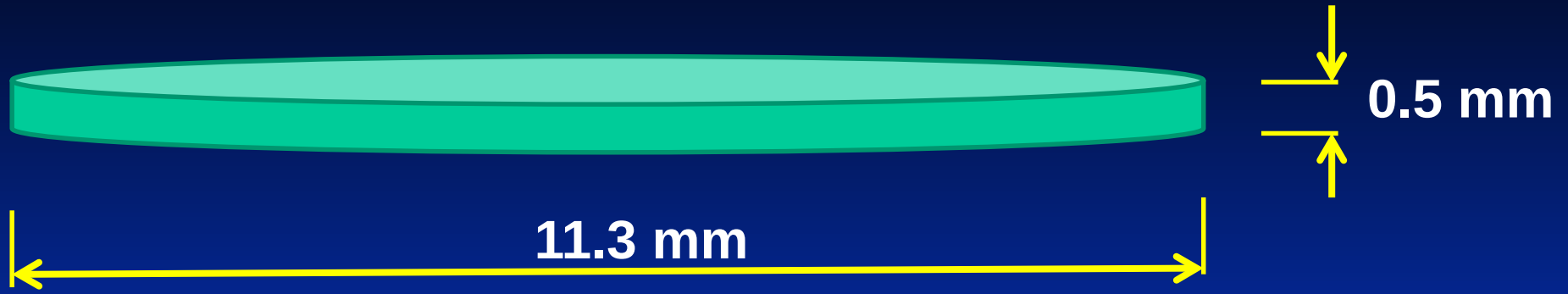
Delacroix vs VARSKIN - Droplet

Droplet 1cm^2 , 0.5mm thick , 0.05ml volume

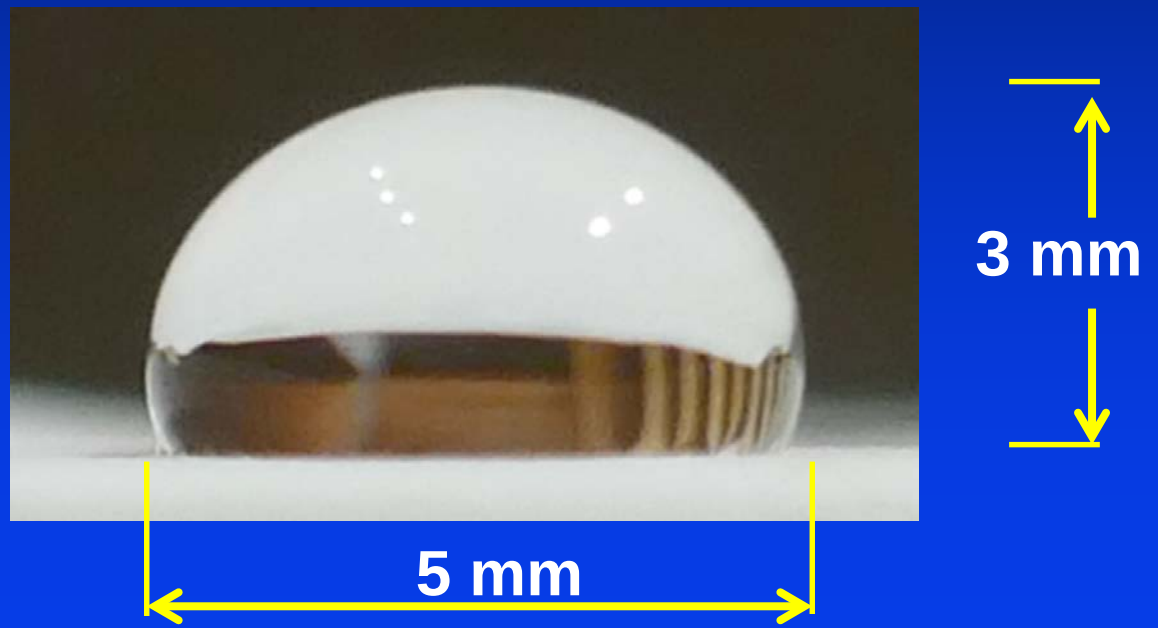


	mSv / min / MBq		
	Delacroix	VARSKIN	Difference
Tc99m	0.15	0.52	+253%
F18	13	12	-8.2%
Y90	23	17	-26%
I123	0.4	0.92	131%
In111	1.1	1.6	49%
I131	9.5	9.1	-4.7%
Lu177	-	6.3	

DELACROIX Droplet to scale 1cm^2 , 0.5mm thick , 0.05ml volume



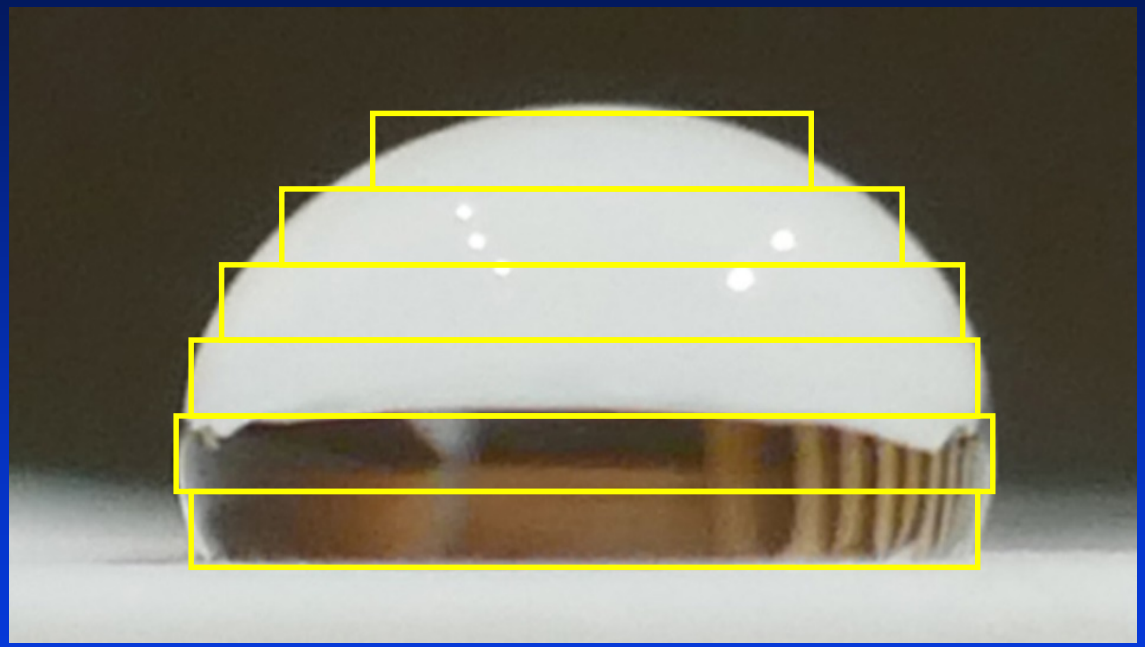
0.05ml Droplet
(on surgical glove)



VARSKIN Droplet model

Photograph of 0.05ml droplet on surgical glove

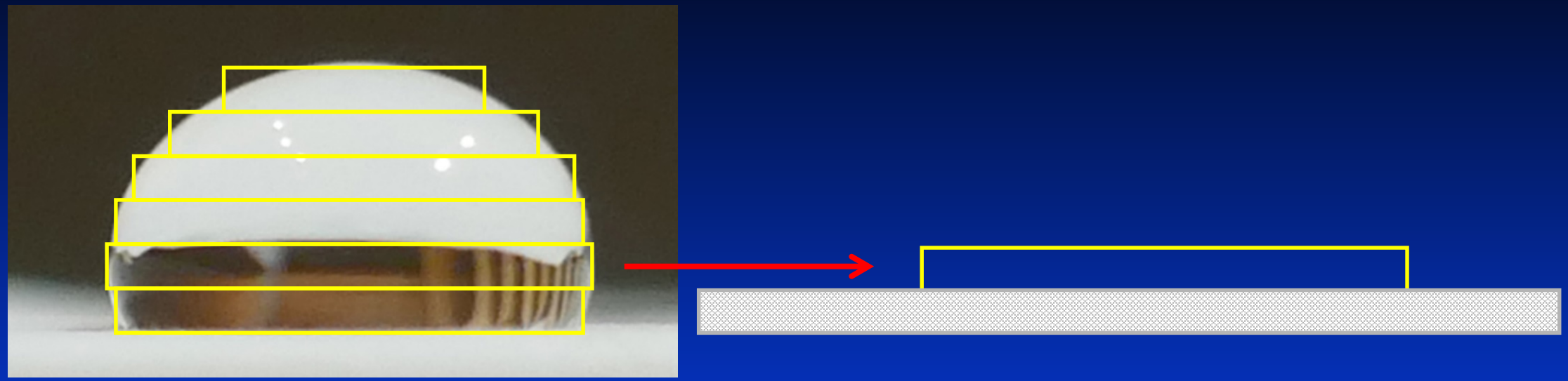
Droplet 0.05ml



model with six 0.5mm thick cylinders?

Dose is weighted sum of the individual cylinder doses

VARSKIN Droplet model

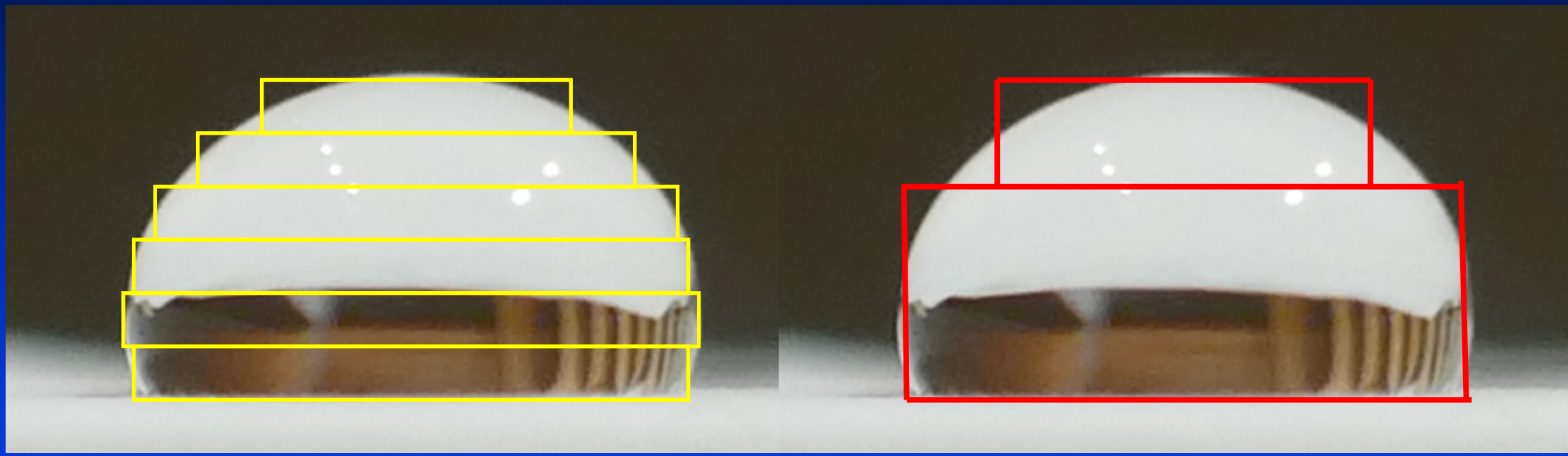


Model as 0.5mm slice + 0.5mm water layer ?

BUT not representative!

- **infinite plane (water) underneath**
- **No Backscatter layer on top**

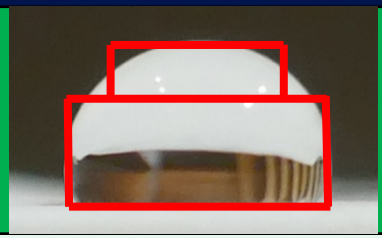
VARSKIN Droplet model
Need a Rethink!



Still some backscatter errors , but now generally small

VARSKIN Droplet Model Comparison

mSv / min / MBq

			Reduction Factor
Tc99m	0.52	0.17	X3
F18	12	5.1	X2.3
Y90	17	10	x1.7

VARSKIN Droplet Model Comparison

mSv / min / MBq

			Difference
Tc99m	0.52	0.17	X3
F18	12	5.1	X2.3
Y90	17	10	x1.7
I123	0.92	0.34	X2.7
In111	1.6	0.61	X2.6
I131	9.1	3.7	X2.5
Lu177	6.3	2.3	X2.8

Effect of Gloves

Sterile Surgical gloves (radiopharmacy)

Thickness 0.2mm

(VARSKIN table has 0.05mm)

Non-sterile Nitrile , latex free (dispensary, injections)

Thickness 0.05mm

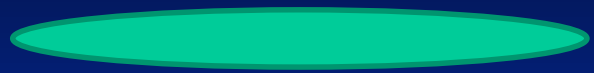
(data not presented)

Still two Contamination situations

(1cm^2 disc)

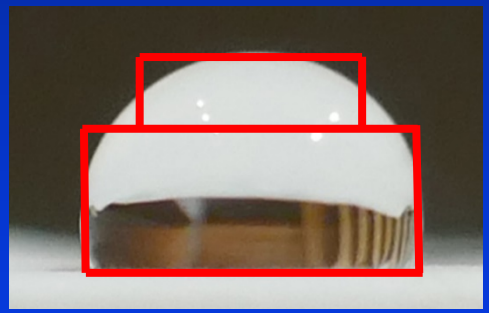
- **Contamination** – ‘Zero’ thickness

  i.e inadvertent ‘pick-up’ contamination on glove



- **Droplet**

  use for obvious droplet contamination on glove



Dose reduction with Surgical gloves for Contamination Model mSv/min for 1MBq/cm^2

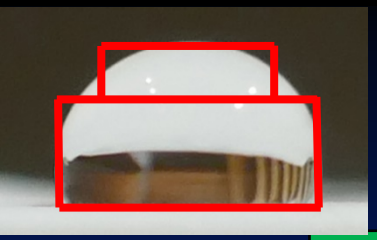
	No glove (direct skin)	Surgical Glove	Reduction Factor
Tc99m	3.6	0.054	x67
F18	25	11.5	x2.2
Y90	24	16	x1.5

Contaminated gloves are easily removed , so doses relate to time worn

Dose reduction with Surgical gloves for Contamination Model mSv / min / MBq

	No glove (direct skin)	Surgical Glove	Reduction Factor
Tc99m	3.6	0.054	x67
F18	25	11.5	x2.2
Y90	24	16	x1.5
I123	5.2	0.16	X33
In111	5.1	1.1	x4.7
I131	22	8.3	x2.7
Lu177	20	5	x4

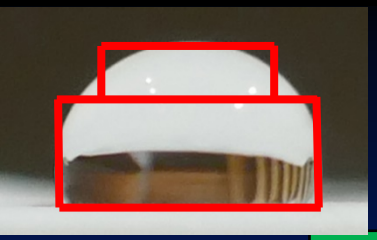
Contaminated gloves are easily removed , so doses relate to time worn



Dose reduction with Surgical gloves for Droplet Model mSv / min / MBq

	No glove (direct skin)	Surgical Glove	Reduction Factor
Tc99m	0.17	0.03	x5.8
F18	5.1	2.7	x1.9
Y90	10	9	x1.1

Contaminated gloves are easily removed , so doses relate to time worn



Dose reduction with Surgical gloves for Droplet Model mSv / min / MBq

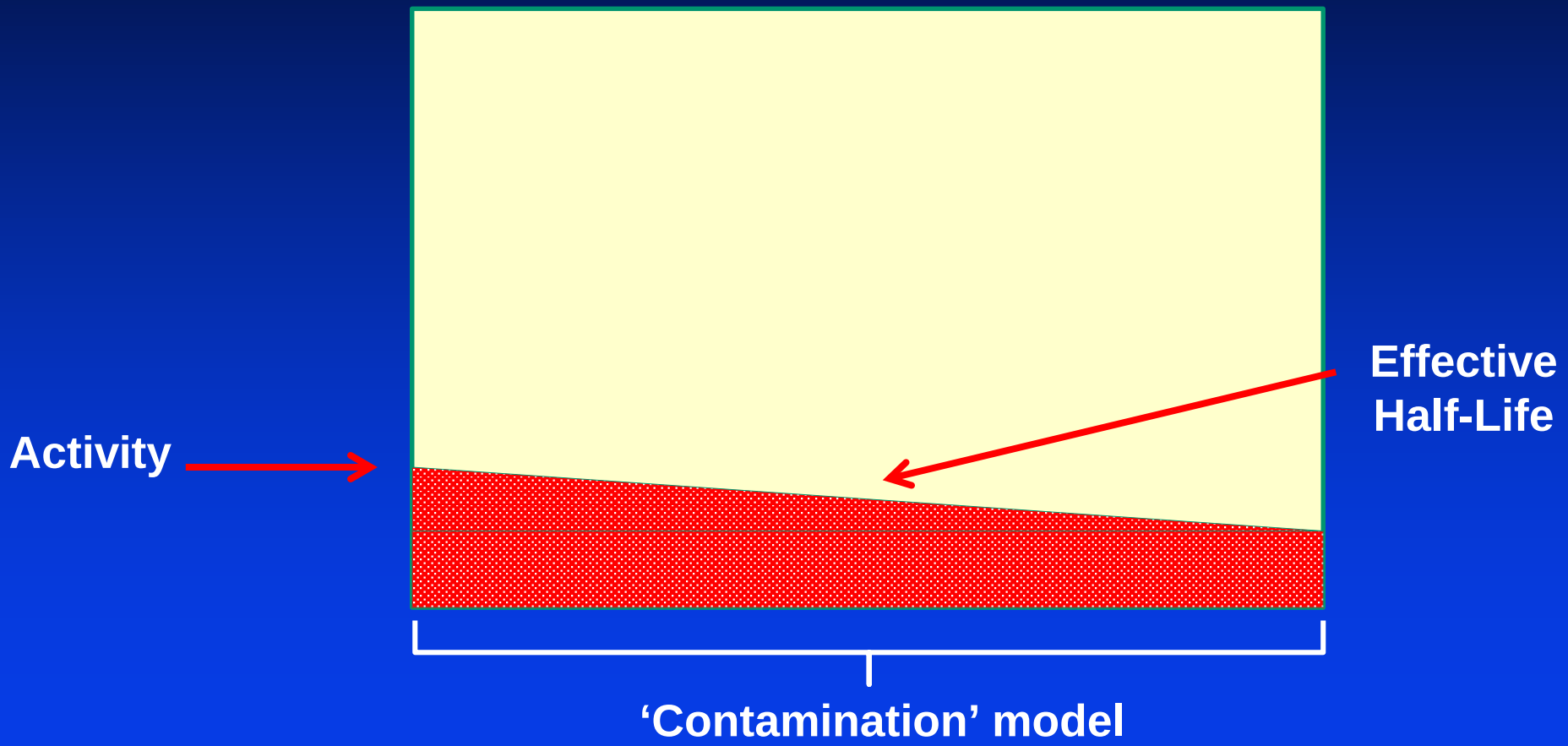
	No glove (direct skin)	Surgical Glove	Reduction Factor
Tc99m	0.17	0.03	x5.8
F18	5.1	2.7	x1.9
Y90	10	9	x1.1
I123	0.34	0.09	x3.6
In111	0.61	0.19	x3.1
I131	3.7	1.7	x2.2
Lu177	2.3	0.73	x3.1

Contaminated gloves are easily removed , so doses relate to time worn

Direct Skin contamination – Total Dose?

Inadvertent activity , fixed . Remnant has effective T1/2

What is the total skin dose?



Skin contamination
Remnant Fractions and Biological Half-Life

Covens et al; long term spot checks ; 560 measurements.

Unsuspected contamination of Tc99m (n = 33) and F18 (n = 7)

80% were localised spots on finger tips – mostly fixed

[From removing patient's butterfly or handling syringe shields without gloves]

Determined effective half-life of the activity on skin

[Pig skin experiments found 2% - 8% remnant fixed contamination]

P Covens et al Nuc.Med. Commun. 2012 33:102

Skin contamination Biological Half-Life

Derived Biological Half-life values

Tc99m 8.1 hr (6 – 11) mean and 95%ile range

F18 8.6 hr (4.5 - 12.7) mean and 95%ile range

VARSKIN gives the total dose based on the physical half-life

(the decay-corrected dose ; use exposure time of ~20x T1/2)

Dose figures based on applying a 10hr biological half life (all radionuclides)

MBq Activity to give 500mSv

- ‘Fixed’ activity only
- biological T1/2 of 10hr

	MBq
	For 500mSv
Tc99m	0.43
F18	0.15
Y90	0.03

Very low activity values!

Ignores dose from initial higher activity causing fixed contamination

Demonstrates need to avoid direct skin contamination in nuclear medicine

Staff education is important

MBq Activity to give 500mSv

‘Fixed’ activity only

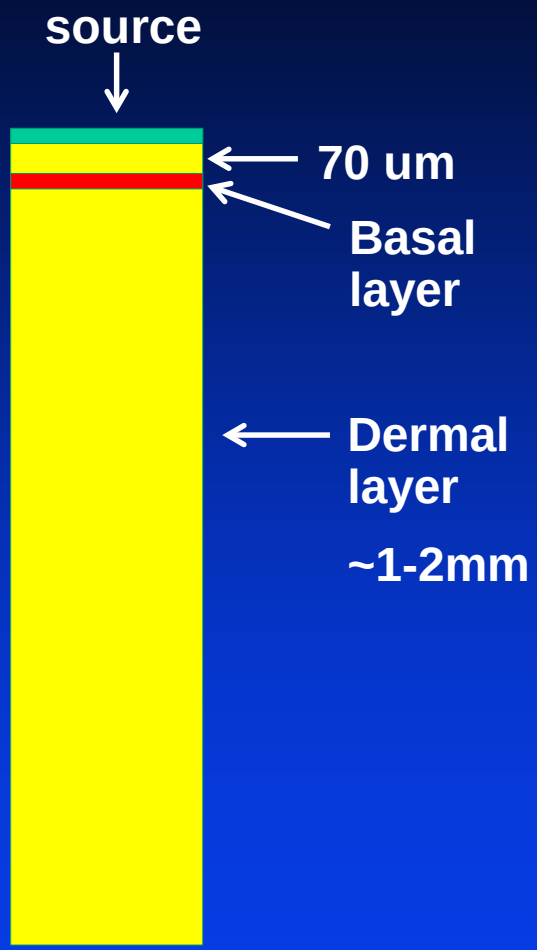
biological T1/2 of 10hr

Demonstrates need to avoid direct skin contamination in nuclear medicine

	MBq
	For 500mSv
Tc99m	0.43
F18	0.15
Y90	0.03
I123	0.19
In111	0.13
I131	0.028
Lu177	0.03

Skin Dosimetry concept

P Covens et al 2013 J. Radiol. Prot. 33: 381



Standard model

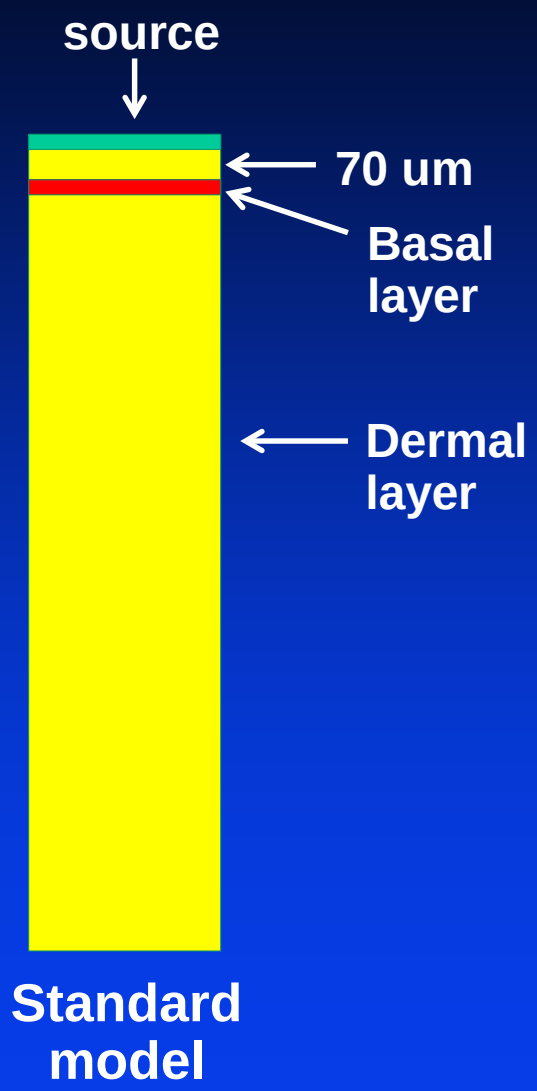
Fingertip

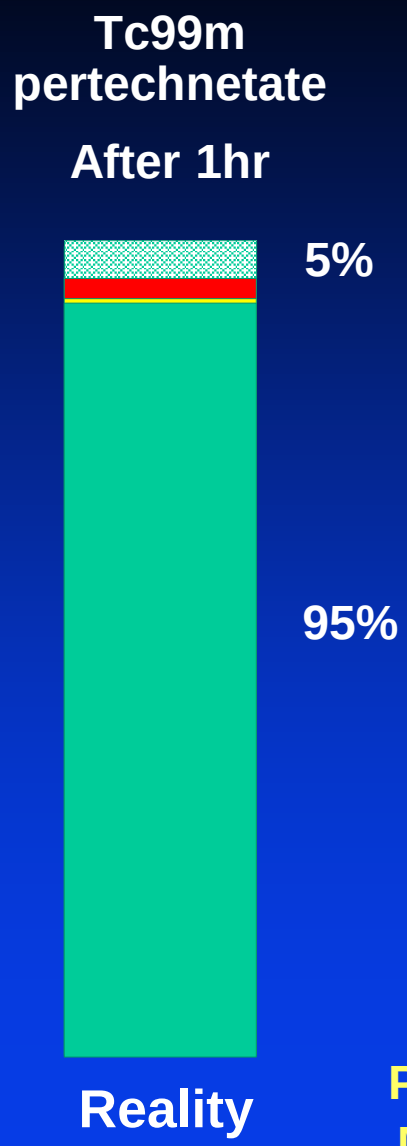
Extra epidermal skin thickness gives substantial finger tip dose reduction

BUT!


These Models are blown out-of-the-water

Dosimetry model - Percutaneous Absorption





- Determine dose from epidermal and dermal sections
- Need to consider BSCF values
- Use weighted components for dynamic dose modelling to give total dose
- Biological half-life is vascular clearance from the dermis

P Covens et al 2013 J. Radiol. Prot. 33: 381
MA Bolzinger et al 2010 Int. J. Pharm. 402: 44

Summary and other factors

- Correct model is vital
- Distance and time from the basal layer is a key component of modelling
- Must avoid direct skin contamination in nuclear medicine
- Gloves essential in nuclear medicine – can also reduce dose
- Staff Education – critical