Skin contamination of nuclear medicine workers: incidence, routes, dosimetry and decontamination

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Introduction
Daily practice in nuclear medicine

Repeated manipulation of concentrated sources

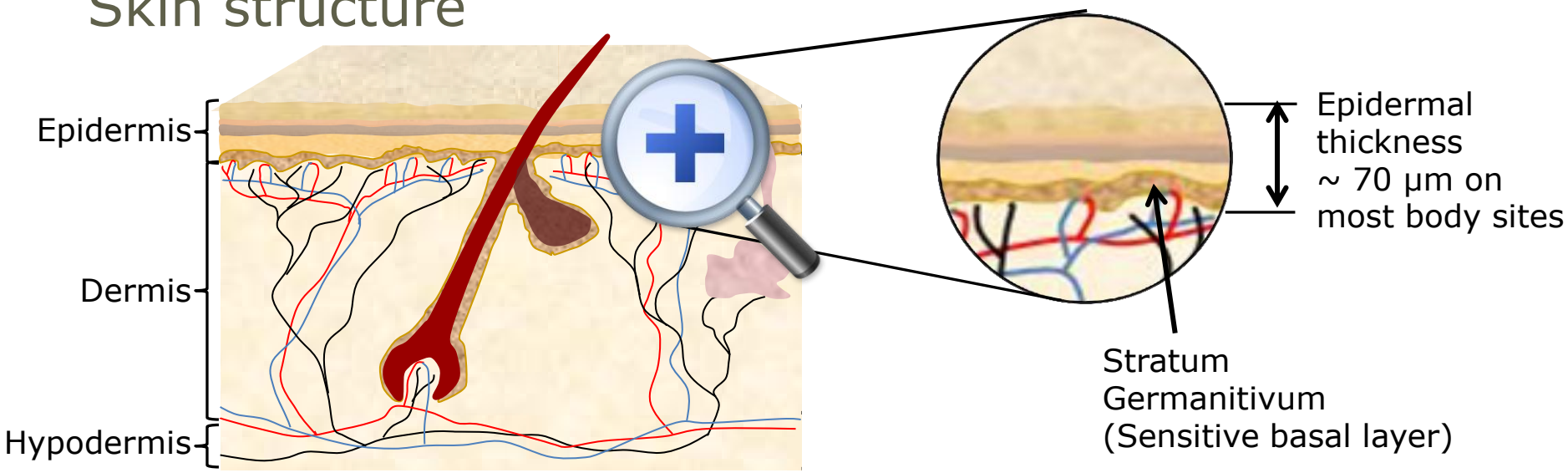
High localised skin doses expected

External irradiation

Skin contamination

The skin in radiation protection

Skin structure



Skin effects after high localised radiation exposure

- Erythema, desquamation, necrosis, dermal atrophy,...
- Function of total dose and the time over which this dose is received
- Do NOT necessarily find their origin in the basal layer

The skin in radiation protection

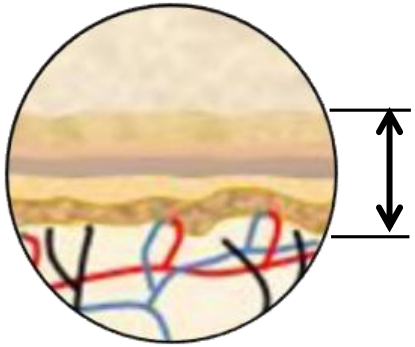
International recommendations on localised skin radiation dose, H_{skin}:

1. **Yearly skin dose limit for workers: 500 mSv**

   "To prevent cosmetically unacceptable skin effects after protracted exposure over many years"

2. **To be averaged over any 1 cm^2 area of exposed skin.**

3. **Skin dose should be assessed at a depth of 70 µm and approached by the operational quantity "Hp(0.07)"**



Localised skin doses in nuclear medicine

Skin doses from external irradiation

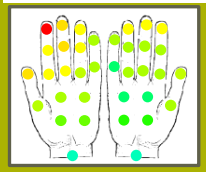
Localised skin doses in nuclear medicine

Skin doses from sealed manipulations

Localised skin doses in nuclear medicine

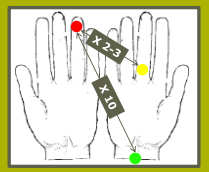
Skin doses from sealed manipulations

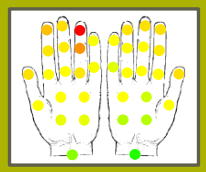
Many studies (local/multi-centre) have demonstrated…



Very non-uniform distribution of skin doses across the hands

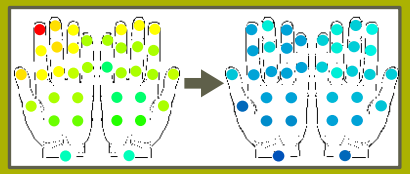
Skin dose at fingertip >>> routine dosimeter locations





Skin dose limit of 500 mSv/y can be exceeded at fingertips for high workload

Optimisation/ automation: substantial dose reduction!



Skin doses from skin contamination

Droplet from a 2 ml syringe with typical ref activity ^{18}FDG

Theoretical skin dose Hp(0.07)= 470 mSv!

Skin dose from sealed manipulations: tip of the iceberg?!

Important factors related to skin contamination dose

Contamination incidence

Contamination activity

Efficacy of decontamination

Skin contamination dosimetry

How can contaminations occur?

Directly

- Accidental spills
- Removal needles/catheters
- Contact body fluids of patients

Cross contamination

- Contaminated surfaces
- Contaminated tools / protective equipment

Detection and quantification of contaminations

Contamination check by workers

- Should be part of standard safety protocols
- Asks for self-discipline
- Quantification mostly limited by…
  "yes/no", "highly/moderately/slightly"

Contamination check by health physics experts / occupational physicians

- Difficult at a later stage (short-live radionuclides)
- Preferably on-site during daily nuclear medicine practice

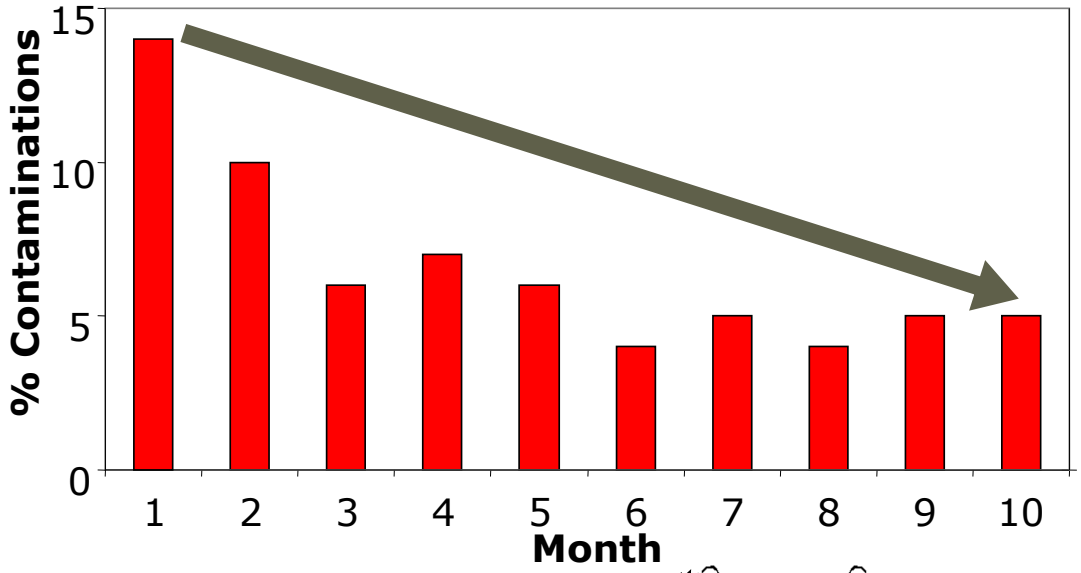
Contamination incidence during 10-month on-site survey

Mapping the contamination incidence among nuclear medicine workers

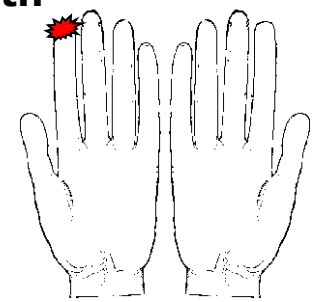
On-site survey 10 months

Protocol based on fast detection/localisation/ quantification

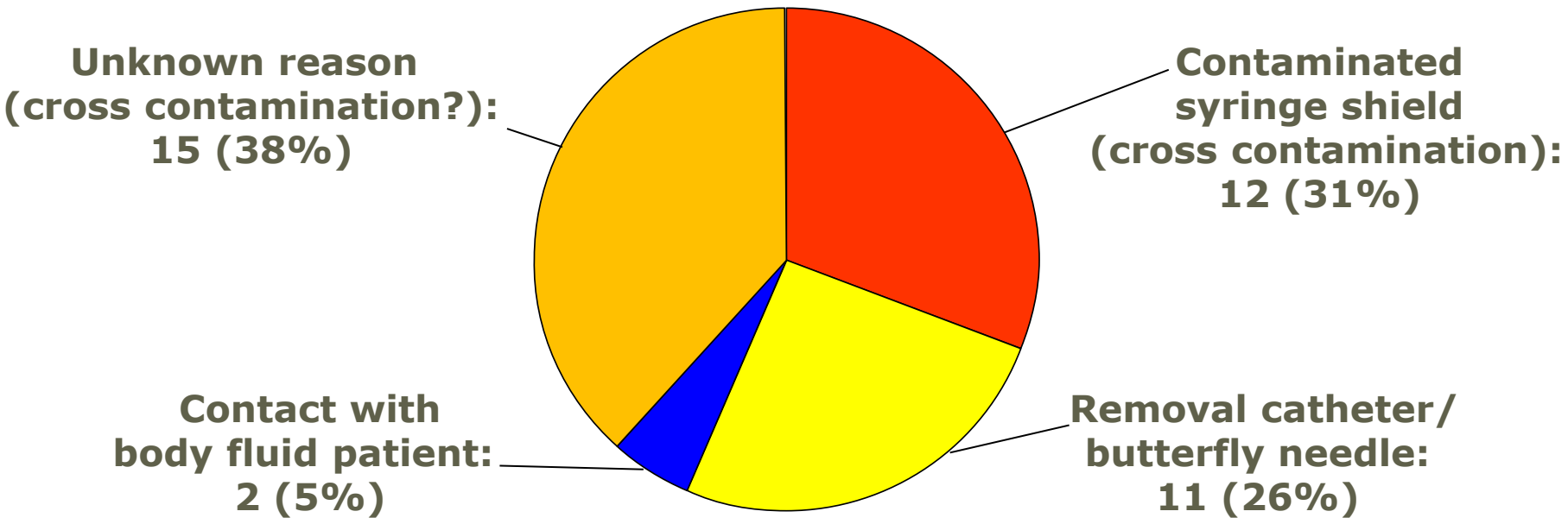
560 inspections carried out over 10 months
40 contaminations found (7% of the cases)



Very localised contamination spots
67% at volar fingertips



Contamination routes during 10-month on-site survey

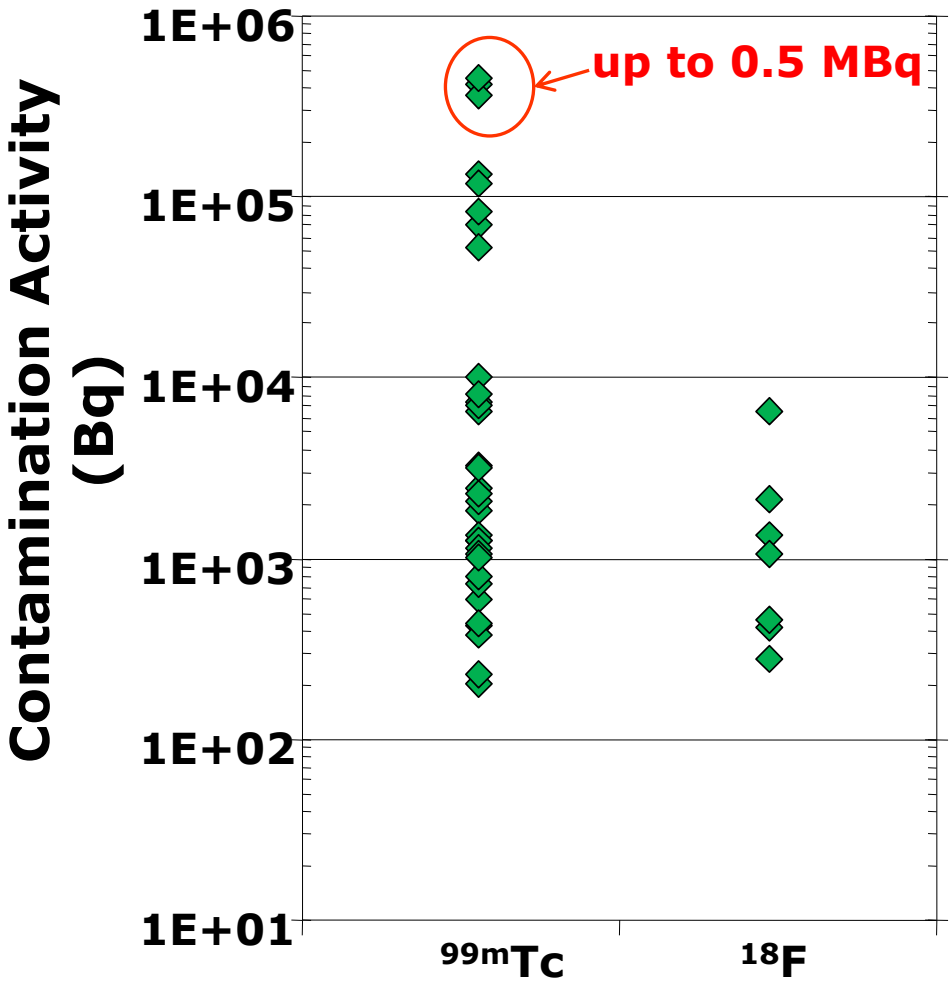


Contamination activities during 10-month on-site survey

Qualification/quantification using portable γ-spectrometer

Identification of the radionuclide

Activity (Bq) over 1 cm² in the highest contaminated area

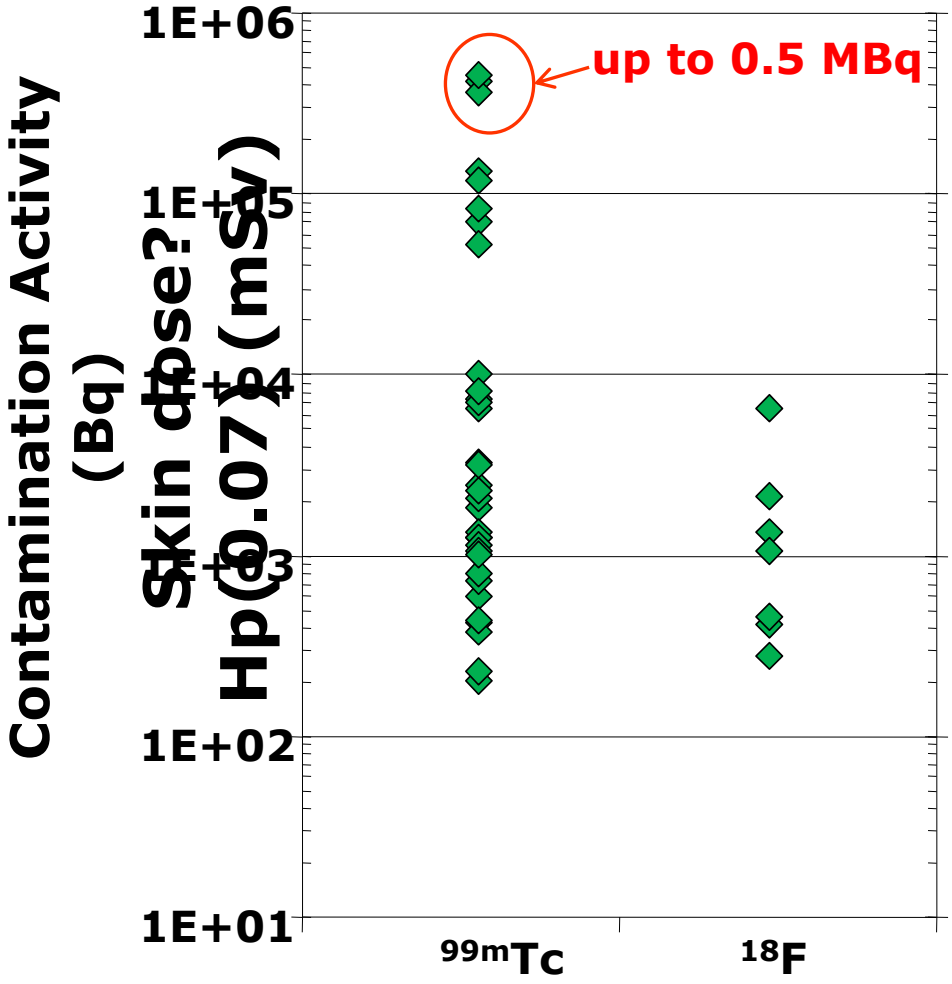


Contamination skin doses during 10-month on-site survey

Qualification/quantification using portable γ-spectrometer

Identification of the radionuclide

Activity (Bq) over 1 cm² in the highest contaminated area



Contamination skin doses during 10-month on-site survey

Qualification/quantification using portable γ-spectrometer

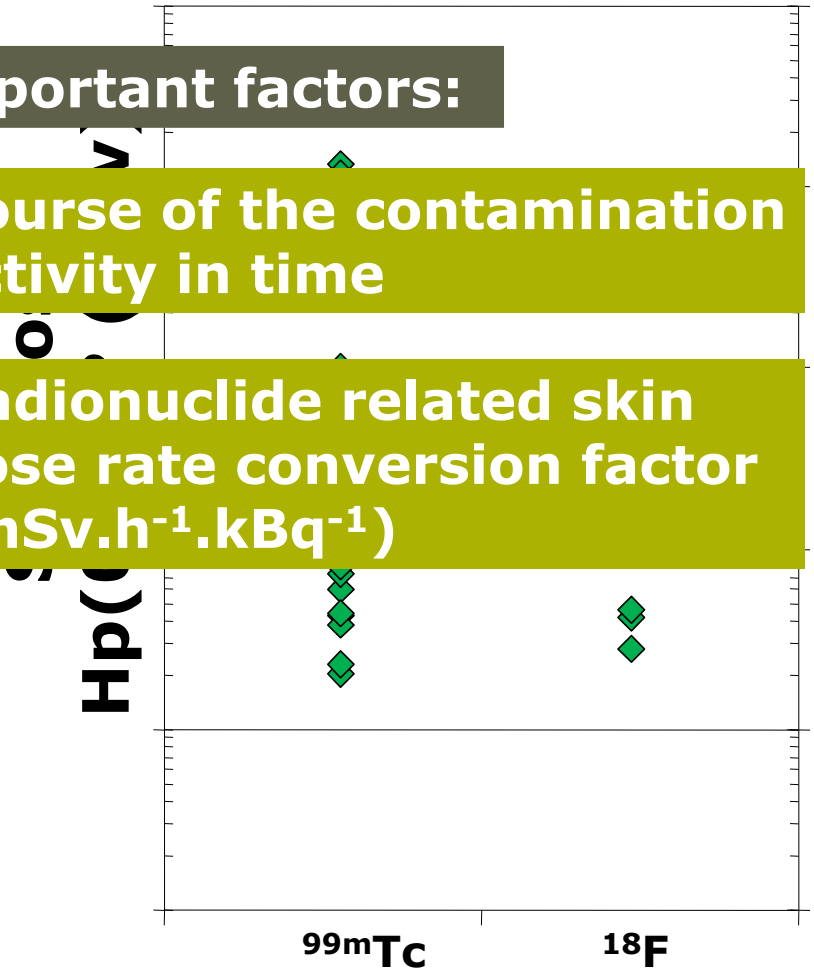
Identification of the radionuclide

Activity (Bq) over 1 cm² in the highest contaminated area

2 important factors:

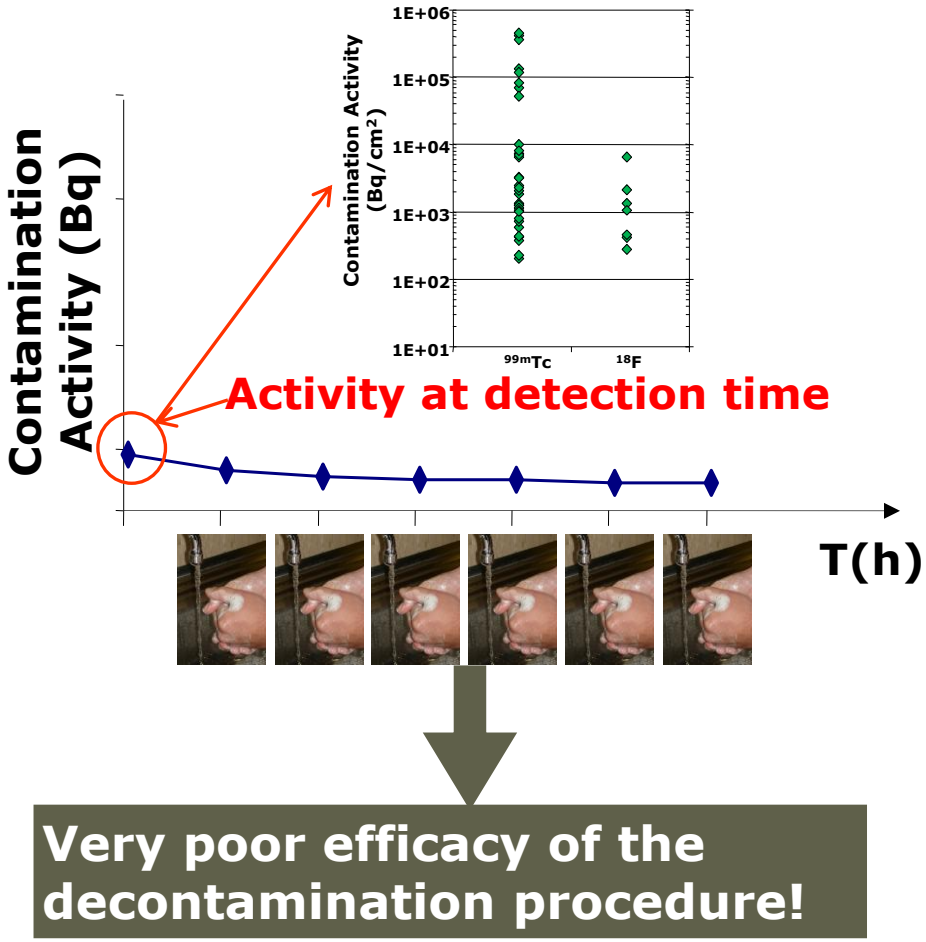
Course of the contamination activity in time

Radionuclide related skin dose rate conversion factor ($mSv.h^{-1}.kBq^{-1}$)



Course of the contamination activity in time

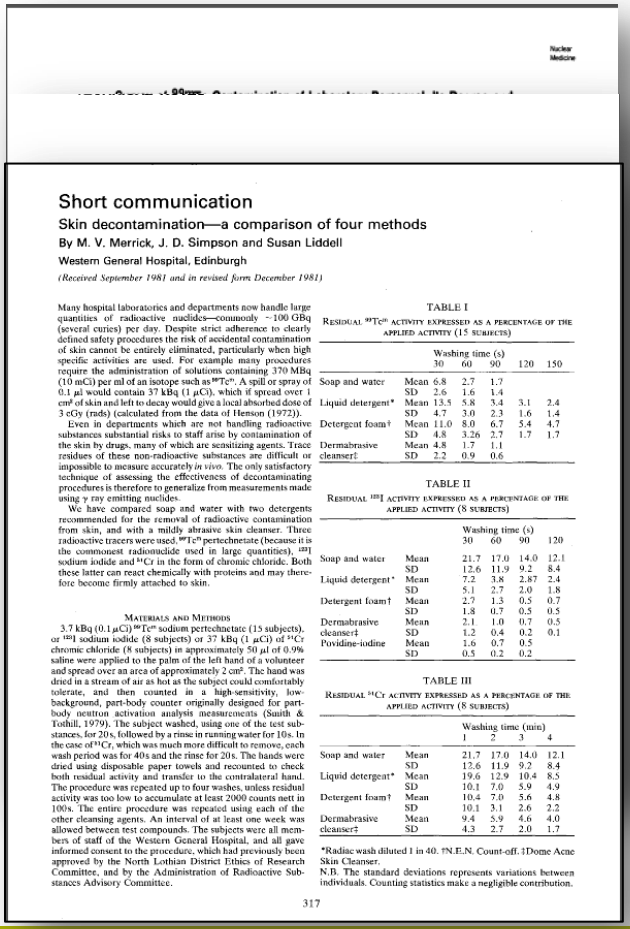
Follow-up of each contamination by repeated quantification procedures



Very poor efficacy of the decontamination procedure!

Efficacy of decontamination

Limited literature data



Nuclear Medicine

Short communication

Skin decontamination—a comparison of four methods

By M. V. Merrick, J. D. Simpson and Susan Liddell

Western General Hospital, Edinburgh

(Received September 1981 and in revised form December 1981)

Many hospital laboratories and departments now handle large quantities of radioactive nuclides—commonly ~100 GBq (several curies) per day. Despite strict adherence to clearly defined safety procedures the risk of accidental contamination of skin cannot be entirely eliminated, particularly when high specific activities are used. For example many procedures require the administration of solutions containing 370 MBq (10 mCi) per ml of an isotope such as $^{99m}Tc^{v}$. A spill or spray of 0.1 µl would contain 37 kBq (1 µCi), which if spread over 1 cm² of skin and left to decay would give a local absorbed dose of 3 cGy (rads) (calculated from the data of Henson (1972)).

Even in departments which are not handling radioactive substances substantial risks to staff arise by contamination of the skin by drugs, many of which are sensitizing agents. Trace residues of these non-radioactive substances are difficult or impossible to measure accurately *in vivo*. The only satisfactory technique of assessing the effectiveness of decontaminating procedures is therefore to generalize from measurements made using γ ray emitting nuclides.

We have compared soap and water with two detergents recommended for the removal of radioactive contamination from skin, and with a mildly abrasive skin cleanser. Three radioactive tracers were used. $^{99m}Tc^{v}$ pertechnetate (because it is the commonest radionuclide used in large quantities), ^{123}I sodium iodide and ^{51}Cr in the form of chromic chloride. Both these latter can react chemically with proteins and may therefore become firmly attached to skin.

TABLE I

Residual $^{99m}Tc^{v}$ activity expressed as a percentage of the applied activity (15 subjects)

		Washing time (s) 30	60	90	120	150
Soap and water	Mean	6.8	2.7	1.7		
	SD	2.6	1.6	1.4		
Liquid detergent*	Mean	13.5	5.8	3.4	3.1	2.4
	SD	4.7	3.0	2.3	1.6	1.4
Detergent foam†	Mean	11.0	8.0	6.7	5.4	4.7
	SD	4.8	3.26	2.7	1.7	1.7
Dermabrasive cleanser‡	Mean	4.8	1.7	1.1		
	SD	2.2	0.9	0.6		

TABLE II

Residual ^{123}I activity expressed as a percentage of the applied activity (8 subjects)

		Washing time (s) 30	60	90	120
Soap and water	Mean	21.7	17.0	14.0	12.1
	SD	12.6	11.9	9.2	8.4
Liquid detergent*	Mean	7.2	3.8	2.87	2.4
	SD	5.1	2.7	2.0	1.8
Detergent foam†	Mean	2.7	1.3	0.5	0.7
	SD	1.8	0.7	0.5	0.5
Dermabrasive cleanser‡	Mean	2.1	1.0	0.7	0.5
	SD	1.2	0.4	0.2	0.1
Povidine-iodine	Mean	1.6	0.7	0.5	
	SD	0.5	0.2	0.2	

TABLE III

Residual ^{51}Cr activity expressed as a percentage of the applied activity (8 subjects)

		Washing time (min) 1	2	3	4
Soap and water	Mean	21.7	17.0	14.0	12.1
	SD	12.6	11.9	9.2	8.4
Liquid detergent*	Mean	19.6	12.9	10.4	8.5
	SD	10.1	7.0	5.9	4.9
Detergent foam†	Mean	10.4	7.0	5.6	4.8
	SD	10.1	3.1	2.6	2.2
Dermabrasive cleanser‡	Mean	9.4	5.9	4.6	4.0
	SD	4.3	2.7	2.0	1.7

*Radiac wash diluted 1 in 40. †N.E.N. Count-off. ‡Dome Acne Skin Cleanser.
N.B. The standard deviations represents variations between individuals. Counting statistics make a negligible contribution.

Materials and Methods

3.7 kBq (0.1 µCi) $^{99m}Tc^{v}$ sodium pertechnetate (15 subjects), or ^{123}I sodium iodide (8 subjects) or 37 kBq (1 µCi) of ^{51}Cr chromic chloride (8 subjects) in approximately 50 µl of 0.9% saline were applied to the palm of the left hand of a volunteer and spread over an area of approximately 2 cm². The hand was dried in a stream of air as hot as the subject could comfortably tolerate, and then counted in a high-sensitivity, low-background, part-body counter originally designed for part-body neutron activation analysis measurements (Smith & Tothill, 1979). The subject washed, using one of the test substances, for 20s, followed by a rinse in running water for 10s. In the case of ^{51}Cr, which was much more difficult to remove, each wash period was for 40s and the rinse for 20s. The hands were dried using disposable paper towels and recounted to check both residual activity and transfer to the contralateral hand. The procedure was repeated up to four washes, unless residual activity was too low to accumulate at least 2000 counts nett in 100s. The entire procedure was repeated using each of the other cleansing agents. An interval of at least one week was allowed between test compounds. The subjects were all members of staff of the Western General Hospital, and all gave informed consent to the procedure, which had previously been approved by the North Lothian District Ethics of Research Committee, and by the Administration of Radioactive Substances Advisory Committee.

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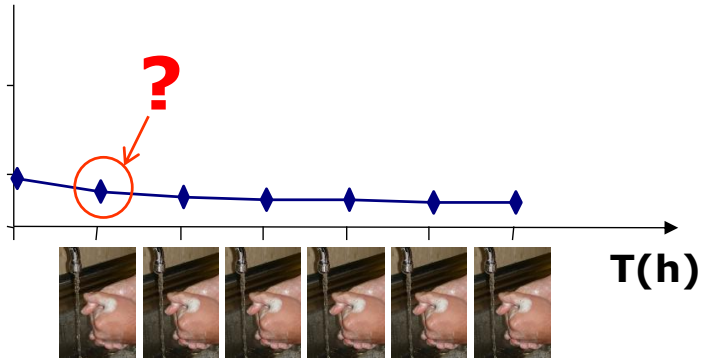
Efficacy of decontamination of ^{99m}Tc-labelled radiopharmaceuticals: >90%

On-site survey:



⇒ Study the efficacy of decontamination in vitro using pig skin samples

Efficacy of decontamination in vitro

108 pig skin samples contaminated, successive quantification, decontamination

Factors:
- **Radiopharmaceutical**
- **Decontamination agent**
- **Absorption time**

- **$Na^{99m}TcO_4$**
- **^{99m}Tc-HDP**
- **^{99m}Tc-Tetrofosmin**
- **^{18}FDG**

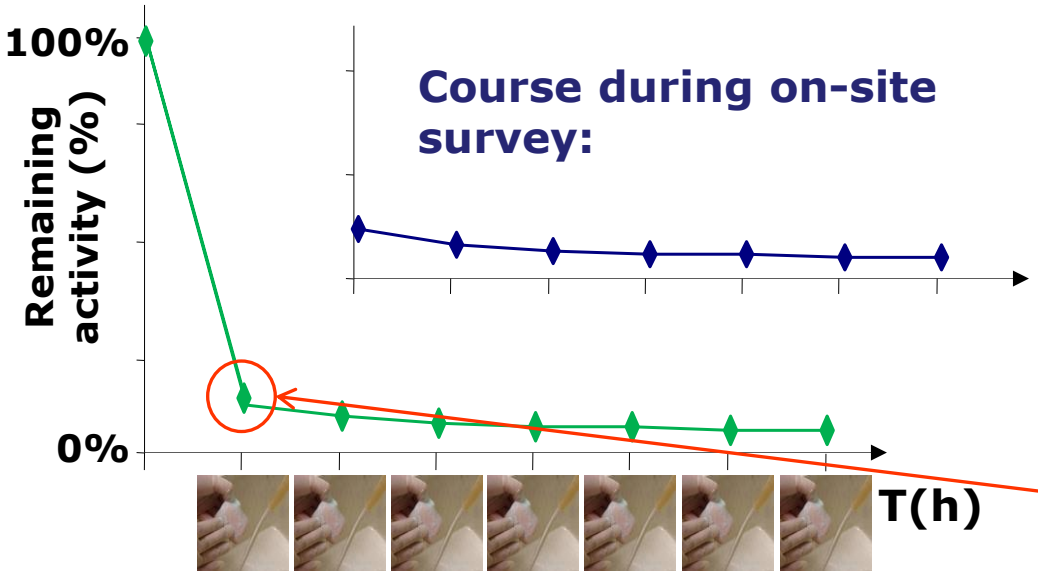
- **Immediate decontamination**
- **Decontamination after 30’**
- **Decontamination after 60’**

Efficacy of decontamination in vitro

108 pig skin samples contaminated, successive quantification, decontamination

Factors: radiopharmaceutical
absorption time
decontamination agent

Typical course during decontamination of pig skin samples:



1st decontamination effective, subsequent are less effective!

1st decontamination during on-site survey already occurred before detection!

Factors influencing 1st decontamination?

Factors influencing the 1st decontamination

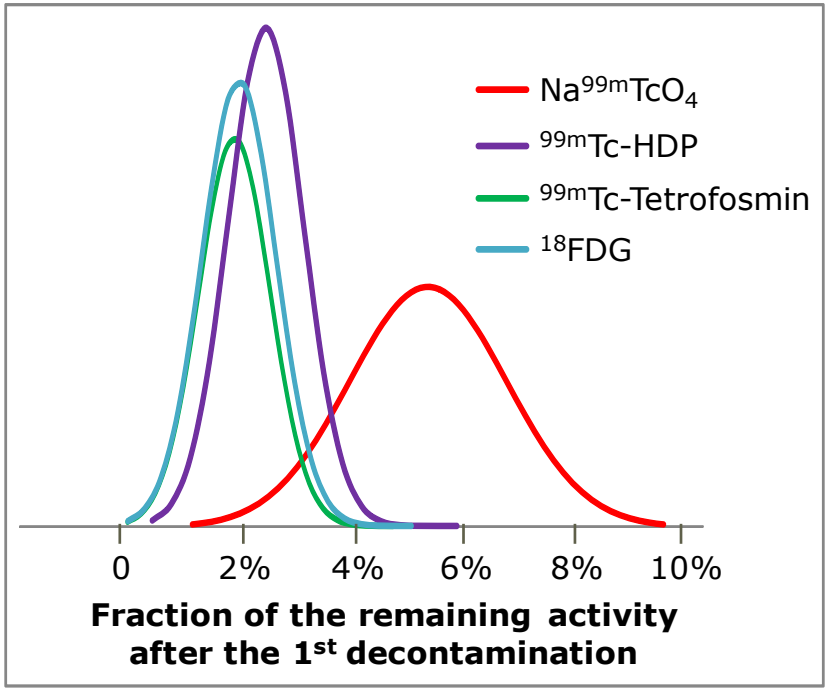
Factors

- **Radiopharmaceutical**
- **Absorption time**
- **Decontamination agent**

↓

Multi-Factor ANOVA

↓

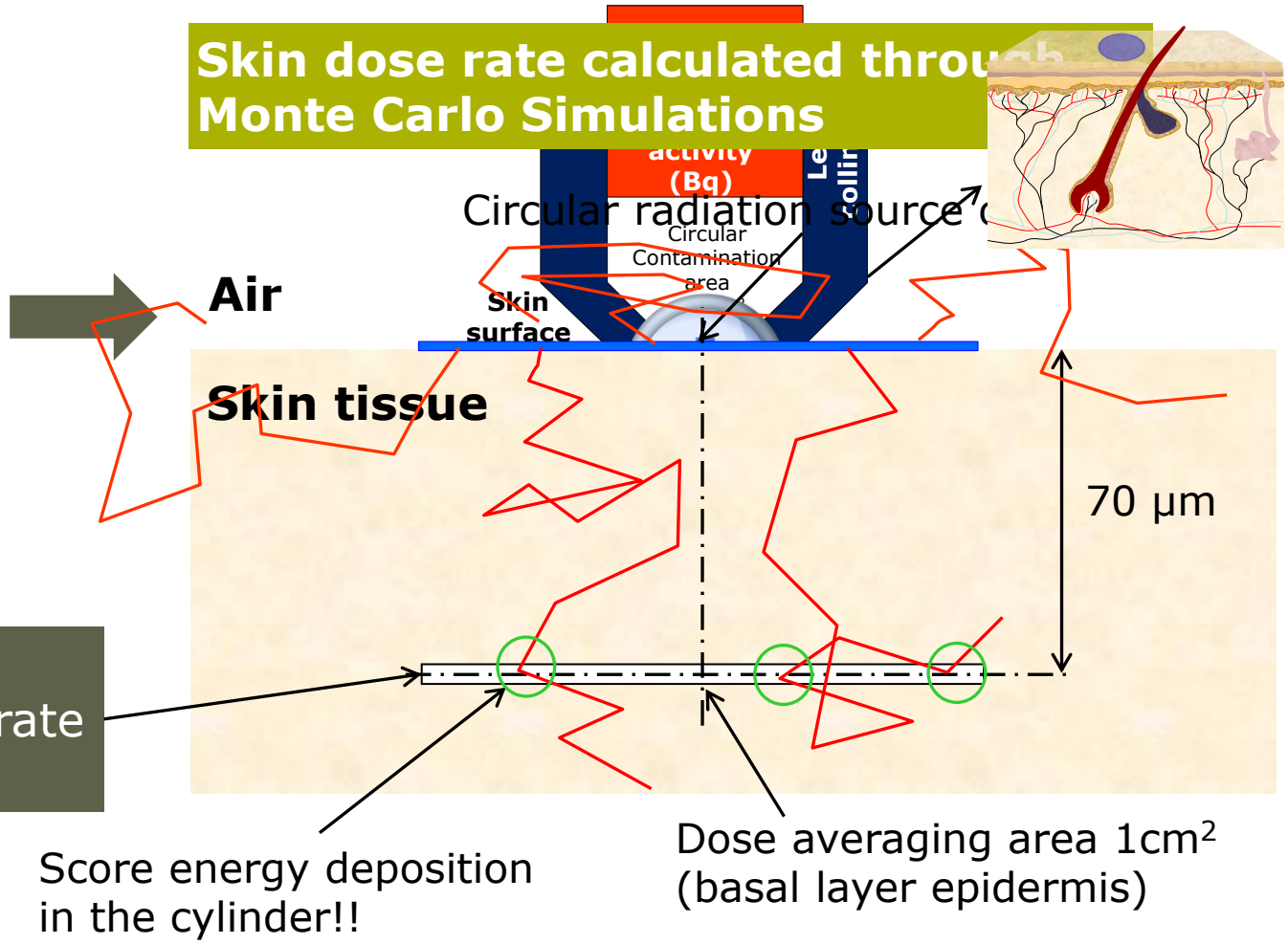


Absorption time has no influence!

Only for $Na^{99m}TcO_4$ a dedicated decontamination agent has a positive effect over neutral hand soap

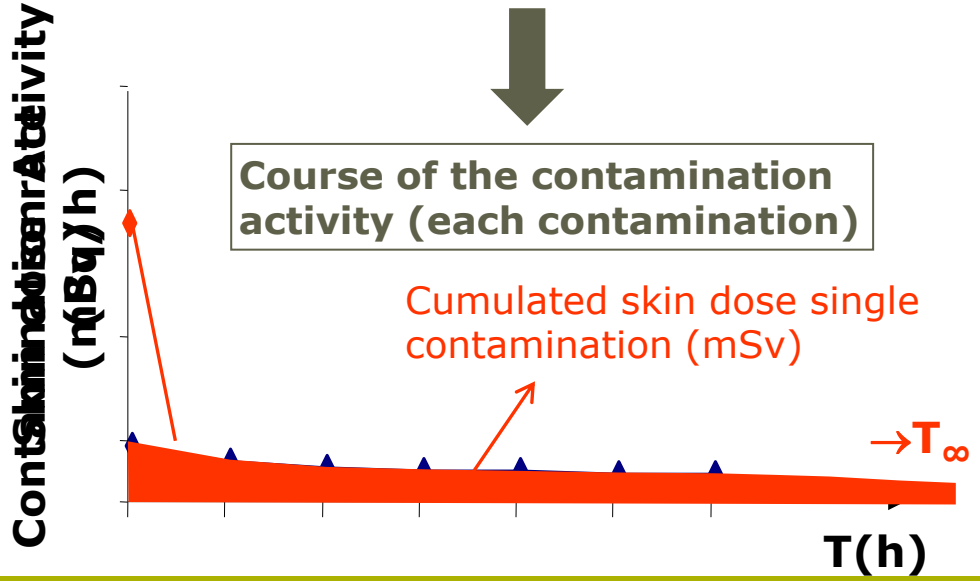
Skin dose rate conversion factors

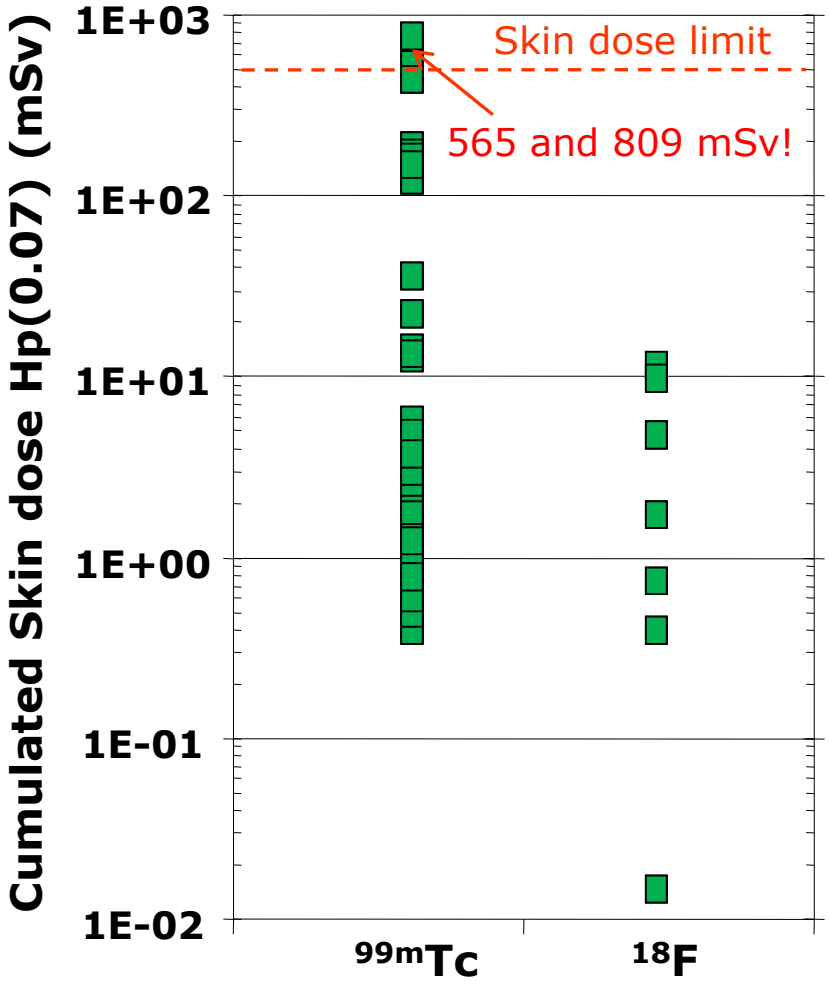
Skin dose rate= energy deposition rate over the cylinder



Skin doses of contaminations during on-site survey

Radionuclide	Skin dose rate conversion factor ($mSv.h^{-1}.kBq^{-1}$)
^{99m}Tc	$2.17\ 10^{-1}$
^{18}F	1.61
> 99% skin dose delivered by electrons	



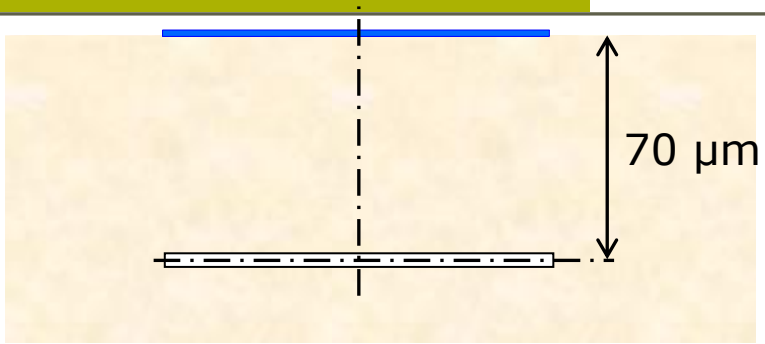


Factors influencing skin dose rate conversion factors

Present skin dose rate conversion factors

Circular source of 1 cm^2 on top of the skin surface

Depth of the basal layer (epidermal thickness): 70 µm



Real situation?

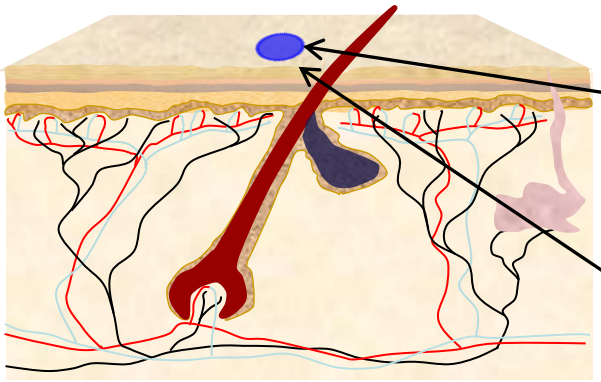
Size of the contamination area?

Epidermal thickness?

Percutaneous absorption?

Size of the contamination area

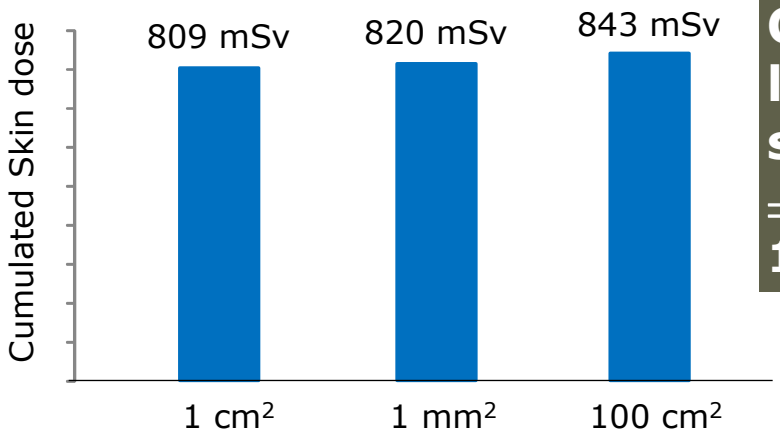
Quantification procedure assumes exactly 1 cm²



Measured activity in concentrated spot (e.g. 1 mm²)

Measured activity part of a large spot (e.g. 100 cm²)

Case of the highest skin dose during the on-site survey

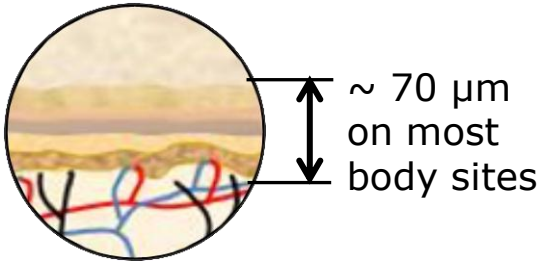


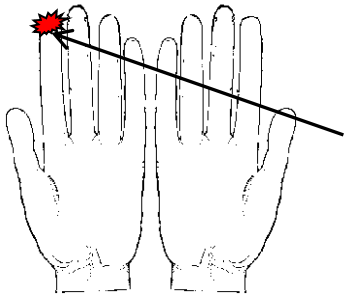
Contamination area: limited influence on skin dose rate:

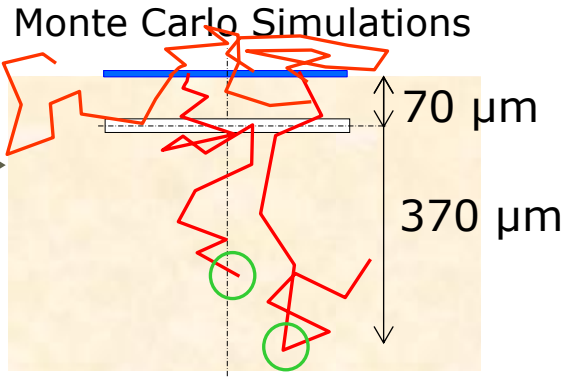
⇒ Quantification over 1 cm²: good approach

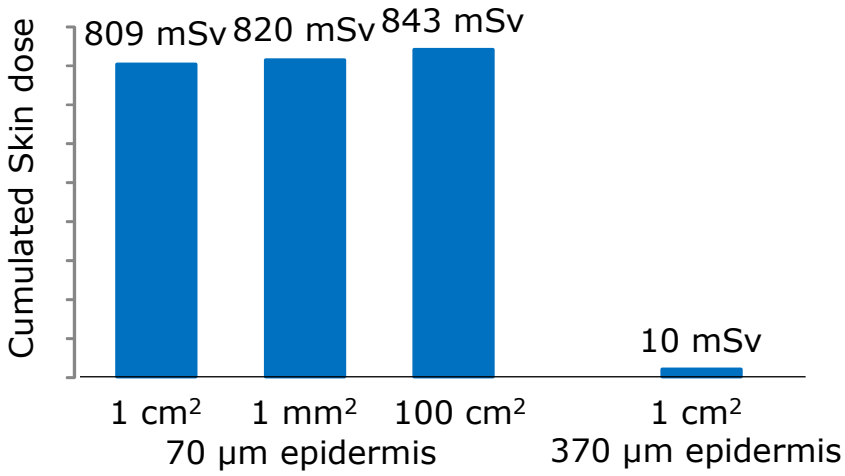
Epidermal thickness

Dose rate conversion factors simulated at a depth of 70 µm (basal layer)









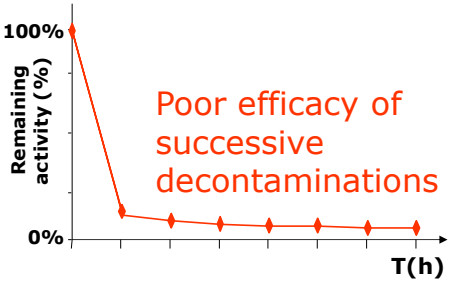
Epidermal thickness:
large influence on the skin dose

Range in tissue is limited for low energy electrons !

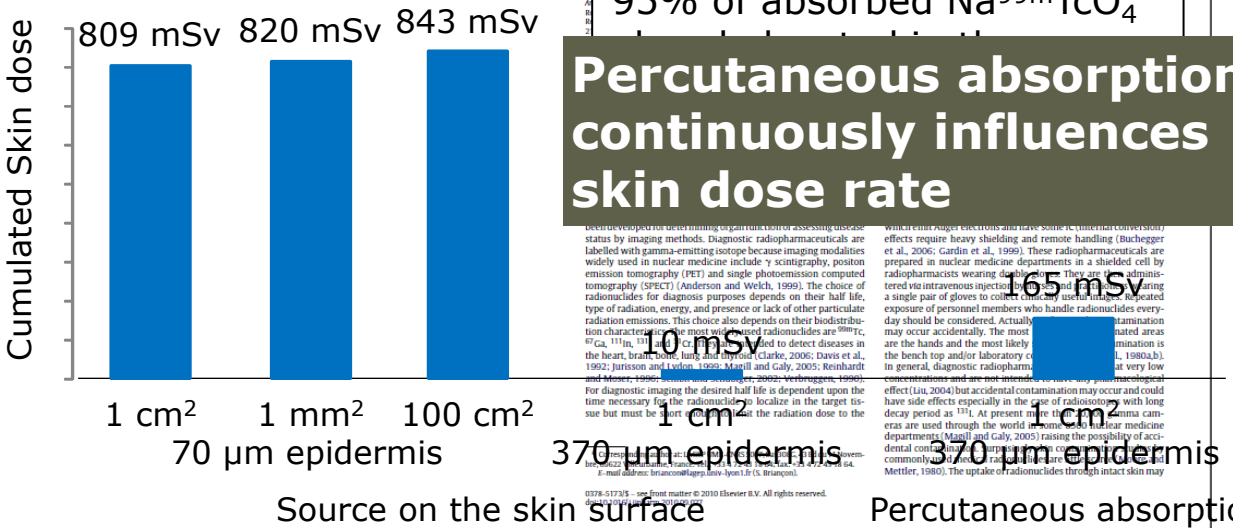
Percutaneous absorption

Source on the skin surface: snapshot!

Percutaneous absorption of the radiopharmaceutical occurs!



Poor efficacy of successive decontaminations



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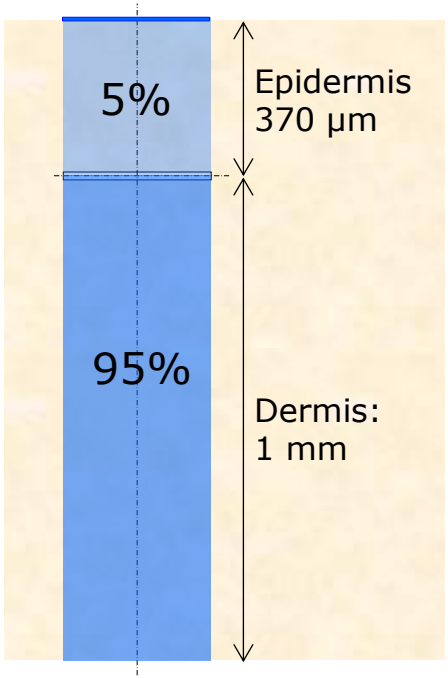
Skin contamination by radiopharmaceuticals and decontamination strategies

M.A. Bolzinger[a,b,c], C. Bolot[d], G. Galy[d], A. Chabanel[d], J. Pelletier[a,b,c], S. Briançon[a,b,c,*]

1 h after contamination:
95% of absorbed $Na^{99m}TcO_4$

Percutaneous absorption continuously influences skin dose rate

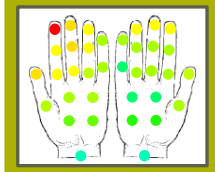
Monte Carlo Simulations



Exposure pathways

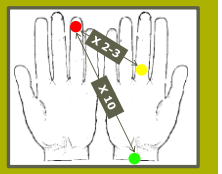
Skin doses from sealed manipulations

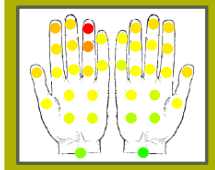
Inevitable!



Very non-uniform distribution of skin doses across the hands

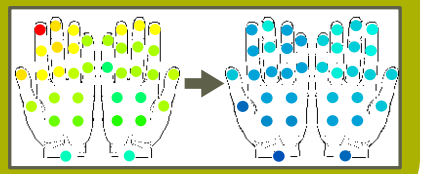
Skin dose at fingertip >>> routine dosimeter locations





Skin dose limit of 500 mSv/y can be exceeded at fingertips for high workload!

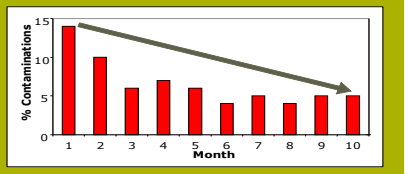
Automatic dispensing and injection: substantial dose reduction!

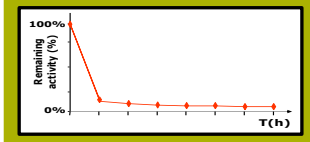


Skin doses from skin contamination

Only present after contamination

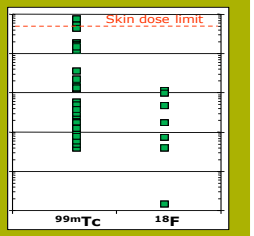
Highly influenced by the incidence

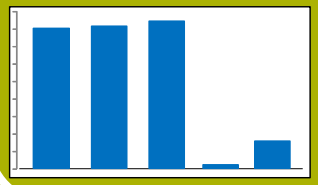




Poor efficacy successive decontamination

Skin dose limit of 500 mSv/y can be exceeded for a single contamination!



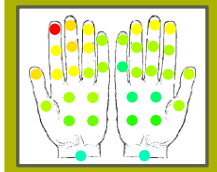


Influenced by epidermal thickness/percutaneous absorption!

Exposure pathways

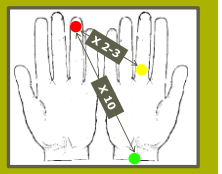
Skin doses from sealed manipulations

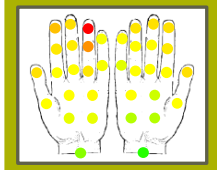
Inevitable!



Very non-uniform distribution of skin doses across the hands

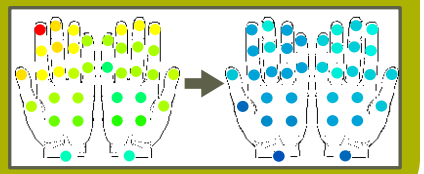
Skin dose at fingertip >>> routine dosimeter locations





Skin dose limit of 500 mSv/y can be exceeded at fingertips for high workload!

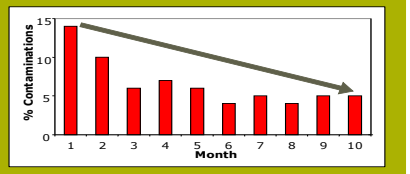
Automatic dispensing and injection: substantial dose reduction!

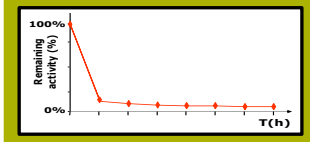


Skin doses from skin contamination

Only present after contamination

Highly influenced by the incidence





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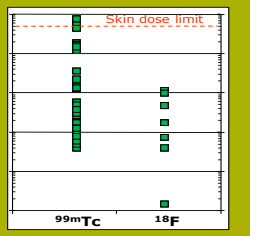

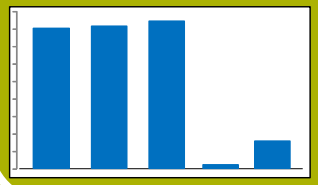

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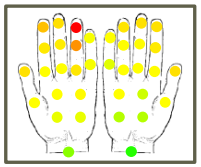

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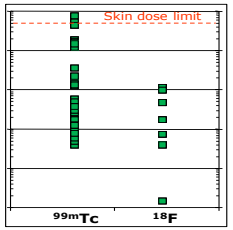
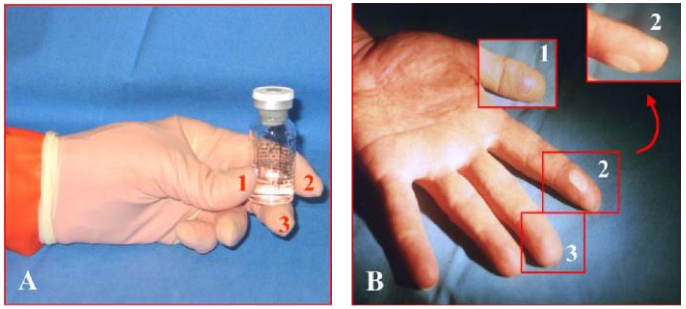


⇒ Localised skin doses can > 20 Sv after a professional career of e.g. 40 years!

Skin effects?

Reported skin effects among workers in nuclear medicine?

Only from accidental high and acute exposure (high energy beta-emitters)!



Cremonesi et al, 2006

Exposure pattern among nuclear medicine worker in routine

Repeated at low-moderate dose rates

Very localised

Protracted (many years)

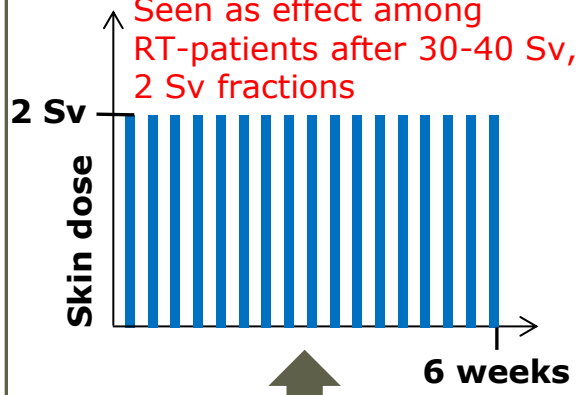
Studies are lacking, clinical effects not reported

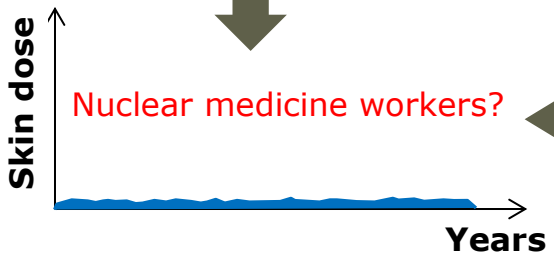
Values that make up the dose limit statement?

500 mSv/y

To avoid late dermal atrophy / telangiectasia

Seen as effect among RT-patients after 30-40 Sv, 2 Sv fractions





70 µm (basal layer)

Conservative approach! Targets at different depths!

1 cm²

To avoid acute ulceration after hot particle exposure!

(1 Sv within 1 h)

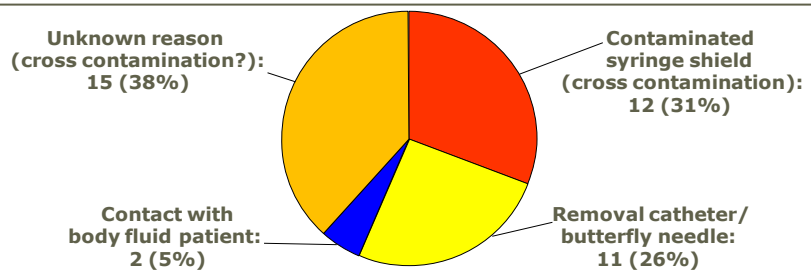
Target depth: 150-500 µm (vascularised region of the dermis)

Hp(0.07) ideal scientific approach to assess potential late skin effects?

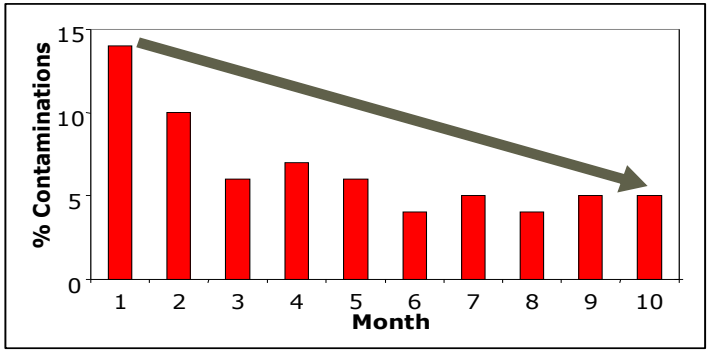
To conclude...
...and take home messages

1 **Skin contaminations regularly occur in nuclear medicine!**

Primarily caused by cross contaminations!



Regular inspections increase awareness and indentify bad habits

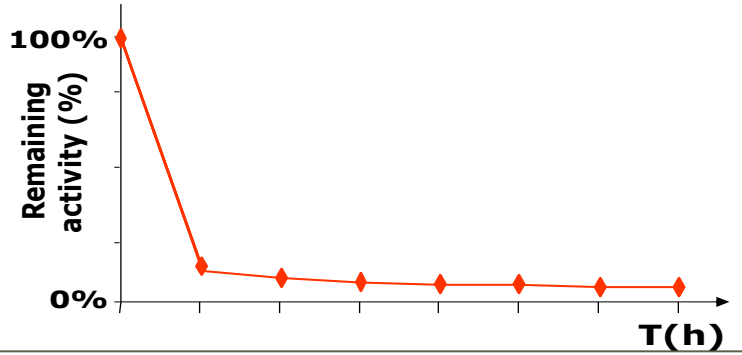


To conclude...
...and take home messages

2 Decontamination?

ASAP!

- **>90% is removed**
- **Reduces high dose rate**
- **Reduces cross contamination risk**



Dedicated decontamination agents?

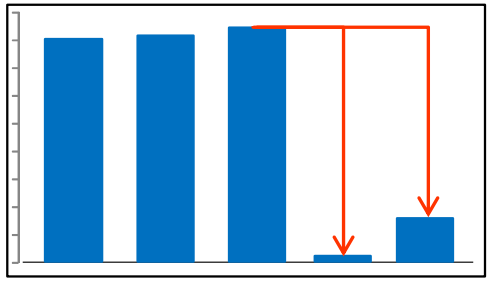
- **Generally no added value**
- **Neutral hand soap easily available in all imaging / injection rooms**

To conclude...
...and take home messages

3 Estimating /evaluating skin contamination doses

Hp(0.07) as a measure for H_{skin}?

- **Not ideal in relation to potential late skin effects of localised exposure**
- **Large influence of epidermal thickness / percutaneous absorption**



Use of Hp(0.07) in practical radiation protection?

- **Yes!**
- **Conservative approach**
- **Standard tool**

Thank you!

Ready to answer your questions