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INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

HOW USEFULL IS THE DOSE ASSESSMENT FOR THE MANAGEMENT OF AN IRRADIATION ACCIDENT

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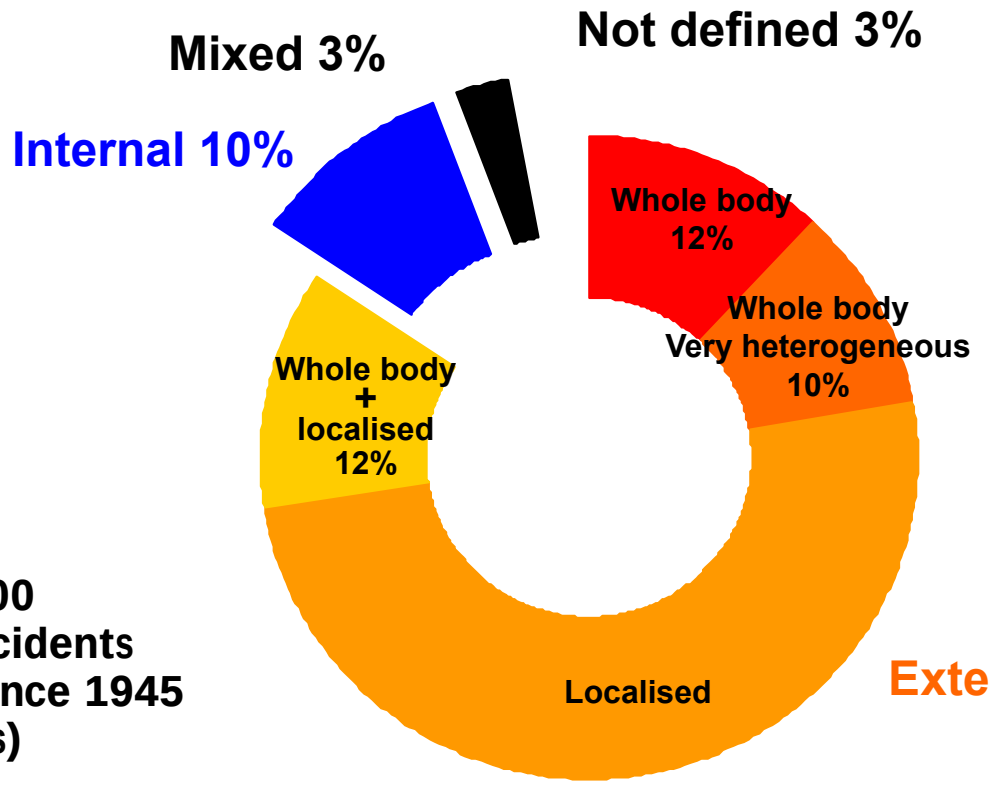
MEMBRE DE ETSON

Radiological accidents: *different situations of overexposure*



More than 600 incidents/accidents are known since 1945 (~200 deaths)

Multidisciplinary expertise and technical support to hospitals

National authorities

Request

IAEA International Atomic Energy Agency

IRSN

Physical dosimetry
Biological dosimetry
Radiopathology

Hospital
i.e. Percy Military Hospital (HIA)

Researchers
Suitable dosimetry techniques
New therapeutic approaches

Physicians
Medical management of the victims

Experienced and reactive teams

Why dosimetry?

- **Medical management of the victims**

  Dose is a marker of damages to tissues and organs which helps the physicians:

  - to evaluate the radio-induced damages
  - to define the therapeutic strategy

- **Aim of the dosimetry:** *assessment of the dose and the dose distribution in the body*

How assess the dose?

…by taking into account the specificity of the accident

Each accident is particular: *type of source, type of radiation, energy, exposure time, scenario…*

…by using complementary means

- **Clinical observations: symptomatology**
- **Biological dosimetry: study of DNA misrepairs**
- **Physical dosimetry:**
  - Dose reconstruction *(experimental & numerical techniques)*
  - Dosimetry on materials collected on the victim

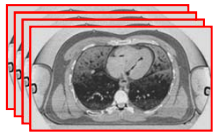
Experimental tools

Dummies equipped with dosemeters

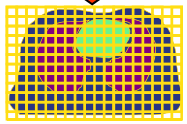
« Small »
dosemeters

Numerical tools (1)

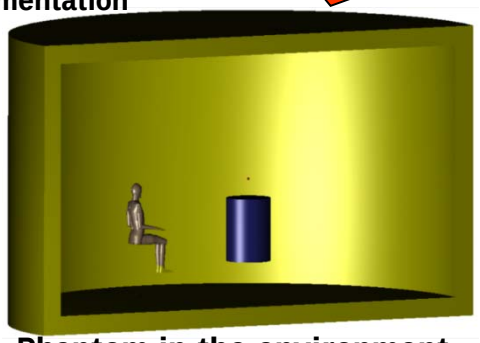
Numerical anthropomorphic model + Monte Carlo calculations



Medical images (CT, MRI)

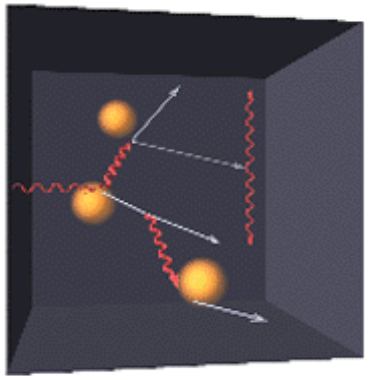


Segmentation



Phantom in the environment

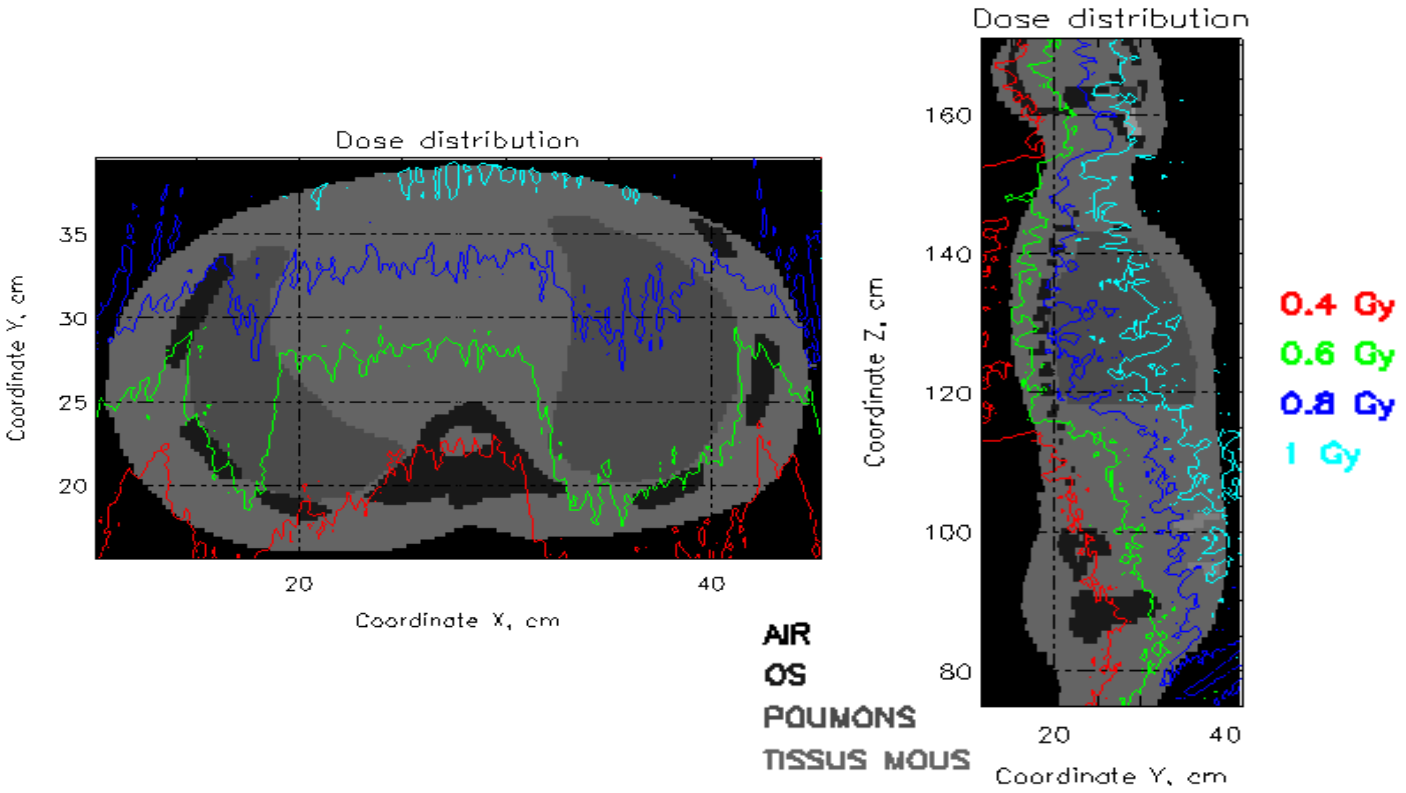
Monte Carlo code



simulation of the transport of particles through matter - determination of the energy deposition

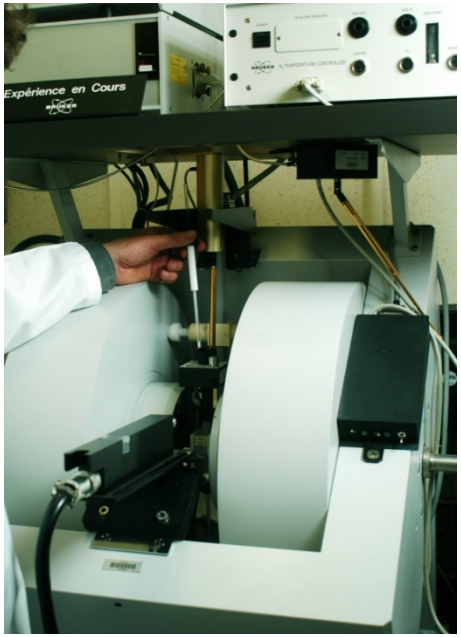
Numerical tools (2)

Voxel phantom: dose distribution (SESAME software)



Retrospective dosimetry using ESR

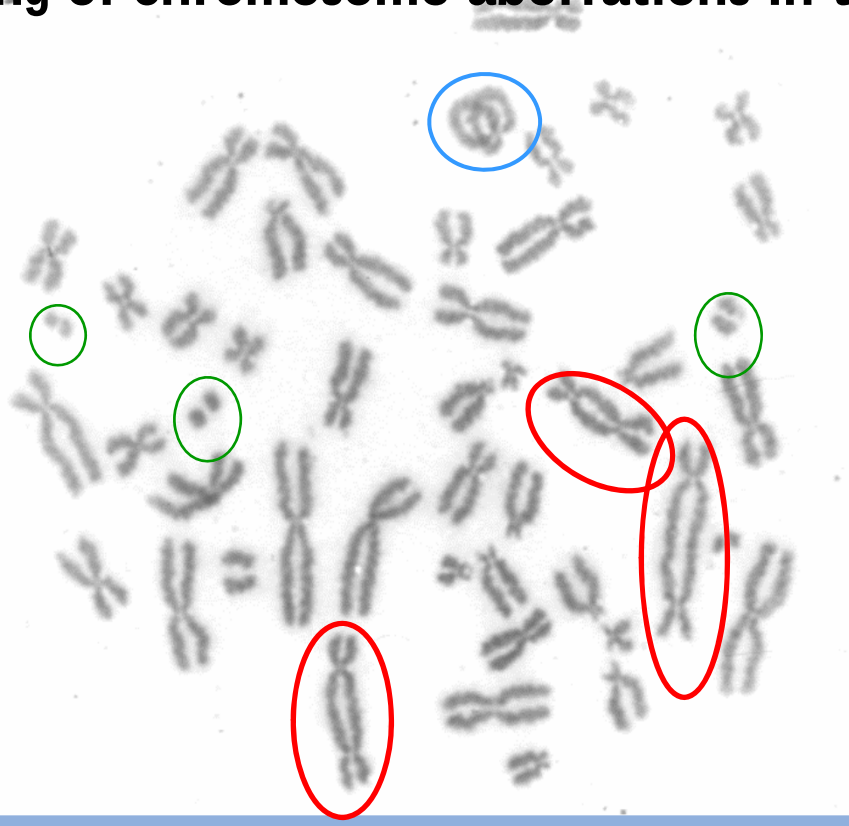
ESR *(electron spin resonance)* **dosimetry: measurement of free radicals created in some irradiated materials**



- « X band » spectrometer (9 GHz) : sample 100 mg
- « Q band » spectrometer (34 GHz) : sample 2-3 mg

Biological dosimetry

Numbering of chromosome aberrations in the blood



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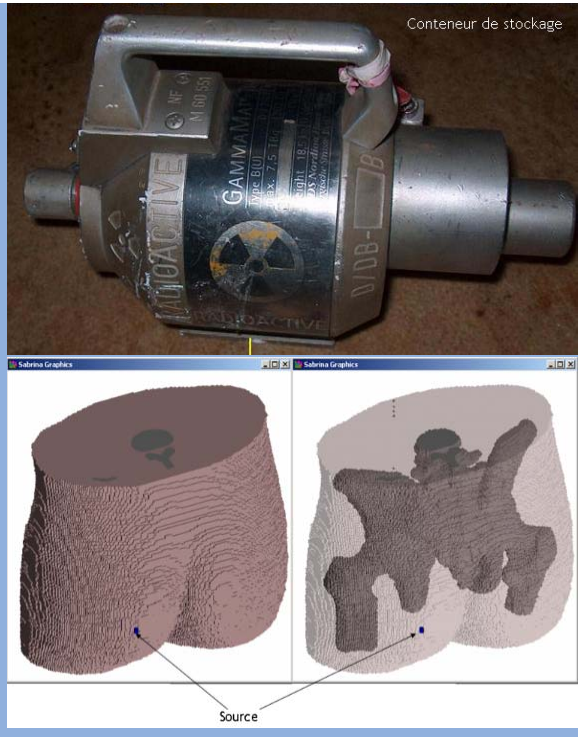
THREE EXAMPLES REPRESENTATIVE OF IRRADIATION ACCIDENT

Chile (December 2005) – localized irradiation

Belgium (March 2006) – whole body irradiation

Peru (January 2012) – localized irradiation to the hands +whole body



MEMBRE DE ETSON

Chile accident: circumstances

Place and date: building site of a manufactory, December 15, 2005

Context: a worker found a ^{192}Ir source from a gammagraphy device. He handled it with his bare hands and put it in the back left-hand pocket of his pants before it was detected by someone with an electronic dosemeter.

source

Source characteristics:
Iridium-192, 3.3 10^{12} Bq (90 Ci)

Irradiation characteristics:
- exposure duration: *10 min in the back left-hand pocket of his pants;*
- suspicion of **localised exposures**: *buttock, hands, head and torso*

The IAEA appointed IRSN to investigate on-site;
The victim was transferred to France on 29 December 2005 for treatment at the Percy Military Hospital

Medical problematic / support of dosimetry

Localized irradiation ⇒ medical management = surgery?

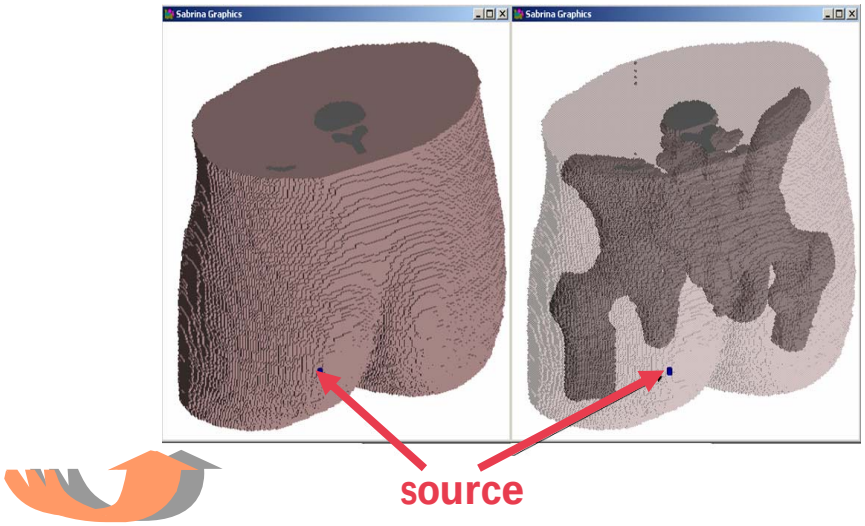
- **Need for an adequate surgery** i.e. remove the correct quantity of tissue to avoid the propagation of necrosis + graft of mesenchymal stem cells (MSC)
- Healthy tissue in appearance the first days or weeks can finally lead to a necrosis if the dose > 25 Gy

⇒ **Objective of dosimetry**: provide the position in depth and in surface of the 25 Gy isodose

Chile accident: *numerical dose reconstruction*

CT images

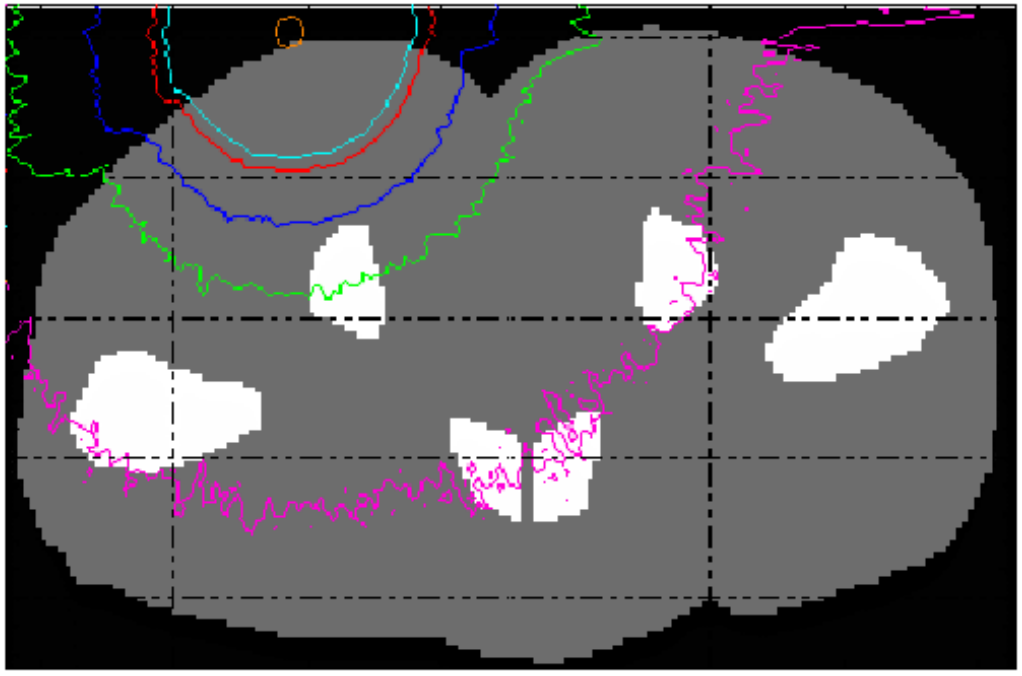
Voxel phantom



Calculations of the dose distribution in different points within the body

Chile accident: *dose reconstruction (10 min exposure)*

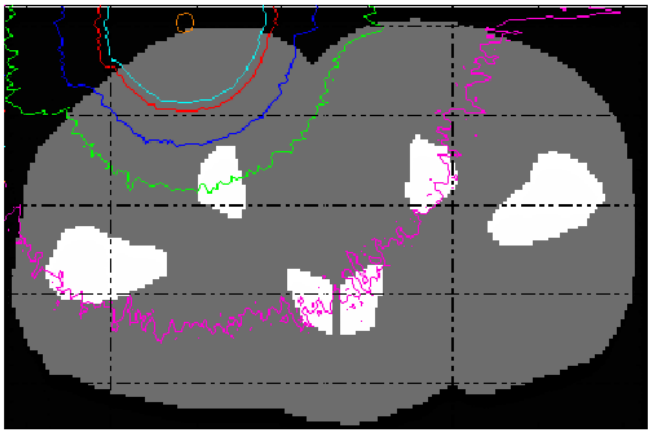
1900 Gy at the surface of the skin
20 Gy at 5 cm in depth



1900 Gy
25 Gy
20 Gy
10 Gy
5 Gy
1 Gy

Chile accident: *surgery (Percy Hospital)*

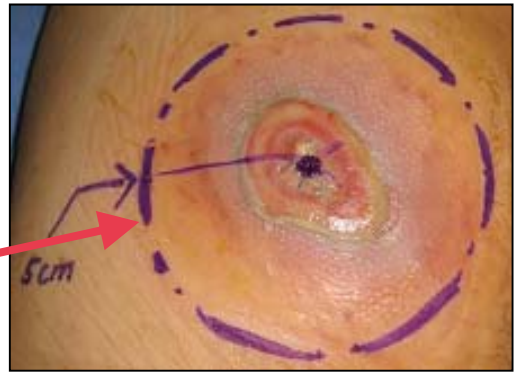
Surgery guided by the dosimetry



1900 Gy
25 Gy
20 Gy
10 Gy
5 Gy
1 Gy

Dose distribution

5 cm



Surgery

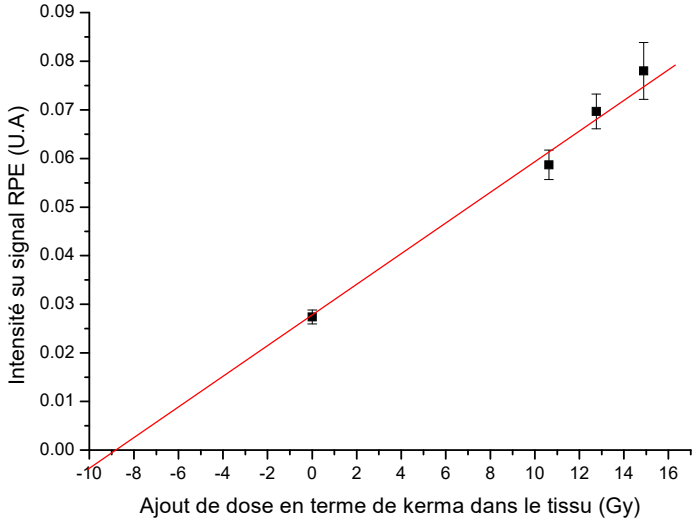
10 months after surgery + skin and MSC grafts

Chile accident: *ESR measurements on teeth*

Assessment of the dose to the head

Tooth 2-4 : *8.5 Gy*

Tooth 4-5 : *5.6 Gy*



Addition dose curve

High dose, but no necrosis expected at the head level

Accident in Belgium: *circumstances*

Place and date: industrial irradiation facility, Fleurus, March 11th, 2006

Context: a worker went inside a cell of irradiation whereas the source was not in the storage position

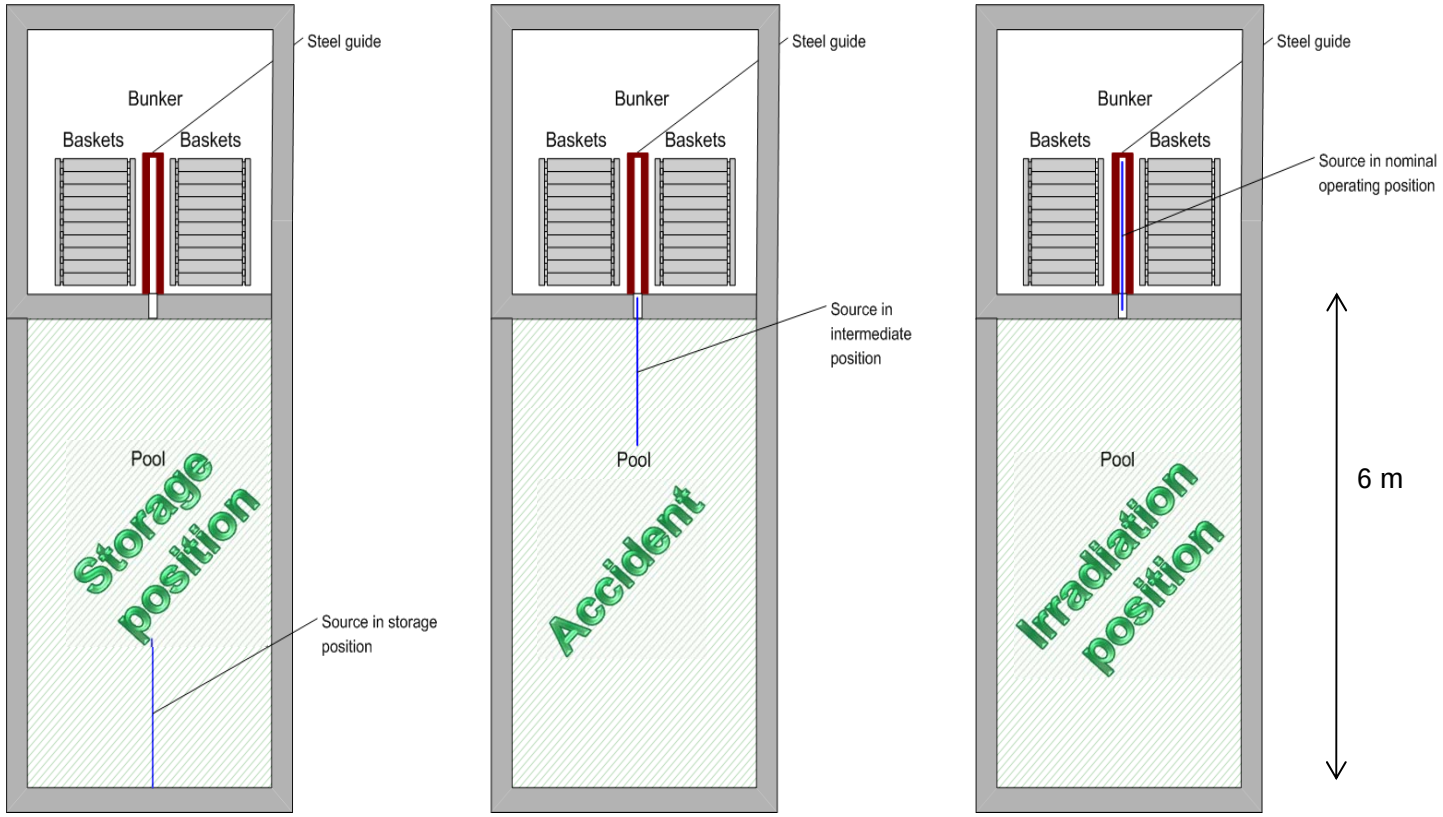
Source characteristics:
cobalt-60, 30000 TBq (800 000 Ci)

Irradiation characteristics :
- exposure duration: 20 s
- **whole body exposure**

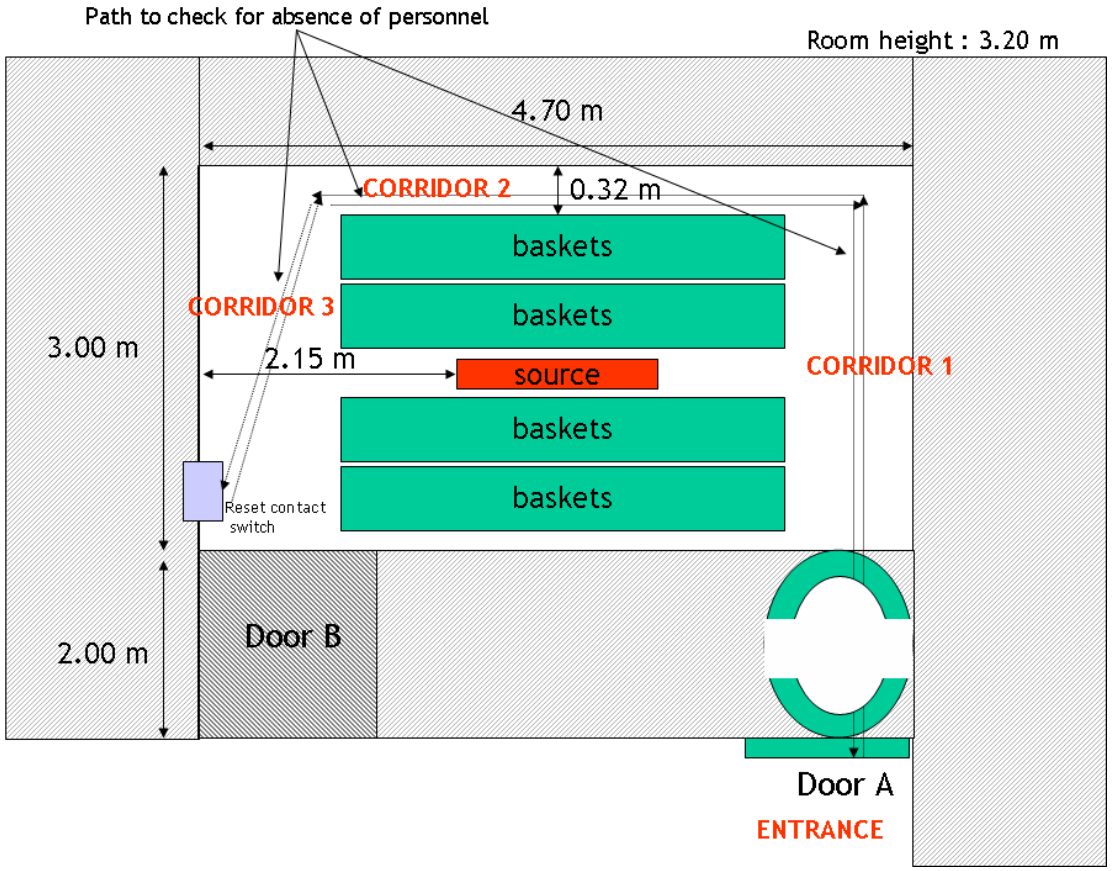
The victim was transferred to the Haematological Department of the Percy Military Hospital on March 31st, 2006

Patient was in medullar aplasia – bone marrow areas were irradiated

Accident in Belgium: *circumstances*



Accident in Belgium: *circumstances*



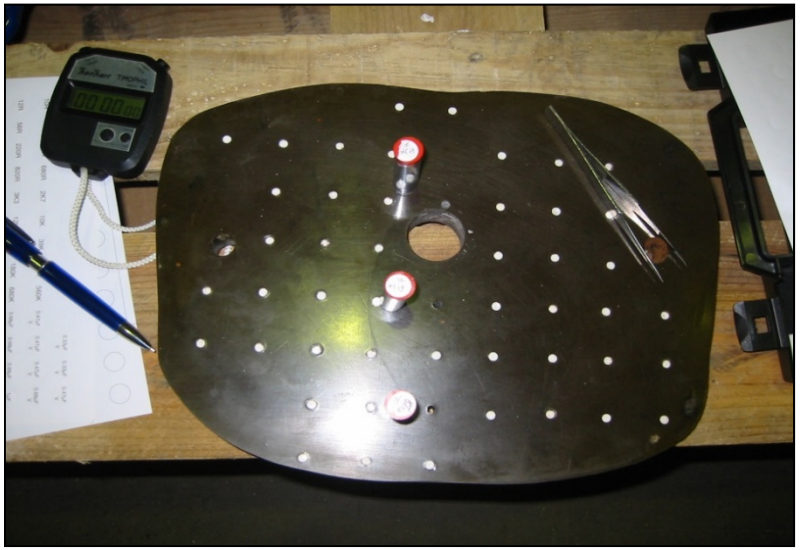
Medical problematic / support of dosimetry

Whole body irradiation ⇨ spontaneous secondary resumption of bone marrow activity?

Important to know if some areas of bone marrow were under-exposed (below 6 Gy if homogeneous) to lead to a spontaneous secondary resumption of bone marrow activity in these areas.

⇨ **Support of dosimetry** to estimate the dose to the different bone marrow areas

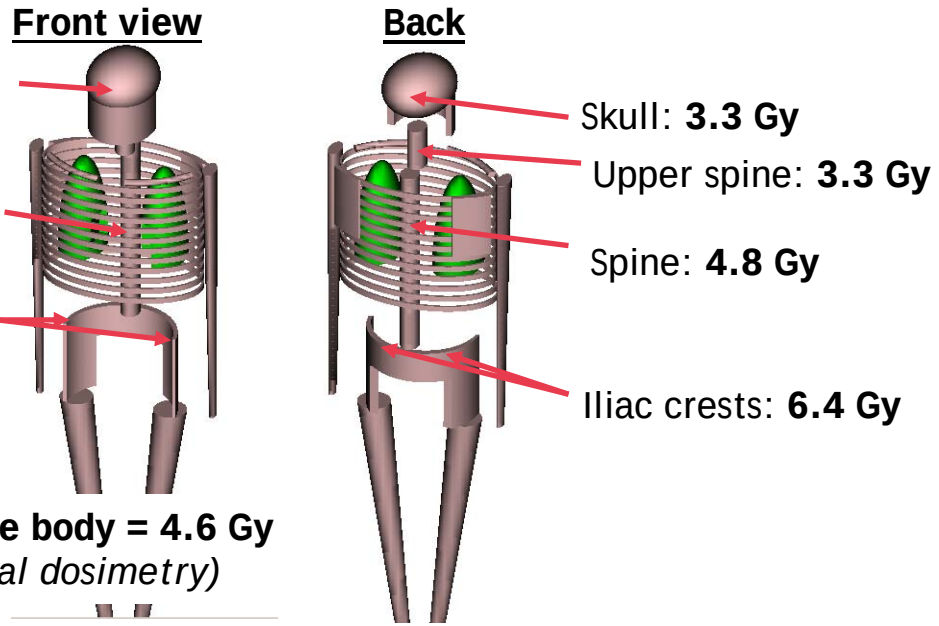
Accident in Belgium: *on site measurements*



Positioning of dosimeters
in a section of the phantom

Tissue-equivalent anthropomorphic phantom fitted with dosimeters and positioned in the irradiation room

Accident in Belgium: *calculations in laboratory*



Mean dose to the whole body = 4.6 Gy
(*coherent with biological dosimetry)*

Dose gradient corresponding to a factor of 2 in AP and between the pelvis and the skull

The fact that some areas of bone marrow are clearly under-exposed compared with others, given the dose levels, suggests spontaneous secondary resumption of bone marrow activity in these areas

Peru accident: *circumstances*

Place and date: hydroelectric company in Chilca, January 12, 2012

Context: 3 workers were conducting in-situ gammagraphy activities in several pipes. The ^{192}Ir source was not in the lead container but somewhere in the flexible cable

Source characteristics:
Iridium-192, 3.6 TBq (98 Ci)

Irradiation characteristics:
- exposure duration: ~ 2.5 hours
- **localised exposure to the hands** + **whole body exposure**

Peru accident: localized irradiation signs

day 6

day 7

day 8

day 11

day 12

day 13

Worker 1

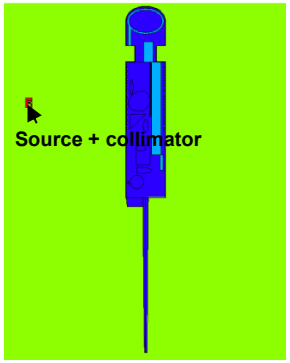
Medical problematic / support of dosimetry

Taking into account the testimony of the operators and regarding the clinical observations and the initial dosimetric data, the **dose is very high and heterogeneous, both to the whole body and to the hands**. These results can be explained only if we consider a **global exposure** in the vicinity of the source for several hours and a **very localised exposure** (finger(s) in contact to the collimator for a very short time).

Localized irradiation
+ Whole body irradiation → MSC graft? Amputation? Hematopoietic problem?

→ **Support of dosimetry** to estimate the dose at the **finger(s)** level and the **dose heterogeneity in the body**

Peru accident: dose reconstruction

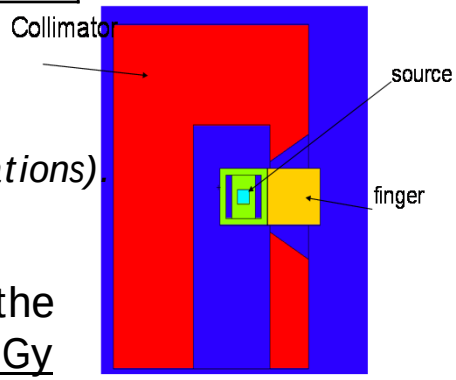


Global exposure configuration

The calculations show that 40 cm is roughly the mean distance between the source and the victim consistent with the 2.5 hours scenario and the dosimetric data results at whole body level and hands obtained by measurements

	Mean trunk dose (Gy)	Tooth (Gy)	Chest (location of the passive dosemeter) (Gy)	Hands (Gy)
Measurement	**2.5 – 3.5***	**4****	**6-7*****	**~35****** (nails)**
Calculations	**2.8**	**3.2**	**6**	**20 (hands)**

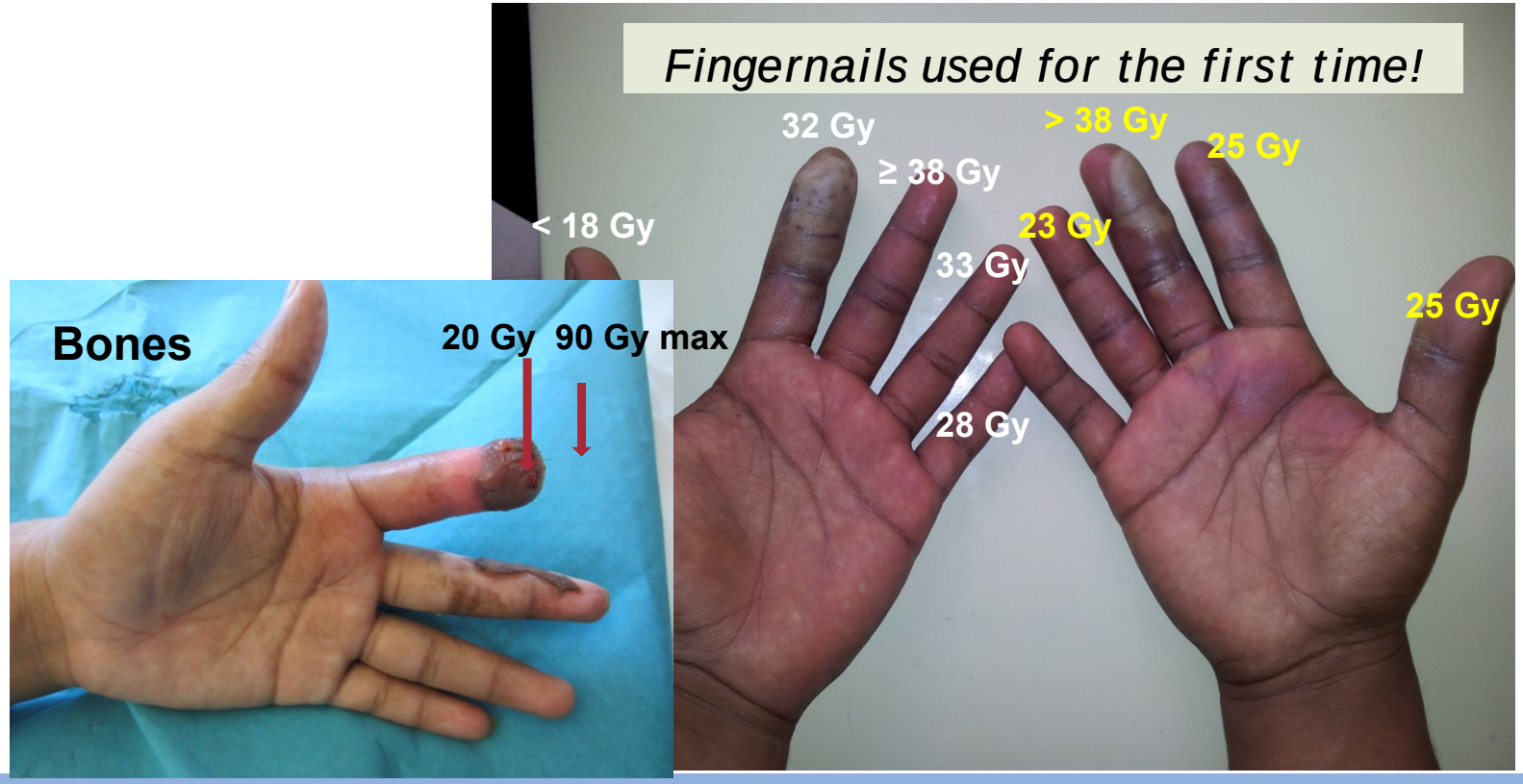
** biological dosimetry*
*** EPR dosimetry – average between both teeth*
**** individual passive dosemeter (from dosimetry lab in Peru)*
***** EPR dosimetry – average among nails (total dose: global + localised irradiations)*



Localised exposure configuration

The additional dose at the entrance of the left index (in contact to the source holder) is 70 Gy for 20 s, and the dose at the nail level is 10 Gy

Peru accident: dose assessment at hands using ESR measurements on fingernails and bones



Conclusion

Dosimetry: a key point for therapeutic strategy

- **Complementary techniques** are needed depending on the **accident configuration**: *biological dosimetry, calculations, ESR…*
- **Localised irradiation on tissue:** surgery area? (*calculation with voxel phantoms)*
- **Localised irradiation at hand:** necrosis? MSC graft? *(ESR on fingernails)*
- **Whole body irradiation:** hematological symptoms? *(biological dosimetry, calculation)*