Contribution of IRSN in the medical management of radiological accidents
Radiological accidents

More than 600 incidents/accidents are known since 1945 (~200 deaths)
Different types of overexposures

Because of the large variety of accidents, a good medical management requires a multidisciplinary expertise and a dedicated technical plateau.
IRSN medical assistance in case of radiological accidents

IRSN provides a multidisciplinary expertise and a technical support to hospitals

- Radiopathology
- Dose assessment
- Support to define the therapeutic strategy

IRSN

Researchers
- Suitable dosimetry techniques
- New therapeutic approaches

Hospitals

Physicians
Victim’s management

Experienced and reactive teams
Dose assessment

The dose assessment is the key point to establish the diagnostic and define the therapeutic strategy

- **Clinical observations**: symptomatology
- **Biological dosimetry**: biochemical parameters…
- **Physical dosimetry**: dose reconstruction using experimental and numerical-anatomical tools and dose from irradiated materials
Clinical observations based on deterministic effects

- **Acute irradiation syndrome (global irradiation)**

<table>
<thead>
<tr>
<th>Mean body dose</th>
<th>1 Gy</th>
<th>5 Gy</th>
<th>10 Gy</th>
<th>20 Gy</th>
<th>50 Gy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hematological symptoms</td>
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<td>Digestive symptoms</td>
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<tr>
<td>Neurological symptoms</td>
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</table>

- **Localized irradiation syndrome**

<table>
<thead>
<tr>
<th>Skin dose</th>
<th>5 Gy</th>
<th>10 Gy</th>
<th>20 Gy</th>
<th>25 Gy</th>
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<tbody>
<tr>
<td>ERYTHEMA</td>
<td></td>
<td>DRY DESQUAMATION</td>
<td>MOIST to WET DESQUAMATION</td>
<td>NECROSIS</td>
</tr>
</tbody>
</table>

Dosimetry: a key point for therapeutic strategy
Conventional biological dosimetry

In case of overexposure suspicion, a biological dosimetry could be useful to assess the dose received by victims

- Numbering of dicentrics and centric rings in the peripheral blood lymphocytes
- Assessment of the mean dose in the body

Blood sample

![Image of blood cells and chromosome fragments]

- Dicentrics
- Rings
- Fragments
Physical dosimetry: experimental tools

If possible, reproduce the accident using experimental tools (dummies...) in conditions as close as possible of the actual ones.
Usually, a dose reconstruction is made using numerical-anatomical model and Monte Carlo calculations.
Construction of a “voxel” phantom of the victim as representative as possible

Medical images of the victim (CT, MRI)

Segmentation step

VIP-Man (RPI, USA)

Child (GSF, Allemagne)

Voxel phantom
Physical dosimetry: numerical-anatomical tools (3)

Calculation of the dose distribution at the tissue and organ level

![Dose distribution diagram](image-url)
Dose measurement on irradiated materials

Dosimetry using ESR (electron spin resonance): measurement of free radicals created in irradiated materials

- Operational technique for accidents implying a small number of victims on biopsy of bone & tooth enamel (~1 mg to 100 mg)
  
  Sensitivity: 0.1 - 0.5 Gy for γ and 1 Gy for neutrons
  
  - Can be used on materials from the environment (glass...)

Materials

IONISATION
Free radicals (unpaired electrons)

Number of unpaired electrons proportional to the dose

ESR spectrometer
Cell therapy is a new promising therapeutical strategy based on stem cell injection having the capacity to acquire morphology and function of the deficient cells after tissue damage.

Example of R&D application: mesenchymal stem cell (MSC) therapy

1. Bone marrow collection
2. Autologous MSC injection

MSC ex vivo expansion
Case report on a localised irradiation: the accident occurred in Chile (2005)
The accident of Chile (2005)

- **Location:** building site for a celluloses manufacture plant, Chile, 15th December, 2005

- **Context:** source used for welding control and found outside its storage container

- **Characteristic of the source:** iridium-192, $3.3 \times 10^{12}$ Bq (90 Ci)

- **Exposure:** manipulation of the source during 40 mn, including 10 mn in the back pocket
Localized irradiation suspected: buttock, hands, head and chest

Clinical symptoms

Hospitalized in France on December 26th, 2005, in the burn treatment department of the Percy Hospital, for a cutaneous radiation syndrome
Numerical-anatomical dose reconstruction

Calculations of the dose distribution at the buttock level

CT images of the patient

Voxel phantom

Dose distribution

1900 Gy
25 Gy
20 Gy
10 Gy
5 Gy
1 Gy
New approach: surgery « guided » by the dosimetry

Surgery

Dose distribution

D > 20 Gy
Φ = 10 cm

1900 Gy
25 Gy
20 Gy
10 Gy
5 Gy
1 Gy
Hand lesion treatment

Skin auto-graft & mesenchymal stem cell (MSC) injection

Skin graft biopsy (back thigh)

D+42 PI

Skin auto-graft & MSC injection
Hand lesion evolution

1 month

2 months

3 months
Buttock lesion treatment after the surgery

Skin auto-graft

MSC injection

204 days P.I.
Lessons learned from the Chile accident regarding the medical management

New therapeutical approach in case of severe radiological burn

- Surgical intervention as soon as possible before the occurrence of the radionecrosis
- Excision of tissues with dose > 20 Gy guided by numerical-anatomical dosimetry
- Classical skin auto-graft associated with cellular therapy: local mesenchymal stem cell injection
- Medical breakthrough in the treatment of irradiated tissue!
Acknowledgements

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French experience in the medical management of radiological accidents during the last decade

- 12 accidents, including 8 via IAEA
- 350 suspected victims, including 47 with deterministic effects
- 23 patients with specific treatments, including 4 using the new therapeutic approach for severe radiological burns (surgery + skin auto-graft + MSC injection)

- GEORGIA Lilo (1996-97): via IAEA, military sources, Cs-137, 11 pers., localised irr., surgery + skin graft
- PEROU (1999): via IAEA, gammagraphy Ir-192, 1 pers., localised irr., surgery + amputation
- GEORGIA Lia (2002): via IAEA, former RTG Sr-Y, 3 pers., localised irr., surgery + skin graft
- POLAND (2002): via IAEA, radiotherapy, 1 pers., localised irr., surgery + skin graft
- CHILE (2005): via IAEA, gammagraphy Ir-192, 1 pers., localised, surgery + skin graft & MSC injection
- SENEegal (2006): gammagraphy Ir-192, 60 suspicions, 3 pers., localised irr., surgery + skin graft & MSC injection
- TUNISIA (2008): via IAEA, gammagraphy Ir-192, 1 pers., localised irr., skin graft & MSC injection
- ECUADOR (2009): via IAEA, gammagraphy Ir-192, 1 pers., localised irr., surgery + skin graft & MSC injection