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Radiation safety in medical sectors

Jérôme DAMET, PhD
Nicolas CHERBUIN

Radiation Protection Group
Institute of radiation physics
Rue du grand pré 1
CH-1007 Lausanne
http://www.chuv.ch/ira/

RADIATION PROTECTION AT HOSPITALS

Course goals

- *Describe the goals and objectives of radiation protection*
- *Describe the role of the actors in radiation protection in hospitals*

What are the goals and objectives of RP? What's the role of RPO/RPE?

@ hospitals? @ Research centres (EPFL, CERN)

Foundations of Radiation Protection

Goal

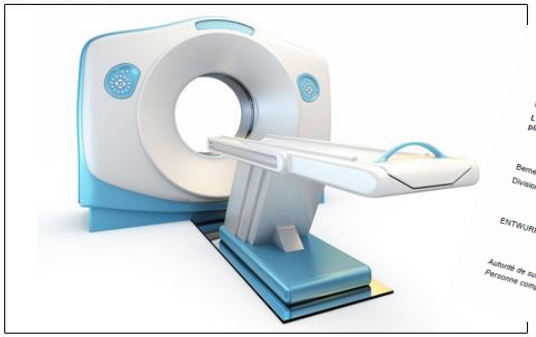
- protect humans and their environment from the effects of ionizing radiation

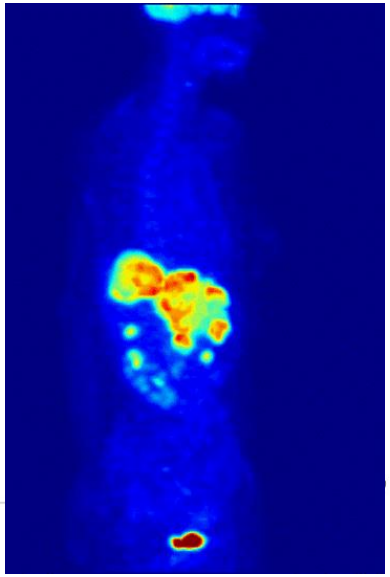
Objectives

- prevent any deterministic pathology caused by irradiation
- limit to an acceptable level all stochastic-type effects

Why/Where do we use ionising radiations in hospitals?

CT scanner





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One of the biggest challenge is probably RP culture itself

Dosimetry can, in some cases, be a real challenge

The IAEA defines safety culture as the assembly of characteristics and attitudes in organizations and individuals which establishes that, as an overriding priority, protection and safety issues receive the attention warranted by their significance

Safety culture is not equally adopted in the medical departments

→ **Radiation Protection and Safety of the Radiotherapy Patients is well established**

For other radiation use in hospitals, the process is still on the way:

→ Radiation protection is one, among many other safety hazards medical staff must deal with
→ Radiation protection is often only summarised by the lead apron for medical staff
→ Sometimes that's our fault... Units (µGy/cm2, mSv, Bq, Ci, ...) aren't easy to understand, eh?

Bonn Call-for-Action - The IAEA held the "International Conference on Radiation Protection in Medicine: Setting the Scene for the Next Decade" in Bonn, Germany, in December 2012.

Bonn Call-for-Action

Action 1: Enhance the implementation of the principle of justification
Action 2: Enhance the implementation of the principle of optimization of protection and safety
Action 3: Strengthen manufacturers' role in contributing to the overall safety regime
Action 4: Strengthen radiation protection education and training of health professionals
…
Action 8: Strengthen radiation safety culture in health care
…

http://www.who.int/ionizing_radiation/medical_exposure/Bonn_call_action.pdf

Radiation protection actors at hospitals

RPO / RPE

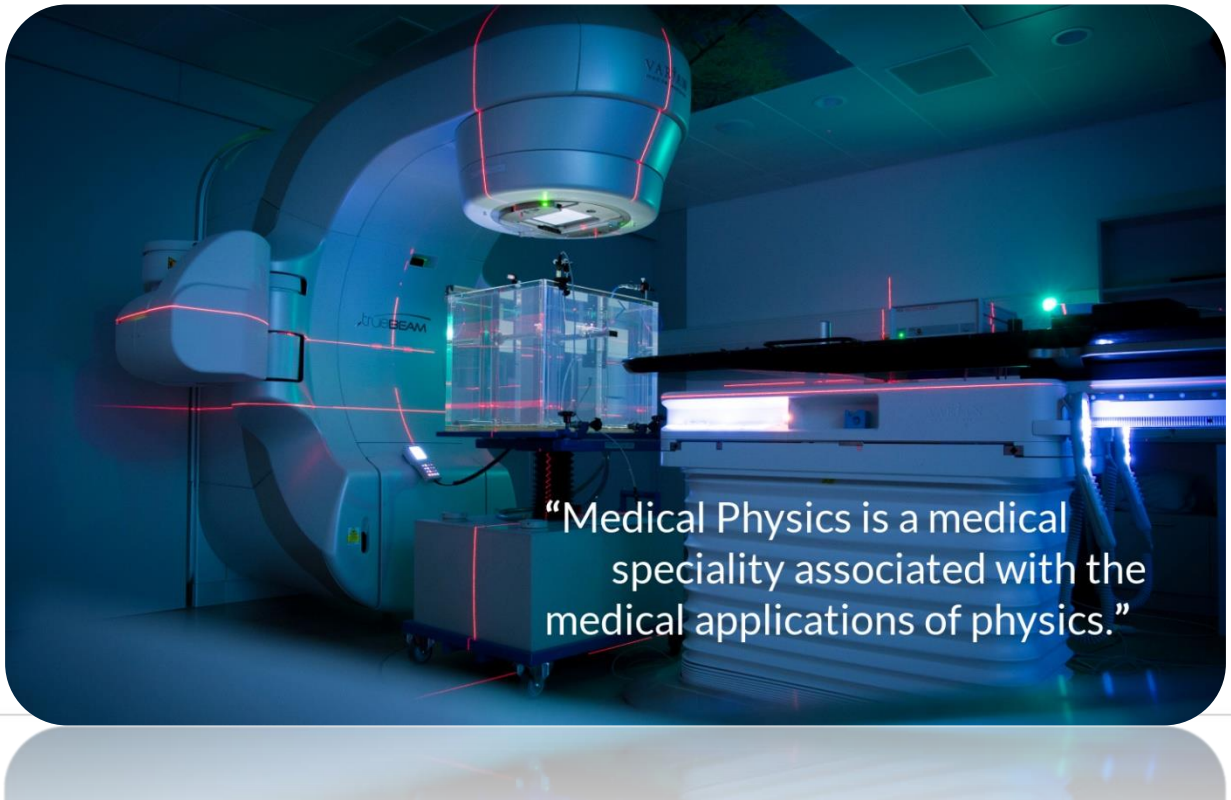
Radiation Protection Officer / Expert

MPE

Medical Physicist → Radio therapy
→ Radio diagnostic

SSRMP certification in medical physics

SGSMP SSRPM SSRFM
Schweizerische Gesellschaft für Strahlenbiologie und Medizinische Physik
Société Suisse de Radiobiologie et de Physique Médicale
Società Svizzera di Radiobiologia e di Fisica Medica
Swiss Society of Radiobiology and Medical Physics



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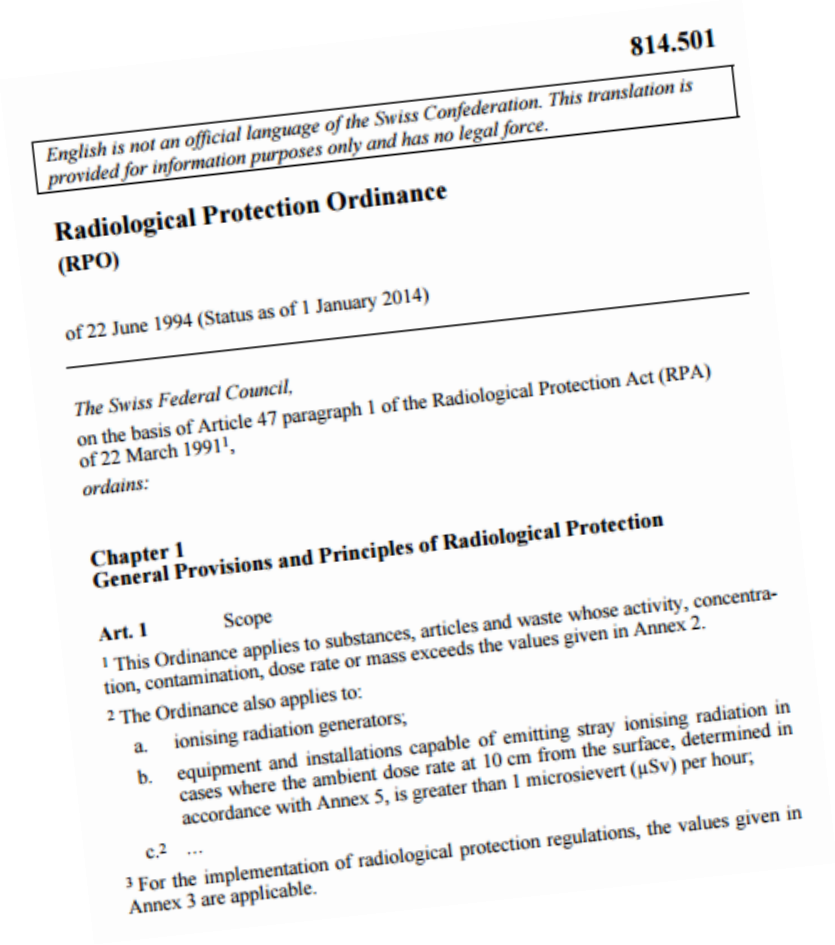

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English is not an official language of the Swiss Confederation. This translation is provided for information purposes only and has no legal force.

Radiological Protection Ordinance
(RPO)

of 22 June 1994 (Status as of 1 January 2014)

The Swiss Federal Council,
on the basis of Article 47 paragraph 1 of the Radiological Protection Act (RPA) of 22 March 1991[1],
ordains:

Chapter 1
General Provisions and Principles of Radiological Protection

Art. 1 Scope

[1] This Ordinance applies to substances, articles and waste whose activity, concentration, contamination, dose rate or mass exceeds the values given in Annex 2.

[2] The Ordinance also applies to:

a. ionising radiation generators;

b. equipment and installations capable of emitting stray ionising radiation in cases where the ambient dose rate at 10 cm from the surface, determined in accordance with Annex 5, is greater than 1 microsievert (µSv) per hour;

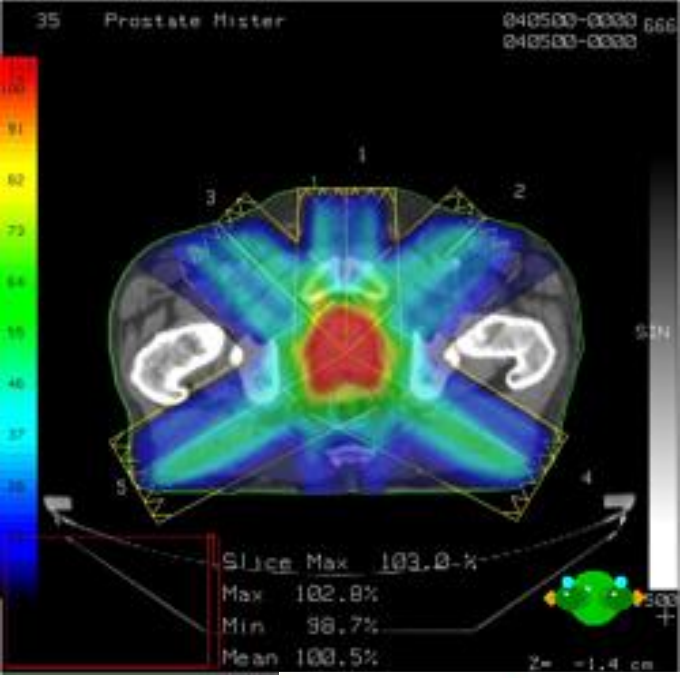
c.[2] ...

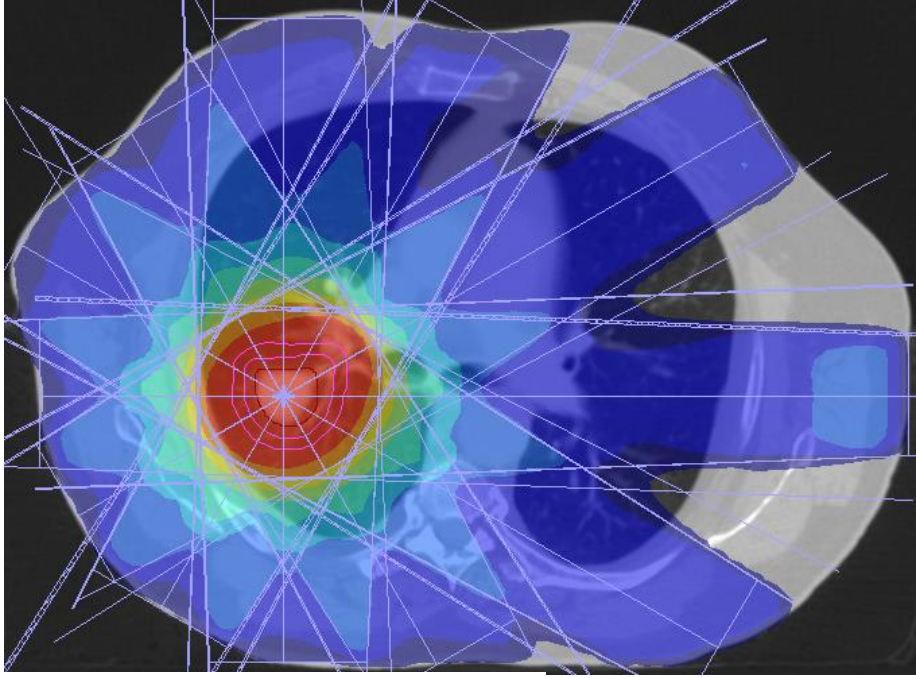
[3] For the implementation of radiological protection regulations, the values given in Annex 3 are applicable.

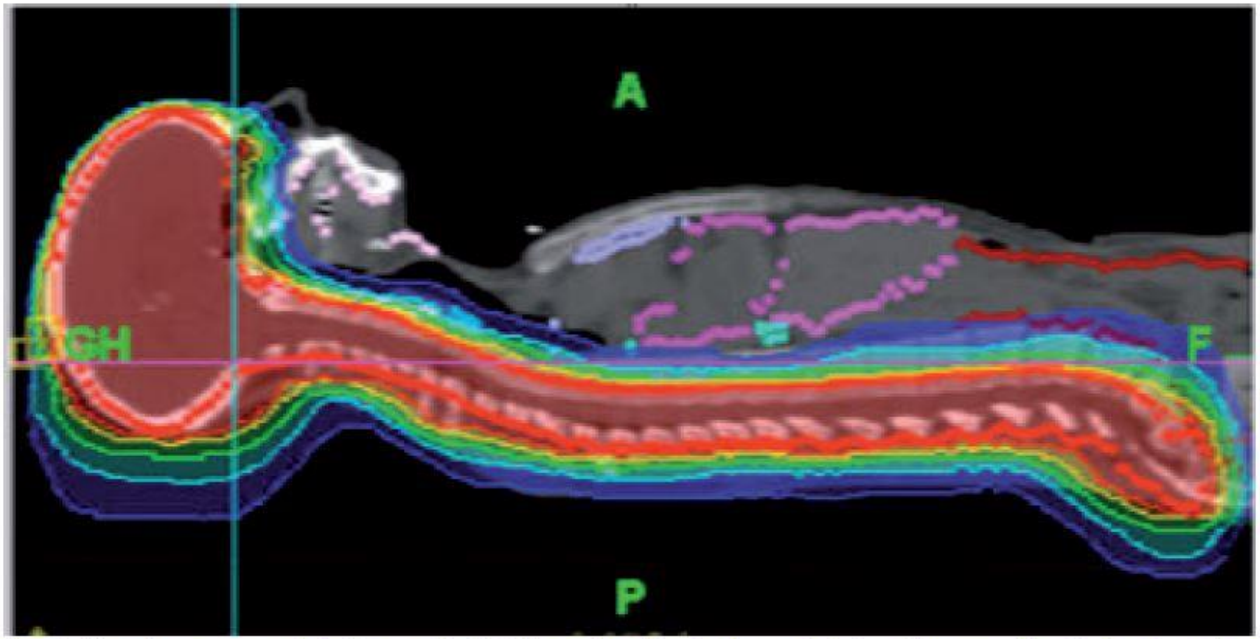
Art 74 Medical radiation generators and medical equipment containing sealed radioactive sources

…

4 In the case of radiotherapy systems or irradiators, the elements relevant to safety and those determining the dose must be inspected at least once a year and whenever a component is changed which could affect the dose rate. The inspection of the dose determining elements must be carried out under the supervision of a **medical physicist** with certification in medical radiophysics from the Swiss Society of Radiobiology and Medical Physics or other equivalent training

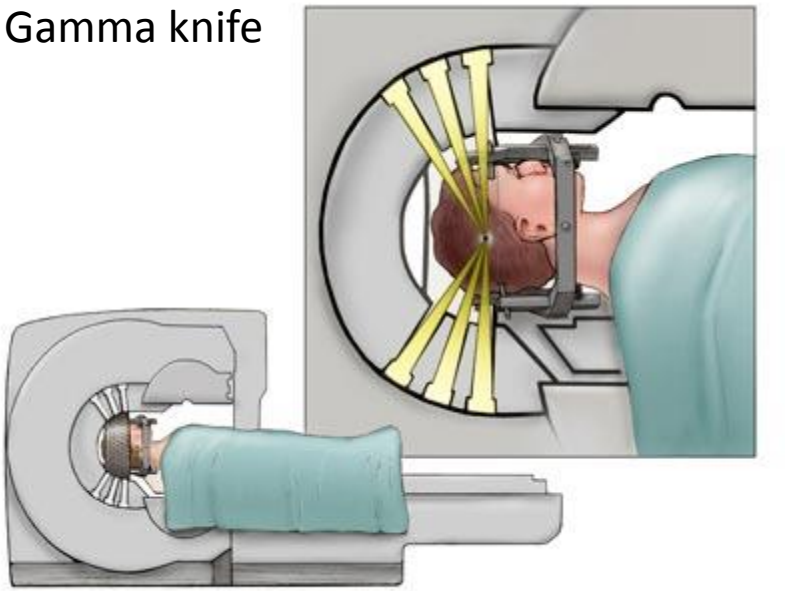




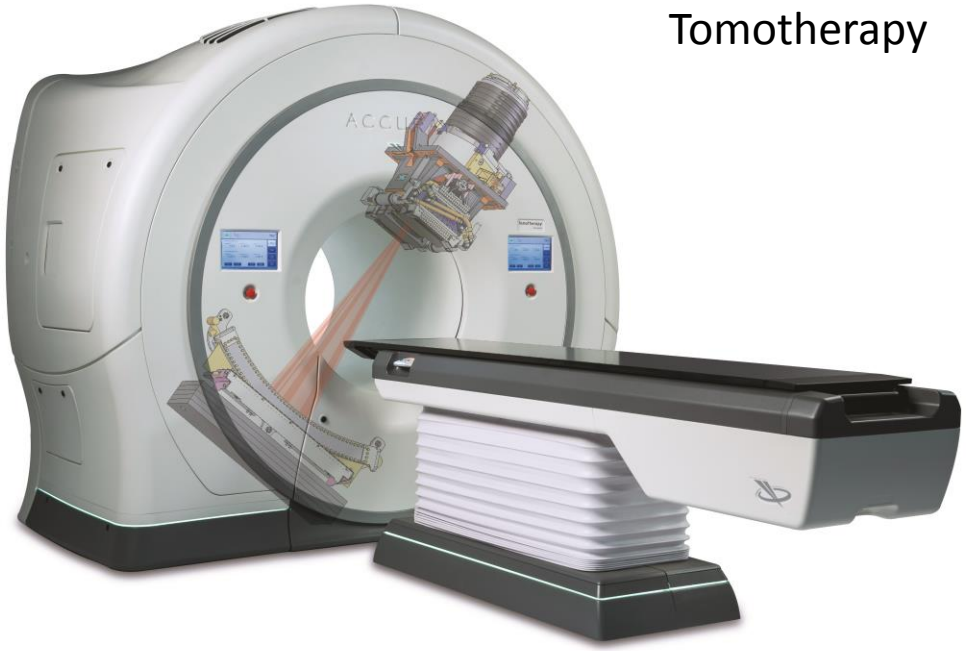


Irradiation du cerveau et de la moelle épinière chez l'enfant avec la Tomotherapy: L'enfant est confortablement allongé, l'irradiation est délivrée en un seul passage et permet cibler la dose au niveau du crâne et de la colonne vertébrale (Zone en rouge)

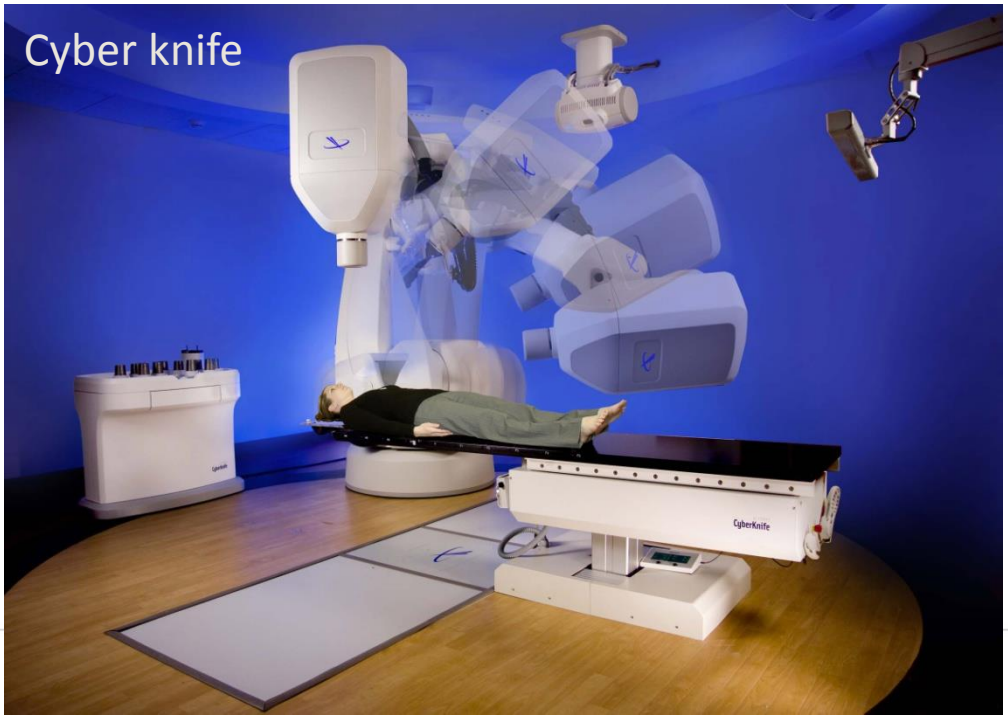
Gamma knife



Tomotherapy



Cyber knife



Imaging and diagnostic procedures

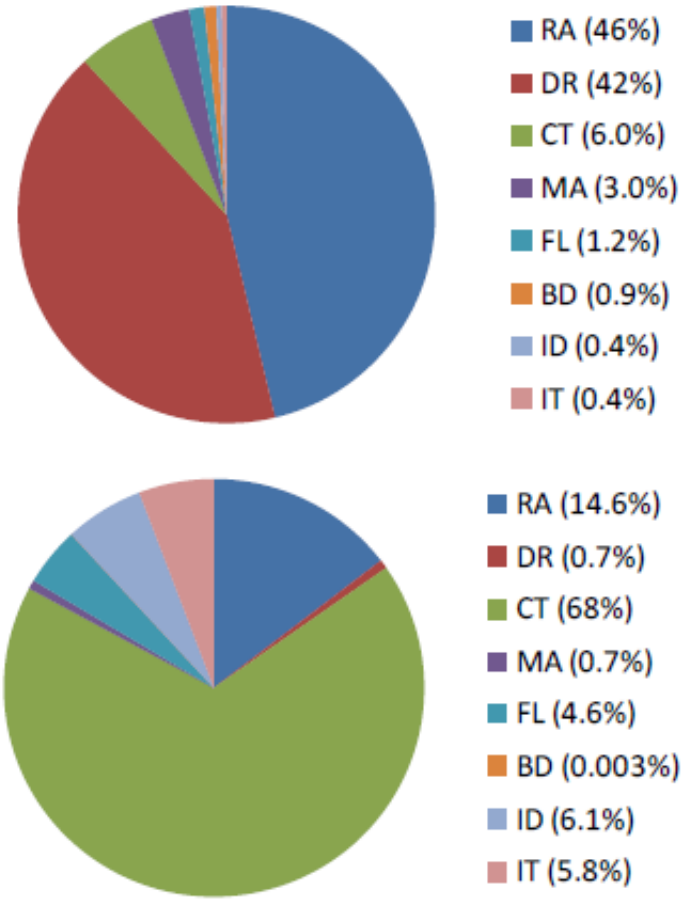


Figure 2: Distribution of the total annual number of examinations (upper part) and the total annual collective dose (lower part) over the various radiological modalities: radiography (RA), conventional fluoroscopy (FL), diagnostic interventional radiology (ID), therapeutic interventional radiology (IT), computed tomography (CT), dental radiology (DR), mammography (MA), bone densitometry (BD).

Table 7: 2008 Swiss annual frequency and dose data

Radiological modality	Number of examinations (in thousands)	Collective dose (man.Sv)	Number of examinations per 1000 population	Effective dose per caput (mSv)
Radiography	6000	1330	780	0.17
Conventional fluoroscopy	153	415	20	0.05
Interventional – diagnostic	56	553	7.2	0.07
Interventional – therapeutic	46	528	6.0	0.07
Computed tomography	780	6150	100	0.8
Dental radiology	5430	63	700	0.01
Mammography	387	62	50	0.01
Bone densitometry	117	0. 31	15	0.00004
Total	13'000	9100	1700	1.2

Interventional radiology procedures

Training
Optimisation of protocols
QA
...

Accident en radiologie interventionnelle

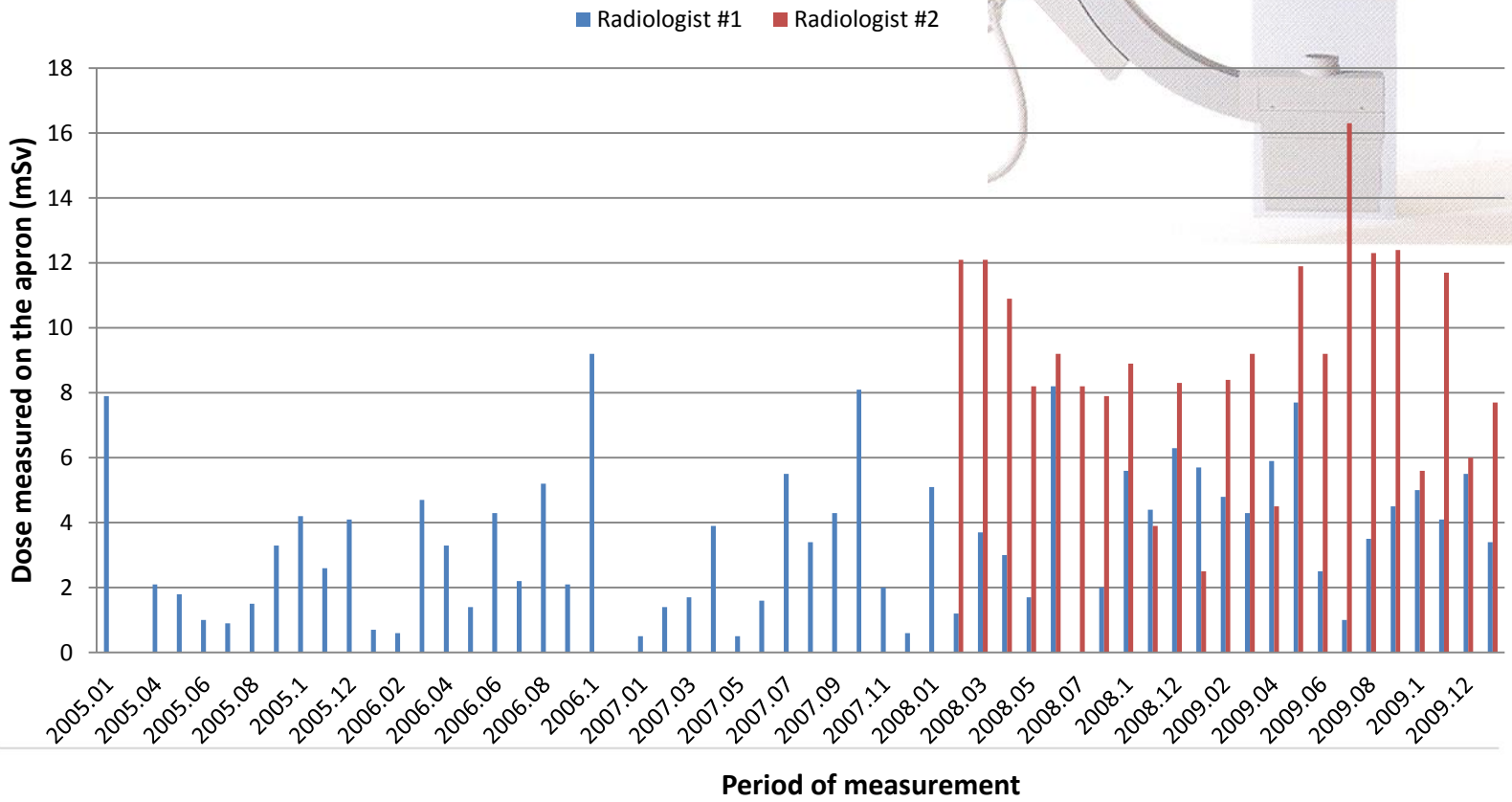


Koenig TR et al. AJR 2001

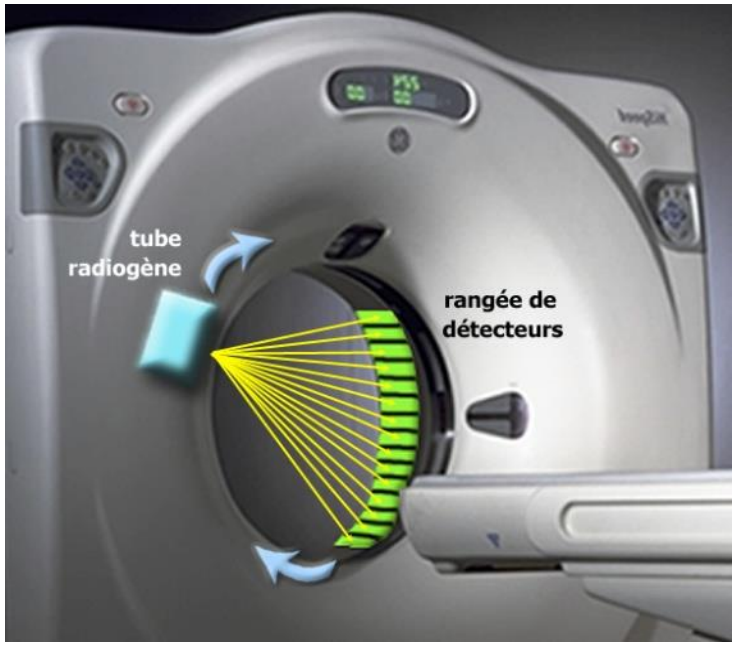
- Une centaine d'accidents liés à des pratiques anormales de radiologie interventionnelle au niveau international;
- Ce chiffre est à rapporter aux 2 millions de procédures de radiologie interventionnelle réalisées chaque année à travers le monde;
- Les lésions les plus sévères ont nécessité un acte chirurgical classiquement pratiqué dans la prise en charge des brûlures radiologiques très sévères.

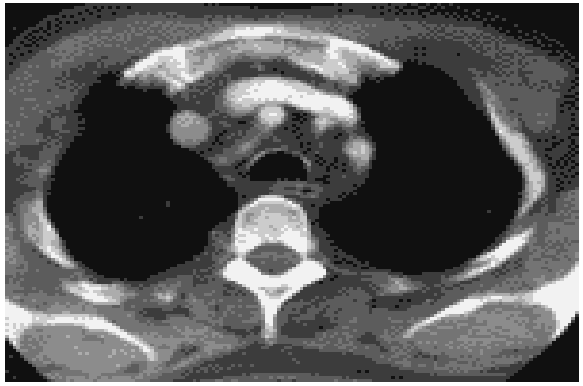
Interventional cardiology procedures

External exposure of medical staff



Computed Tomography



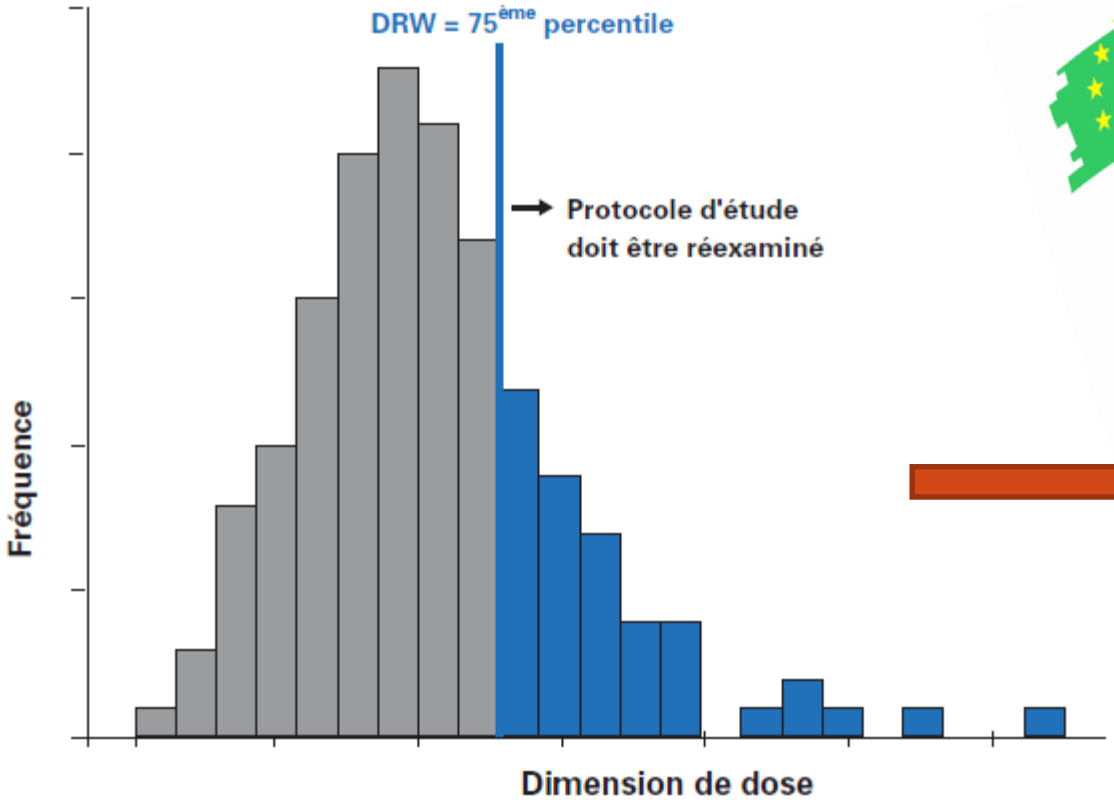


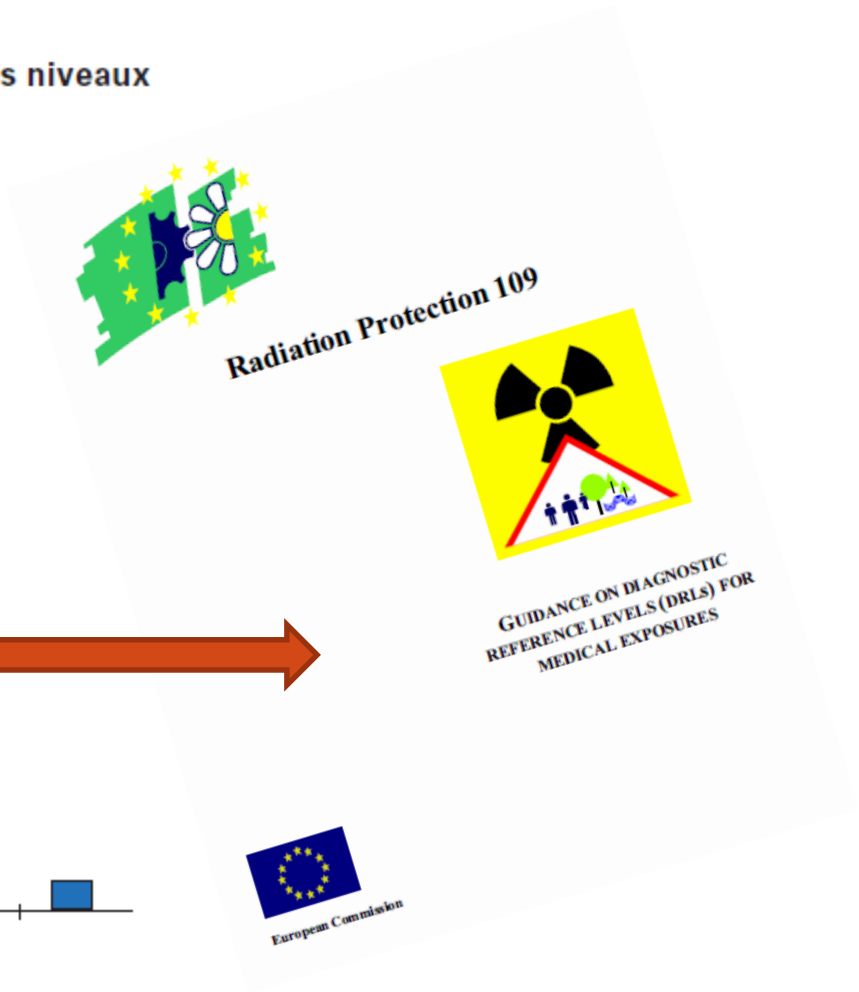
Dosimetry issues:

- CTDI – CT dose index
- DLP
- E
- How is the effective dose calculated?

Diagnostic Reference Levels

Figure 7 : Représentation schématique visant à déterminer les niveaux de référence diagnostiques





https://rpop.iaea.org/RPOP/RPoP/Content/InformationFor/HealthProfessionals/1_Radiology/ComputedTomography/diagnostic-reference-levels.htm

Radiation Protection Officers and Experts

Radiation protection in the medical sector is the duty of many actors

Radiological Protection Act
(StSG/LRaP)

22 June 1991 (State of 1 January 1995)

The Federal Assembly of the Swiss Confederation,
having regard to articles 24quinquies, 24septies, 27sexies, 64 and 64bis of the Federal Constitution[1],
having regard to the message from the Federal Council of 17 February 1988[2],
herewith enacts the following statute:

Article 16 Responsibility inside Companies

[1] The licence-holder or the persons in charge of an enterprise shall bear responsibility for ensuring compliance with the regulations on radiological protection. For this purpose, they shall be required to deploy an appropriate number of experts and to give them the necessary powers and resources.

[2] It shall be the duty of all persons working in the enterprise to support company management and the experts in measures pertaining to radiological protection.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Eidgenössisches Departement des Innern EDI
Bundesamt für Gesundheit BAG
Direktionsbereich Verbraucherschutz

Seite 1 / 4

Abteilung Strahlenschutz
www.str-rad.ch

Referenz / Aktenzeichen: L-03-04md.doc
Erstellt: 12.11.2004
Revisions-Nr. 0

Merkblatt L-03-04
Aufgaben und Pflichten des SV im Bereich der Anwendung ionisierender Strahlung

At Lausanne University hospital, IRA provides consulting and support services to local RP experts

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Département fédéral de l'intérieur DFI
Office fédéral de la santé publique OFSP
Unité de direction Protection des consommateurs

Division Radioprotection
www.str-rad.ch

Référence du document: L-03-04wf.doc
Etablie le: 12.11.2004
Révision n°: 0

Directive L-03-04

Tâches et devoirs de l'expert en matière d'utilisation des rayonnements ionisants

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Confederazione Svizzera
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Rôle de l'expert en radioprotection

Dans les tableaux ci-dessous, ces deux domaines ont été distingués :

A Installations génératrices de radiations ionisantes

B Utilisation des sources radioactives

Remarque :
Cette liste n'est pas exhaustive. Elle recense les activités principales de l'expert, prenant en compte non seulement les tâches établies par la loi, mais aussi les exigences spécifiques des entreprises.

5.1 Tâches générales

	A	B
Conseils au titulaire de l'autorisation et au personnel en matière de radioprotection	✓	✓
Désignation – par des instructions écrites fondées sur les normes et directives – des personnes exposées aux rayonnements dans l'exercice de leur profession et qui doivent être soumises aux contrôles dosimétriques	✓	✓
Contrôle du respect des directives en matière de radioprotection et des conditions d'autorisation (contrôles du fonctionnement des appareils, mesures de construction, indications des locaux)	✓	✓
Vérification que le comportement des personnes exposées aux rayonnements dans l'exercice de leur profession soit conforme aux règles de radioprotection (p.ex. comportement dans les secteurs de travail, utilisation de couples écran-film adéquats)	✓	✓
Elaboration d'informations pour les patients, en collaboration avec le médecin qualifié	✓	✓

5.2 Tâches administratives et organisationnelles (ORaP art. 132)

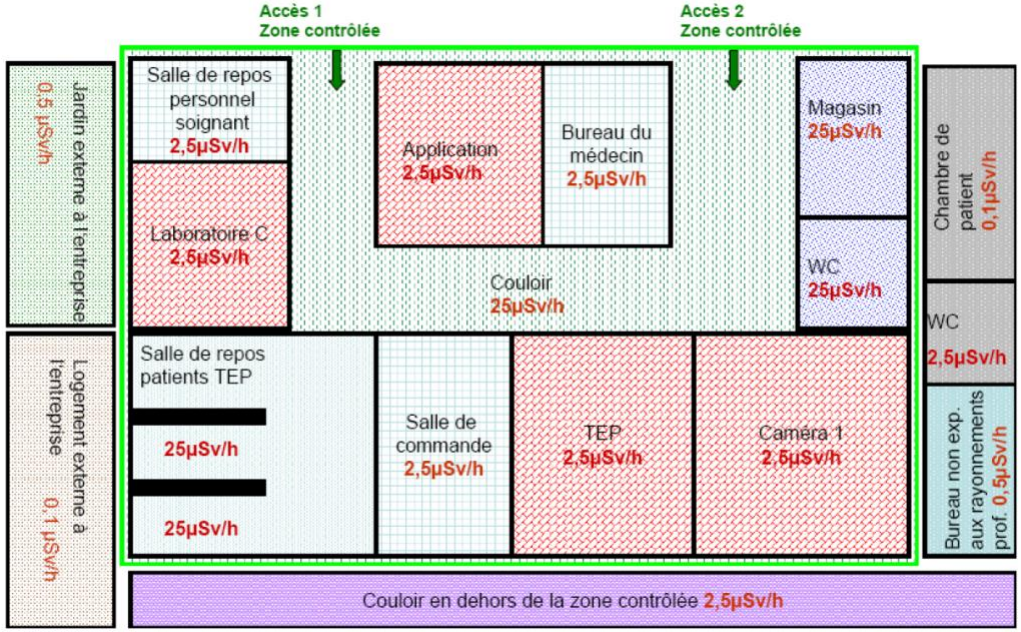
	A	B
Etablissement pour l'entreprise d'instructions concernant : - les comportements conformes aux règles de radioprotection - les méthodes de travail - les procédures lors d'incidents (cf. 5.6)	✓	✓
Suivi et coordination des autorisations, interlocuteur auprès des autorités	✓	✓
Organisation et surveillance de la dosimétrie des personnes, enregistrement des doses déclarées mensuellement (ORaP, art. 42-43, annexe 5 ; directives de l'OFSP L-06-01 et R-06-03)	✓	✓
- externe (irradiation sur le corps entier et sur des parties du corps)	✓	✓
- interne (surveillance d'incorporation par des mesures de tri)		✓
(Vérification en cas de surdoses, maintien de l'obligation de port, mesures à prendre lors de dépassements réguliers des doses limites)	✓	✓
Contrôle des commandes de substances radioactives		✓
Réglementation du transport de substances radioactives à l'intérieur de l'entreprise (Osrou art. 16)		✓

RPO's duties must be set in writing by the authorization holder who takes on radiation protection responsibility in his/her company (ORaP, Art. 132)

RPO may delegate some of his/her duties

<u>The following tasks relate specifically to the RPO</u>:

- outfitting (and also planning) of working areas
- organizing radiation protection and managing working areas
- monitoring and supervision of working areas and working methods
- managing administrative tasks
- communication with the supervising authority
- basic training and continuing education of collaborators in radiation protection practices.

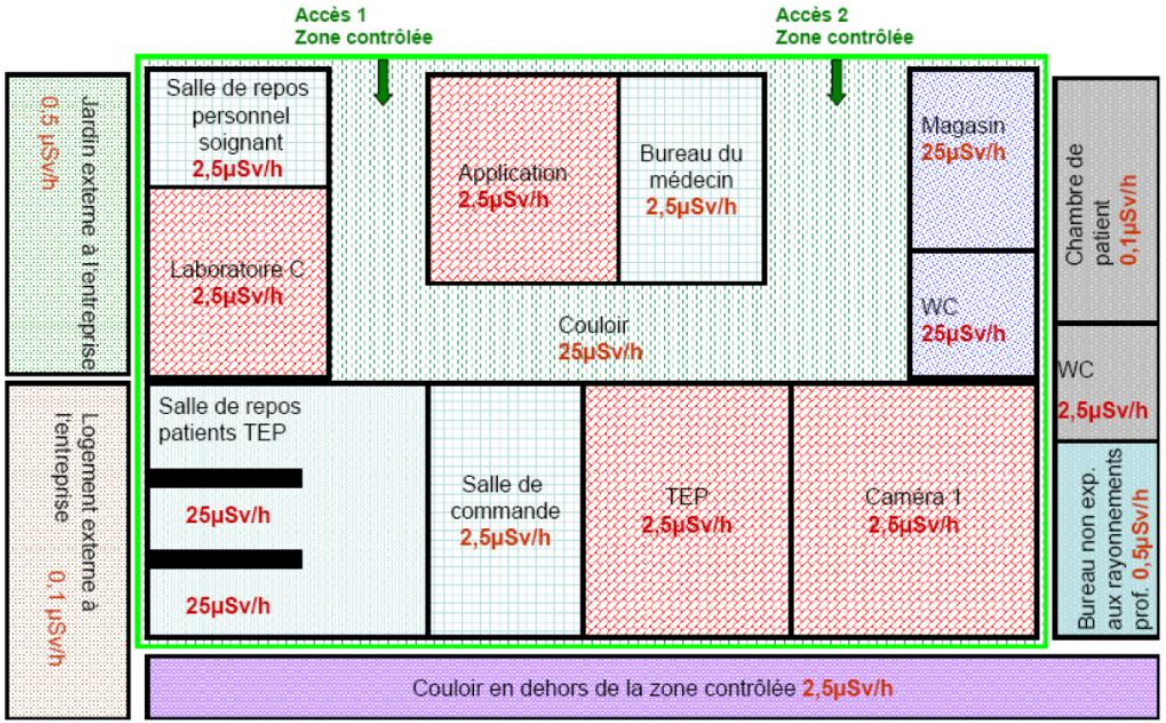


1.Outfitting

In terms of outfitting the working areas, the RPO'S duties are the following:

•designation of working areas
•organizing working areas, such as: distribution, outfitting, shielding
•establishing effective working methods from a radiation protection perspective
•acquisition and maintenance of radiation protection measuring instruments;
•acquisition of protective gear (apron, thyroid shields, gloves,…). The RPO verifies that protective gear is available, in sufficient quantities, and is correctly and systematically used.
•preparation of internal guidelines with respect to radiation protection, as well as measures to take in case of accident or fire. The RPO ensures that these instructions are known and applied by the individuals involved.

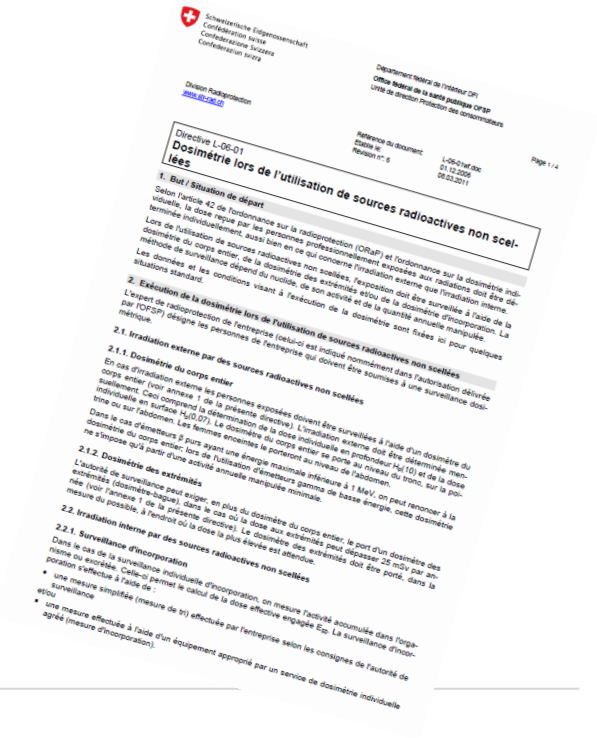
Directive L-07-04
Valeurs directrices pour les débits de dose ambiante dans les services de médecine nucléaire



2. Organization and management

In terms of organizing and managing radiation protection, the RPO has the following duties:

• designate those individuals having occupational exposure to ionizing radiation
• organize personal monitoring. This involves, on the one hand, ensuring that everyone exposed to external radiation wears a dosimeter, and, on the other hand, defining any internal dosimetry needs and establishing necessary screening measurements for internal contamination
• declare to the Suva anyone having occupational exposure to ionizing radiation to ensure medical supervision
• organize and manage purchasing, transport, receiving, storage and disposal of radioactive substances
• manage radioactive waste
• manage laboratory waste water
organize maintenance and monitoring of installations


Directive L-06-01
Dosimétrie lors de l'utilisation de sources radioactives non scellées

3. Monitoring and supervision

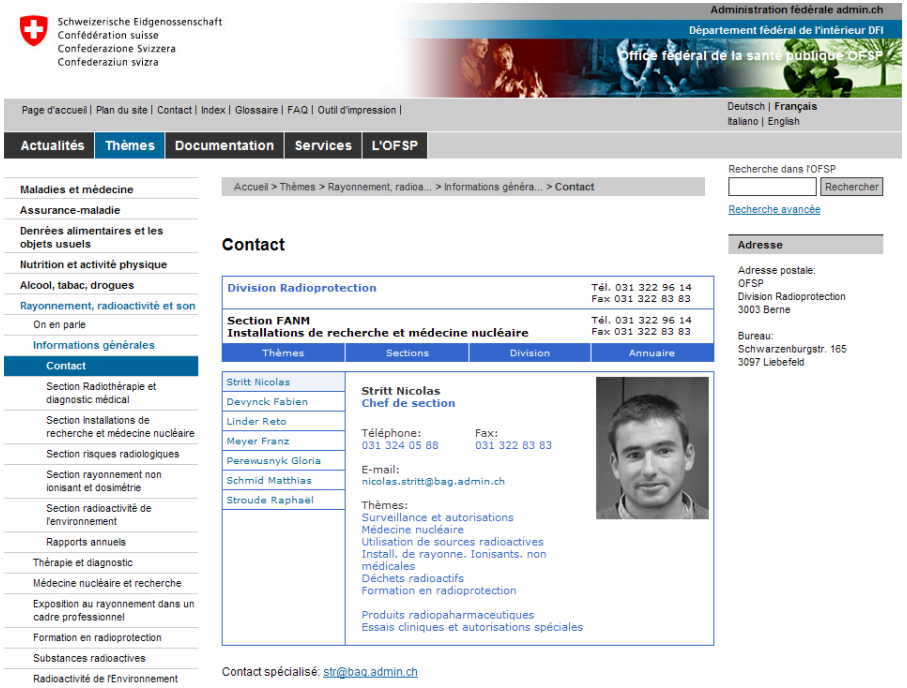
In terms of monitoring and supervising working areas and working methods, the duties of the RPO are the following:

• analyze results of personal dosimetry from individuals with occupational exposure to ionizing radiation and remain in regular communication with those individuals regarding those results
• monitor installations and working areas for contamination and external irradiation
• check shielding and dose rates
• monitor the integrity of sealed radioactive sources
• supervise trials or any work involving any special risks
• regular monitoring in working sectors, mainly in the laboratories
• monitor the stability of installations
• supervise the behavior of individuals without occupational exposure to ionizing radiation (reception, repair services, visitors, etc).

4. Administration

In terms of radiation protection administration, the RPO has the following duties:

- provide information and internal training for individuals having occupational exposure to ionizing radiation
- update paperwork concerning the acquisition, use and elimination or disposal of radioactive substances
- manage authorizations for using ionizing radiation
- update personal dosimetry documents



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5. Communication with the supervising authority

Swiss Federal Office of Public Health (FOPH)
Swiss Accident Insurance Fund (SUVA)
Swiss Federal Nuclear Safety Inspectorate (ENSI)

The RPO must immediately contact the supervising authority in the following situations:

- change in authorization conditions (changes concerning the installation, data involved with the building and the construction of the installation or even the area where radioactive sources are stored)
- purchasing and use of new radiological installations
- exceeding any dose limit values
- radiological incident or accident
- clinical trials with radiation
- suppression of working sectors (stop of activity)
- change of RPO.

Requests to change the conditions of an authorization must be made prior to any change and modifications must not occur until authorization has been received.

6. Training in radiation protection

The training of individuals who may be exposed to radiation is mandated by Article 6 of the law on radiation protection and the training methods are described in Articles 11 through 22 of ORaP. Details of this training are established in a departmental technical ordinance. Training targets the following objectives:

- acquiring the necessary basic knowledge for understanding the risks associated with radiation and the means of protection
- acquiring the basic principles of radiation protection and practical methods destined to protect workers, patients, the general public and the environment
- acquiring knowledge of the legislation and administrative procedures linked to using ionizing radiation

Example

The department in which you work for five years plans to move into a new research center.

The new building is currently under construction on the university campus.

You are asked, as expert in radiation protection, to plan the relocation of a laboratory of type B where unsealed sources of H-3, P-32, CI-36, I-129, Po-210 are used.

The activities in the new lab will include those of a post-doc who will be hired for a project based on animal cytogenetic techniques involving labeling with P-32 (1.5 MBq per experiment).

Example II

You've be hiring as expert in radiation protection for a new research center which plan open a new facility where unsealed sources of H-3, F-18 and I-125 will be used.

The laboratory is under construction and the director got the license from the authorities

You are asked to choose and buy the instrument for this facility.

Example III

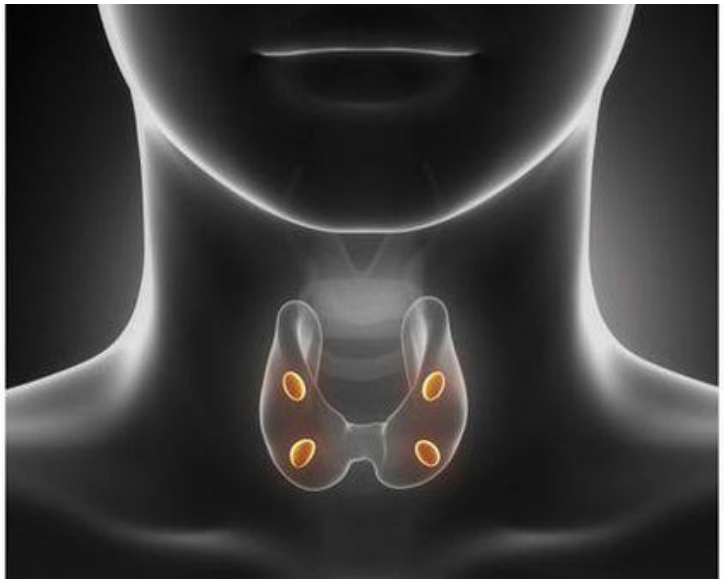
You've be hiring as expert in radiation protection for a new research center which plan open a new facility where unsealed sources of F-18 , Tc-99m, I-125 and Cs-137 will be used.
A sealed source of Co-60 (50 kBq) is also used for calibration of instruments

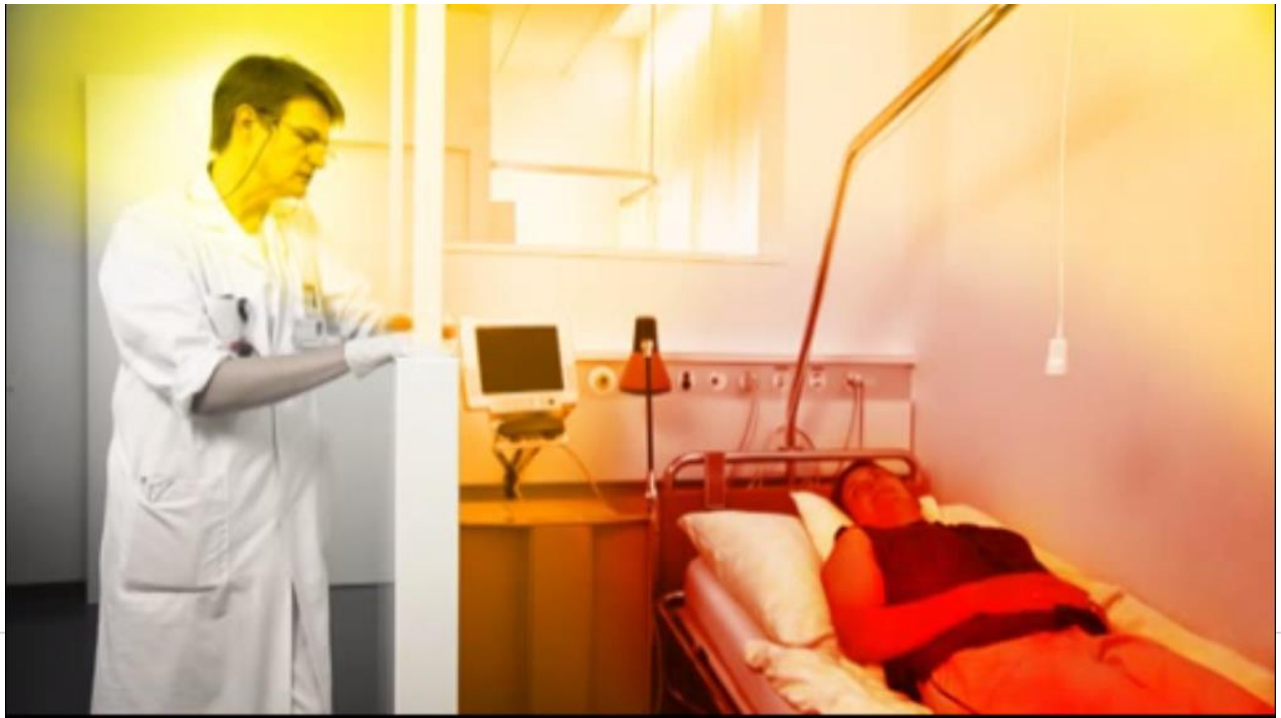
Five new technicians, a PhD student and a post-doc will join the team.

You are asked to explain them the risks they may face in the laboratory and explain the safety procedures.

Few examples the RP group had to face last year and on-going research projects

Shielding optimisation for I-131 treatment rooms





Shielding design for I-131 treatment rooms

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Référence du document: L-07-03mf.doc
Etablie le: 22.11.2004
Révision n°: 2 06.01.2009

Directive L-07-03

Blindage de chambres de patients en thérapie I-131

1. But de la directive

L'ordonnance sur l'utilisation des sources radioactives non scellées ne comprend aucune indication sur les dimensions du blindage de chambres de patients en thérapie ou sur des parois mobiles.En vue d'une utilisation uniforme, la présente directive fixe les conditions minimales à respecter pour les chambres des patients I-131.

The RP group provides consulting and support services to local radiation protection expert for shielding calculation and licence application

- for CHUV
- other hospitals

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4. Schéma de calcul général

4.1 Facteur d'atténuation

$$\text{Facteur d'atténuation } F = h_{10} \cdot \frac{0{,}5 \cdot A_{max}}{j \cdot a^2}$$

Soit :

h_{10} = 62 (µSv/h)/GBq à 1 m de distance de la source radioactive I-131 (annexe 3 ORap)

A_{max} = activité maximale appliquée (cf. point 3.2 de cette directive)

j = débit de dose ambiante adminissible (annexe 1 de cette directive ou annexe 2 de l'ordonnance sur l'utilisation des sources radioactives non scellées)

a = distance entre la source de radiation et l'endroit à protéger (conformément au point 3.4 de cette directive)

4.2 Epaisseur du blindage

$$d = \frac{\text{poids de l'unité de surface}}{\text{masse volumique du matériel}}$$

Soit :

- Poids de l'unité de surface en g/cm^2, à relever en tenant compte du degré d'atténuation et du matériel de blindage selon le diagramme figurant à l'annexe 2
- Masse volumique du matériel de blindage en g/cm^3: Pb: 11,3 ; Fe: 7,8 ; baryte: 3,2 ; béton: 2,2

5. Exemple de calcul pour un corridor à l'extérieur de la zone contrôlée

5.1 Calcul du facteur d'atténuation nécessaire

h_{10} I-131 = 62 (µSv/h)/GBq à 1 m
A_{max} = 7,4 GBq
j = 2,5 µSv/h
a = 3 m

$$\text{Facteur d'atténuation } F = \frac{62\,\mu Sv/h \cdot m^2 \cdot (0{,}5 \cdot 7{,}4\,GBq)}{GBq \cdot (3m)^2 \cdot 2{,}5\,\mu Sv/h} = 10{,}2$$

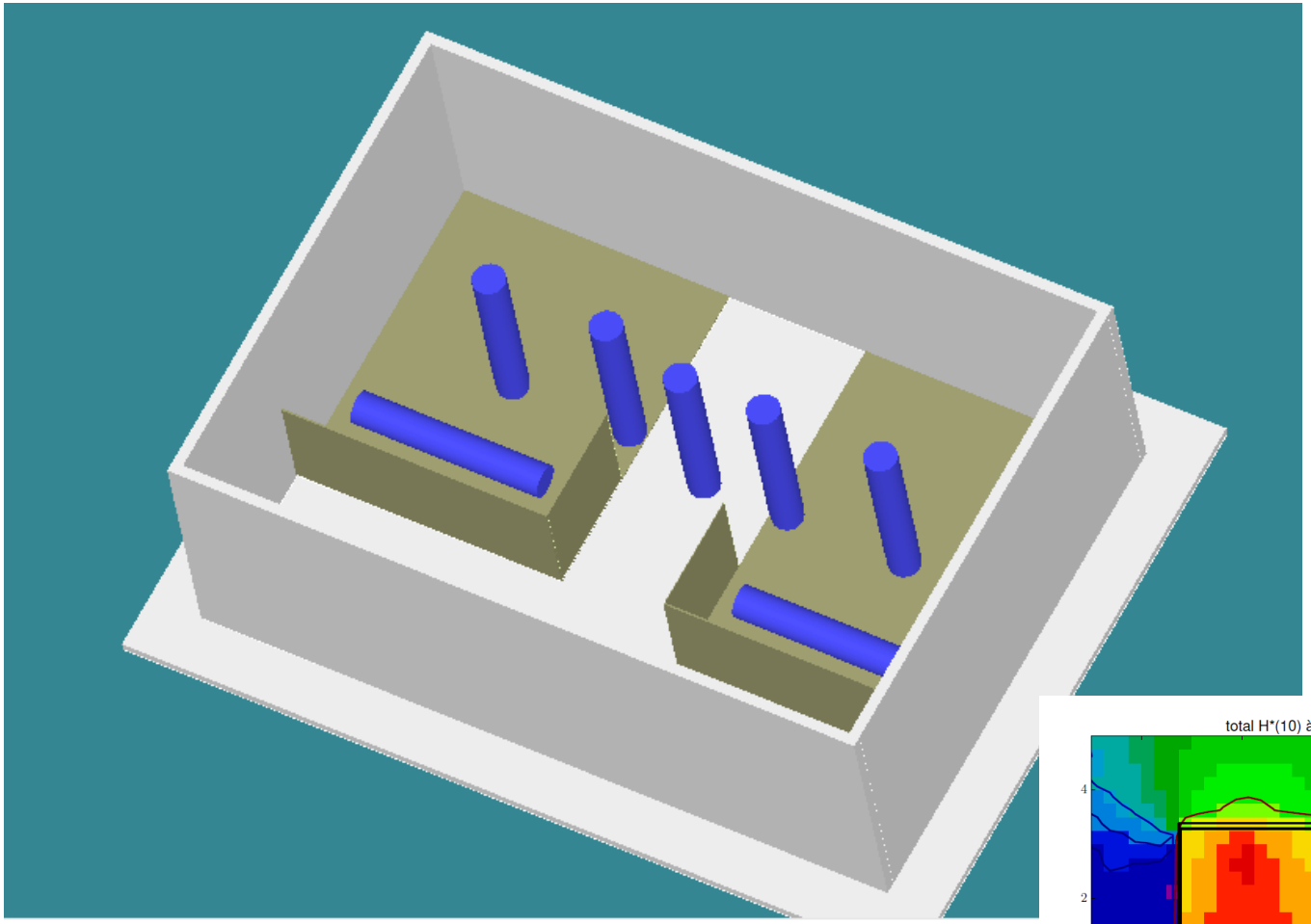
5.2 Calcul du blindage nécessaire

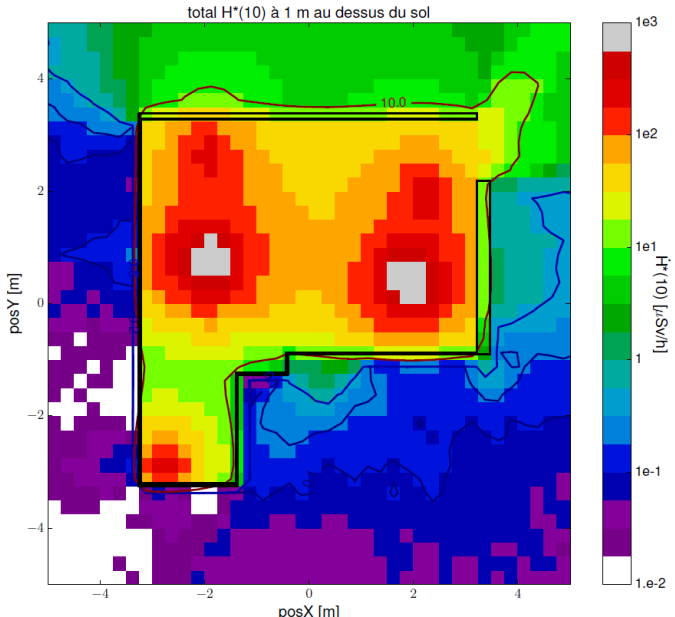
Selon le matériel de blindage utilisé, le degré d'atténuation nécessaire indiqué à l'annexe 2 permet de définir le poids de l'unité de surface et d'en déduire la masse volumique du blindage.

Le facteur d'atténuation F = 10,2 correspond à un poids d'unité de surface de 12 g/cm^2 (plomb). On en déduit l'épaisseur du plomb pour le blindage avec une densité de 11,3 g/cm^3, au moyen de la formule suivante :

$$\text{Epaisseur du blindage } d = \frac{12\,g/cm^2}{11{,}3\,g/cm^3} = 1{,}1 \text{ cm de plomb}$$

Simulation Geant4 – Shielding optimisation for I-131 treatment rooms





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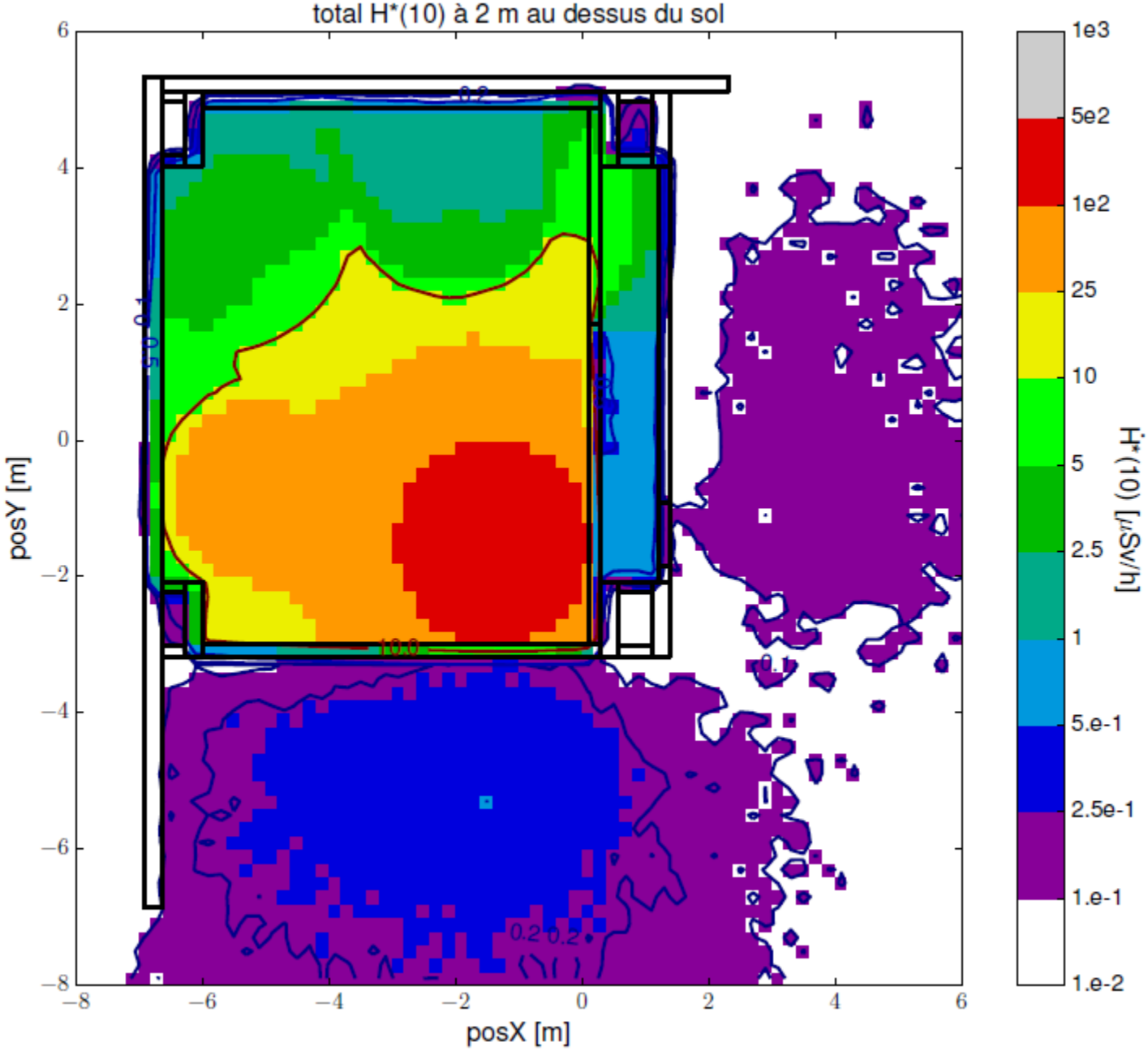
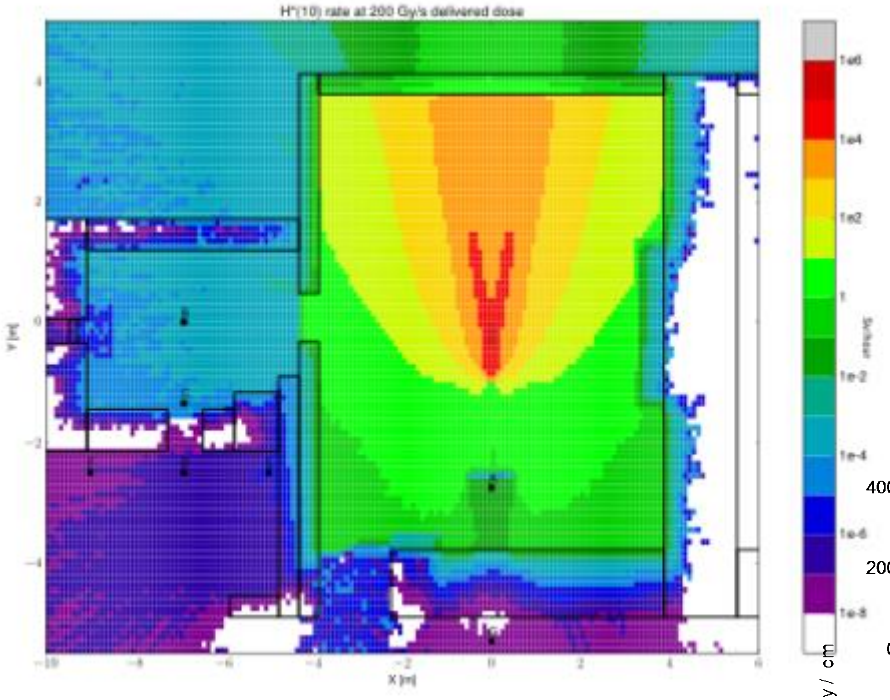
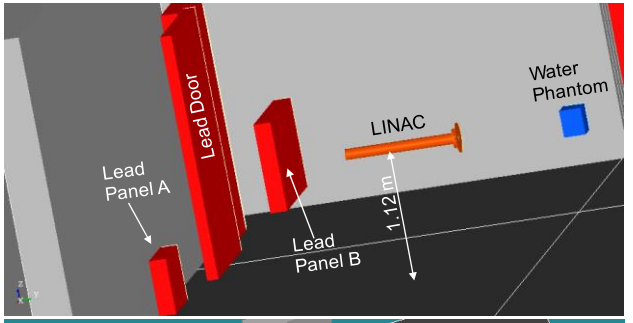
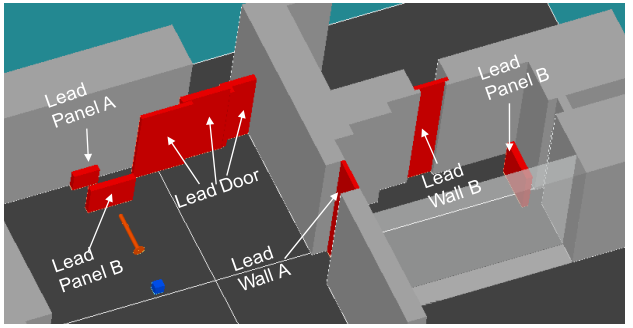
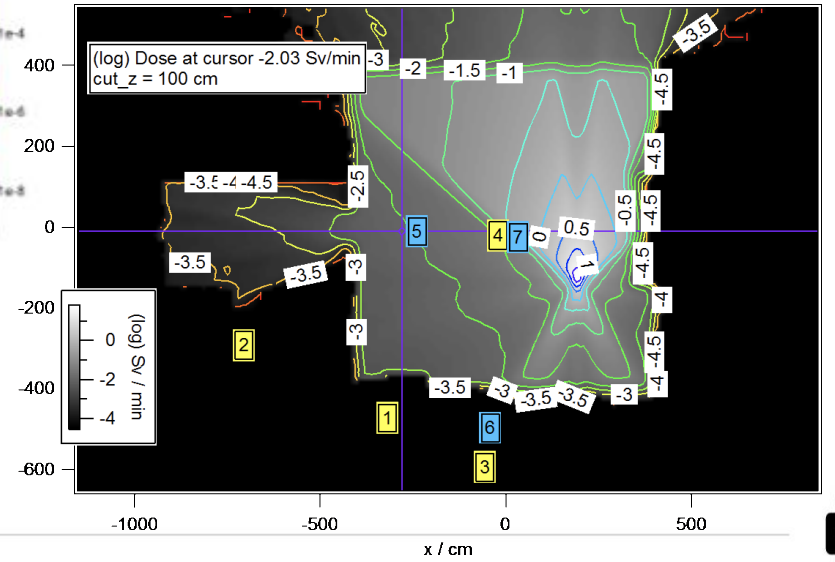

total H*(10) à 2 m au dessus du sol
posY [m]
posX [m]
6
4
2
0
−2
−4
−6
−8
−8
−6
−4
−2
0
2
4
6
10.0
0.2
0.1
1e3
5e2
1e2
25
10
5
2.5
1
5.e-1
2.5e-1
1.e-1
1.e-2
Ḣ*(10) [μSv/h]

Ultra high dose rate radiation therapy (FLASH)

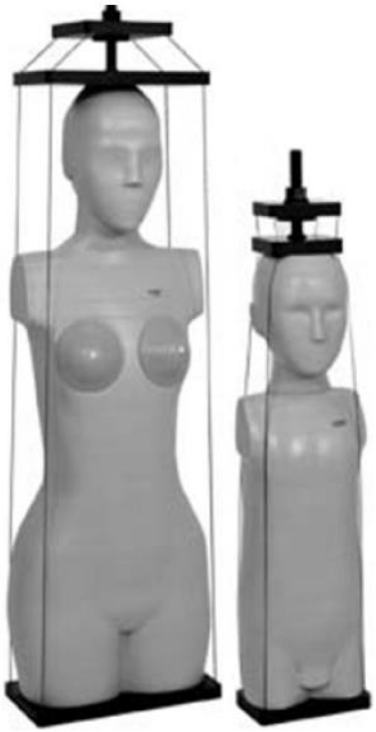

H*(10) rate at 200 Gy/s delivered dose
y [m]
x [m]
y / cm
Sv/min


Lead Door
LINAC
Water Phantom
Lead Panel A
Lead Panel B
1.12 m


Lead Panel A
Lead Door
Lead Panel B
Lead Wall B
Lead Panel B
Lead Wall A


(log) Dose at cursor -2.03 Sv/min
cut_z = 100 cm
(log) Sv / min
x / cm

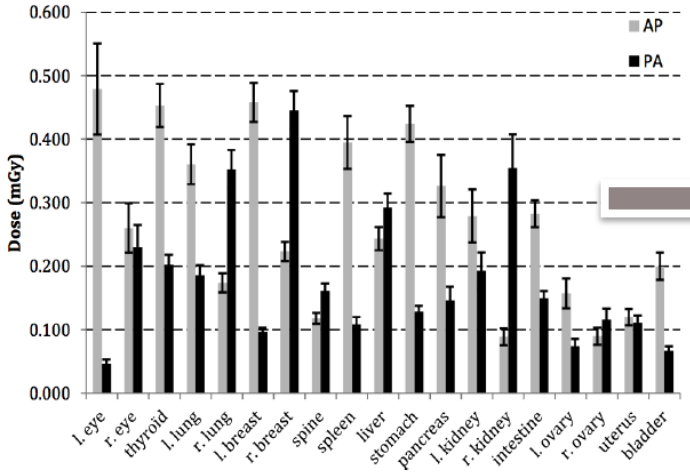
- CIRS Phantoms



Organ dose measurements

- TLD-100 inserted in the slices

On request of medical staff, procedures can be compared



The effective dose

$$E = \sum_T W_T \cdot H_T = \sum_T W_T \sum_R W_R \cdot \bar{D}_{T,R}$$ [J/Kg] = [Sv]

Measurements performed by the Radiation Protection Group of the Lausanne University Hospital
EOS system, O-Arm system, CT procedures ...

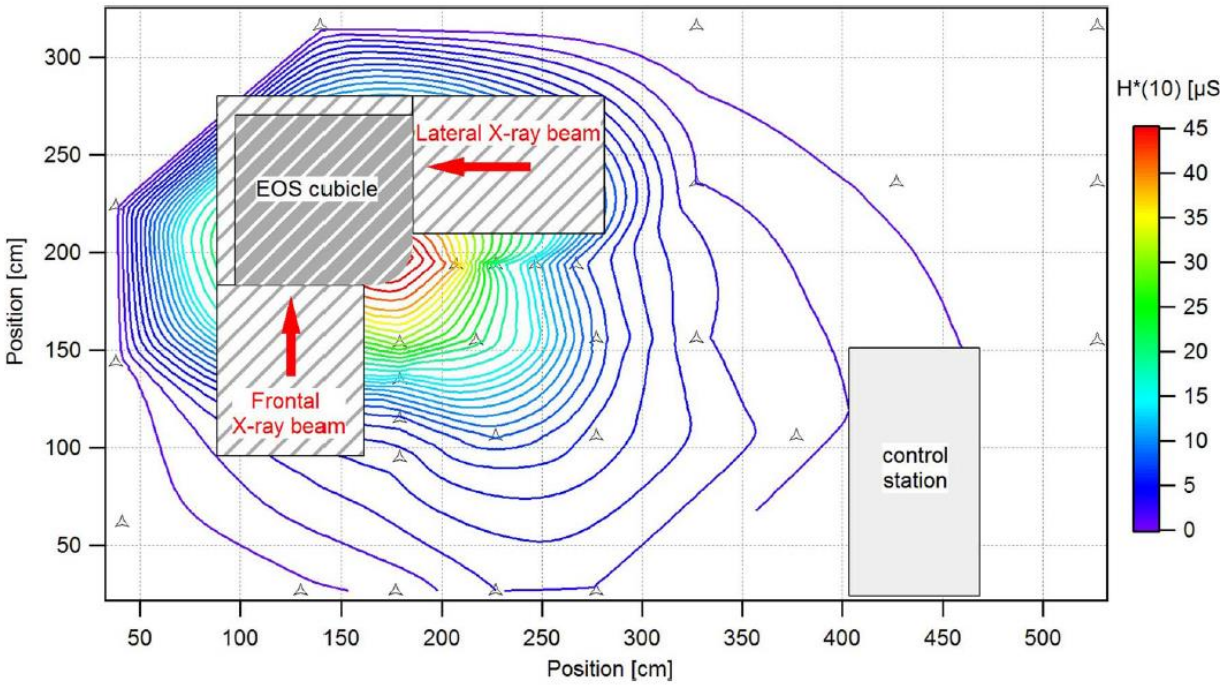


FIG. 2. Isodose curves of $H^*(10)$ in μSv for scatter radiation inside the EOS radiological room for one full spine examination.

The study confirmed the relevance of the use of a protective apron when the medical staff or parents have to stand near to the cubicle during the examination with the EOS system.

Scoliosis diagnosis requires an adequate imaging quality to analyze the deformity of the spine and to determine the extent of the curvature

Patients with scoliosis are often young girls for whom multiple radiological examinations during late childhood and adolescence increases consequently the lifetime risk of developing a radio-induced cancer, especially the risk of breast cancer.

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CHUV

DOSIMETRIC CHARACTERISATION OF THE O-ARM® IMAGING SYSTEM

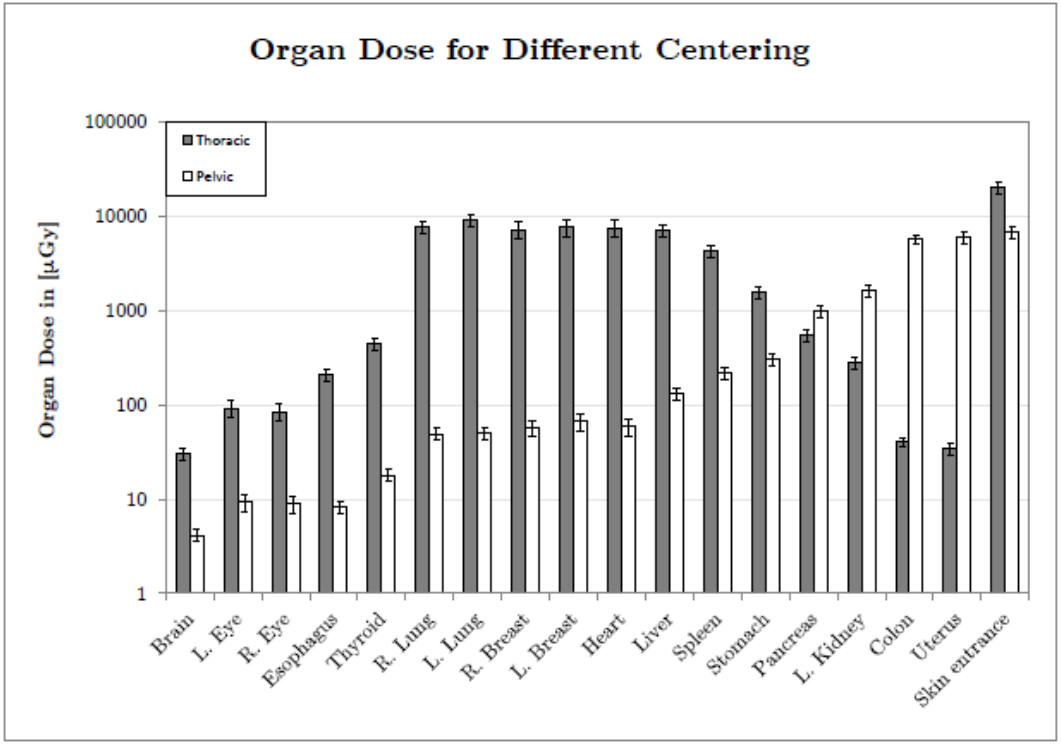
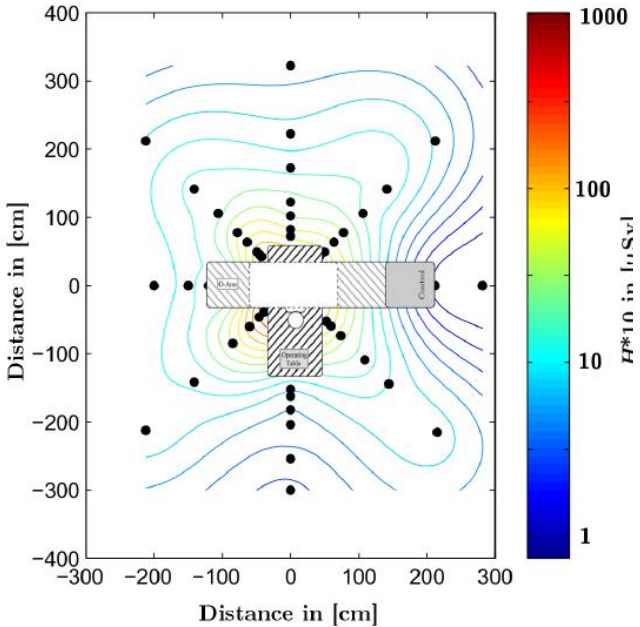
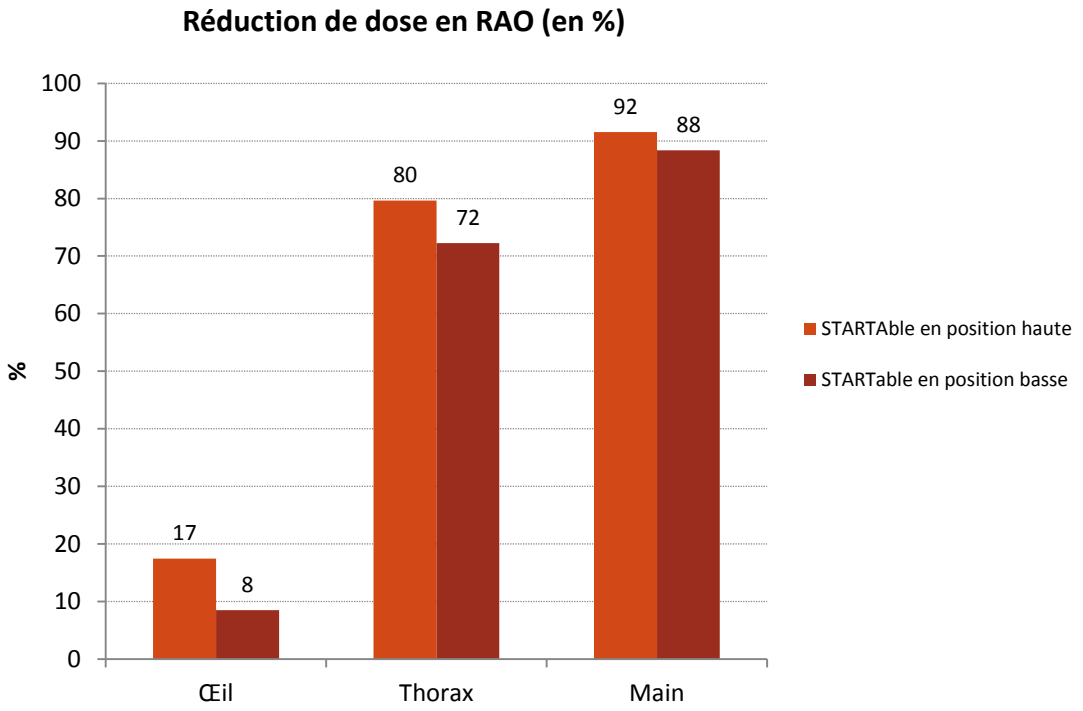


Figure 28 – Complete list of absorbed organ doses for both pelvic and thoracic examinations. The absorbed dose scale is logarithmic, and organs are listed in order from top to the bottom of the body.



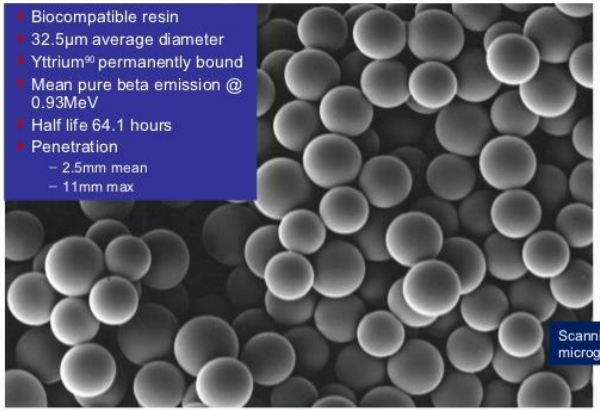
Radiation protection device assessment



Intervention for decontamination in a type B laboratory

SIR-Spheres microspheres

- Biocompatible resin
- 32.5µm average diameter
- Yttrium^{90} permanently bound
- Mean pure beta emission @ 0.93MeV
- Half life 64.1 hours
- Penetration
  - 2.5mm mean
  - 11mm max



1. Data on file, Sirtex Medical Limited

18

582-U-0712

Characteristics of contaminants brings new challenge for the intervention squad.

Characterisation of activated items from cyclotron

ActiWiz software

CERN | HSE Occupational Health & Safety and Environmental Protection Unit

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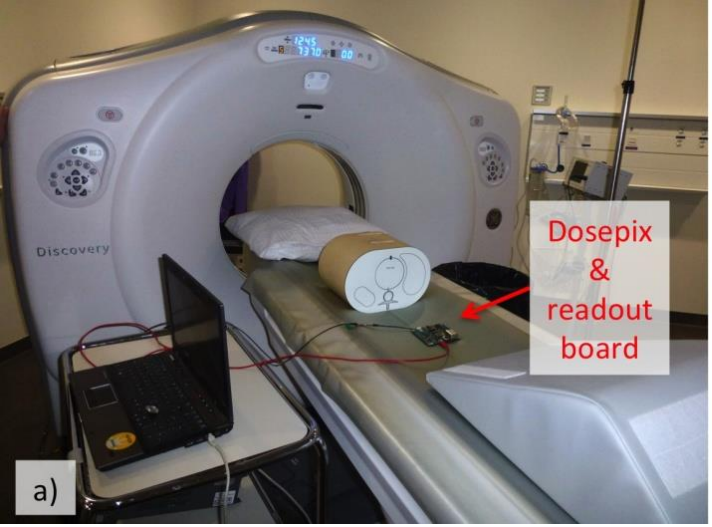
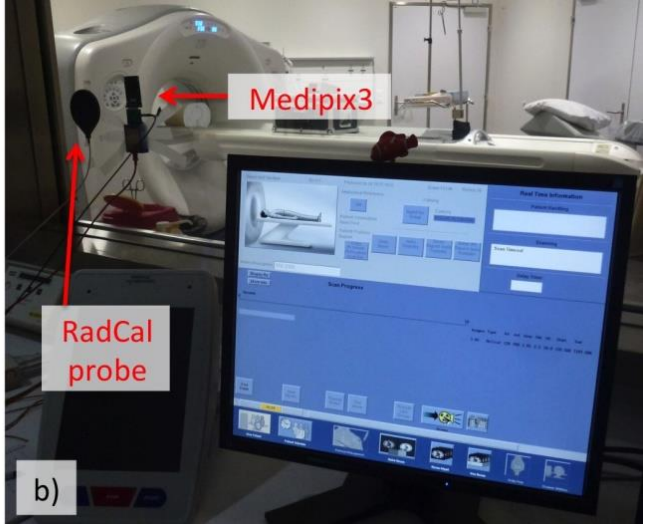
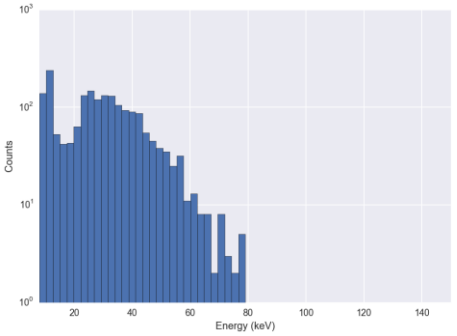
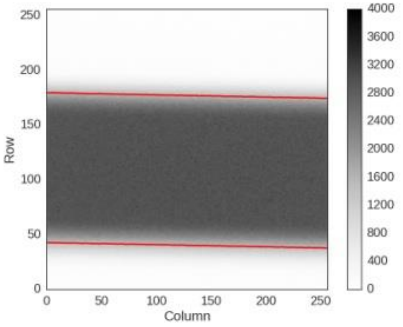




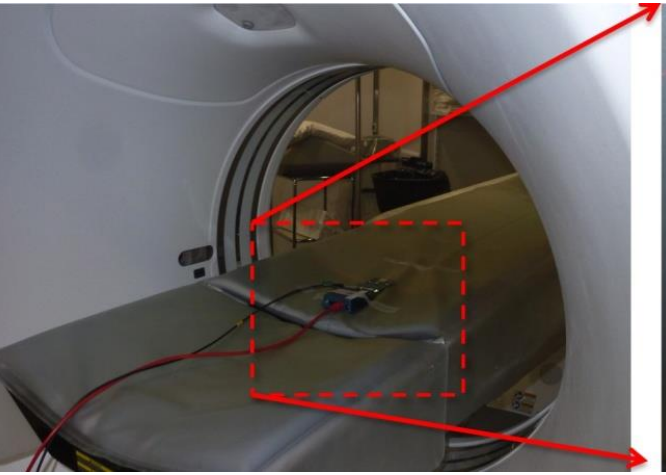


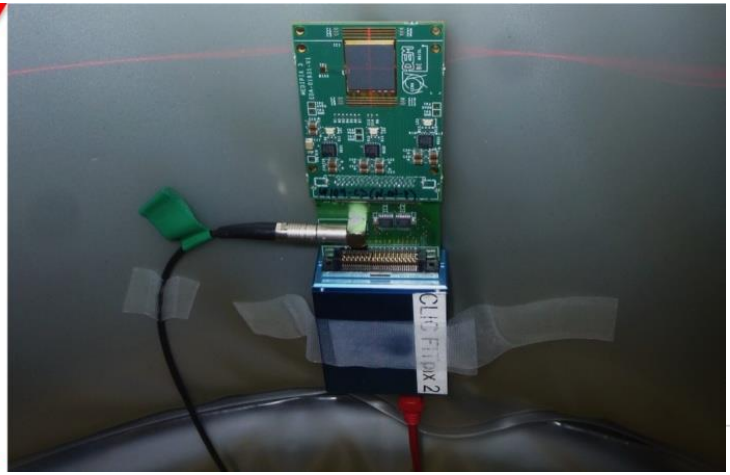
Position 4, on the height of the couch

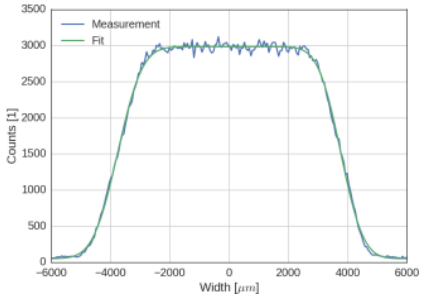
Energy spectra measurements CT scan room



Beam collimation measurement with a Medipix3 chip Medical physics QA

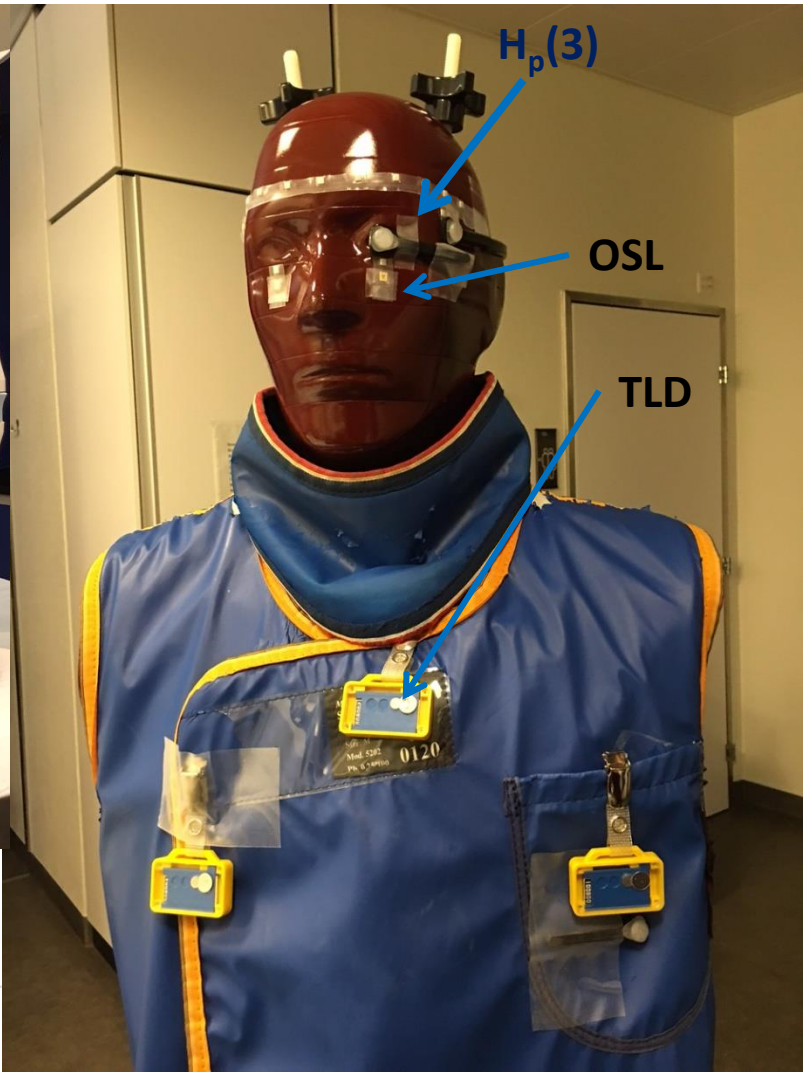






– Characterisation of the scatter radiation fields in interventional radiology/cardiology procedures.
– Develop a personalised eye lens electronic dosimeter used on the Dosepix chip.

Project funded by the CERN Medical Application Committee



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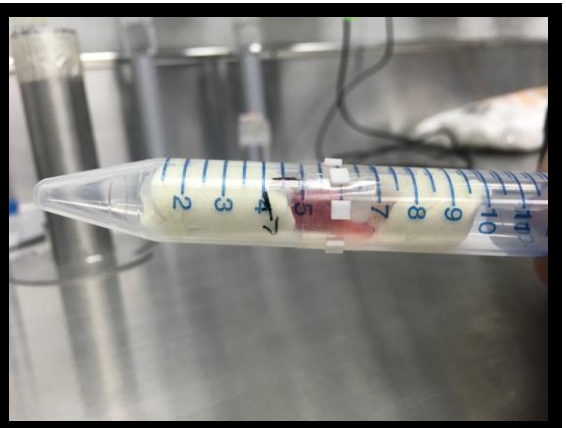
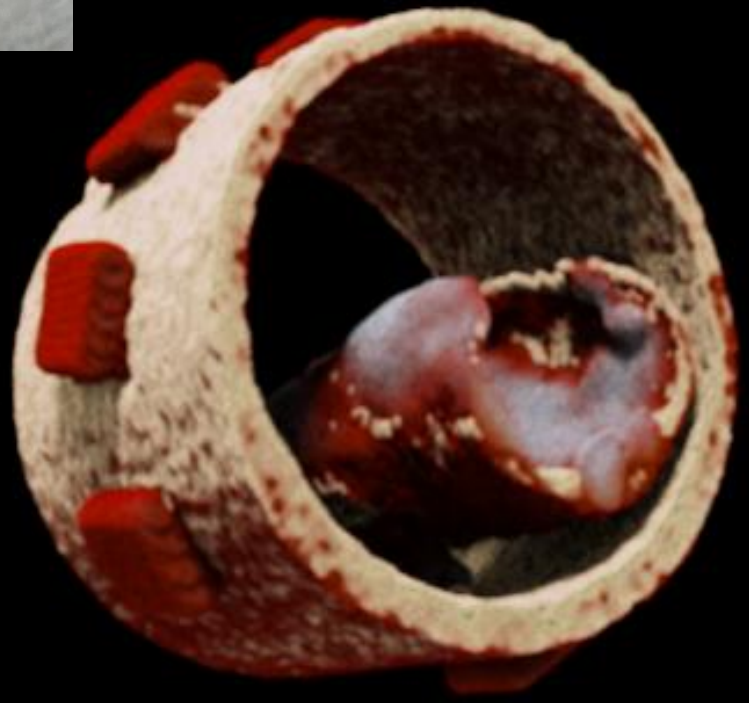
Development of a personalised dosimetry software for spectral CT

R&D + **RPE and MPE** + Radiologists

Project in collaboration with the CERN dosimetry group and universities of Otago and Canterbury in New Zealand

A full dosimetry characterization of the scanner is required and crucial for the human version that's currently under construction, to reduce and optimize as much as possible patients' exposure.

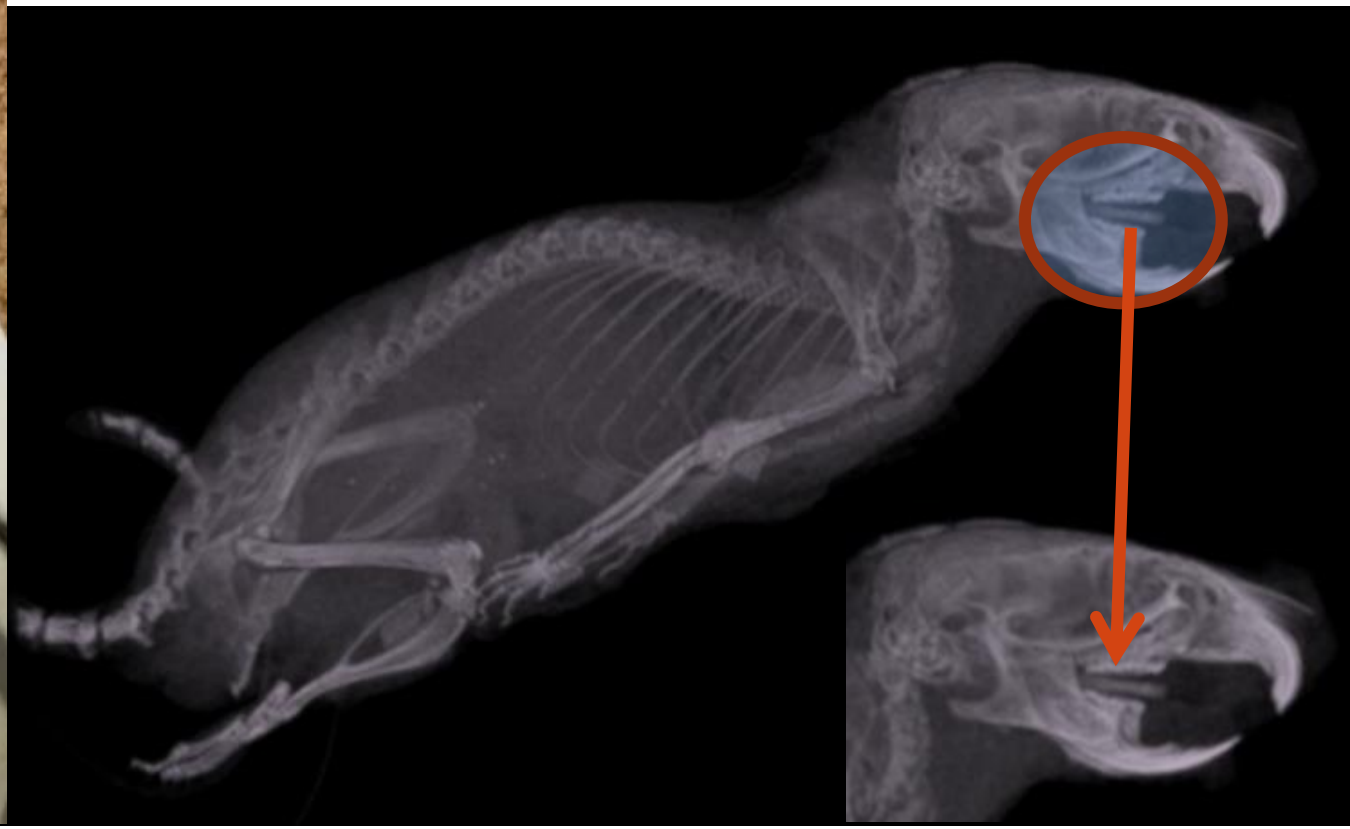




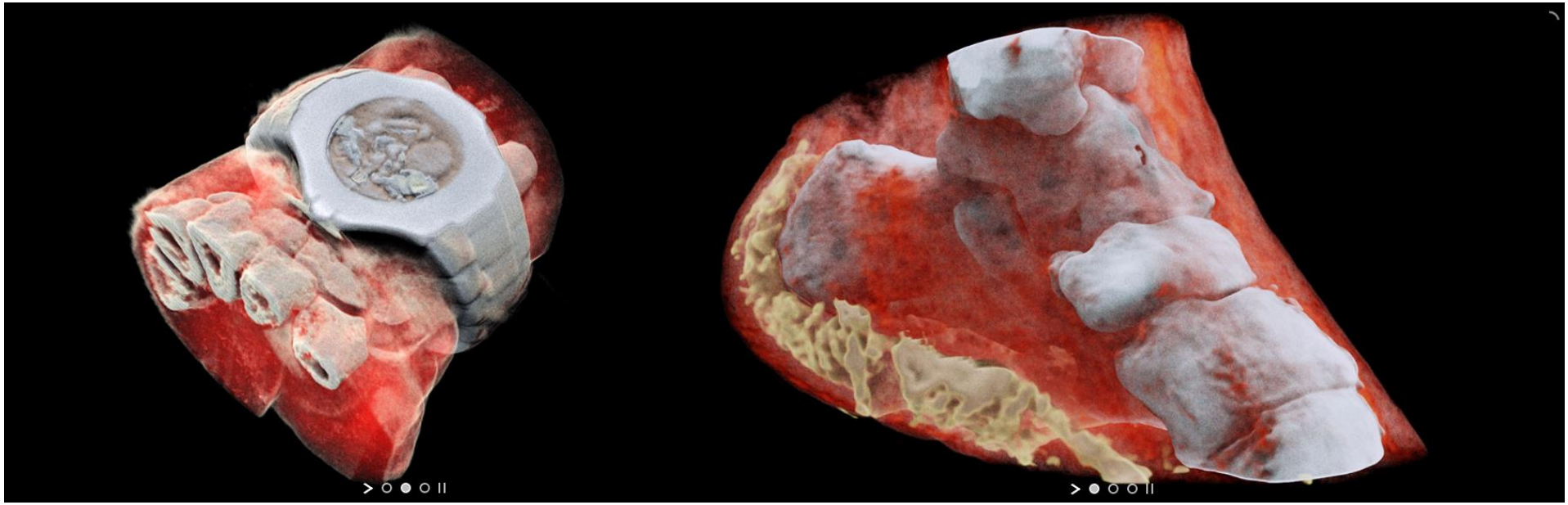
1. Lipid like – yellow
2. Calcium like – greyish / whitish
3. Water like – red

Please note that falcon tube behaves as lipid and water-like in material decomposition; probably due to its elemental composition which has low-density materials

Fist organ dose measurements on mice with the MARS-CT scanner using TLDs placed in plastic bags inserted in a mouse



07.2018: First human imaging with a spectral CT based on solid-state digital detectors



www.marsbioimaging.com/mars

RADIATION PROTECTION AT HOSPITALS

Course goals

- *Describe the goals and objectives of radiation protection*
- *Describe the role of the actors in radiation protection*
- *Give advices in radiation protection in particular situations*