Radiation risk assessment of a medical workplace

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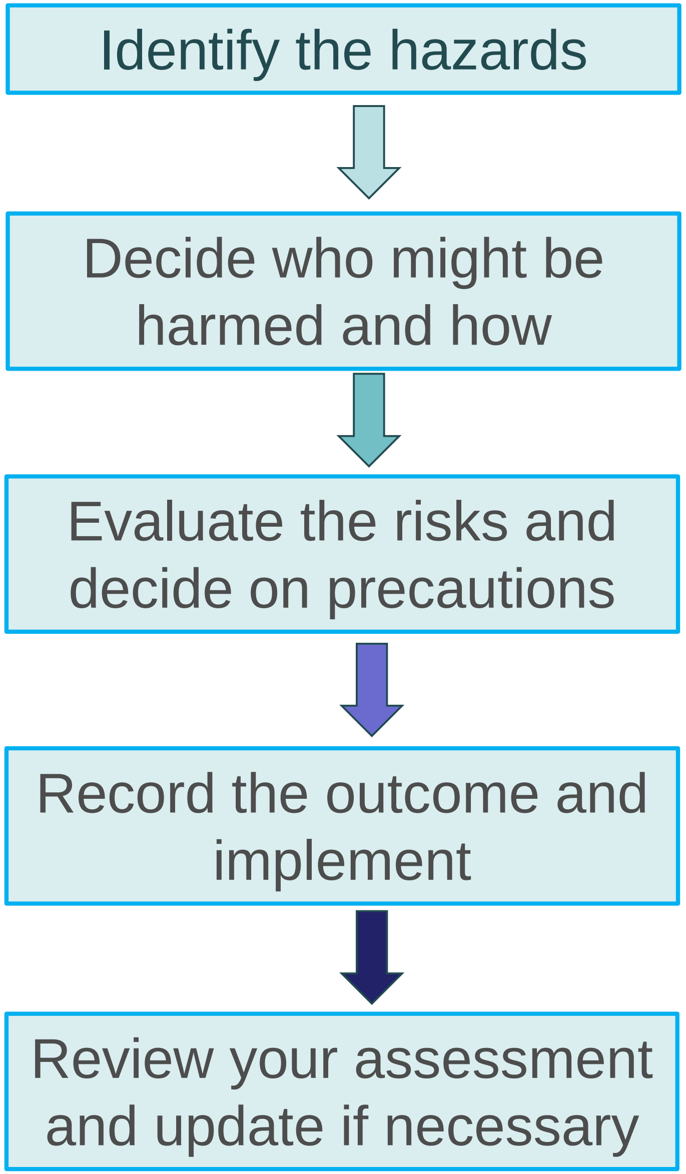
Risk management in radiation protection

- Strategy based on balance of risks and benefits
- ICRP – internationally recommended system of radiological protection
- Three basic principles
  - Justification – net benefit to society
  - Optimization – ALARA
  - Dose limitations

Risk assessment



Risk assessment of the workplace

When?

- Prior to the start of a new work practice with source(s) of ionising radiation
- Before significantly altered work with sources of radiation

Purpose ?

- Evaluate the possibility of exposure to worker and members of the public
- Identify the nature and extent of any radiation hazard that might arise from the intended use of the source, or from an accident or occurrence that can be foreseen

Outcome

- Identify the areas where protective measures should be implemented to reduce exposure to radiation
- Drafting of good radiation protection and safety procedures

Medical workplaces with radiation risks

The “usual suspects”: diagnostic imaging departments

X-rays in radiology department, cathlab and operating theaters

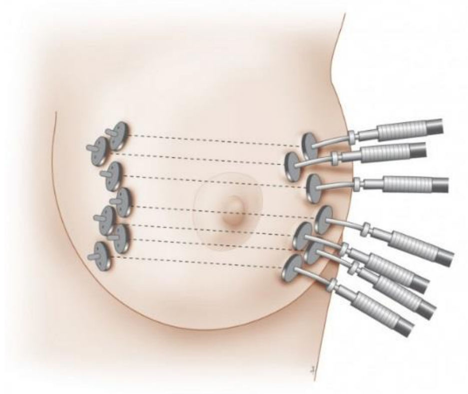


Radioactive tracers in nuclear medicine

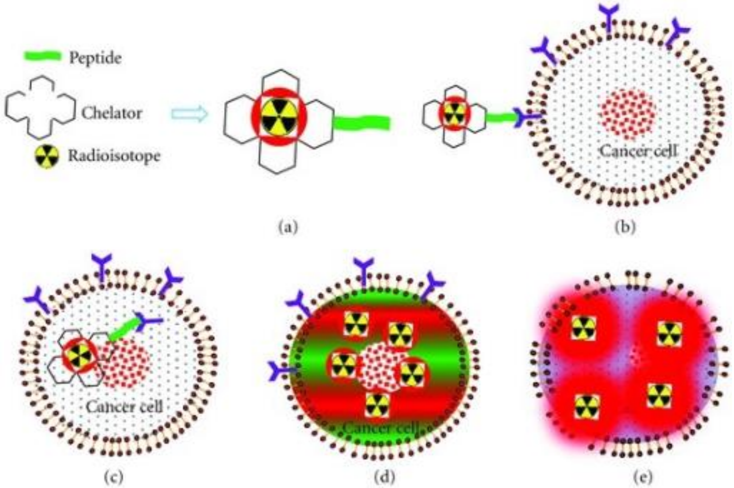

Medical workplaces with radiation risks

The “usual suspects”: radiotherapeutic treatments

medical accelerator



HDR and PDR brachytherapy



radionuclide therapy

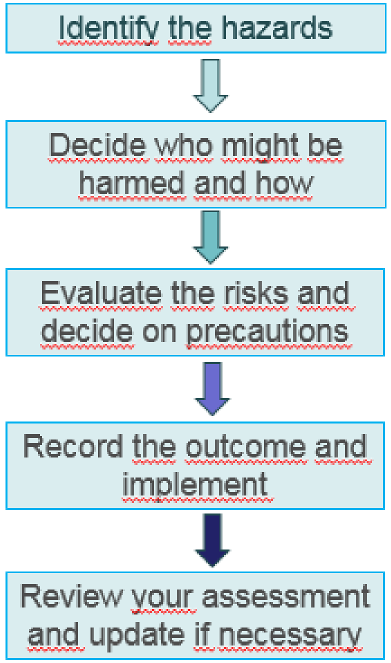
Medical workplaces with radiation risks

But also: production of radiopharmaceuticals within the cyclotron facility and GMP cleanrooms


And radioactive waste management, decommissioning of old radiation devices,…




Step 1: identify the hazards



- **Exposure to external radiation** arising from
  - **close proximity to**
  - **limited shielding of**
  - **prolonged exposure to a source**

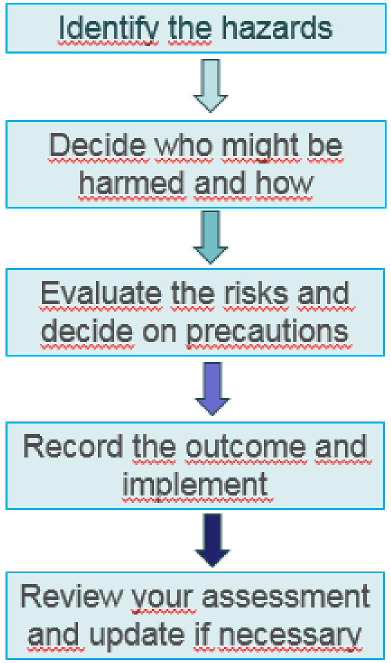
  In addition to **normal operation** consider non-routine operations such as alignment/adjustment and maintenance of equipment.

- **Internal radiation exposure** through **ingestion, inhalation, inoculation or skin absorption**. This could occur as a direct result of **poor containment**, the potential for **contamination**, or **inadequate ventilation controls** (e.g. fume cupboards).

- **Exposure of workers** involved in **handling and disposing of any radioactive waste** (including excretions from the radionuclide therapy patient).

- **Radioprotection in medical facility is part of integrated risk management (patient safety, mechanical safety, infection control,…)**

Step 2: who might be harmed and how



WHO?

- Occupational exposed personnel **who handles the radioactive sources/ radiation equipment**
- Medical personnel that **comes in contact with the patient who receives radionuclide therapy**
- Technical personnel **who does the maintenance** of the radiation equipment/ ventilation system in the controlled area with possibility of airborne radioactive contamination
- Personnel that **caries out the radioactive waste management**, internal **transport of the radioactive source**
- **Persons who aid the radionuclide therapy patient** (family members, …)

Step 2: identify who might be harmed and how

HOW?

Outline the practice/experiment: describe the radiation procedure, amounts of activity, duration, frequency, location.

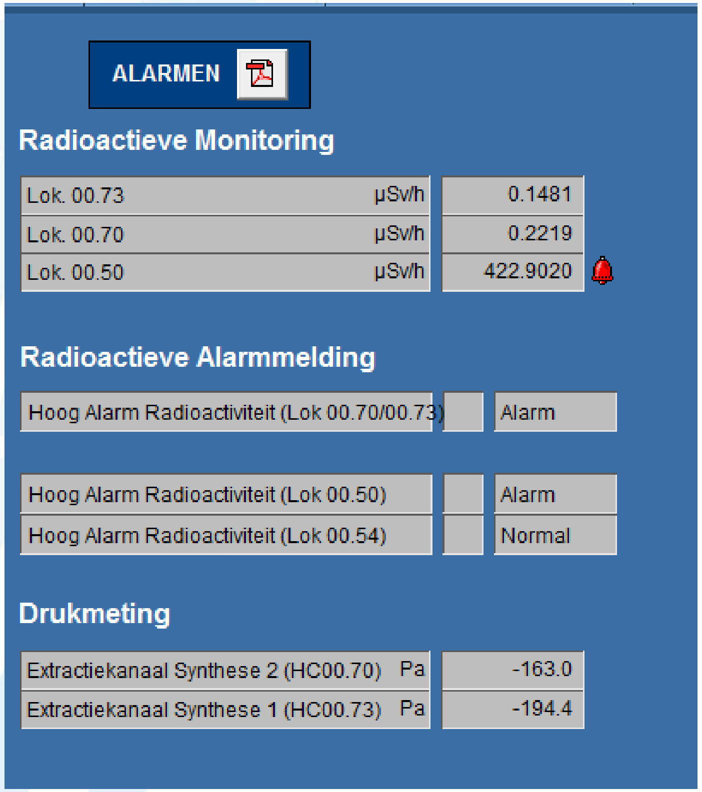
Dose Estimation: prediction of the possible dose assuming that the radiation protection controls are successfully implemented.

- **External doses** can be estimated by:
  - measurement of similar operations using a radiation monitor, for example from indicative dose rate measurements (uSv/hr)
  - calculation: at distances from sources of relevant activity and summated for typical time spent per year.
  - reference to indicative information (scientific literature,...).

In the case of machine sources of radiation a survey may be required to establish dose rates in the vicinity under various operating conditions, including maintenance and adjustment etc.

Estimation of exposure: dose measurement

Area monitoring

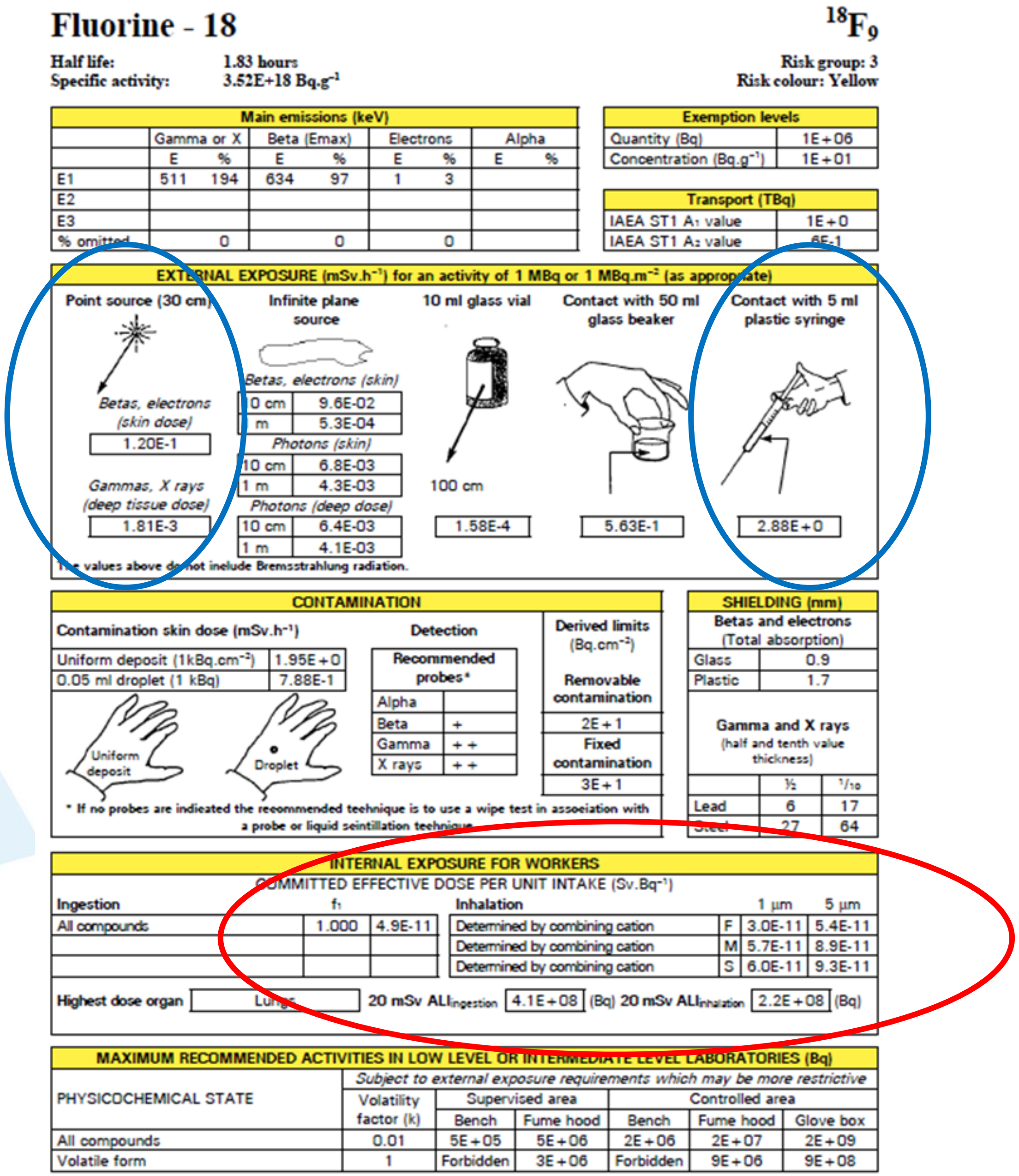


Personnel monitoring

Estimation of exposure: dose calculation

External

Internal



Fluorine - 18

$^{18}F_9$

Half life: 1.83 hours
Specific activity: 3.52E+18 Bq.g^{-1}

Risk group: 3
Risk colour: Yellow

Main emissions (keV)								
	Gamma or X		Beta (Emax)		Electrons		Alpha	
	E	%	E	%	E	%	E	%
E1	511	194	634	97	1	3		
E2								
E3								
% omitted		0		0		0		

Exemption levels	
Quantity (Bq)	1E+06
Concentration (Bq.g^{-1})	1E+01

Transport (TBq)	
IAEA ST1 A_1 value	1E+0
IAEA ST1 A_2 value	6E-1

EXTERNAL EXPOSURE (mSv.h^{-1}) for an activity of 1 MBq or 1 MBq.m^{-2} (as appropriate)

Point source (30 cm)

Betas, electrons (skin dose): 1.20E-1

Gammas, X rays (deep tissue dose): 1.81E-3

Infinite plane source

Betas, electrons (skin)	
10 cm	9.6E-02
1 m	5.3E-04
Photons (skin)	
10 cm	6.8E-03
1 m	4.3E-03
Photons (deep dose)	
10 cm	6.4E-03
1 m	4.1E-03

10 ml glass vial — 100 cm: 1.58E-4

Contact with 50 ml glass beaker: 5.63E-1

Contact with 5 ml plastic syringe: 2.88E+0

The values above do not include Bremsstrahlung radiation.

CONTAMINATION

Contamination skin dose (mSv.h^{-1})	
Uniform deposit (1kBq.cm^{-2})	1.95E+0
0.05 ml droplet (1 kBq)	7.88E-1

Uniform deposit — Droplet

Detection: Recommended probes*	
Alpha	
Beta	+
Gamma	+ +
X rays	+ +

Derived limits (Bq.cm^{-2})	
Removable contamination	2E+1
Fixed contamination	3E+1

* If no probes are indicated the recommended technique is to use a wipe test in association with a probe or liquid scintillation technique.

SHIELDING (mm)

Betas and electrons (Total absorption)	
Glass	0.9
Plastic	1.7

Gamma and X rays (half and tenth value thickness)	½	1/10
Lead	6	17
Steel	27	64

INTERNAL EXPOSURE FOR WORKERS

COMMITTED EFFECTIVE DOSE PER UNIT INTAKE (Sv.Bq^{-1})

Ingestion	f_1	
All compounds	1.000	4.9E-11

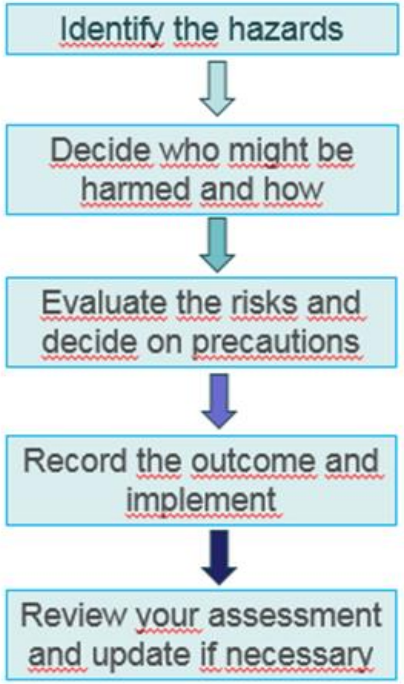
Inhalation		1 µm	5 µm
Determined by combining cation	F	3.0E-11	5.4E-11
Determined by combining cation	M	5.7E-11	8.9E-11
Determined by combining cation	S	6.0E-11	9.3E-11

Highest dose organ: Lungs — 20 mSv $ALI_{ingestion}$ 4.1E+08 (Bq) — 20 mSv $ALI_{inhalation}$ 2.2E+08 (Bq)

MAXIMUM RECOMMENDED ACTIVITIES IN LOW LEVEL OR INTERMEDIATE LEVEL LABORATORIES (Bq)

PHYSICOCHEMICAL STATE	*Subject to external exposure requirements which may be more restrictive*					
	Volatility factor (k)	Supervised area		Controlled area		
		Bench	Fume hood	Bench	Fume hood	Glove box
All compounds	0.01	5E+05	5E+06	2E+06	2E+07	2E+09
Volatile form	1	Forbidden	3E+06	Forbidden	9E+06	9E+08

Step 2: who might be harmed and how

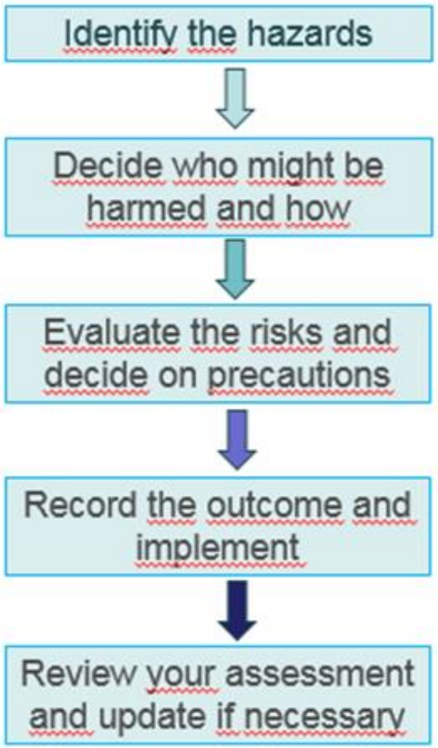


HOW?

Dose Estimation:

- **Internal doses** can be received through inhalation of volatile radioactive emissions, absorption through the skin (accidental spillage or contaminated surfaces) or by ingestion.
  - The procedure should be evaluated to identify those steps and **identify the controls to be applied to restrict** this.
  - An indication of the potential for internal hazard can be gained from **comparison of the ALI (Annual Limit on Intake)** for the isotope with the quantity to be handled.

Step 3: Evaluate the risks
Decide on precautions



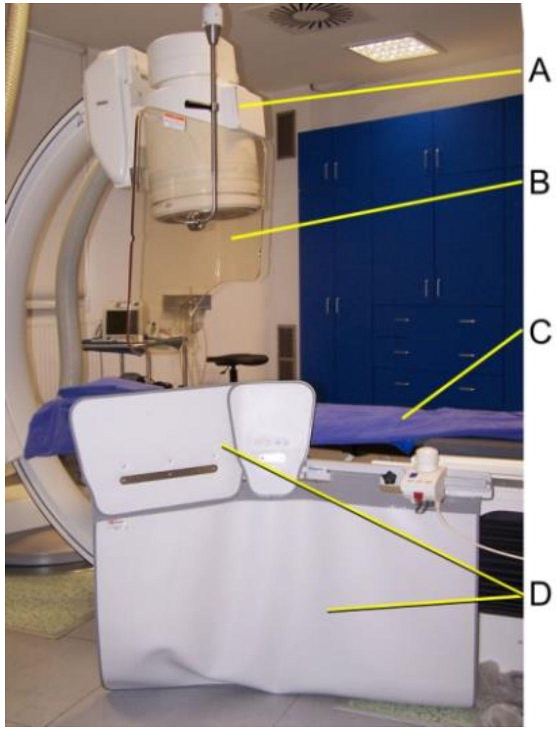
Control of Exposure

Description of the steps taken to control radiation exposure, both external and internal:

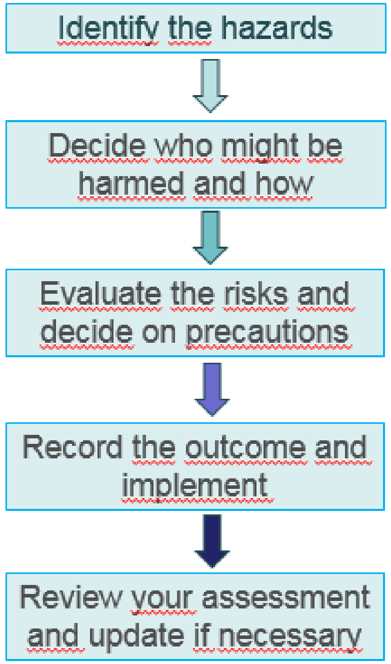
- **Physical precautions:**
  - Designation and suitability of the workplace
  - Access restriction
  - Containment
  - Shielding
  - Safety features

- **Procedural precautions:**
  - design of procedure: work procedure, procedure describing the safety features, incident procedure, training of the work practices involved, of the safety measures being taken
  - competence of personnel: education on new techniques, optimization,…

Access restriction – Containment - Shielding



Step 4: Record the outcome + implement



- The methods to reduce or eliminate exposure will need to be incorporated into the local rules and/or experimental protocols.

  Logbooks: inventory on contamination monitoring, storage of sources,…

- The radiation worker(s) concerned should receive information, instruction and training in the risks of the work and the safe conduct of this.

  Records of training should be maintained

- Effective supervision to confirm procedures/safety measures are operating correctly

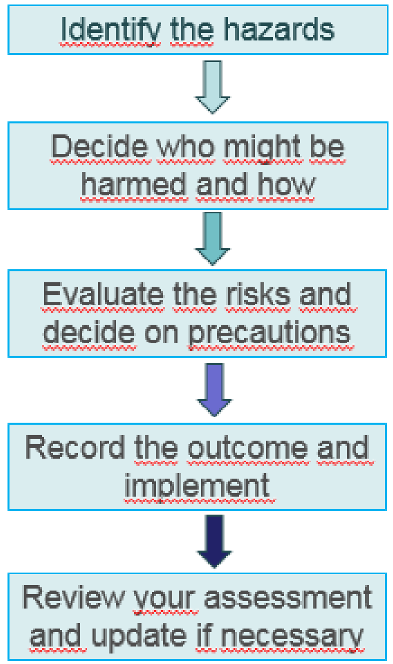
  Keeping records of the regular control of safety features installed

  Installation of a warning system in case of faulty equipment with a safety function

  Permanent radiation monitoring in high risk areas

Implement your radioprotection plan on the work floor while following the clinical goals

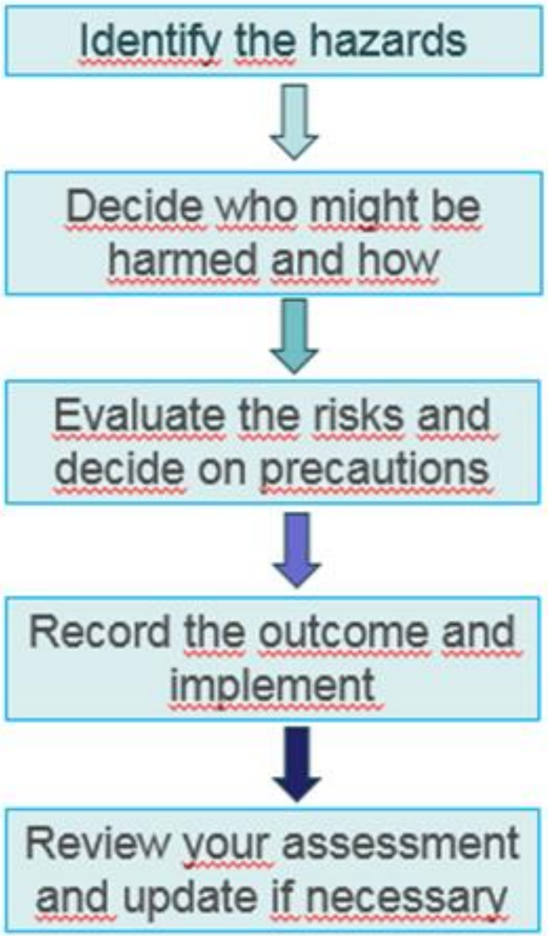
Step 5: Review your assessment
Update if necessary



Examples that would require a review of the risk assessment

- The introduction of a new radioactive source of a much larger activity, or a source emitting a different type or quality of radiation
- The introduction of new work practices which require new radioactive sources or irradiating apparatus e.g. in radiotherapy, nuclear medicine
- The introduction of unsealed sources in an area where only sealed sources have previously been used
- Work station modifications, including engineering controls and safety features
- Changes to processes or methods of work.

Risk assessment making high activity Y-90 radionuclide therapy agents



Step 1: Y-90 is a high energetic beta-emitter. It is used for RNT purposes, so at high activities (GBq) and in liquid form

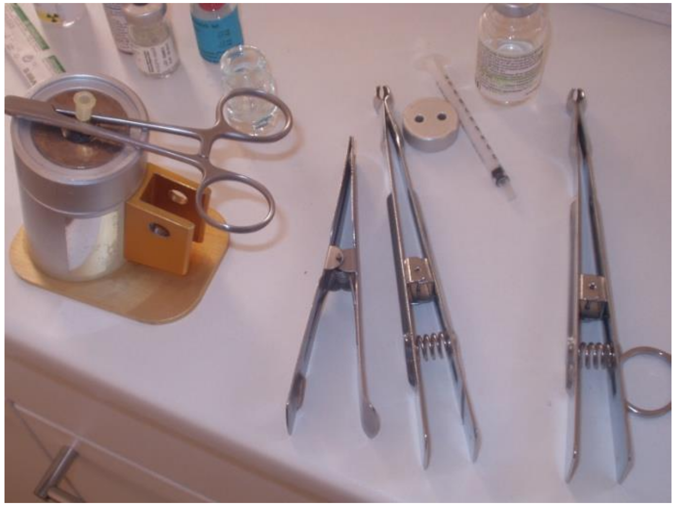
Step 2: The operator handling the radiopharmaceutical

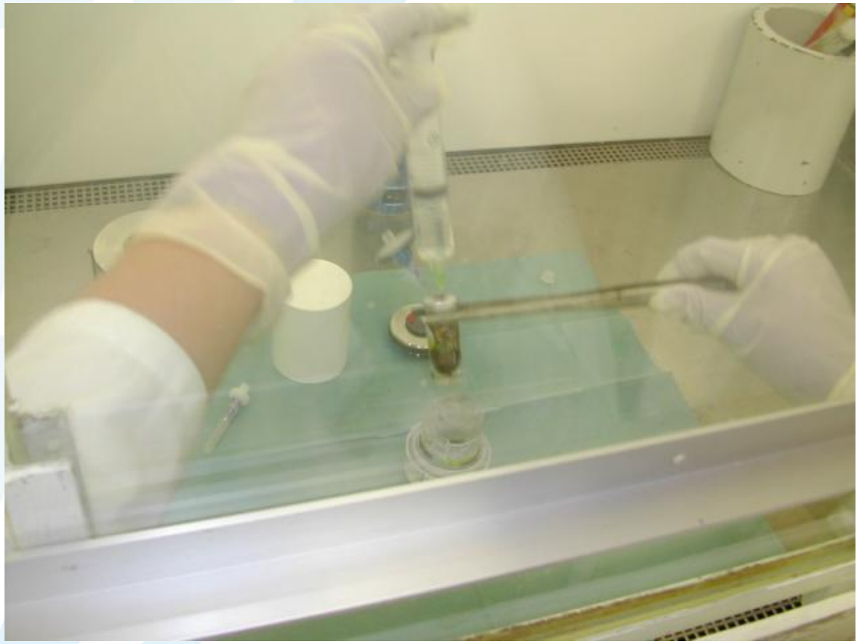
Step 3: Risks are external and internal exposure
Contamination → avoid spills and direct contact with the pharmaceutical fluid, work in a dedicated workspace (eg. Shielded LAF-cabinet)
Manipulation can result in high finger dose → use tweezers (distance principle); syringe shielding and plexi screens (shielding principle)

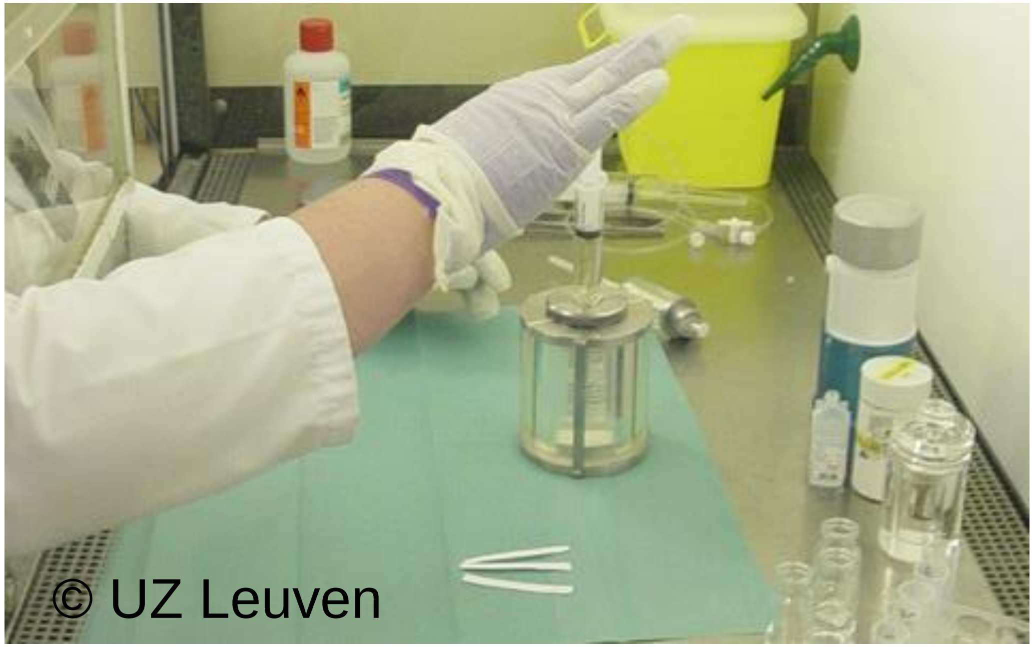
Step 4: follow-up of finger dose, write SOP

Step 5: optimize safety measures based on dose results

Risk assessment making high activity Y-90 radionuclide therapy agents



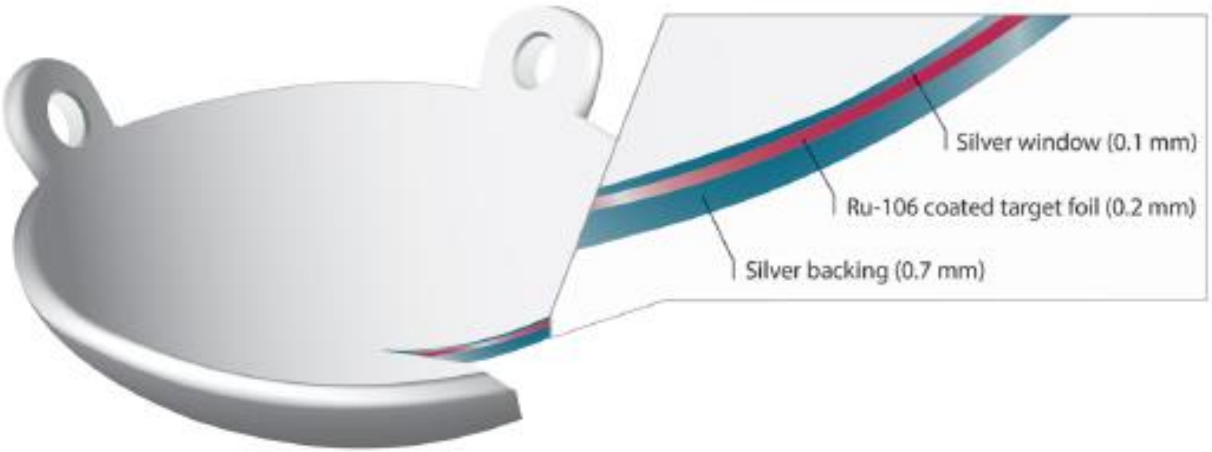


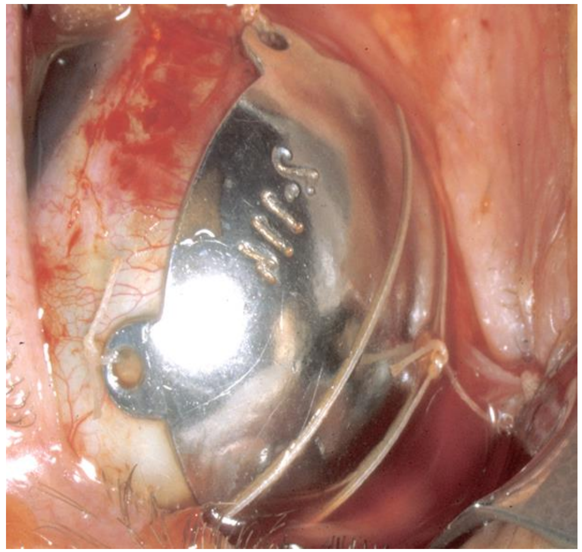


Risk assessment for the introduction of Ru-106 eye plaques in brachytherapy for eye tumours

Unique Plaque Design

The core of the Ru-106 Eye Applicator consists of a foil coated with Ru-106/Rh-106. This core is safely encapsulated within pure silver sheets. The silver backing acts as a radiation shield and absorbs approximately 95 % of the beta radiation.

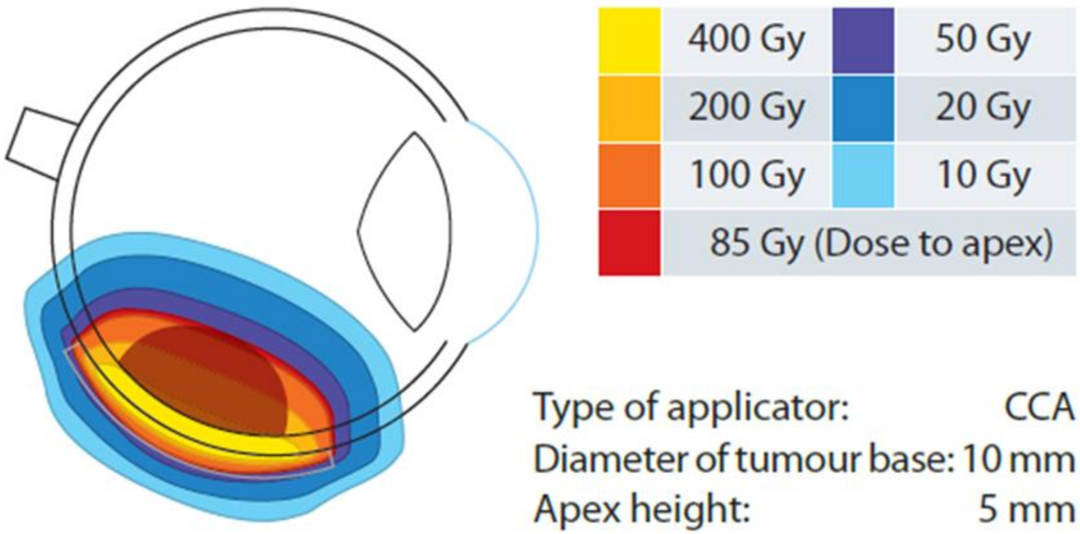




Step 1: identify the risk

- Ru-106 / Rh-106 => Pd-106: Sealed source, ß-emitter (ßmax: 3,5 MeV)
- Reusable up to 18 months: Needs steam sterilisation after application (max. 50 cycles)
- Produced with nominal reference dose rate of 80 mGy/min based on the shipping date. Production-related tolerances ranging from -10% to +60% are possible.
- Application time: 3 – 7 days

Risk: external exposure



High dose at the base of the tumour while sparing the organs at risk.

Step 2: Who might be harmed and how

- Equivalent dose rate around the patient ?

  Assumptions: Source activity: 20 MBq , shielding: 1.5 cm tissue

  Estimated equivalent dose rate due to γ-radiation: At 10 cm: 55 μSv h-1

  At 30 cm: 15 μSv h-1

  At 1 meter: 1 μSv h-1

  β radiation is completely absorbed by the patient

	Handeling	Locatie	Medewerker(s)	Type zone
1	Indienststelling en geregelde fysische controle applicator	168.01.07.07 (berging 3)	Medewerker radioprotectie	Bewaakt
2	Applicator klinisch vrijgeven	168.01.07.07 (berging 3)	Medisch fysicus	Bewaakt
3	Applicator gereedmaken voor sterilisatie	168.01.07.07 (berging 3)	Medewerker Oka oogziekten	Bewaakt
4	Applicator steriliseren in de volledig afgeschermde Sterilisatiecontainer	Sterilisatie OKA oogziekten – 168.01.07.03	Medewerker Sterilisatie	
5	Applicator aanbrengen op het oog van de patiënt	E770 - OKA oogziekten	Oogchirurg	
6	Verpleging van patiënt met de applicator	E 722	Verplegend personeel	
7	Applicator verwijderen-ontladen van de patiënt	E770 - OKA oogziekten	Oogchirurg	
8	Applicator schoonmaken en opslag in loodkluis	168.01.07.07 (berging 3)	Medewerker Oka oogziekten	Bewaakte

Step 3: Evaluate the risks + Decide on precautions

Radioactive encapsulated source:

- Provide shielding for source and workstation
- Lockable storage
- Symbol of ionizing radiation: designated area
- The necessary protective equipment is present: tweezers to manipulate source, source and sterilization container, ...
- Emergency procedure present + contact details of who to contact
- Regular leak/wipe tests to verify the integrity of the source ...

New medical application:

mandatory commissioning = approval of type of source and testing of safety devices

Quality Control (QC) =

- calibration test of the source: medical physics
- intactness encapsulated source: health physics

Voor – en zijaanzicht van de werkpost in lokaal 168.01.07.07 .

Step 4: Record the outcome + implement

Doserate during manipulation of the source

Voor de verschillende Ru-106 oogapplicatoren worden de volgende maximale dosistempi gemeten (in µSv/h) op het moment van indienststelling op 11 januari en op 1 februari 2018.

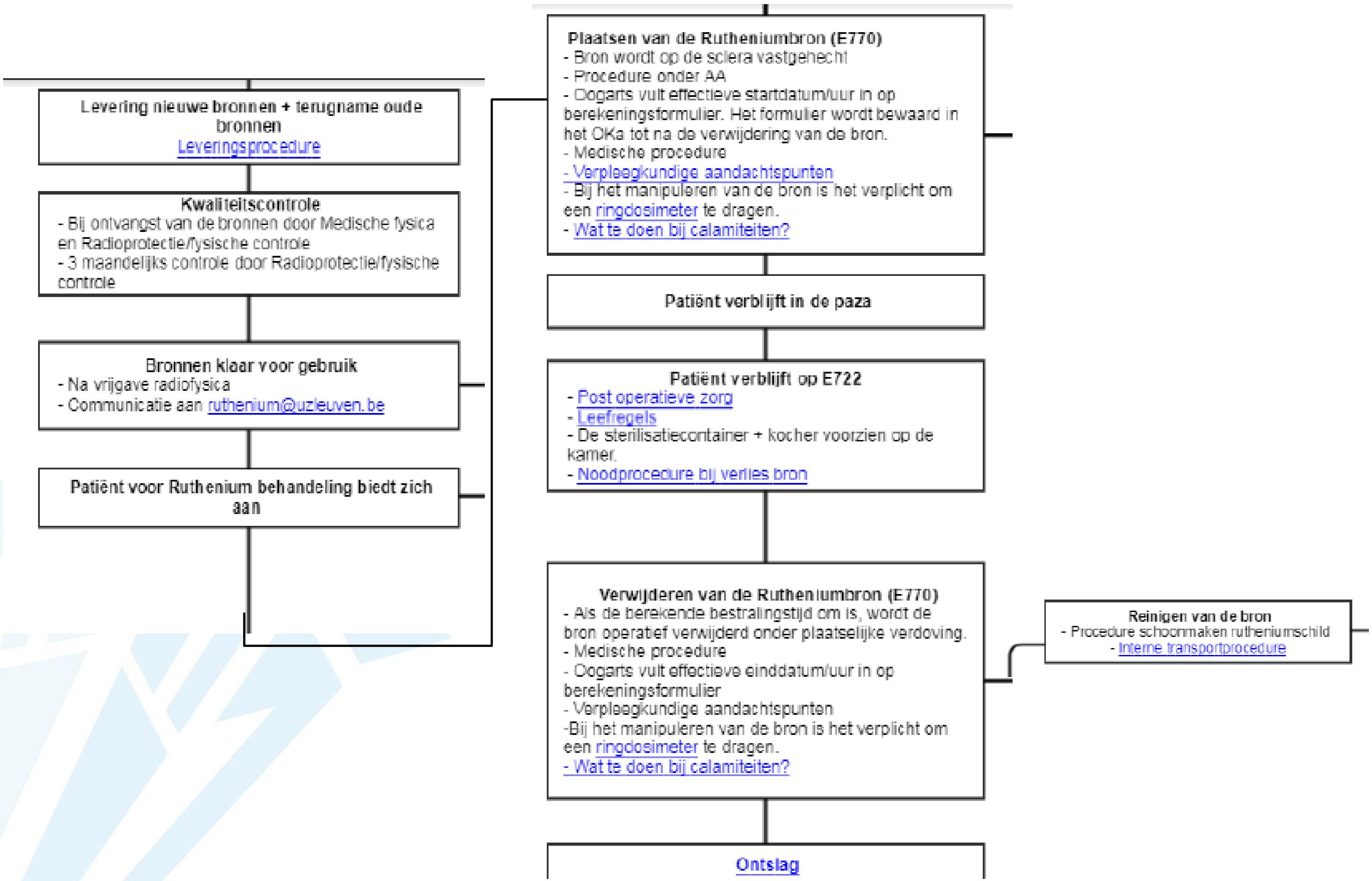
Ruthenium oogapplicator	Holle zijde Hp(10) γ-straling	Holle zijde Hp(0.07) β-straling	Bolle zijde Hp(10) γ-straling	Bolle zijde Hp(0.07) β-straling
CCA (#2297) @ contact	22000	50000	460	2000
CCA @ 5 cm	3500	10000	250	950
CCA @ 12 cm	2400	6200	80	210
CCA @ 30 cm	780	1600	25	60
CCA @ zijopening loodkasteel	100	150	5	20
CCA @ voor operatorscherm	< 1	6	< 1	6

Dose rate during cleaning of the source

Bron ondergedompeld in potje waterige oplossing min. 5 cm hoog gevuld (bron met de bolle kant naar boven)	
CCA @ 3 cm (bij contact aan zijkant)	52
CCA @ 5 cm (waar potje wordt vastgehouden)	40
CCA @ 7 cm (vlak boven potje)	32
CCA @ 30 cm (boven potje)	6
CCA @ 100 cm (boven potje)	1

Step 4: Record the outcome + implement

SOP: integrate in the total medical workflow



Thank you

More information? niki.bergans@kuleuven.be