TG 117: Radiological protection for PET imaging

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Objective

DRAFT REPORT FOR CONSULTATION: DO NOT REFERENCE
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Radiological Protection in Positron Emission Tomography

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- ✓ Public consultation (Aug-Dec 2023)
- ✓ Workshop

- ✓ Approved for publication (May 2024)

Positron Emission Tomography (PET)

- **Nuclear medicine imaging procedure**
- **Multimodal imaging particularly with**
  - computed tomography (CT)
  - magnetic resonance (MR)

PET importance

- **The number of scans has increased in recent years.**
- **Increasing the patient effective dose delivered in nuclear medicine.**

Radiation doses

- Administered activity
- CT utilization

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Positron Emission Tomography (PET)

PET radionuclides

- **Short half-lives**
- **High energies of annihilation photons (511 keV)**

→ **Particular challenges for staff radiological protection**

The publication provides guidance on

- patient
- public
- occupational

radiological protection in PET

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Radiological Protection in Positron Emission Tomography

1. Introduction
2. PET and PET/CT principles
3. PET/CT facility design
4. Imaging equipment life cycle
5. Justification and optimisation of PET, PET/CT and PET/MR
6. Optimisation related to the medical exposure of patients, carers/comforters, and research volunteers
7. Radiation protection for the public
8. Optimisation for staff
9. Dose management and quality assurance program
10. Education and training in radiological protection

PET and PET/CT principles

- Patient preparation
- Performance of the PET/CT scanner
- Acquisition and reconstruction parameters

➢ Image quality
➢ Dose received by the patient

New PET equipment

✓ Improved resolution
✓ Extended field of view
✓ Increased sensitivity
✓ Extended acquisition modalities
✓ Improved reconstruction techniques

➢ Reduce image noise
➢ Without increasing administered activity

PET radionuclides need (short half-life)

- on-site cyclotron
- fast distribution system
- generator systems

➢ **Requires specific radiological protection for the staff**

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PET and PET/CT principles

- Patient preparation
- Performance of the PET/CT scanner
- Acquisition and reconstructi

➢ Image
Dose re

radiological
protection

New PET

Knowledge of the technology

- ✓ PET, principles and technology
- ✓ CT Technology
- ✓ PET/CT
- ✓ PET/MR
- ✓ Cyclotron
- ✓ Clinical applications and radiopharmaceuticals

uires (short half-life)

- yclotron
- fast distribution system
- generator systems

➢ **Re ecific**
ra protection
for

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PET/CT facility design

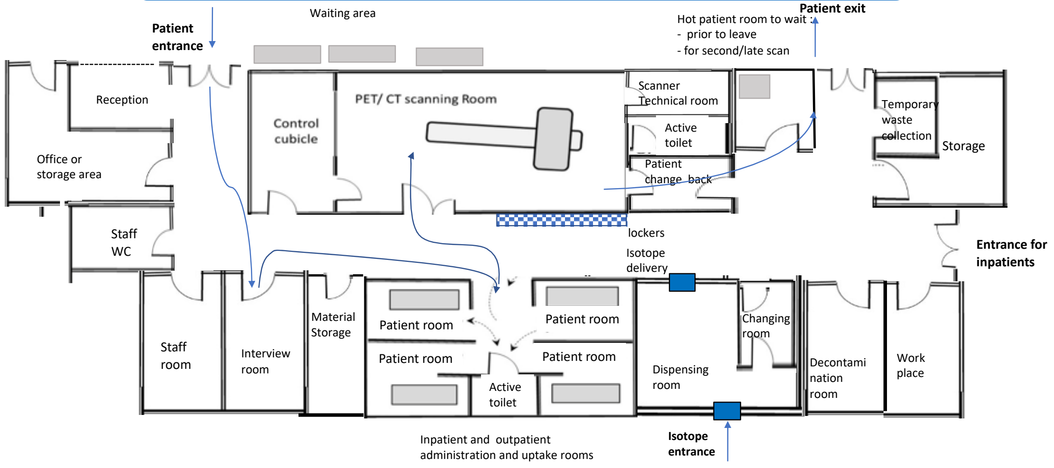
Planning and layout of the PET facility

Direct impact on radiological protection for

- patients
- staff
- public

Protection against
- ✓ Irradiation
- ✓ Contamination

movement of the patient



Radionuclide production
- Cyclotron vaults
- Radionuclide transfer systems

Pharmaceutical preparation
- Laboratory facilities

Imaging part of the facility
- Administration and resting rooms
- Scanner room

shielding and automation

PET/CT facility design

Key points

- **Cyclotron vaults** should be planned and constructed primarily to protect against **secondary neutron** radiation and **concrete** is the primary material normally used.
- Shielding requirements will depend on the incorporation of **self-shielding.**
- **Radionuclide transfer** systems within a cyclotron facility should be designed **to minimise leakage** and staff exposure, and pressures and airflow designed **to limit spread of any airborne contamination.**
- PET/CT facilities require **shielding** against almost **continuous low dose rate exposure from 511 keV** photons emissions and **short higher dose rate CT** x-ray exposures.
- Protection of walls against **511 keV photons** using **concrete** will dominate shielding requirements, but scattered **CT x rays** must be **considered** for the scanning room doors and windows.
- **Handling of PET radiopharmaceuticals** during synthesis, filling vials and dispensing in shielded syringes should be **automated as much as possible**.
- **Patients remain in the PET facility** for several hours including a rest period following 2-[^{18}F]FDG administration that may be 60 minutes. **Planning movement of the patient through the department** to minimise exposure of staff members is crucial.
    - The provision of shielded rooms for resting patients, the location of active toilets to minimise distances of any patient movement, and the siting of patient facilities adjacent to the scanning room are all important.

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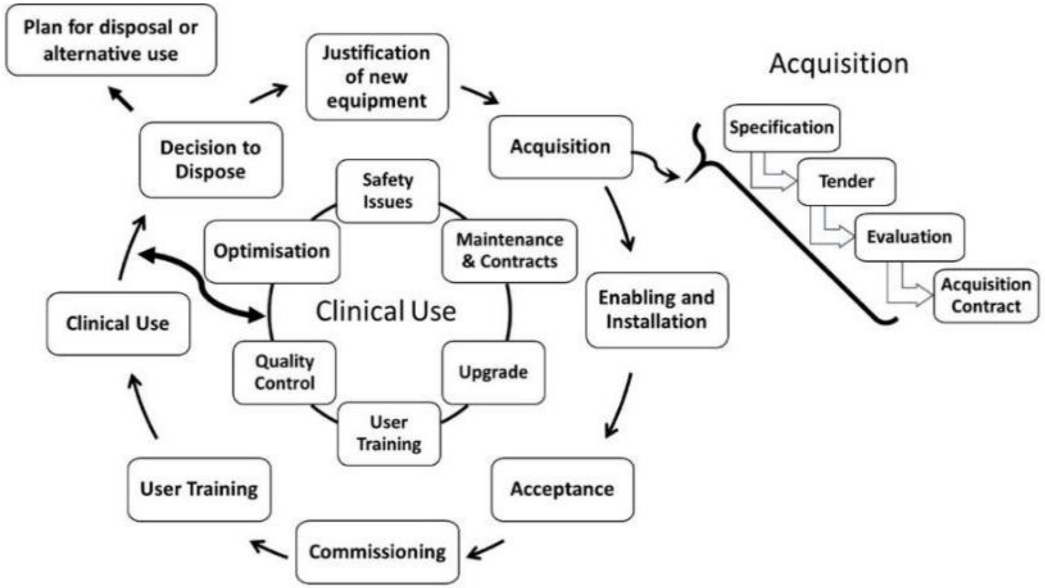
Imaging equipment life cycle

Key points

- The equipment life cycle is a well **understood concept,** and describes medical equipment, including imaging equipment, from 'cradle to grave'.
- **The skills of each of the professionals** involved should be respected in a **team approach,** using the methodology, expertise, and the process controls available **for the optimal management of equipment** throughout its **life cycle**.
- The **stages in the planning and creation** of a PET/CT **facility** include justification, specification, acquisition, installation, acceptance, commissioning, user training, before the system is put into clinical use.



- The **QA programme** should comprise **equipment performance evaluation during clinical use,** and include QC measurements to verify that systems and components of the PET/CT imaging system **operate effectively and meets specifications.** They should include **appropriate maintenance** arrangements in place and require a system for ongoing **staff training** after upgrades, **periodic review** of policies and procedures, and review of dose misadministrations and near miss events.

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Justification and optimisation of PET

Key points

- **Justification** of PET, PET/CT, and PET/MR should be established by **considering** the characteristics **of evolving imaging technologies**, and especially by **taking advantage of the unique hybrid imaging features** with PET/CT and PET/MR.
- **Evidence on diagnostic accuracy and clinical value** of PET, PET/CT, and PET/MR is increasingly **endorsing appropriate use** in clinical areas including oncology, neurology, and cardiology.
- The use of PET, PET/CT, or PET/MR **for an individual patient should be justified**, which can be facilitated in clinical situations by following **referral criteria** or appropriateness **criteria** that have been **proposed by professional bodies**.
- Consideration of the **estimated radiation dose to the patient** from the PET radiopharmaceutical and the CT scan **and desired image quality** will form **part of the justification and optimisation process** for PET/CT imaging.

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Optimisation related to the medical exposure

Key points

- The **total radiation dose** from a PET/CT examination is the combined dose from the **PET radiopharmaceutical** and from the **CT**.
- **New** PET, PET/CT, or PET/MR **hardware and software**, operated by appropriately **trained and educated staff**, can **optimise radiological protection**, through **reducing radiation dose** while **maintaining image quality**.
- ICRP recommends the **constitution of national DRLs to optimise protection** in the medical exposure of patients for diagnostic and interventional procedures including PET and PET/CT. DRL values **are not static**.
- **Infants and children** have a higher risk of cancer after radiation exposure, versus adults. This patient population deserves **special consideration relative to justification and optimisation** in the PET and the CT components of the procedure.

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Radiological protection of the public

Key points

- Patients undergoing diagnostic PET radiopharmaceutical studies generally **do not pose a significant radiation risk to the public**

- **Radiological protection measures** **for**

✓ Administered activity ✓ Distance ✓ Time ✓ Shielding ✓ Facility design ✓ Restricted access	➢ other patients ➢ non-radiation workers ➢ general public

during the PET radiopharmaceutical uptake period and during PET/CT imaging

Optimisation for staff

Key points

- **Radiation sources** in a PET/CT or PET/MR installation include the cyclotron, the PET radionuclide generators, the radiopharmaceutical, the CT scanner, sealed sources used for calibration and quality control, patients themselves, and radioactive waste; producing the possibility of exposure to the nuclear medicine staff due to **irradiation, and external and internal contamination**.
- The **dose to staff** in a PET/CT or PET/MR facility can **be optimised by applying basic radiological protection practices**, such as, maintaining **distance** from the radiation source or patient, performing operations in the shortest possible **time**, and using appropriate **shielding** whenever practicable.
- **Dosing schedules** for patients which **lower administered activity** will reduce staff exposure.

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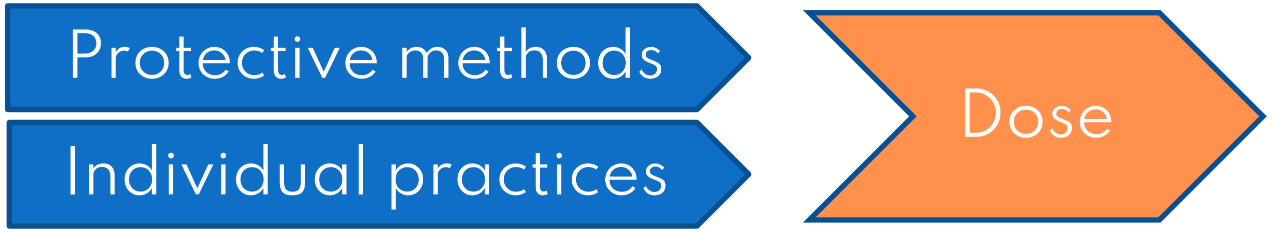
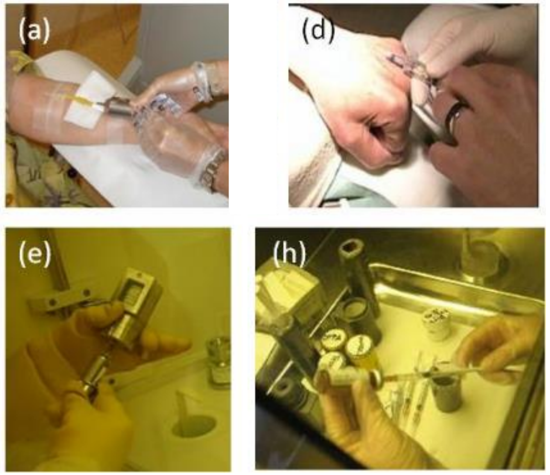
Optimisation for staff

Key points

- **Patient preparation and co-operation** are important factors in **minimising of contact time** and **in increasing the distance** between patient and staff member.
- The **most important** factor that has decreased staff exposure is the use of **automatic dispensing and infusion systems**.
- The **optimisation of the working practice** and the application of **shielding for the vial and syringe** are the most important factors in reducing the magnitude of **doses to the fingers**.



Good and bad



Optimisation for staff

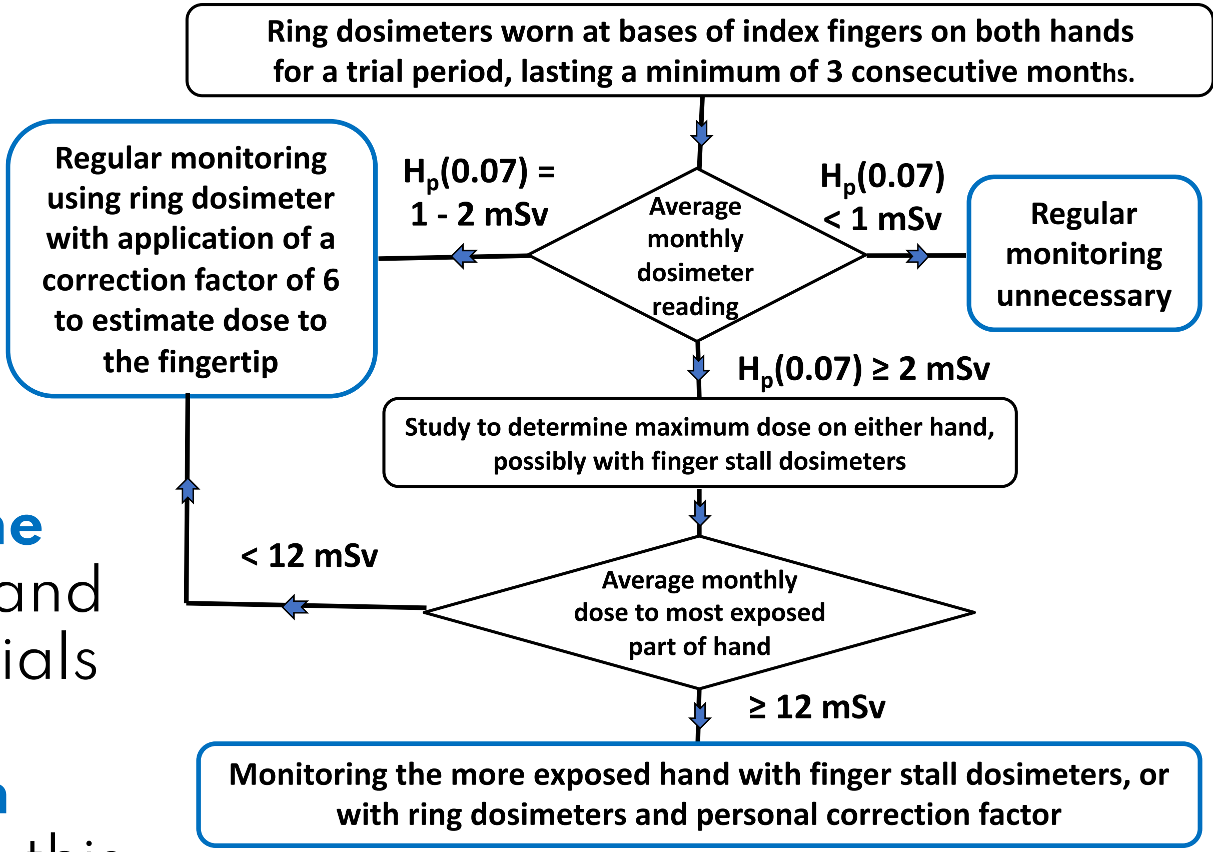
Key points

- **Whole-body monitoring** should be carried out based on **monthly** measurements, and an **$H_p(10)$** measurement from a dosimeter worn on the upper body will also provide an approximate **indication of dose to the eye lens.**
- An **individual monitoring** program for **internal contamination** should be decided **based on risk assessment**.

Optimisation for staff

Key points

- Dose distribution across the **hands** varies between individuals, depending on **technique** and the **use of shields**, but the most exposed area of the hand is usually the **tip of the index finger of the non-dominant hand**.
- Monitoring extremity doses with **ring dosimeters** is recommended. It is important to have **an indication of the maximum dose** over the two hands, and measurements on both hands, with trials using finger stall dosimeters, and subsequent **application of correction factors** are recommended to achieve this.



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Dose management and quality assurance program

Key points

- **Quality Assurance** and **Quality Control** program in PET or PET/CT
  - ➢ **must address and ensure radiological protection and safety** related to
    - medical
    - occupational
    - public

    } exposures

- **Each member** of the medical imaging team has **a crucial and defined role** and **must obtain proficiency in radiological protection**
- **The QA program must include metrics**
  - ➢ to demonstrate that the goals and objectives of the program are being met

- Each facility should have **a system for reporting and reviewing undesired events**

  (accidents, misadministration, near misses)

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Education and training in radiological protection

Key points

- **It is a key issue**
- **Responsibilities and needs**
  - Detailed by international stakeholders
  - For all groups of health professionals in a PET or PET/CT facility
- **The health professional** performing the procedures in the facility **must obtain proficiency in radiological protection and safety through**
  - formal education
  - training
  - continuous professional development

  - due to legal requirements
  - to guarantee safety for
    - Patients
    - Workers
    - Public in general

- **Educational programmes**
  - Based on educational documents and tools
  - Developed by stakeholders and some Scientific Societies and Councils

Summary
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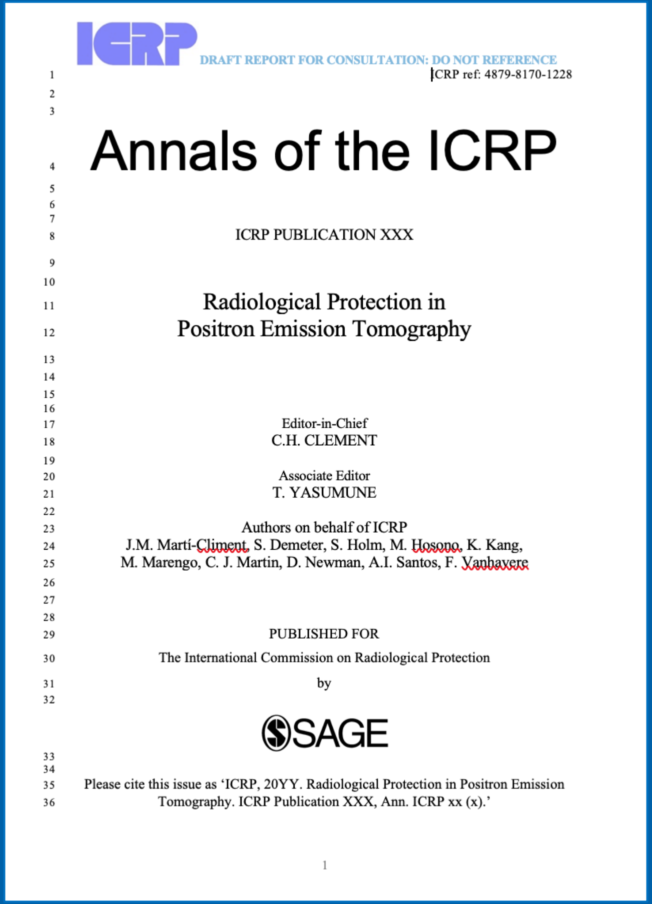
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I acknowledge contributions from other members of

ICRP Task Group 117

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Thank you for your attention

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