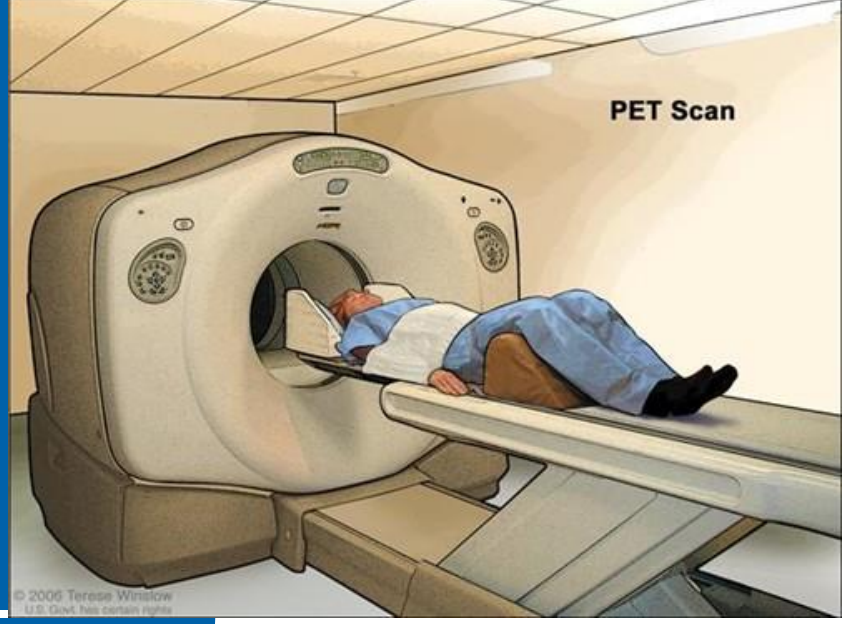
Radiological Protection in PET and PET/CT

Optimisation for staff



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Staff exposed

PET production

Laboratory technologists, Chemists, Physicists, Cyclotron and PET Engineers

PET facility

Physicians, NM technologists, Nurses and Medical Physicists

- **Radiopharmaceutical production**
  Cyclotron operation and maintenance, quality control and dispensing.
- **PET/CT or PET/MR imaging area**
  Radiopharmaceutical preparation Administration to the patient
- **Patient becomes the source**
  Escorting patient, positioning of patient on the scanner bed and patient imaging.

Risk Assessment

Annual dose limits

- Effective dose 20 mSv
- Skin dose extremities 500 mSv
- Lens of the eye 20 mSv
- Dose constraints 0.3 mSv / 1 mSv / 2 mSv?

- Consider activities that might lead to exposures
- Assess doses from different practices
- Potential doses can be calculated from data relating to different radionuclides
- Plan patient journey through the department
- Contributions of individual sources should be summed for comparison with dose constraint.

Sources of Exposure

1) Vials with Radiopharmaceutical

- **512 keV γ-rays from PET radionuclides**
- **Dose rate 0.14 μSv/h per MBq at 1 m from unshielded ^{18}F source**
- **Dose rate 0.03 – 0.1 μSv/h per MBq at 1 m from patient after ^{18}F injection**
- **^{18}F 1.83 h half-life: Higher activities have to be injected to allow for decay**

2) Patients after administration

3) CT scanner during imaging procedure

512 keV γ-rays are more penetrating than 140 keV ^{99m}Tc γ-rays so more shielding materials is needed

Protection against 512 keV γ-rays

	Lead	Concrete
Half value thickness	5 mm	45 mm
Tenth value thickness	17 mm	

Radiopharmaceutical production

Cyclotrons have a neutron flux around target

Cyclotron procedures

- Cyclotrons will be operated from a shielded control area
- Radiopharmaceuticals are produced in shielded hot cells using automatic synthesis modules
- Minimise activity handled at each step
- Use remote control to move loaded vials and syringes
- Typical annual doses to cyclotron staff 0.5-2 mSv

Neutron does rate meters

Radiopharmaceutical production

Neutrons activate cyclotron targets

Cyclotron maintenance

- Activated targets can deliver high dose rates (100s μSv/h) during maintenance
- Preventive maintenance should be scheduled at times when residual activity will be at its lowest (e.g. Sunday or Monday).
- A radiological survey should be carried out to assess dose levels prior to starting any work.
- Handling tools should be used to avoid β-particle exposures from direct contact with activated parts
- Staff should wear gloves and single use filtered masks to prevent inhalation of activated dust particles

PET/CT Facilities: Exposure to vials and syringes

- Receipt of containers with vials for single or multiple administrations
- Measurement of activities in vials
- Drawing up activity into a syringe
- Transporting syringes from dispensing unit
- Injection of the radiopharmaceutical dose

Shielding

- Shielding for the vial and syringe is the single most important factor in reducing doses to the finger tips
- Transport container protected with 2.5 cm lead walls
- Lead pig to shield syringe - 5 cm lead

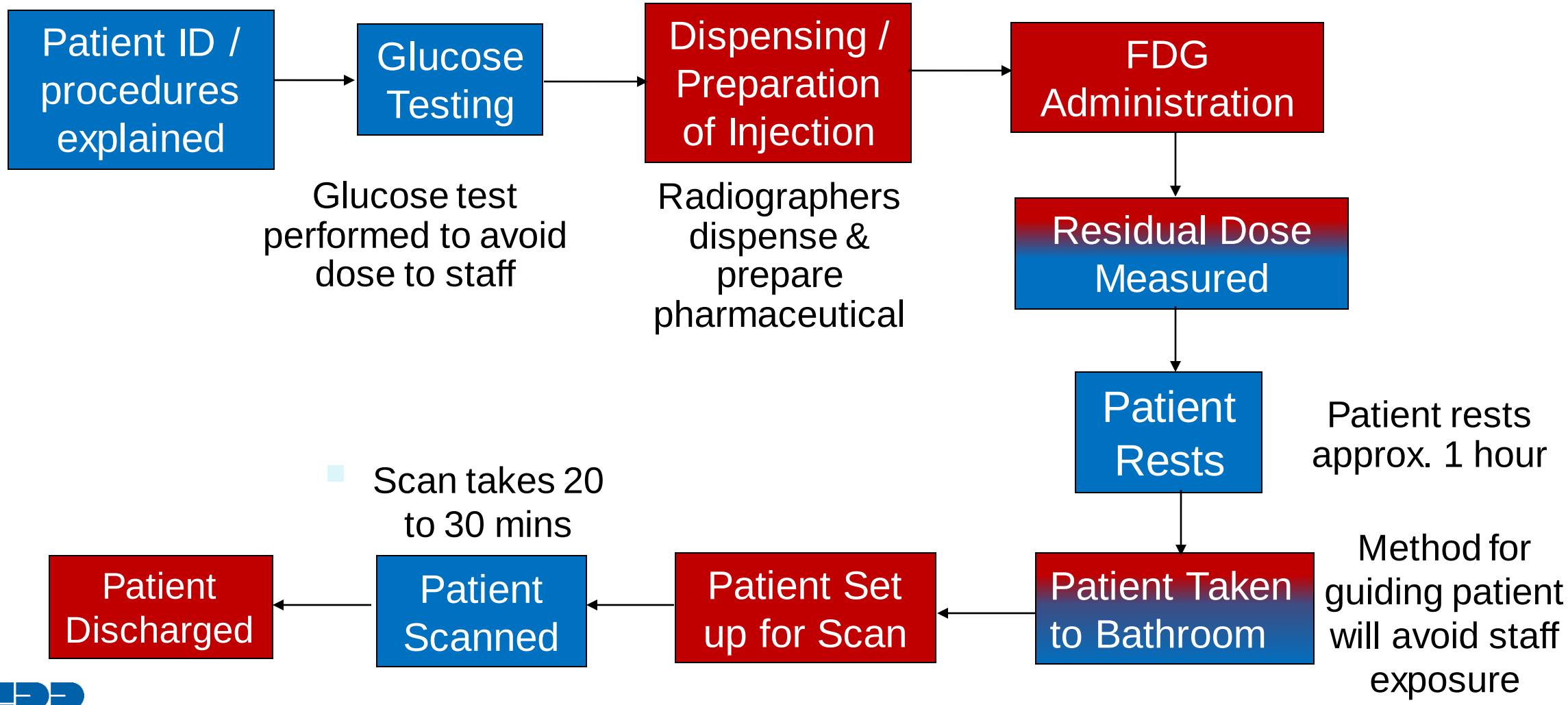
Optimising staff protection during dispensing

- Shielding vials and syringes is crucial
- Use tools to increase distance between the fingers and the source
- Exposures vary significantly from one worker to another, so operational protocols should be evaluated carefully
- All procedures should be practiced first through a training programme with inactive materials until the operator is proficient

Automatic dispensing and infusion

- Use of automatic systems is the most important factor that has lowered staff exposure
- An automatic dispenser can reduce body dose by 30% - 90% and finger doses by 80% - 90%

Patient Journey with Periods of exposure



Body doses from attending patients

- Dose rates may be 300 – 800 μSv/h next to a patient after injection and 50-120 μSv/h at 1 m, declining to 20-70 μSv/h after an hour.
- Typical doses for any tasks attending a patient are 1-2 μSv, so the technologist or nurse may receive 3 to 14 μSv from each patient

Any procedure that requires staff to stand close to the patient for several minutes will increase their dose.

- Taking blood samples for quantitative PET studies - 14 μSv
- Carrying out blood pressure measurements - 10 μSv

- **Each patient remains within facility for up to 2 h**
- **Multiple patients may be resting in department for 8 hours every day**

Precautions for attending patients

- Plan patient movement through department carefully.
- Provide information and have any discussion with patient prior to injection
- Eliminate lines of sight from resting patients to staff
- Encourage patients to empty their bladder and visit rest room on their own
- View patient remotely during the uptake period

Hand dose

Positrons make up the main component of skin dose

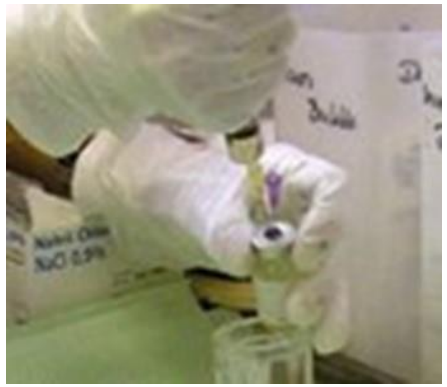
Dose rate at point of contact of 5 ml unshielded syringe containing 400 MBq of ^{18}F is 20 mSv min^{-1}

A wide range in extremity doses reported literature 0.2 – 5 μSv/ GBq

The thumb and index finger often receive higher doses, but the finger depends on individual practice.

There is no consistent pattern in the more exposed hand

The use of shields for syringes and vials is necessary to reduce finger doses



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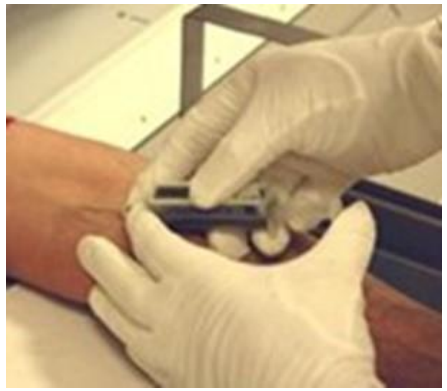

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Do not guide a syringe needle with your finger

Eye dose

Eye doses range from 1 to 50 μSv GBq^{-1} depending on the staff group

- Measured eye lens and whole-body doses are comparable with Hp(3)/Hp(10) ranging between 0.7 and 1.0
- The eye lens dose may be greater during radiopharmaceutical preparation
- Laboratory eyewear (2 mm polycarbonate) has little effect on the dose from ^{18}F, as the positrons are stopped within the syringe, but gives some reduction for ^{68}Ga positrons

Contamination

- **50% contamination incidents involve staff skin or clothing**
- **Doses from skin contamination can be substantial**

Precautions to avoid spread of contamination

- Wear gloves and protective clothing
- Use splash shields where appropriate
- Work over trays to contain spillages

Exposure rates from radioactivity on the skin

Radionuclide	Half-life	Personal dose equivalent rate Hp(0.07) mSv/h	
		Uniform deposit (1 kBq/cm^2)	0.05 ml droplet (1 kBq)
^{11}C	20.4 min	1.95	1.12
^{18}F	1.83 h	1.95	0.788
^{68}Ga	1.13 h	1.81	1.25

100 kBq of ^{18}F would give a dose rate of 3 mSv/min

Contamination monitoring

- Measure contamination during and after a manipulation
- Monitor staff leaving radionuclide areas with monitor in location with low background

Summary

- A variety of staff may be exposed: Physicians, technologists, nurses and physicists
- Radiopharmaceutical production includes cyclotron operation and maintenance
- PET radiations are penetrating, making shielding more difficult
- Shielding of syringes and vials will reduce body and hand dose significantly
- Use of automated systems for synthesis is recommended
- The patients are a major source of exposure
- Plan the journey of the patient through the department to minimise contact
- Have any discussions with patients prior to injection
- Use protective clothing and monitor regularly to reduce risks from contamination
- Review and analyse doses and feed back into improvement in procedures

Thank you for your attention

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