
Practical Aspects of Radiation Safety for Using Fluorine-18

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Objective: The use of positron-emitting nuclides is becoming routine in nuclear medicine departments today. Introducing these nuclides into the nuclear medicine department can be a smooth transition by instituting educational lectures, radiation safety protocols and patient education. The radiation safety concerns of the technical staff, physicians and ancillary personnel are important and must be addressed. Nuclear medicine departments can be optimistic about implementing PET imaging while staying well within ALARA guidelines. After reading this article, the technologist should be able to: (a) describe at least three ways to reduce the radiation dose to the technologist during the performance of PET imaging procedures with ^{18}F ; (b) discuss the relationships between gamma-ray energy, the amount of activity administered to a patient, exposure time and occupational dose; and (c) describe one strategy to minimize the radiation dose to the bladder in patients who have received ^{18}F .

Key Words: PET imaging; fluorine-18; radiation safety

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Fluorine-18-labeled fluorodeoxyglucose, a glucose analog, is the principal positron-emitting diagnostic radiopharmaceutical used for metabolic imaging in nuclear medicine departments (1,2). Fluorine-18 decays by positron emission from the nucleus, followed by collision of the positron with a nearby electron. Two 511-keV photons result which are emitted 180° apart. The 511-keV photons are the result of the conversion of the mass of the electrons into energy. Table 1 provides radiation dosimetry data for ^{18}F -FDG (3–6).

The 511-keV energy of the annihilation photons is 3.65 times the energy of the 140-keV gamma photons from $^{99\text{m}}\text{Tc}$ and 1.40 times that of ^{131}I . The penetrating ability of these high-energy photons is significantly greater, as is the value of the gamma-ray dose constant. Technologists and physicians must become familiar with the physics behind the technology to appreciate the precautions needed to reduce occupational radiation exposure. In addition to gamma-ray dose constants, occupational

radiation dose is related to the amount of source radioactivity and the length of time an individual is exposed to the source. The radioactivity source may be the radiopharmaceutical vial, the unit dose syringe or the patient after administration of the radiopharmaceutical.

After intravenous injection, FDG is distributed to all organs of the body in proportion to cellular glucose metabolism. The brain has the highest uptake of ^{18}F -FDG due to its continual demand for glucose for metabolism. Fluorodeoxyglucose is concentrated in any actively metabolizing tissue. Imaging may begin after an uptake period of at least 30 min and an uptake time or up to 1 h has been recommended. The principle route of excretion of ^{18}F -FDG is through the urinary system.

OCCUPATIONAL RADIATION EXPOSURE CONCERNS

Nuclear medicine technologists will incur more radiation exposure from procedures using high-energy emitters. The NRC guidelines state that the whole body of an occupational worker may not exceed 5 rem/yr total effective dose equivalent and the extremities less than 50 rem/yr. A ring badge must be worn to ensure the technologist's hand doses are within NRC limits. The proper method of wearing personal monitors should be reviewed before initiating routine procedures. Ensure that everyone who prepares, injects and handles isotopes has been issued the required film badges and is wearing them correctly. Pocket dosimeters should be made available for all individuals not issued a film badge. Reinforcing the ALARA concepts of time, distance and shielding will minimize radiation exposure to the occupational worker.

Time

Radiation dose is directly related to the time of exposure. Less exposure time means less total radiation exposure. Reducing the time spent in the vicinity of radiation is often one of the most difficult tasks. Patient care needs require the technologist to spend time at the patient's side.

There are several ways to reduce the time a technologist handles the isotope:

Limit the time spent preparing doses for injection;

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TABLE 1
Radiation Dosimetry for Fluorine-18-FDG*

Radiopharmaceutical: ^{18}F -2-fluoro-2-deoxy-D-glucose (FDG)

Radionuclide: ^{18}F

Physical half-life: 109.8 min

Mode of decay: positron emission, electron capture

Principle radiations: 511-keV annihilation photons (1.94 per decay)
640-keV (E_{max}) positron (0.97 per decay)

Activity administered

Adult: up to 10.0 mCi

Child: 0.15 mCi/kg

Organ doses (assumes 20% elimination in the first 2 h):

Target organ	mGy/mBq	mrad/mCi
Bladder wall	0.17	629
Heart	0.065	240
Brain	0.026	96
Kidneys	0.021	77
Uterus	0.020	74
Ovaries	0.015	55
Testes	0.015	55
Adrenals	0.014	51
Small intestine	0.013	48
Liver	0.012	44
Pancreas	0.012	44
Spleen	0.012	44
Red marrow	0.011	41
Lungs	0.011	41
Thyroid	0.0097	36
Other tissue	0.011	41

Effective Dose: 0.74 rem for an adult who received 10.0 mCi ^{18}F

*Information is from references 5 and 6.

- Obtain unit doses of FDG rather than a multidose vial;
- Calculate the volume needed before attempting to draw up the dose if the radiopharmaceutical is only available in multidose vials;
- Take extra care to keep the dose shielded;
- Rotate all of the technologists through the tasks of drawing and assaying doses and injecting the patients; and
- Obtain and maintain intravenous access to reduce the time needed for injection; patient intravenous access will ensure that the dose is not wasted.

Distance

Distance is the technologist's least expensive form of radiation protection. By increasing the distance between the radiation source and the staff member, the rate of exposure will be considerably reduced according to the inverse square law. Examples of the application of this principle include the use of long-handled tongs for moving the vial from the lead vial shield to the dose calibrator.

The patient becomes the radiation source postinjection. Con-

sideration must be made as to where administration of the activity to the patient will be made and where the patient will wait during the uptake period to reduce exposure to other patients and staff. If the patient must walk through the department, ^{18}F will be detected by single-photon imaging systems and this may interfere with studies being acquired. Once the patient is placed on the scanning table, the technologist should be able to monitor the patient from a distance.

Shielding

Shielding intended for 140-keV photons is not sufficient for 511-keV photons. The half-value layer for $^{99\text{m}}\text{Tc}$ is 0.17 mm of lead and increases to 4.1 mm of lead for ^{18}F ; 1.61 in. of lead are required to effectively shield the 511-keV photons. Syringe shields, dose transporters, L-shields, lead safes and rolling shields are commercially available. If the distance in the room is not sufficient to adequately decrease radiation exposure to the staff, it is advisable to place a rolling lead shield between the patient and the staff.

Careful planning should eliminate the need to lead-line walls and doors, especially when planning a new department. A properly constructed lead fort (castle) made with lead bricks may be more cost-effective than a lead safe. Dose transporters can be replaced by placing lead shielding on a rolling cart. There is no substitute for a 511-keV syringe shield.

Shipments of ^{18}F should be monitored and placed in an appropriate storage location on arrival. It is not acceptable for the delivery person to deposit the shipment anywhere other than the nuclear pharmacy area of the nuclear medicine department.

Spills of ^{18}F are cleaned and decontaminated following the same procedures as for any isotope spill. Additional shielding around the waste container may be needed, depending on the size of the spill and the storage location of the waste.

PATIENT CONCERNS

Patients are to be made as comfortable as possible before starting the imaging study to minimize patient motion during the study. Velcro body wraps and lower extremity cushions are used to improve patient comfort.

The critical organ is the urinary bladder, which receives 629 mrad/mCi assuming that 20% of the injected activity is voided at 2 h (Table 1). Patients should increase their fluid intake and be encouraged to repeatedly empty their bladders after the study. Following these instructions will decrease the radiation dose to the bladder.

CONCLUSION

The use of positron-emitting nuclides is becoming routine as nuclear medicine evolves. Apply ALARA concepts to decrease occupational radiation exposure. Continuing staff education is imperative, as is careful development of standard

operating procedures for the safe implementation of ^{18}F -FDG imaging.

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