University of Pennsylvania
Environmental Health and Radiation Safety

Diagnostic Energized Equipment
Radiation Safety Manual

(Reviewed: August 2024)

I. Proper Operating Procedures

A. Proper Operating Procedures for Radiographic Units

1. Limit the primary x-ray beam to the smallest area possible consistent with the objectives of the clinical examination.

2. Align the x-ray beam properly with the patient and the CR or digital image receptor.

3. Remain behind a protective barrier (i.e., a leaded glass wall or a leaded door) during the entire radiographic exposure, unless adequate performance of the examination requires your presence.

4. Observe the patient during the exposure from the protected area.

5. No person should routinely hold patients during diagnostic examinations. When a patient must be held in position for radiography, a mechanical supporting or restraining device should be used. Pregnant women or persons under the age of 18 years should not be permitted to hold patients. If a patient must be held by someone, that individual shall be protected with appropriate shielding devices such as protective aprons and gloves. Positioning should be arranged so that no part of the holder's torso, even if covered by protective clothing, will be struck by the useful beam and so that the holder's body is as far as possible from the useful beam. [*Reference: NCRP Report 102, 2.4(h)*]

6. Provide protective garments (lead aprons and/or shielding) for all individuals whose presence in the room is necessary during the radiographic exposure.

B. Proper Operating Procedures for Fluoroscopic Units

1. Only persons required for the fluoroscopic procedure should be in the room during the procedure.

2. As in a radiographic procedure, use the smallest possible beam area to reduce patient exposure and scatter radiation.

3. Perform visual observation of the alignment of the image intensifier or flat panel detector, x-ray tube, and the patient prior to the initiation of a fluoroscopy procedure.

4. Minimize fluoroscopic doses by reducing the fluoroscopic time used. Fluoroscopic time, of course, varies with different patients, the type of the examination, and the complexity of the clinical study.

5. Operators should use the timing device to indicate an audible preset time, which will serve as a reminder to keep procedures as short as possible. According to State regulations, the predetermined time may not exceed 5 minutes [PA 221.41a].

6. Use the shortest possible distance from the image intensifier or flat panel detector to the patient. The Automatic Exposure Control (AEC) on the fluoroscope will automatically increase the radiation output of the fluoroscope when longer distances are used.

7. The fluoroscopist should wear a thyroid shield, leaded gloves, and glasses, as necessary, to reduce exposure to the thyroid, extremities, and eyes.

8. Uses of “Low Dose” and “Pediatric” modes are recommended when available.

9. Patient dose rates are reduced with the use of pulsed fluoroscopy. It is recommended that pulsed fluoroscopy be utilized when its use is consistent with the clinical objectives of the procedure.

10. If the operator has questions regarding the use of various operating modes, they may be directed to the Medical Physicist. Please contact (215) 898-7187 for further information.

C. Proper Operating Procedures for Mobile Diagnostic Units

If proper care is not taken, mobile equipment has a greater potential than standard diagnostic equipment for unnecessary radiation exposure of personnel and patients.

1. If possible, stand at least 2 meters (~6.5 ft.) away from the tube head and the patient. Distance is often the best possible protection from radiation. [PA 221.34a.(f)(2)]

2. It is important that only individuals necessary for the diagnostic examination be in the vicinity. Individuals who are required to remain in the room should wear protective garments (lead aprons and thyroid shields) or should be located behind a protective shield.

3. Wear protective garments of 0.5 mm lead equivalence when at a distance less than 120 cm (~4 ft.) from the useful beam, and a minimum of 0.25 mm lead equivalence at distances greater than 120 cm. [PA 221.11.(e)]

D. Proper Operating Procedures for Computed Tomography Units

1. Use a scan plane position device, such as a light field or laser, to indicate directly or indirectly the position of the slice plane(s) on the patient within 2 mm. [NCRP 3.9.1(e)]

2. Observe the patient during the CT exposures either directly from the control area or by use of a viewing system. [PA221.203.(b)]

3. Only individuals whose presence is necessary should be in the CT x-ray room during exposures. All such individuals should be protected with leaded aprons and/or portable shields.

4. Operators should evaluate the size of the patient, and adjust the operating parameters (kVp, mAs, etc.) to take the patient size into account. Dose modulation systems (i.e. CareDose 4D, Smart mA, Z-DOM, etc.) should be used when applicable to reduce unnecessary radiation to the patient.

E. Proper Operating Procedures for Dental Units

1. Only persons required for a radiographic procedure should be in the radiographic room during exposure. All persons must be adequately protected by protective garments. *[References: NCRP 35, 4.4; PA221.11.(e)].*

2. Align the x-ray beam and the film or image sensor very carefully with the area to be radiographed.

3. Stand behind protective barrier and observe the patient during the dental exposure.

4. Neither the operator nor the assistant shall hold the film or digital image receptor in place for the patient during the exposure. Use the film or digital image receptor holder devices during the exposure.

II. Techniques of External Radiation Protection

Control radiation exposure levels via four basic methods:

A. Maximize the distance from radiation source.

B. Minimize the radiation exposure time.

C. Shield the radiation source properly and shield personnel.

III. Shielding

A. Patient Shielding

Gonadal shielding offers little or no radiation safety benefit and has the potential to increase dose to the patient if not properly positioned. Gonadal shielding shall not be provided to patients unless it is specifically requested by the patient and it will not interfere with the diagnostic procedure.

B. Personnel Shielding

Personnel who remain in the room during examinations must be protected by proper shielding.

1. All personnel in the room during an exposure should wear protective garments. These garments are to be of 0.5 mm lead equivalence when at a distance less than 120 cm (~4 ft.) from the useful beam, and a minimum of 0.25 mm lead equivalence at distances greater than 120 cm. [PA 221.11.(e)]

2. Personnel who are likely to be exposed to high levels of scattered radiation to the thyroid during any procedure should wear thyroid shields as well.

3. Leaded glasses can greatly reduce the exposure of the eye lenses to scattered radiation in fluoroscopy, especially for physicians.

4. Any person who must have his or her hand near the primary beam (as in cases in which no other means are available to immobilize a patient) should wear leaded gloves to reduce exposure of the extremities.

C. Structural Shielding

Prior to installation of new imaging equipment, replacement of existing imaging equipment, or modification to rooms where ionizing radiation will be emitted a medical physicist shall conduct a structural shielding design assessment to specify required radiation shielding. This survey is conducted prior to clinical use of the room. Rooms which house stationary x-ray equipment have been designed with sufficient shielding in the walls to provide protection to anyone outside of the room. Do not tamper with the integrity of the shielded walls. If any personnel notice structural changes, such as holes drilled into walls, Environmental Health and Radiation Safety (EHRS) should be notified as soon as possible.

IV. Pregnant Patient and Pregnant Worker Policy

A. Patient
Special consideration must be given to the protection of the embryo or fetus of women known to be, or potentially, pregnant. A patient of childbearing age should be questioned to ascertain the likelihood of pregnancy. If the patient is found to be pregnant or likely to be pregnant, the physician or radiologist should be consulted to decide whether this radiation dose to the patient is justified.

B. Personnel
An employee should contact the EHRS either directly or through a supervisor when she knows or suspects that she is pregnant. If for personal reasons an employee does not wish to disclose pregnancy to her supervisor, confidential disclosures can be made directly to EHRS.

V. Badging and Dosimetry Policy

A. Personnel Dosimeter Policy
EHRS uses personnel monitoring to identify inadequate or improper radiation safety practices and potentially serious radiation exposure situations. EHRS will issue proper personnel dosimeters when evaluation of equipment reveals that the radiation dose to personnel could potentially be larger than ALARA limits per calendar quarter to the whole body (125 mrem).

Radiation workers are monitored by EHRS. All radiation workers must conscientiously wear the radiation monitoring devices provided by the EHRS. These devices may include body and/or ring dosimeters.

B. Dosimeter Placement
Interpretation of the measured dose depends on the placement of the dosimeter. All personnel must wear their dosimeters correctly. The following list indicates where the dosimeters are to be worn:

1. TLD or Luxel Body Badges are to be worn above any protective clothing at collar level.

2. Ring Dosimeters are to be worn so that the employee's name is facing the source of radiation.

Personnel must return all monitoring devices promptly at the end of each predetermined wear period, so that the radiation dose can be evaluated. If any dosimeter has received a dose higher than the ALARA trigger level (Table 1), the employee will be notified and the reason for the high reading will be investigated. Measures will be taken to keep radiation doses below these trigger levels whenever possible:

Table1. ALARA Investigation Trigger Levels

	Radiology	Cardiac Catheterization
Whole Body	125 mrem/calendar quarter	375 mrem/calendar quarter
Extremities	5000 mrem/calendar quarter	5000 mrem/calendar quarter

C. Dose Reports
Dosimeter wearers can contact EHRS directly to review their dose history. Personnel dosimetry information may also be accessed online via the badge manufacturer's website. Instructions for accessing a wearer's dose history online can be found at https://ehrs.upenn.edu/radiation-safety/topics/clinical/personnel-monitoring.

D. Pick-up and Drop-off of Dosimeters
EHRS delivers new dosimeters to each department immediately prior to the start of the new wear period. Each group should have one person who is responsible for the distribution of dosimeters. The used dosimeters should be returned to the designated personnel. EHRS will pick up the used dosimeters at the beginning of the new wear period for analysis.

E. Regulatory Limits
Federal and State regulations require radiation exposures of staff and members of the general public to be below certain regulatory limits. In practice, radiation exposures are only a fraction of these limits. These regulatory limits are displayed in Table 2.

Table 2. Regulatory Limits on the Exposure of Staff and the General Public to Radiation.

	Staff	General Public
Whole Body	5000 mrem/year	100 mrem/year
Lens of the Eye	15,000 mrem/year	N/A
Extremities & Skin	50,000 mrem/year	N/A

VI. Quality Assurance Program

The quality assurance program will ensure that doses to patients are in accordance with the standards of good practice set forth by the American College of Radiology

A. Technologist quality assurance program
Quality assurance tests required to be completed by the technologist vary by the state in which the facility is located in. The state specific QA tests and their required frequencies are specified in the Pennsylvania and New Jersey regulations.

B. Physics evaluations of energized equipment
All equipment is tested annually by EHRS to ensure that equipment not only meets regulatory requirements, but also provides adequate image quality with an appropriate radiation dose to the patient. New equipment shall be tested by a qualified medical physicist before clinical use. Any modifications or replacement of equipment parts that can affect radiation dose or image quality shall be reported to EHRS so that a medical physicist can perform an evaluation within the required time period.

C. Inspection of protective garments
Perform an annual inspection of the shielding garments, such as lead aprons and lead gloves, to ensure the integrity of these items.

D. Response to reported problems
Make all repairs on the units as soon as possible. Send repair documentation to authorized personnel upon completion of the repairs.

E. Visual inspection
Report all conspicuous problems with energized equipment or with shielded rooms, as well as any other safety problems observed by personnel to EHRS immediately.

VII. Diagnostic Equipment

A. Registration of Diagnostic x-ray Units
Pennsylvania and New Jersey regulations require that all radiation-producing equipment be registered with their respective Department of Environmental Protection. This registration is performed by EHRS when new equipment is installed, and the registrations are renewed on an annual basis. EHRS also maintains a listing of all units currently registered.

B. Acquisition of New Diagnostic x-ray Units
It is the responsibility of clinical personnel to notify the EHRS upon acquisition of any new diagnostic equipment. Authorized EHRS personnel will conduct a radiation safety survey on all new units prior to patient use. EHRS will also make the necessary shielding determinations for stationary x-ray producing units prior to their installation.

C. Disposal or Transfer of Diagnostic x-ray Units
Clinical personnel must notify the EHRS of any diagnostic equipment intended for disposal or transfer to another facility. EHRS will ensure that the proper notifications to State Agencies are made.

VIII. Important Phone Numbers

University of Pennsylvania, Environmental Health and Radiation Safety:

Monday – Friday during business hours **(215) 898-7187**

On-Call Physicist for assistance after hours **(215) 573-6626**

CHOP Radiology Physics and Engineering Director:

Erfan Akbari (215) 590-4320