Radiation Safety Manual
for
Linear Accelerators and Radioactive Materials
Used in the
Radiation Oncology Department

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Environmental Health and Radiation Safety
3160 Chestnut Street, Suite 400
Philadelphia, PA 19104
**GENERAL**

**Regulatory Oversight**

The Pennsylvania Department of Environmental Protection (PA DEP) is responsible for regulating radiation safety aspects of linear accelerators and radioactive materials.

The PA DEP regulations for the proton facility are found in Title 25, chapters 217, 219, 220, 224, 228, and 230 of the Pennsylvania Code.

These documents can be found at [http://www.pacode.com/](http://www.pacode.com/). Note that many of these regulations incorporate regulations from Title 10 of the Code of Federal Regulations. These can be found at [http://www.nrc.gov/reading-rm/doc-collections/cfr/](http://www.nrc.gov/reading-rm/doc-collections/cfr/).

Environmental Health and Radiation Safety (EHRS) is responsible for maintaining radiation safety and ensuring compliance with applicable radiation safety regulations within the facility.

**Radiation Safety Notification**

EHRS must be notified immediately if the following occur:

1. Unexpected radiation levels are measured;
2. An unexpected exposure to radiation occurs;
3. Any safety mechanism malfunction (e.g., interlock, radiation detector, emergency stop).

**Training requirements**

Radiation Oncology staff should receive radiation safety training initially and as an ongoing part of their professional development. The formal education of radiation oncologists, medical physicists, and therapists includes radiation biology, physics, radiation instrumentation, and safety precautions. It is important that they receive refresher training on these topics and training on new equipment and techniques as part of continuing education.
Posting and Labeling

Entrances to the treatment rooms must be properly posted with “Radiation Area” or “High Radiation Area” signs as applicable, or must be continuously controlled while radiation is present. Warning lights outside of accelerator, high dose-rate remote afterloader (HDR), and Gamma Knife treatment rooms must warn if the accelerator is on or the sealed source(s) is exposed. Separate permanent radiation monitors must give a visual indication that radiation is present and must be visible before a person enters a high radiation area.

SHIPPING AND RECEIVING RADIOACTIVE MATERIAL

Package Receipt for Packages Containing Radioactive Material

Upon receipt, all packages containing radioactive material must be locked in an area that can be accessed only by radiation workers with knowledge that material is present. If it is not possible to lock up the package immediately, the package must be constantly attended by a radiation worker until it can be locked up.

Proper procedures are required for packages containing radioactive material. If the package has a DOT label – a square-on-point label that is either white or half white and half yellow and has the words “Radioactive I,” “Radioactive II,” or “Radioactive III” – it must be surveyed within three hours of delivery. The labels are illustrated below. Packages that do not have a square-on-point label but are damaged such that the radioactive material might have been hurt or lost also must be surveyed right away.

To survey an incoming package, first, measure the highest radiation dose rate at one meter from the surface using an ion chamber. If the package label is “Radioactive I” or does not have a square-on-point label, the radiation exposure at one meter should be very small and in no instance should it be more than 5 µSv/h (0.5 mrem/h). If the package
label is “Radioactive II” or “Radioactive III,” the Transportation Index on the label is the highest dose rate at one meter from the surface in units of mrem/h that was measured by the shipper of the package. If the reading is much higher than the label indicates, it probably signals that something is wrong with the package. If the radiation exposure rate at one meter is more than twice the expected value based on the label, set the package aside and immediately contact Radiation Safety.

Next, measure the highest radiation dose rate at about 1 cm from the surface of the package with an ion chamber. For a package with package label “Radioactive I” or without a square-on-point label, the radiation exposure at 1 cm should be no more than 5 µSv/h (0.5 mrem/h). If the radiation dose rate from one of these package exceeds 10 µSv/h (1.0 mrem/h), set the package aside and immediately contact Radiation Safety. If the package label is “Radioactive II” or “Radioactive III,” the radiation exposure at 1 cm should be no more than 2 mSv/h (0.2 rem/h). If the radiation dose rate from one of these packages exceeds this value, set the package aside and immediately contact both Radiation Safety and the carrier who delivered the package. The notification to the carrier is required by the regulations. Radiation Safety will make the required notification to the Pennsylvania Department of Environmental Protection.

Third, the surface of the package should be checked for removable contamination by wiping it with a dry filter paper or similar material with moderate pressure. If possible, an area of 300 cm² should be sampled, which is about a 100 cm (3 foot) wipe with the wipe pressed by the thumb (i.e., the pressing thumb makes a contact area about 3 cm wide). The area wiped does not have to be continuous. The contamination on the wipe should not be greater than 22 dpm per square centimeter wiped (2.2 dpm if the package contains alpha emitting radionuclides). If the area wiped is 300 cm² wipe the total activity on the wipe should be less than or 6600 dpm (660 dpm total per 300 cm² if the package contains alpha emitting radionuclides). If it is not, immediately contact Radiation Safety and the carrier who delivered the package. The notification to the carrier is required by the regulations. Radiation Safety will make the required notification to the Pennsylvania Department of Environmental Protection.
Finally, if the package contains radioactive material that is not a brachytherapy source or other permanently sealed source, wear gloves and protective outer clothing while opening the package. Wipe the outside of all enclosed containers to check for contamination. If any is found, decontaminate the containers promptly. Dispose of radioactive material from the decontamination properly.

Shipping Radioactive Source and Other Radioactive Material

For many of the shipments of radioactive material from the Radiation Oncology Department, a service provider is the shipper of record for the package. For example, when the old HDR source is removed from the unit, Varian is the shipper for the return. The Varian service engineer packages the source and prepares the necessary shipping paperwork. In these cases, lock the prepared package in a secure location such as the storage area for the low-dose brachytherapy sources and contact Radiation Safety to arrange to have the package picked up. At Pennsylvania Hospital, contact Tom Price at Thomas.Price@uphs.upenn.edu or at 215-829-5425. At other facilities, contact Keith Brown at keith@ehrs.upenn.edu or at 215-651-0541.

For all other shipments, Radiation Safety should check the documents for the shipping container, package the material, prepare the shipping paperwork, and arrange to have the package picked up. If it is not damaged, preserve the container in which the material was originally received. If the vendor is willing to supply the results of the testing on that container, it may be able to be reused. As far ahead of the shipment as possible, contact Keith Brown at keith@ehrs.upenn.edu or at 215-651-0541. The material to be shipped and the shipping container, if any, should be locked in a secure location that is appropriately posted such as the storage area for the low-dose brachytherapy sources.

ACCESS TO HIGH DOSE-RATE RADIATION TREATMENT ROOMS

Restrictions on Access to Treatment Rooms

During radiation therapy, no one but the patient can be in the treatment room. At all other times when radiation is in use, other than diagnostic x-rays, no one is allowed in the treatment room.

Security of Treatment Rooms and Treatment Devices

When patients are not being treated, linear accelerator treatment rooms are not required to be locked so long as the accelerator controls are locked and the key removed. The HDR must be locked in its cabinet when it is not in use. The controls must also be locked and the keys removed. A room with an HDR will be open when other radiation-producing devices in the room are in use, but when unattended the room must be locked. Likewise, when the Gamma Knife is not in use the controls must be locked and the keys removed, and when it is not attended, the Gamma Knife treatment room must be locked.
Because the quantity of radioactive material in the Gamma Knife meets the International Atomic Energy Agency criteria for a “Category 1 Source,” there are a number of additional security measures and devices associated with the Gamma Knife. Individuals needing unescorted access to the Gamma Knife should contact Pennsylvania Hospital security to begin the process to gain access to the room housing the Gamma Knife.

**Bypassing Door Safety Interlocks**

The following requirements must be met before the safety interlock on any treatment room door may be bypassed:

1. A written permit, signed by the Radiation Safety Officer (RSO), must be issued authorizing the activity.
2. The permit will include a procedure to compensate for the lack of interlocks which must be followed while they are disabled.
3. A notice must be posted at the operator’s position during the time the interlock is disabled warning that it is disabled.
4. The device’s permanent log must include a record detailing the disabling of the interlock including the start time and end time.
5. The interlocks must be re-enabled as soon as possible.

If you believe work you intend to do requires bypassing the interlocks on the door of a treatment room, contact Radiation Safety as far in advance of the work as possible as it will take some time to prepare the necessary permit.

**ACCESS TO RADIOACTIVE MATERIAL**

**Storage of Implant Sources and Radiopharmaceuticals**

Rooms used to store low dose-rate implant sources must be locked at all times. Access to the room must be limited to only those individuals who need access. The same is true of any unsealed material the Department uses, as it has in the past in research studies. Typically, unsealed material is delivered to and kept in a hot lab belonging to the Nuclear Medicine Department.

**Security of Radioactive Material While in Use**

Sources that are transported to an operating room for implantation must be attended or locked in an area accessible to only Radiation Oncology personnel. Temporary implants of radioactive sources, administrations of radioactive material by infusion or other method that administers the radiopharmaceutical over an extended period and administrations which require that the patient be hospitalized because of potential dose to the public must be coordinated with Radiation Safety.
EMERGENCY PROCEDURES

Individuals Detected in Vault or Treatment Room

If someone other than the patient is detected (via video system or other detection system) in a treatment room when radiation is present (other than individuals intentionally in the room during diagnostic x-ray exposures or Gamma Knife treatments), operators should immediately eliminate the radiation (stop the accelerator beam, retract the HDR source, or shut down the Gamma Knife) from the room via the console. The person in the room should be taken from the room and asked to wait for Radiation Safety to interview him or her for a dose reconstruction. Radiation Safety should be contacted immediately.

Staff in a Treatment Room When Beam is Turned On or Source Extended

If you are inside vault or room when the accelerator beam is turned on, the HDR source is extended into the room, or the Gamma Knife sources are exposed, push the nearest emergency stop button at once. Exit the room and contact Radiation Safety immediately. Radiation Safety will take your dosimeter for expedited processing and will issue a spare to you for the remainder of the monitoring period. It is unlikely the dose received will be great enough to require notification of the PA DEP, but if it is, Radiation Safety will make the required notification.

Accelerator Beam Is Stuck “On” in a Treatment Room

The accelerator beam will be considered stuck “on” if the beam does not stop:

• when the preset dose has been reached
• when requested
• when paused

Should this happen, press an emergency stop button. If the beam stays on, trip the main breaker for the accelerator. Notify Radiation Safety immediately once the beam has been shut off or the room cleared.

HDR Source Is Stuck Out in the Treatment Room

The high dose-rate remote afterloader source will be considered stuck out if it does not return to the shielded position:

• when the preset time has been reached
• when requested
• when paused

Should this happen, follow the emergency procedure for the HDR that is posted at the console. Notify Radiation Safety immediately once the source has been shielded or the room cleared.

Gamma Knife Stuck “On”
The Gamma Knife will be considered stuck “on” if it fails to move the patient out and close the shutter:
- when the preset time has been reached
- when requested
- when paused

Should this happen, follow the emergency procedure for the Gamma Knife that is posted at the console. Notify Radiation Safety immediately once the sources are shielded or the room is cleared.

**Lost Source**

At the end of a low dose-rate brachytherapy treatment if the number of sources is either less or more than the expected number, contact Radiation Safety immediately. If the returned number is too high, Radiation Safety will make a record of the reason for the discrepancy for review during PA DEP inspections. If the returned number is too low, it could be that one or more sources are lost. Radiation Safety will determine what steps to take to locate the missing sources and will make any notifications that are required.

**Leaking Source**

Leaking low dose-rate brachytherapy sources may be detected during routine testing of the sources. They may also be found during post implant and post removal surveys: if radioactive material is found in one of these surveys where no brachytherapy source is present, it should be assumed to have leaked from a brachytherapy source. Contact Radiation Safety immediately. Radiation Safety will help in determining whether, in fact, the activity is from a leaking source and will make the required notifications to the PA DEP.

**Accidental Exposure**

In case of accidental exposure of anyone to radiation, whether gamma or x-ray, immediately contact Radiation Safety.

**Emergency Notification (Radiation Safety)**

Keith Brown………………………215-898-2106 (office) or 215-651-0541 (cell)
William Davidson……………………215-898-2133 (office) or 215-651-0537 (cell)
Main office……………………………215-898-7187
After hours……………………………215-573-6626

If your call is not answered, call the HUP operator…215-662-4000
The HUP operator has a list of home telephone numbers for the Radiation Safety Staff.
EQUIPMENT

Radiation Dosimeters

Radiation Safety will supply radiation dosimeters (badges) for all personnel who are required by regulation to be monitored and to any others that the Department wishes to monitor. Dosimeters supplied by Radiation Safety are for use within the University of Pennsylvania Health System only and are not to be worn at any other facility.

Individuals required by the regulations to wear personnel dosimeters will do so at all times when working around any radiation source within the University or the Health System. Dosimeters may be worn anytime personnel are on duty except when receiving medical care whether routine or for an on the job injury. Whole body dosimeters should be worn between the waist and shoulders, with the name plate facing away from the body. Ring dosimeters should be worn with the wider portion facing the palm. This is opposite to what seems natural, but it puts the radiation measurement element pointed towards the work being done.

When not in use, personnel dosimeters will be stored in the designated low background area. If a dosimeter is inadvertently not returned at the end of the employee’s shift, the employee will bring the dosimeters to work the next time he or she is on duty.

All personnel monitoring results are maintained by Radiation Safety and are available for review. In addition, personnel monitoring results are routinely distributed to each department.
Permanent Radiation Monitors

Permanent radiation monitors are located in all of the treatment rooms. The monitors have a visual alarm that is activated when the radiation level exceeds the preset level. The purpose of these permanent radiation monitors is to let individuals who are inadvertently in the treatment room know that the accelerator beam has been turned on, the HDR source has been extended, or the Gamma Knife sources have been exposed.

Basic radiation survey instruments

Ion chamber (instrument on the left)
Mainly used for determining photon radiation levels
For quantitative measurement – What is the radiation level?

Geiger-Müller (GM) meter (instrument on the right)
Mainly used for detection of radiation/contamination
For qualitative measurement – Is a source present? Is the object contaminated? Has the object become activated?
CCTV Monitors and Intercoms

Regulations require CCTV cameras in all treatment rooms so that operators are able to see that no individuals other than patients are present when the accelerator beam is turned on or the HDR or Gamma Knife source(s) is exposed. At least one camera must be working during each treatment. Because the CCTV cameras are also important to patient care, it would be extremely unusual to not have cameras working during treatment.

The regulations also require an intercom system in the treatment room that allows the patient to communicate with the operators and vice versa. During each treatment, the intercom must be working and operators must be able to hear the patient. Note that if the volume of the music in the treatment room is too high it can prevent the patient’s ability to communicate with the operators. Music volume should be kept low enough so that communication with the patient is not impacted.

RADIATION EXPOSURE

Dose limits

The annual whole body limit for occupationally exposed “radiation workers” is 50 mSv (5000 mrem).

Pregnant Workers

If someone is pregnant or believes they may be pregnant, she should contact Radiation Safety to learn about the provisions in the regulations for voluntarily allowing her dose to be limited. Radiation Safety will also review her dose history, discuss her potential for receiving significant dose during her pregnancy, and discuss the risk of prenatal radiation exposure. If appropriate, Radiation Safety will provide suggestions for reducing radiation dose during the pregnancy. Again, declaration of pregnancies is entirely voluntary, so if a woman contacts Radiation Safety she can still decline the additional precautions that are offered. All conversations concerning her pregnancy will be kept confidential. If the pregnancy is declared, the PA DEP dose limit to the fetus of a declared pregnant woman will be 5 mSv (500 mrem) during the entire pregnancy.

ALARA Policy

The acronym ALARA, which stands for "As Low As Reasonably Achievable," means that the Health System and the University should make take reasonable actions to ensure that the radiation doses to individuals are as far below the regulatory limits as is practicable. As a way of monitoring that doses are being kept low, Radiation Safety sets “ALARA levels” at 10% of the regulatory limits. Radiation Safety will notify individuals when personnel exposures exceed ALARA levels. These exposures will be investigated and reviewed by the Radiation Safety Committee.
Rules of thumb for working around radiation

1. Distance – maximize distance from the source (inverse square law)
2. Time – minimize time around a source of radiation
3. Shielding – when it is necessary to work in the vicinity of radiation and radioactive materials, use shielding to reduce the radiation dose.

Audits

Radiation safety audits will be conducted by the radiation safety staff periodically. Results of the audits will be communicated to the Radiation Oncology Department.
CONTACTS

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