1. ASRT Animation

2. Welcome

3. License Agreement

4. Objectives
After completing this module, you will be able to:
   - List the radiation safety units of measure.
   - Name and describe the 3 pillars of radiation safety.
   - Define ALARA.
   - Discuss different shielding methods.
   - Describe radiation protection for fluoroscopic procedures.

5. Units of Measurement
When discussing radiation safety, there are several common units to measure the amount of radiation technologists and patients receive. Conventional units are not always organized in relation to other units but have been used since an earlier discovery. SI units, or “Système International d'Unités”, were developed after World War II. SI units have been adopted internationally to standardize reporting for various measurements, including radioactivity, and are the preferred units of measurement in international and scientific circles even though conventional units continue to be used in some areas. Conventional units of measure and SI units are not equivalent regardless that the same parameter is being measured.

6. Measuring Radiation Exposure
Radioactivity describes the activity and decay process of radioactive materials. The conventional unit is the curie and the SI unit is the becquerel. Radiation absorbed dose is the amount of energy that is deposited in matter. The conventional unit is the rad and the SI unit is expressed in gray.

Exposure is measured when radiation ionizes air creating an electrical charge. The conventional unit of measurement for exposure is the roentgen and the SI unit is expressed using coulombs per kilogram. Air kerma is replacing coulombs per kilogram and roentgens as the standard measure of radiation intensity in air and is expressed in milligrays. An example of this expression is 300 milligray per centimeter squared. Air kerma often is used in digital systems with dose area product, or DAP.

Dose equivalent measures the biological effects of radiation exposure. The conventional unit is the rem and the SI unit is the Sievert. Dose equivalent accounts for the type and energy of radiation that is absorbed. For example, alpha radiation is more damaging than X radiation. Therefore, the calculation for dose equivalent is expressed as the product of absorbed dose, total gray, and a radiation weighting factor, which in the case of alpha radiation is 20. The radiation dose is then identified in milligray.

7. Radiation Protection
The basic principles of radiation protection for technologists haven't changed a great deal since digital imaging was introduced. The 3 pillars of radiation protection continue to be time, distance, and shielding. Another important factor of radiation safety is that personnel wear radiation monitoring devices.

8. Time
Time is the first pillar of radiation safety. Limiting time in the examination room is an obvious way to apply this principle. For example, using positioning devices such as sandbags or tape to help a patient hold a position for an exam, rather than assisting the patient, allows technologists to leave the room and avoid exposure to radiation.
Fluoroscopy is an area in which time is a particular concern. Even though fluoroscopy is helpful to guide needle or tube placement, it can be overused. Fluoroscopic equipment must have an audible timer that sounds every 5 minutes to remind the user of the passing time. This signal is mandated by federal law to protect the patient, along with everyone else in the room. It provides a gentle reminder to the radiologist or technologist that “fluoro is on.”

Fluoroscopy floor pedals also can be used to pulse the exposure and lower dose. Just as in a general radiographic room, only the people who are necessary for completing the examination should be in a fluoroscopic room during a procedure. All other individuals can limit their time and exposure by staying outside of the room.

9. Distance
The second pillar of radiation safety is distance. Distance principles benefit patients and technologists as their proper application can greatly reduce radiation exposure. Moving the patient closer to the x-ray source increases entrance skin dose and magnification. Patient exposure, as well as, geometric magnification can be minimized when the image receptor is closer to the patient and the x-ray source is further away. Keep in mind the technical settings for source-to-image receptor distance as they apply to image quality.

Most of the radiation exposure technologists receive comes from scatter radiation from the patient, not from the x-ray tube. The x-rays escaping from the tube housing are called leakage radiation. In the United States, government regulations limit this type of radiation, when measured at 1 meter from the tube, to an air kerma of 0.88 mGy per hour, or 100 milliroentgen per hour. The other major radiation exposure sources come from the primary beam striking the patient and the subsequent scatter radiation emitted by the patient.

The primary beam is not, and should not be, the major source of occupational radiation exposure because technologists should not place any part of their body in the primary beam. This leaves scatter radiation as the source that accounts for the most radiation exposure to the technologists.

Because most of the technologist’s radiation dose comes from radiation scattered from the patient, it’s important that a technologist increases his or her distance from the patient during an examination. The intensity of scatter radiation decreases as it travels away from the patient. This is a practical way to apply the inverse square law. Moving a few steps away from the patient greatly reduces exposure to scatter radiation.

10. Shielding
Shielding is the 3rd and final major pillar of radiation protection for technologists. There are 2 major forms of shielding. Structural shielding is built into the construction of an examination room. Personal shielding is any type of shielding that protects the individual. An example of personal shielding is the lead aprons technologists wear during a radiographic procedure.

11. Structural Shielding
Structural shielding generally is not something a technologist controls on a daily basis. Before examination room construction, medical physicists calculate the requirements for adequately shielding an examination room. Calculating the exact shielding requirements is based on the distance of the wall from the radiation source, the number of exams performed in the room, the length of time people occupy the adjoining rooms, and the level of control technologists have over individuals in adjacent rooms. Then, experiments are conducted to ensure that the shielding performs effectively before the room is put into service.

Structural shielding protects people outside the examination room from any radiation that otherwise might penetrate the walls. In some situations, the floor is shielded to protect people below the examination room. The need for shielding surrounding the exam room may explain why so many radiology departments are located on the lowest floor of a medical facility.
12. Structural Barriers
There are 2 main types of structural barriers used for radiography examination room construction. Primary barriers are built into walls that a primary beam might strike. Because they must block the primary radiation, primary barriers must be equivalent to at least 1/16 inch, or 1.6 mm, of lead. Secondary barriers, on the other hand, must protect against weaker, scattered x-ray photons. Secondary barriers of a 1/32 to 1/64 inch, or 0.8 mm to 0.4 mm, lead-equivalent generally can absorb secondary radiation. Mobile secondary barriers provide radiation protection for medical personnel who don’t need to be in the room for a specific part of an examination but who could be called in during an emergency.

13. Personal Shielding
Lead aprons, gloves, protective glasses, and thyroid shields are additional protection worn by radiology personnel during radiographic procedures. Even though technologists are protected by lead shields, they must use the other pillars of radiation protection, such as limiting the time in the procedure room and maintaining a maximum distance from the patient during the examination.

14. Lead Aprons and Accessories
Lead aprons most often are worn during fluoroscopic procedures or portable radiography. Most lead aprons contain 0.25 to 0.5 mm of lead-equivalent material. The thickness of lead in an apron depends on the kVp used in an exam. For example, if the kVp for an exam averages 100 or more, personnel must use a lead apron with a lead-equivalent of 0.5 mm or more. Depending on the thickness of the lead and style, some aprons can weigh up to 20 pounds or approximately 10 kg.

Thyroid shields often are sold along with every lead apron and are clipped to the apron to keep the personal protective items together. Thyroid shields cover the radiosensitive organs of the neck during fluoroscopic procedures and vary in thickness from 0.25 to 0.5 mm of lead-equivalent material. There also are lead impregnated protective glasses designed to reduce radiation exposure to the lens of the eye from scattered x-ray photons.

15. Lead Gloves
Technologists and other personnel must wear lead gloves during fluoroscopic exams or whenever the operator's hands are likely to be in close proximity to the primary beam. Lead gloves generally are made of 0.25 mm lead-equivalent material that allows some movement and flexibility.

16. Storage of Protective Devices
Lead aprons, gloves, and thyroid shields must be properly stored when not in use. Most often these protective devices are stored on racks or hooks located outside of the examination room. If storage hooks are not available, shields should be kept flat or rolled. Aprons, gloves, and thyroid shields should never be folded because they crack over time. Once cracks form, radiation can pass through the protective device and strike the wearer. For this reason, all aprons, gloves and thyroid shields must be checked for cracks annually. Some institutions perform these checks under fluoroscopic guidance. Keep in mind such a practice increases occupational exposure to the technologists performing the evaluation.

17. Bucky Slot Cover
Fluoroscopy units also contain a Bucky slot cover of at least 0.25 mm lead-equivalent thickness. The Bucky slot cover fills the opening underneath the fluoroscopy table left vacant when the Bucky assembly is moved out of the way for a fluoroscopic procedure. If this gap isn’t filled, the radiologist and technologist receive high doses of radiation since the x-ray tube is sometimes located beneath the table of the fluoroscopic unit. In recent years, manufacturers have begun positioning the tube over the table much like a standard radiographic unit.

18. Protective Curtain
A protective curtain on the control tower of a fluoroscopic unit is another form of shielding for personnel in the examination room. The curtain provides an additional safety measure against scatter radiation during fluoroscopy. The protective curtains found on fluoroscopy units usually have 0.25 mm lead-equivalent thickness.
19. Personnel Monitoring Devices
Although monitoring personnel exposure is not a form of radiation safety, it’s an important aspect of a radiation safety program. Properly monitoring radiation exposure provides radiology personnel with information to help them manage and reduce exposure over time.

There are several types of personnel monitoring devices. Film badges, contain a small piece of radiographic film that is processed and then measured for radiographic density. This measurement estimates the amount of radiation received. Thermoluminescent dosimeters, or TLDs, contain a small crystal that absorbs radiation. When heated, the crystal emits light that is measured to estimate the radiation dose.

Optically stimulated dosimeters, or OSLs, contain a small piece of aluminum oxide that measures the radiation exposure. When the aluminum oxide is struck by a laser beam, it emits light that is measured and accurately reflects radiation doses.

Pocket dosimeters typically are not used by technologists daily because of the cost. When they are used, pocket dosimeters are placed in a reading device each day to immediately read the radiation dose.

20. Dosimeter Readings
All dosimeters should be worn in the same spot at collar level every day to ensure an accurate reading for the torso, thyroid, head, and neck. Ideally, all staff in a department should wear dosimeters in the same place to help the radiation safety officer, or RSO, to accurately compare doses. The monitor should be worn outside a lead apron, not underneath it.

A radiation safety officer collects personnel monitoring devices monthly, bimonthly or quarterly, depending on departmental protocols. Once reports are made available the dosimeter readings are documented. The readings are provided to radiology personnel annually so that procedural changes can be made if necessary.

21. Occupational Exposure Limits
In the United States, acceptable occupational exposure limits for selected anatomical structures and the annual effective dose limit for radiation workers is provided by the National Council on Radiation Protection and Measurements, or NCRP. Recommendations are listed specifically on NCRP Report No. 116. According to this report, the whole-body dose for occupational exposure to the skin is 5 rem, or 50 mSv, the limit for the lens of the eye is 15 rem, or 150 mSv, and for other tissues and organs is 50 rem or 500 mSv. The occupational exposure limit for the hands, feet, and thyroid also is 50 rem, or 500 mSv.

22. Knowledge Check

23. Knowledge Check

24. Radiation Safety for Patients
Not much has changed in terms of radiation safety for technologists working with digital imaging. A tube still emits x-rays, scatter occurs, and technologists protect themselves with the traditional radiation safety principles; time, distance and shielding.

Radiation safety principles for patients also must be taken into consideration. Additionally, there are specific changes in practice affecting the patient when moving into the digital environment.

25. ALARA
As there are occupational dose limits for imaging personnel, there also are dose limits for patients. To better understand what the acceptable limits are, technologists refer to the ALARA principle.

ALARA is an acronym that stands for “as low as reasonably achievable” and is the guiding force behind all radiation protection for patients in radiology. Because patients can be quite ill and several radiographic examinations might be necessary to provide appropriate care, it is not ethical to limit the radiation dose
for a particular patient by eliminating some examinations. The guiding principle for radiology must take into consideration whether the least amount of radiation required for performing an examination, that is in the best interest of the patient, was used. Technologists can reduce the exposure to patients in many ways while maintaining high image quality standards. Again, the 3 major principles of radiation protection, time, distance and shielding, come into play as these values also apply to patients.

26. Time
Limiting the amount of time a patient is exposed to ionizing radiation is primarily a radiation safety concern in fluoroscopy yet still presents obvious concerns for the other imaging modalities using ionizing radiation. Again, this concept refers to limiting fluoroscopy use to those times when the examination is necessary. Techniques to limit patient exposure time include using last image hold and pulse fluoroscopy along with reminding the patient to remain still during the examination.

27. Distance
Distance is another radiation safety principle that applies to patient protection during fluoroscopy. Many fluoroscopic units are designed with the tube below the patient and the image receptor, or image intensifier, above the patient. This brings the patient closer to the x-ray source than in general radiography. The configuration markedly increases the patient’s entrance skin exposure and, in extraordinary cases, can cause severe radiation burns.

For this reason, minimum standards for source-to-skin distance have been established. For stationary equipment the source must be at least 15 inches, or 38.1 cm, away from the patient and for mobile fluoroscopy units the source must be 12 inches, or 30.5 cm, from the patient’s skin. Distance also can affect dose in radiographic procedures. The use of a 44- to 48-inch, or 111.8 to 121.9 cm, source-to-image receptor distance improves detail and increases the amount of anatomical information on the image, while decreasing patient entrance skin exposure. Also, using the shortest object-to-image receptor distance in both fluoroscopy and general radiography will limit patient dose.

28. Shielding
Shielding is almost an art form when it comes to protecting patients. Skill and practice are involved in accurately placing a lead shield to protect radiosensitive organs while not obscuring important anatomy. The 3 types of protective shielding used during imaging procedures are lead aprons, contact shields, and shadow shields.

29. Lead Aprons
Lead aprons are available for patients and are used similarly to their application for radiology personnel. However, the half-aprons used for chest radiography cover only the lower half of the patient’s trunk, draped around the patient’s waste. The shield is placed to reduce the amount of radiation reaching radiosensitive structures in the lower abdomen and pelvis. Structures covered by the lead apron were not recorded on the image receptor and, therefore, do not add to the diagnostic value of the image.

If the area covered by the lead apron is included in the captured image data set, the displayed image will appear overly gray. The poor image display is caused when the digital imaging system attempts to compensate for additional data outside the expected data set for a routine PA chest radiograph.

30. Contact Shields
Contact shields are lead shielding that is laid directly on the patient. Technologists place these shields between the x-ray tube and radiosensitive organs, generally the gonads and breasts. This type of shielding is most often used during hip or scoliosis studies. On a finished radiograph the contact shield appears bright as a result of x-ray attenuation.

31. Shadow Shields
Shadow shields consist of a piece of lead attached to a movable arm that extends from the x-ray tube tower. The technologist can move the shield so that it is located over the area to be protected. It is called a shadow shield because it casts a shadow on the radiosensitive organs, indicating on the patient the
region that requires shielding. Shadow shields are useful when patient positioning makes contact shields impractical.

32. Collimation
Collimation is another radiation safety technique used to reduce the patient’s radiation dose, with the added benefit of improving radiographic contrast. Manual collimation requires more practice and skill to master, along with an excellent knowledge of anatomy. The manual controls on the side of the collimator reduce the size of the radiation field to only the area of interest and limit the tissue exposed to radiation. In turn, this action reduces scatter radiation.

Positive-beam limitation, or PBL, refers to automatic collimation. The lead shutters in the collimation device limit the radiation field size to the image receptor area when an image receptor is placed in the cassette tray and pushed into the table. Although most state regulations allow room for slight variations, automatic collimation ensures that technologists won’t expose the patient beyond the image receptor area. This is important for 2 reasons. First, using collimation reduces the volume of tissue outside the area of interest that produces additional scatter. Additional scatter degrades the image. More importantly, exposing any portion of a patient’s body to the primary beam when that portion is not an area of interest is contrary to the ALARA principle.

33. Technical Factors
Technical factors are selected by the technologist on the control panel and affect patient dose and the outcome of image quality. In general, high milliamperage seconds, or mAs, and low kilovoltage peak, kVp, techniques increase patient dose more than low mAs and high kVp techniques. The tradeoff in using high kVp techniques is a decrease in radiographic contrast. Therefore, most departments select an optimal kVp range for specific exams. This range provides an adequate contrast level and reduces patient dose to the lowest possible intensity.

Technique charts are used for several reasons. The first is to minimize patient exposure across a wide variety of patient variables. A second reason to utilize technique charts is to produce consistent image quality in terms of signal to noise ratio and contrast to noise ratio.

Ultimately technique charts are important because they balance image quality and patient dose. Technique charts are vital in digital imaging because digital image processing adjusts for variations in exposure without visually changing image brightness and contrast. Without use of technique charts in digital radiography, patients could be consistently overexposed increasing their radiation dose without altering image quality.

34. Technique Charts
Several types of technique charts are available but they all share certain characteristics. Technique charts include technical factors such as the mA setting, time, and kVp. Technique charts designed for newer radiographic equipment might only include mAs and kVp settings because newer controls use those settings almost exclusively.

Additional technical factors often included on a technique chart are the appropriate SID for a specific exam, the image receptor size and receptor type, collimation, focal spot size, automatic exposure control, or AEC, photo cell use and cell configuration, grid ratio, and all angles required for specific examinations. The 3 main types of technique charts are fixed kVp, variable kVp, and technique charts designed for use with AEC systems.

35. Fixed kVp Technique Charts
Fixed kVp charts use different kVp settings for different body parts. The settings are based on the ability of the x-ray beam to penetrate the anatomical structures. This setting is called an optimal kVp. The mAs is then adjusted based on the thickness of the body part.

This technique chart lists ranges for the thickness of anatomical structures. The technologist changes the mAs based on these small, medium or large estimates.
36. Variable kVp Technique Charts
Variable kVp charts use a fixed mAs for specific anatomical structures, and then the technologist varies the kVp depending on the thickness of the body part. In the case of variable kVp charts, precise measurements are very important because the kVp is adjusted for each centimeter change in part thickness.

37. Variable vs Fixed kVp Charts
The techniques associated with variable kVp charts generally produce high radiographic contrast and result in a high radiation dose to the patient. On the other hand, fixed kVp chart techniques, usually create images with lower radiographic contrast and result in a lower dose to the patient.

When comparing analog and digital systems, typically, the relationship between fixed and variable kVp technique charts, and the resulting image contrast, is more apparent with analog imaging equipment than digital imaging systems. In digital imaging systems, the look up table, or LUT, assigned to the image is the primary controller of the image contrast.

38. Automatic Exposure Control
Equipment with automatic exposure control relies on the ability of the detectors to measure the amount of radiation exiting the patient and reaching the image receptor. Once the detectors receive a required amount of radiation, the electronic circuit controlling the radiation production in the x-ray tube is stopped, and the exposure to the patient and image receptor is terminated.

The first, and most important reason for using a technique chart with automatic exposure control devices, is that the chart assures the technologist delivers the lowest dose possible for a given body part. Additionally, if the correct kVp is used the resulting image should be of the best diagnostic quality. The second reason for using a technique chart with AEC devices is the chart contains important information needed to guarantee that image quality for a given body part is consistent across a broad spectrum of patients.

AEC-equipped devices require technologists to be skillful in positioning the patient over the activated cell. Correct positioning assures consistent and accurate alignment of the anatomy of interest to the detector elements that calibrate the radiation exposure delivered to the image receptor.

39. AEC Technique Chart
AEC technique charts typically include the optimal settings for specific anatomical structures. The mA setting determines the rate of exposure reaching the detector elements, and the kVp setting assures optimum beam penetration of the anatomical structures being imaged. Settings for the backup timer are provided to limit the maximum allowable exposure in the event the AEC does not terminate the exposure.

The AEC technique chart also lists the detector element, or combination of detector elements, that is most appropriate for the body part being examined. The optical density setting, or plus and minus settings, help the technologist adjust the reaction of the detector cells to compensate when the body part of interest cannot be positioned over the activated cell.

40. Filtration
The NCRP recommends adding filter material so that total filtration is a minimum of 2.5 mm aluminum-equivalent to the tube when a setting of 70 kVp or higher will be used. Low energy x-ray photons add very little to the radiographic quality of an image and greatly increase the patient dose. Filtration is added to the area just beneath an x-ray tube to harden the beam by absorbing low energy x-rays created inside the device.
In addition, technologists can add filtration to many x-ray tubes to limit the x-ray beam for individual examinations. A device for adding a filter may be located on the collimator or on the operator’s console. Technologists should consult their supervisors before altering beam filtration.

41. Grids
Grids are not considered radiation safety devices although they are a consideration of proper radiation exposure techniques. The grid is located between the patient and the image receptor so that the grid absorbs scatter radiation from the patient before it reaches the image receptor and degrades the image contrast. Because the grid absorbs a portion of the primary beam, the technologist must increase technique to compensate for the absorption. The change in technical factors from using a grid results in increased patient dose.

Increases in technical factor selection depend on the grid ratio and the corresponding grid conversion factor. The grid conversion factor for each grid ratio selected is multiplied with the recommended mAs. Performing a radiographic examination with no grid uses a grid conversion factor of 1 which essentially results in selecting the mAs as recommended on the technique chart. When repeating that same radiographic exposure using a grid with an 8:1 ratio, the mAs selection has to be 4 times higher, requiring 4 times more radiation, to maintain image quality.

To reduce patient dose when using a grid, a technologist chooses the lowest ratio grid that will produce a diagnostically useful image. Most radiographic examination tables don’t allow technologists to quickly exchange grids, but many wall-mounted units offer quick and easy ways to exchange grids depending on the source image distance used for the examination.

42. Tissue Thickness Grid Ratio Changes
Changing the grid ratio alters a radiation beam’s ability to reach the image receptor. Remember that grid ratio is based on the relationship between the height of the lead strips found in a grid and the width of the gap, or spaces, between lead strips. Lead strips inside the grid housing are angled to align with the direction of the primary beam. The grid for a radiographic examination table is located between the tabletop and the image receptor.

Using a grid with a higher ratio increases the volume of lead strips within the covering and the space from one lead strip to the next. The grid attenuates more of the beam exiting the patient before it reaches the image receptor. A lower grid ratio is the reciprocal. Fewer lead strips within the casing with smaller spaces between each piece of lead. In turn, the grid attenuates less of the beam exiting the patient before it reaches the image receptor.

The primary purpose of grids is to reduce the unwanted scatter and secondary radiation that reaches the image receptor when the beam exits the patient. There is a variation in radiation passing through the grid depending on the ratio of the grid being used. When more radiation successfully exits a patient and passes through the grid, the number of photons that reach the image receptor increases. As the grid ratio decreases the variations between the beam exiting the patient and the surrounding tissues also decreases. Reducing the beam variation that reaches the image receptor causes all structures in an image to take on the same level of opacity.

43. Patient Position and Projection
The way a technologist positions a patient also can affect the dose the patient receives, especially to radiosensitive organs such as the thyroid, breast, and reproductive organs. The patient’s entrance skin exposure is much higher than the exit exposure. Therefore, positioning the patient so that radiosensitive organs receive the exit radiation dose ensures that those organs receive a much lower dose.

The direction of the x-ray beam for the posteroanterior view compared to the anteroposterior view of a scoliosis examination is a good example of the effect positioning can have on a patient’s entrance skin exposure. A PA scoliosis x-ray examination delivers far less radiation to sensitive organs than an AP scoliosis radiograph. For this reason, the PA projection should be used whenever possible.
44. Reducing Repeats
Achieving a quality image on the first attempt is perhaps the most important way a technologist can reduce radiation exposure to a patient. Every other technique is minor compared to eliminating a repeated image or an entire examination because of single, small oversight. Repeat examinations occur because technologists must deal with complications that only become known after the radiographs are taken such as patient motion, equipment issues, body habitus, and various pathologies.

Experience, skill, and patience are characteristics that can help technologists to reduce individual repeat rates and decrease patient dose overall. The positive effect of good patient communication cannot be underestimated. A patient who understands what is expected during the examination is less likely to move and cause a repeated exam.

45. Knowledge Check

46. Knowledge Check

47. Digital Imaging and Patient Dose
Digital imaging systems haven't changed the fundamental radiation protection principles for either the patient or the technologist. However, factors inherent in digital imaging affect a patient's radiation dose when proper care is not taken during the radiographic procedure. The processing codes used by digital imaging receptors change the appearance of an image, making it difficult to use the image as visual evidence of overexposure. On the other hand, many positive attributes of the digital image receptor help reduce a patient's overall radiation exposure.

Digital imaging can't compensate for poor positioning, motion, or gross overexposure or underexposure, but the automatic rescaling software and other processing techniques used in digital imaging have reduced exposure related repeat exams.

48. ALARA
One issue technologists encounter when a radiology department changes to digital imaging is the potential for gross overexposure. The reason for this increased risk is that technologists no longer have the visual connection between the exposure and an image's appearance.

The image that displays on the monitor is based on automatic rescaling of the pixel intensities from the histogram analysis. The exposure to the image receptor is evaluated based on pixel intensities. If the exposure level is appropriate, the image looks fine. However, if the receptor is overexposed, rescaling adjusts the brightness to make the image look acceptable.

Therefore, there is a potential for overexposure because a technologist sees an image display that doesn't offer obvious clues that the chosen exposure factors were incorrect.

The technologist could use higher technical factors than necessary to avoid repeated examinations, but this notion is flawed. The average technologist has a repeat rate of 5% or less, and many of these repeated exams are related to positioning, not exposure. Thus, it's unethical to overexpose 100% of patients to avoid the possibility of repeating a tiny percent of examinations because of incorrect exposure factors. Technologists have a duty to choose the appropriate exposure factors based on sound scientific principles and to minimize radiation dose to patients.

49. Automatic Rescaling
Automatic rescaling of the pixel values of the image data can lead to overexposing the patient. Automatic rescaling alters the output pixel intensity in order to have consistent image brightness even when there are errors in exposure technique.

At the bottom of the graph the white line is a reference histogram for a specific body part when the correct exposure is delivered to an image receptor. The histogram in black simulates the data collected when an image receptor is overexposed.
Automatic rescaling creates an image that is visually acceptable across every level of exposure within the dynamic range of the receptor. However, no image is acceptable at the point where the receptor is incapable of responding when it’s saturated with radiation.

50. Exposure Latitude and Overexposure
The dynamic range of the digital system is the range over which the system is capable of creating an image. Exposure latitude is the range of exposure variation that a department has defined as being acceptable for producing diagnostic images. Exposure latitude refers to the amount of radiation needed to produce a diagnostic image. Image software cannot correct for improper exposure levels.

Technologists must still use the correct amount of radiation for the patient condition, the anatomical part, and the image receptor. Overexposure and underexposure are simply that, either too much or too little radiation to a body part and the receptor.

Digital detectors have a wide dynamic range, with an essentially linear response to exposure. This means that kVp doesn't have the same effect on digital receptors as it does on film-screen receptors. Applied processing codes affect contrast more than kVp levels. The red line represents the linear response range of a receptor to varying amounts of exposure. The numbered boxes correspond to the placement of image data captured from 3 different levels of receptor exposure.

An image created at level 1 or lower would exhibit brightness and contrast that likely would be acceptable, but the image would demonstrate a noticeable-to-unacceptable amount of image noise. The noise would appear as graininess or random blotchy patterns within the image. An image created in the level 2 range would demonstrate acceptable image brightness, contrast, and noise. An image created in the level 3 range would demonstrate acceptable brightness but could risk being unacceptable because of decreased image contrast resulting from an excessive amount of scatter radiation that strikes the image receptor.

51. Digital Imaging and ALARA
Using collimation in digital imaging is essential. Technologists should remember three key concepts when combining collimation, digital imaging, and ALARA.

First, digital imaging receptors are especially sensitive to scatter radiation. So everything technologists can do to prevent scatter or unwanted radiation from reaching the digital image receptor greatly improves the image. Collimation improves image quality and reduces patient dose.

Second, technologists must collimate using the radiographic equipment in the examination room, rather than using masking software at the technologist's workstation. Masking places a black cover over the white area of an image created by true collimation. Masking reduces eye strain for the viewer. Although it's possible to mask an image electronically to make it appear tightly collimated, this is not the software’s purpose. Masking with the computer instead of collimating with the radiographic equipment will not reduce the negative influence of scatter. The absence of collimation also increases patient dose.

Third, when using digital equipment, it's essential that technologists collimate in a way that the equipment software recognizes. Manufacturers can provide approved patterns, but in general most exams are best acquired using collimation borders parallel with the edges of the image receptor. Failing to properly adjust the collimator can cause an exposure field recognition error and possibly lead to repeating the exam.

52. Documenting the Exposure Indicator
Exposure indicators track radiation exposure to the image receptor and are part of the patient's permanent medical record. When the technologist changes the exposure indicator for any image, that change must be noted on the patient's chart. Technologist's professional practice standards recommend documenting all such modifications.
Departments audit exposure indicator documentation as part of a quality assurance and quality control program. These audits compare the original exposure indicator retrieved from the technologist workstation to the exposure indicator in the patient’s records.

53. kVp and Dose Reduction
Using higher kVp values is a strategy that is widely debated. In fact, technologists sometimes question whether a higher kVp should be used for some studies and a lower kVp be used for others as an element that is considered the art behind creating a quality radiograph.

With a digital receptor, technologists can use different kVp values than they use with an analog image receptor. Technologists can increase kVp levels slightly in digital imaging because the kVp no longer primarily controls the radiographic contrast in the image. Processing codes applied to the image data determine the radiographic contrast. Changing kVp values may require modifying the existing image processing codes to ensure an appropriate display of image data.

Increasing the kVp allows technologists to reduce the level of exposure to the patient when applying the 15% rule. The 15% rule states that a 15% increase in kVp permits the technologist to reduce the mAs by one-half, while maintaining the necessary exposure to the receptor.

54. Applying the 15% Rule
By applying the 15% rule, using a higher kVp and lower mAs, radiation exposure to the patient is reduced. As the kVp increases and mAs decreases to compensate, the entrance skin exposure, or ESE, to a patient decreases dramatically. For example, when a technical setting of 70 kVp and 48 mAs is used for a particular examination, the patient will receive an ESE of 122 mR. If the technologist uses 90 kVp instead, this allows for a lower mAs of 14 which will decrease the ESE to only 67 mR.

Processing algorithms produced 2 wrist images with a similar display appearance, even though there is a 10-kVp difference. The 65-kVp image is associated with a lower dose to the patient compared with the 55-kVp image because of the combination of higher beam quality and lower mAs value. The digital image receptor allows the technologist to decrease patient exposure by applying the 15% rule. Using less mAs by decreasing time will also reduce the possibility of motion.

Some radiology departments use a grid for knee radiographs at 60 to 70 kVp. The digital receptor allows technologists to increase kVp values. Processing algorithms produced 3 knee radiographs that demonstrate how difficult it is to see significant differences in the images. However, because of the combination of higher beam quality and lower mAs value patient dose will decrease. Increasing the kVp significantly reduces the patient's exposure level and certainly helps the technologist adhere to the ALARA principle.

As a final example, radiography of the posterior ribs produced at 75, 85, and 95 kVp also represent similar display appearances. With a digital receptor, the technologist increased the kVp and decreased the mAs to significantly reduce the patient’s entrance skin exposure.

55. Processing Codes
Remember that in analog imaging the characteristic curve demonstrated a film’s density and contrast characteristics, based on the curves’ slope, height, and depth. In much the same way, processing codes for digital imaging receptors can manipulate the way contrast and brightness are displayed on a digital image.

There are different ways of looking at the same image data. For example, steeper lines represent increased image contrast; lines that are lower on the scale can show increased brightness, and lines that are higher on the scale can demonstrate darker shades of gray and black. The digital imaging system manager can adjust these codes for individual anatomical areas to match the technical factors the system manager selected.

56. Processing Code Applied
Regardless of the kVp that was used, after a technologist applies processing codes to the raw image data the images become nearly identical. Because this effect can be created it provides another mechanism for technologists to apply to reduce patient exposure and adhere to the ALARA principle.

The application of processing codes makes differences difficult to detect. It’s hard to see a difference between the image created at 75 kVp and the image created at 130 kVp. However, the increase in kVp and reduction in mAs has practical limits. After a point, the mAs is too low and results in an image with excessive noise that does not adequately display the anatomical structures.

57. Grids and Dose
In analog imaging, the technologist manipulates the mAs when increasing the grid’s ratio, as in changing from a 5:1 to an 8:1 grid. The technologist increases the mAs value to maintain the signal level to the receptor. The adjustment in mAs doubles the patient dose.

In digital imaging, a better alternative when using grids is to increase the kVp value to achieve an appropriate signal level at the receptor. The change in kVp does not change image appearance because processing codes determine image display characteristics. Increased kVp produces more x-ray photons and a beam with greater penetrating power. These 2 factors strengthen the signal at the receptor and decrease patient exposure. An increase in the kVp value only, when changing from a 5:1 grid to an 8:1 grid in digital imaging increases the patient dose by 25%. Basically, increasing kVp without decreasing mAs will increase patient dose.

58. Selecting kVp
Increasing kVp is a viable way to decrease the entrance skin exposure when also decreasing mAs. The digital image receptor can reduce radiation exposure to the patient through higher kVp and proportionally lower mAs values.

If a technologist selects a kVp value that is too high, there is a risk of degrading image quality. When the kVp is too high and the mAs is too low, an insufficient number of photons strike the receptor. A random pattern of photons in the beam are recorded and used to produce the image; the human eye sees this pattern as noise.

To prevent noise, technologists should use accurate technique charts. Technique charts help balance the need to produce consistently high-quality images with the obligation to adhere to the ALARA principle.

59. Acceptable Image Noise
In digital imaging, a processing algorithm controls the contrast and brightness, or display appearance, of the digitally acquired image. This arrangement disconnects the display appearance of the image and the exposure level delivered to the image receptor. The disconnect is positive in that the technologist can use techniques to reduce the level of exposure to the patient and still produce images of high diagnostic quality. The radiologist’s feedback on a range of sample images helps determine the level of image noise that is considered to be acceptable.

60. Setting Technique Charts
Contrast detail phantom images produced at 3 different exposure levels; 0.1, 0.4 and 1.0 mR, each have a different noise level. Additionally, the comparison of very small to very large objects within the phantom is variable. Noise affects the ability to see structures in the image.

The variations in contrast and noise levels demonstrate why it’s important for radiologists to set the unacceptable level of noise. Once this level is determined, the technique chart can be established for the institution’s image receptors.

61. Dose Reduction
When comparing images acquired using differing exposure levels, one low and the other higher, the resultant noise demonstrates deviations in the ability to easily see differences in contrast. The image on
the right used an exposure level, or mAs, that was one half of the mAs that was used for the other image. The increase in image noise results in the decreased ability to visualize differences in image contrast.

The selection of technical factors impacting the exposure of the receptor greatly influences dose to the patient and the noise seen on the image. It’s important to realize that as image noise increases, image quality is negatively affected. On the other hand, it also is important to recognize that as noise decreases, radiation exposure to the patient increases. It is important to balance patient dose with acceptable image quality.

62. Radiation Safety Responsibility
Radiologic technologists should always take radiation safety into consideration, for themselves, the patient, and other staff members. The technologist should implement the 3 pillars of radiation protection, time, distance, and shielding whenever performing a procedure. These safety practices, along with ALARA, ensure technologists deliver the lowest possible radiation exposure, while maintaining high image quality. Technologists must become familiar with the radiation safety policies and procedures of the facility.

63. Knowledge Check

64. Knowledge Check

65. Conclusion
This concludes Essentials of Digital Imaging: Module 6 – Dose Reduction and Patient Safety. You should now be able to:

- List the radiation units of measure.
- Name and describe the 3 pillars of radiation safety.
- Define ALARA.
- Discuss different shielding methods.
- Describe radiation protection for fluoroscopic procedures.

66. References


Carter CE, Vealé BL. Digital Radiography and PACS. St Louis, MO; Mosby Elsevier; 2009.

