Steps to Manage Radiation Dose During the Examination
Image Gently: Steps To Manage Radiation Dose During the Examination

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What is the goal of this module?

Provide the medical imaging professional with information to create diagnostic quality images while properly managing radiation dose during pediatric fluoroscopy.

Welcome to the online educational module “Image Gently: Steps to Manage Radiation Dose During the Examination.” The goal of this module is to provide the medical imaging professional with sufficient information to create diagnostic quality images while properly managing radiation dose during pediatric fluoroscopy. This goal will be achieved if the user is knowledgeable about the operation and controls found on most state-of-the-art fluoroscopes. Operational differences in interventional, general purpose and mobile C-arm fluoroscopes are addressed. For example, the image is a drawing of a typical control panel for a general purpose fluoroscopic unit. Each rectangle, circle, or lever shown controls a unique feature of the fluoroscope. Some of the discussion in this module is beyond the scope typically found in texts currently used in many radiologic technologist training programs. It may be necessary for the experienced radiologic technologist to guide users of new equipment or those with less experience in pediatric fluoroscopy. These training modules underscore the important role of the radiologic technologist in clinical practice when performing diagnostic imaging examinations of children.
Learning Objectives:

1. Explain the basic operation of fluoroscopic equipment.
2. Identify areas of fluoroscopic practice that can reduce radiation dose to the pediatric patient during fluoroscopy.
3. List equipment configuration adjustments that affect dose to pediatric patients during fluoroscopy.
4. Discuss the relationship between fluoroscopic image quality and patient dose.

At the completion of this module, the participant will be able to:

1) Explain the basic operation of fluoroscopic equipment.
2) Identify areas of fluoroscopic practice that can reduce radiation dose to the pediatric patient during fluoroscopy.
3) List equipment configuration adjustments that affect dose to pediatric patients during fluoroscopy.
4) Discuss the relationship between fluoroscopic image quality and patient dose.
What are anatomical programs and what is their purpose?

- Allow the operator to correctly select the type of exam and patient size.
- Anatomical programs are presets programmed into the fluoroscope by the manufacturer or end user designed to select appropriate settings of the fluoroscope for the type of exam and patient size selected.

Anatomical programs allow the operator to correctly select the type of exam and patient size, which in turn selects the appropriate multiple controls of the fluoroscope. The anatomical programs are presets programmed into the fluoroscope by the manufacturer or end user. These programs influence the air kerma rate of the fluoroscope for preconfigured clinical exams such as the abdomen, kidney, mesenteric artery or pelvis as a function of patient size in the drop down menu illustrated in the figure. The filter type and thickness, voltage across the x-ray tube, x-ray tube current, and pulse width all affect the amount of radiation production by the fluoroscope and the radiation reaching the patient and image receptor. While radiologic technologists typically think of variations between two fluoroscopes as "differences in calibration," these differences are actually a result of unique design choices made by different manufacturers.
How does the radiologic technologist work with the physician and QMP to ensure that appropriate pediatric default anatomical programs are available on the fluoroscope?

- Most state-of-the-art fluoroscopes allow multiple configurations to be placed into the fluoroscope’s anatomical programs.
- The appropriate examination and patient size is requested by the selection of one or two settings.
- The labeling of default settings may not be appropriate for pediatric imaging.

It is critical that the radiologist and radiologic technologist work with the QMP to establish consensus for the appropriate default settings of the fluoroscopic unit for pediatric examinations. Because of the large combination of pediatric patient sizes and types of examinations, most state-of-the-art fluoroscopes allow multiple configurations to be placed into the fluoroscope’s anatomical programs in an organized fashion. This feature allows operators to choose appropriate settings and radiographic techniques for a given patient and examination with one or two simple selections.

However, the fluoroscope’s labeling of default settings can be confusing. For example, what do “small, medium and large” indicate? Does this indicate a “small, medium or large adult” or a “small, medium or large child”? The default settings may have been configured in the factory, so they may not be properly adjusted for children. The illustration shows different patient sizes from one manufacturer that are more descriptive than most. In this case, by default, one can probably safely assume that the “small” selection indicates a small adult-sized patient. The radiologic technologist should work with the
physician and QMP to reach a consensus in evaluating proper setup and labeling of default settings to eliminate ambiguities and to ensure good pediatric patient care.
Can I use the same technique settings for a patient of the same size for the same exam on two different fluoroscopes and deliver the same radiation dose to the patient?

- More than likely, no.
- Two fluoroscopes will not use the same technique factors for patients of the same size, nor would identical technique factors result in the same radiation dose to the patient.

It is probably not possible to use the same technique settings for a patient of the same size and for the same exam on two different fluoroscopes and deliver the same radiation dose to the patient. However, the operator may be able to select similar anatomical programs on two separate fluoroscopes for a given patient. For example, the figure shows that the operator could select the subclavian artery in the drop down menu on two different machines provided both machines offered this anatomical choice. However, this does not ensure that the two machines will use similar technique factors. Due to unique designs by manufacturers, variations between models by the same manufacturer, or software revisions on identical models by the same manufacturer, two fluoroscopes probably will not use the same technique factors for patients of the same size, nor would identical technique factors result in the same radiation dose to the patient. The fluoroscope with higher technique factors may actually be delivering a lower radiation dose to the patient.
A single fluoroscopic image, such as a last-image-hold (LIH) image, is noisier than a radiographic image, but it’s also achieved at a lower dose. The radiation dose to the patient from an LIH image is approximately one-tenth of the dose from a radiographic image. The radiographic image, with less noise, provides better image quality, particularly of soft tissues.

The image on the left of a rabbit thorax is a last-image-hold image. There is more noise and less detail displayed than in the image on the right acquired with a radiographic technique, which delivers approximately 10 times more radiation dose to the patient and the image receptor.
Are there regulations that limit how much radiation a patient can receive from a fluoroscopic exam?

- There are no regulations that limit how much radiation a patient can receive from a fluoroscopic exam.
- The direct medical benefit from the fluoroscopic exam should outweigh any risk from ionizing radiation associated with the exam.
- The Joint Commission (TJC) defines a sentinel event as the delivery of 15,000 mGy to a patient’s skin over a time span of 6 months to a year.

The maximum entrance air kerma rate to the patient during fluoroscopy is capped at approximately 88 mGy/min in the normal fluoroscopy mode. However, the actual air kerma rate is very dependent on the thickness of the child as illustrated in the diagram. The air kerma rate for the smallest neonate is approximately 25 times less than the air kerma rate for an average-sized adult on a properly configured fluoroscope.

There are no regulations that limit how much radiation a patient can receive from a fluoroscopic examination. The direct medical benefit from the fluoroscopy study should outweigh any risk from ionizing radiation associated with the examination. The operator should understand the design features of the fluoroscope, which either reduce the fluoroscopic air kerma rate or the dose of each image acquisition. They also should be competent in the use of these features in order to manage the total radiation dose delivered to the entire range of pediatric patient sizes.
Even with optimized fluoroscopic equipment, there may be a clinical need that justifies and results in a substantial radiation dose to the patient. The Joint Commission (TJC) defines a sentinel event as the delivery of 15,000 mGy to a patient’s skin over a time span of 6 months to a year. While this does not prevent the operator from exceeding this dose level during complex interventional examinations that may address life-threatening situations, the TJC’s rule is a strong deterrent to exceeding this dose level.
What is the purpose of default settings on the operator's controls at the beginning of a study?

- Default settings determine the rate of radiation production at the beginning of the examination.
- Radiologic technologists should ensure the appropriate default settings are activated prior to each study.
- The department's quality assurance program should include default-setting guidelines.

Default settings determine the rate of radiation production at the beginning of the examination. The goal is to provide a diagnostic quality image at a properly managed radiation dose as illustrated in the figure. These control settings should be carefully selected to provide dose rate levels appropriate to the physical size of the child and the complexity of the examination. If the image quality provided by the default is unacceptable to the operator, the operator will adjust the controls to provide the necessary image quality. Using this approach, the operator properly manages both image quality and patient radiation dose. If the default settings provide better image quality than necessary at the start of the exam, the operator receives no visual prompt to adjust the fluoroscope's control settings to manage either the patient dose or image quality. The radiologic technologist should check the fluoroscope prior to the beginning of each study to ensure that the appropriate default settings are activated. The department's quality assurance program should include default-setting guidelines.
What is continuous fluoroscopy?

- When radiation is continuously emitted from the fluoroscope, 30 separate images are captured per second.
- Continuous fluoroscopy creates blur or motion unsharpness from moving objects because the beam is on too long to freeze involuntary patient motion.

The operator uses the foot or hand switch on the fluoroscopy machine to turn the x-ray beam “on or off.” When the switch is depressed, radiation is continuously emitted by the fluoroscope as shown in the figure, which illustrates radiation output over time for continuous fluoroscopy. The tube current typically ranges from 0.5 to 6 mA according to the patient’s size. The continuously acquired image data is divided into 30 separate images (frames) each second. Since the frame rate is not adjustable in this mode, the length of time the beam is “on” for each image is approximately 33 msec. This time period is too long to properly freeze involuntary patient motion of the pediatric patient. Therefore, using continuous fluoroscopy creates blur from moving objects. This is called motion unsharpness. Historically, all fluoroscopy was continuous until the introduction of pulsed fluoroscopy in the late 1990s.
What is pulsed fluoroscopy?

- The x-ray beam is started and stopped (pulsed) to produce each single fluoroscopic image.
- The number of images per second is equal to the number of pulses per second.
- Pulse widths for children are ideally less than or equal to 6 msec.
- Unsharpness of moving objects in the fluoroscopic image is significantly reduced.

In pulsed fluoroscopy, the x-ray beam is rapidly started and stopped (pulsed) to produce each fluoroscopic image. The number of images per second is equal to the number of pulses per second. The figure shows that three pulses of radiation have occurred, resulting in the creation of three fluoroscopic images. On most modern fluoroscopes, the operator can select the pulse rate within the range from 1 pulse/sec to 30 pulses/sec. The pulse width, defined as the duration of each pulse is ideally less than or equal to 6 msec for children and less than or equal to 10 msec for adults. Because these pulse widths are much shorter than the 33 msecs used in continuous fluoroscopy, unsharpness of moving objects in the fluoroscopic image is significantly reduced.
Is the range of tube current different for pulsed vs. continuous fluoroscopy?

- The number of x-rays used to generate each fluoroscopic image is the same for continuous and pulsed fluoroscopy.
- Since the duration of the pulse during pulsed fluoroscopy is less than 33 msec, the tube current is increased so the number of x-rays used to produce a fluoroscopic image is independent of the mode used.

The tube current during each pulse of fluoroscopy is increased compared to continuous fluoroscopy, so the number of x-rays used to generate each fluoroscopic image is the same for either mode of operation. This is necessary to maintain similar levels of noise in the fluoroscopic image for either mode of fluoroscopy. This is illustrated in the figure where the product of tube current (mA) and pulse duration are equal for each image acquired in both continuous (A) or pulsed (B) fluoroscopy. The tube current for continuous fluoroscopy is relatively low. Each image is acquired over a 33 msec period. The product of the two, current x time (mAs), associated with each fluoroscopic image is represented by the area of the yellow, dotted rectangles, horizontal for continuous mode and vertical for the pulsed mode. Because the area of the horizontal and vertical rectangles is equal, the dose per image in both modes is similar resulting in similar noise characteristics in the final images.
Pulsed fluoroscopy at 30 pulses per second does not reduce the radiation dose to the patient compared to continuous fluoroscopy. In both types of fluoroscopy, 30 images are generated each second. If the patient size, exam, image noise and mAs are constant, the radiation dose rate to the patient will be essentially unchanged. The image illustrates the position of the child relative to the major components of a general fluoroscope found in a typical radiology department.
Does pulsed fluoroscopy at pulse rates < 30 frames per second reduce the radiation dose to the patient?

- Assume that the dose per pulse of radiation is the same regardless of the frame rate.
- If the frame rate is cut in half, e.g., 30 to 15 frames per second, the dose rate to the patient will be cut in half.

The figure illustrates that pulsed fluoroscopy at 15 pulses per second generates half as many images as 30 pulses per second. Because the dose of each pulse is the same, patients receive half as much radiation dose. Further reductions in pulse rate will result in lower patient dose rates.
Can pulsed fluoroscopy rates be too low?

High frame rate images:

Cardiac margin and tip of catheter are sharp on all margins.

While lower pulse rates deliver less radiation dose to the patient, fewer fluoroscopic images per second are also created. This reduces temporal resolution in the image, that is, the ability to image moving objects continuously and clearly. Therefore, during dynamic studies where clinical objects of interest are in continual motion, such as an infant’s heart, the operator must weigh the desire to reduce patient dose against the need for satisfactory temporal resolution.
What are appropriate pulse rates for pediatric fluoroscopy?

- Pediatric cardiac studies require rates of 30 pulses/second.
- Noncardiac interventional studies typically require 15 pulses/second for pediatrics.
- General fluoroscopic studies of the GI track or bladder can use as low as 1-4 pulses/second.

Pediatric cardiac studies require frame rates of 30 pulses/second while adult cardiac studies are typically imaged at 15 pulses per second. The pediatric studies require 30 pulses/second because infants and children have a more rapid heartbeat than adults. Non-cardiac interventional studies typically require 15 pulses/second for pediatrics and 7.5 pulses/second for adults. General fluoroscopic studies of the gastrointestinal tract or bladder can typically be performed with frame rates from 1 to 4 pulses per second for either pediatric or adult patients.
How does x-ray tube voltage affect the energy of the x-rays produced and the formation of the image?

- The KV setting determines the maximum energy within the x-ray beam.
- The fluoroscopic x-ray beam contains a continuum of x-ray energies.
- Higher energy x-rays exit the patient and contribute to the formation of the x-ray image.
- Lower energy x-rays absorbed in the patient increase the patient’s dose.

The voltage (kV) applied across the x-ray tube determines the amount of energy carried by each x-ray, which determines the ability of the x-ray to penetrate the child’s tissues. The KV setting determines the maximum energy x-ray within the beam. In the x-ray beam spectrum in the figure, an 80 kV setting created a few maximum energy x-rays of 80 keV. This fluoroscopic x-ray beam contains a continuum of x-ray energies below the maximum value. In this example the most frequent x-ray energy present in the beam, the effective energy, is approximately 36 keV. The higher energy x-rays, greater than the effective energy, tend to exit the patient and contribute to the formation of the x-ray image. The lower energy x-rays, less than the effective energy, tend to be absorbed by the patient. These low energy x-rays increase patient dose without contributing to image formation.
How does x-ray tube voltage affect pediatric patient dose and image quality during fluoroscopy?

Figure A. 50 kV. Higher dose. Higher contrast.

Figure B. 120 kV. Lower patient dose. Lower contrast.

Because higher voltage (energy) x-rays more efficiently penetrate the patient, an increase in the voltage reduces the number of x-rays required to produce an x-ray image. Therefore, patient dose and subject contrast in Figure B, are reduced compared to Figure A. Figures A and B were created with 50 and 120 kV respectively with the same dose to the image receptor. The inherent contrast in the phantom for both images is the same since the aluminum objects are identical and the phantom thickness is constant at 7 cm thick. As described previously, for a given image, objects 1, 3, 4, 6, 7 and 9 are the same contrast. Objects 8 is double the thickness of object 5, which is double the thickness of the object 2. Again the objects in the first group of 6 objects are at a contrast level greater than object 5, but less than the object 8. In Figure B objects 2 and 5 are difficult to see along with some of the missing corners to the squares in the outer two columns. The loss of subject contrast with an increase in voltage prevents increases in voltage with the intent of reducing patient dose. During pediatric interventional fluoroscopy, the iodine in contrast agents improves tissue contrast in the image to a greater degree when the voltage does not exceed 80 kV. Higher voltages, up to 100 kV, may be used when barium is the contrast agent for upper or lower GI studies in pediatric patients.
The tube current determines the rate of x-ray production or number of x-rays per unit time. The number of x-rays produced by the x-ray tube and reaching the image receptor is directly proportional to the tube current if all other technique factors are equal. An increase in tube current reduces the amount of noise in the image, but increases the patient dose. Eight hundred and 10 mA were used to produce Figures A and B, respectively, with all other technique factors held constant. As the patient dose increased eightyfold, a reduction in noise in the image improves the visibility of detail of the 9 objects. Since the tube current and patient dose increase more rapidly than the noise falls, this is not an effective way to improve image quality while managing patient dose. The contrast level of the objects in the two images are identical, but the objects in Figure B are more difficult to see than A because of the increase in quantum mottle (noise) in the image.
How does pulse width affect patient dose and image quality during fluoroscopy?

Pulse width is the length of time x-rays are produced during the creation of a single image. Increasing the tube current or the pulse width during a pulse of radiation increases the number of x-rays used to create an image. Eight hundred and 10 msec were used to produce Figures A and B, respectively, with all other technique factors held constant. In this case, the patient dose increased 80-fold in the improved image, Figure A, with noticeably reduced noise levels. Any increase in the tube current or pulse width has the same effect on the management of patient dose and image quality; image degradation in this and the previous question is similar. But this is only true because the phantom used to produce the two images is stationary. The tube current should be increased to its maximum before increasing the pulse width when imaging patients because an increase in pulse width also results in more motion unsharpness especially in pediatric patients who are constantly moving.
What is beam filtration in fluoroscopy?

- Beam filtration is removing low-energy x-rays from the fluoroscopic beam to reduce radiation dose by placing a sheet of material (the filter) in the x-ray beam to attenuate the low-energy x-rays.
- Low-energy x-rays that are not removed by the filter increase the patient's radiation dose without improving the image quality.

Beam filtration is achieved by positioning a sheet of material (a filter) within the tube housing to intercept the x-ray beam to remove low-energy x-rays. Adding filtration changes the shape of the bremsstrahlung curve. Because the maximum energy of the x-rays in the beam is determined by the selection of the high voltage, the maximum energy x-ray is not altered by additional filtration. However, the effective energy, the energy corresponding to the peak of the curve, is shifted to the right with additional filtration. In addition, the area under the curve is reduced, which represents the intensity or the total amount of energy that is carried by the x-ray beam. If the low-energy x-rays are not removed by the filter, their energy is deposited in the child’s tissues, increasing the radiation dose without improving image quality. Historically, the filter material was aluminum.
What filters are used on state-of-the-art fluoroscopes today?

- Copper is a common filter material in use in fluoroscopic units today.
- Thickness of copper filters on interventional fluoroscopes ranges from 0.1 to 0.9 mm.
- General fluoroscopic tables typically provide a 0.1 to 0.3 mm copper filter.
- Mobile fluoroscopes typically have fixed added filters of 0.1 to 0.2 mm copper.

Today, most fluoroscopes can interchange filters of different thicknesses composed of material with an atomic number higher than aluminum. These added filters more effectively remove low-energy x-rays and allow the higher-energy x-rays to reach the patient. Copper is a common example. Copper filters on interventional fluoroscopes range from 0.1 to 0.9 mm copper. General fluoroscopic units typically provide 0.1 and 0.2 and sometimes 0.3 mm copper filter. Mobile fluoroscopes typically have a fixed copper filter thickness of 0.1 or 0.2 mm of copper.
Why are thicker added filters important during fluoroscopy of small children?

For any sized patient, as the added filter thickness increases, the entrance dose to the patient decreases relative to the entrance dose to the image receptor. This results in equal or slightly better image quality at a reduced patient dose. However, as a child’s size increases, added filter thicknesses must be reduced. The fluoroscope can only produce a finite number of x-rays per second. As patient size increases and attenuates more x-rays, a thinner filter, which attenuates fewer x-rays, must be used to ensure the appropriate number of x-rays reach the image receptor. This phenomenon is illustrated in the image, which plots the filter thickness used by one manufacturer as a function of patient thickness simulated by the thickness of a plastic phantom constructed of PMMA, a synthetic resin. Note that 0.9 mm copper is used for patient’s body parts less than 3 inches thick. For patients in the 3-to 6-inch range of thickness, 0.6 mm of copper is used. The copper thickness is reduced to 0.3 mm for patient thicknesses in the 7-to 8-inch range. For patients greater than 8 inches in thickness, a 0.2 mm copper thickness is selected.
State-of-the-art fluoroscopes automatically adjust voltage, tube current, pulse width and added filtration within specified ranges as more or fewer x-rays are needed to penetrate the patient. The order in which the fluoroscope changes these parameters affects the management of patient dose and image quality for pediatric patients. As illustrated in the chart on the left, if the filtration increases, the voltage should be reduced to limit the loss of subject contrast in the image in the patient thickness range of 0 to 6 inches, which is the size of the smaller pediatric patients. The chart on the right demonstrates that after the added filtration and high-voltage combination is selected, the tube current and pulse width should increase to deliver the correct number of x-rays to the image receptor in the 0- to 6-inch range of patient thickness. The tube current rather than the pulse width should be increased when more x-rays are needed, provided the x-ray tube has not reached the maximum allowed tube current. If the technologist or operator suspects that the fluoroscope is not following the hierarchy described above when changes in radiation output are necessary, he or she should contact the QMP or service engineer to investigate the fluoroscope’s programming.
Fluoroscopes with aluminum filtration should increase the voltage from 65 to 120 kV as patient size increases from the smallest to largest patients as illustrated in this chart. The minimum allowed voltage for the smallest patients should be about 65 kV. While voltages from 40 to 60 kV for the smallest patients or body parts can be used, these lower voltages result in significantly higher patient doses with little improvement in image quality. The default setting for the minimum voltage with a standard filtration of 3 mm of aluminum during pediatric imaging is approximately 65 kV. Despite the loss of subject contrast in the image, the largest patients must be imaged in the 110- to 120-kV range to obtain adequate penetration without exceeding the maximum fluoroscopic dose rate of 88 mGy/min. If the fluoroscope is not operating within these recommended ranges, the technologist should contact the service engineer to investigate the operation of the unit.
What are the voltage recommendations when using added copper filtration for patients of all sizes?

When copper or other higher atomic number filters are used, the voltages used for the largest patients are the same because the copper filters are removed by the fluoroscope. When smaller children are imaged, the added thickness of copper dictates the appropriate voltage to maintain contrast in the image. For example, a mobile C-arm or tilting table general purpose fluoroscope that provides a fixed 0.1- or 0.2-mm copper filter should not use voltages less than 65 kV for the smallest patients. An interventional fluoroscope should increase the added filtration as patient width decreases from 18 to 10 cm. As the added copper filtration increases from 0.1 to 0.9 mm, a decrease in voltage from approximately 70 to approximately 55 kV restores some of the contrast in the image that was lost when the copper filtration was added. These three images illustrate this concept. Figure A is created without copper filtration at 70 kV. One can detect the object because its subject contrast is different than its background. Figure B is created at 70 kV with 0.9-mm copper added in the x-ray beam; note the loss of contrast in the image. Figure C is created with the 0.9 mm copper filtration in the beam and a reduction of the high voltage to 56 kV. While all of the subject contrast of A is not recovered in C, the subject
contrast of C is significantly improved relative to B. Unless the fluoroscope is equipped with an appropriate pediatric configuration, these recommended voltages and filter thicknesses will probably not be used automatically, which may needlessly increase the patient dose rate. If the technologist or operator suspects that the fluoroscope is not functioning within these recommendations, he or she should contact the QMP or service engineer to investigate the fluoroscope’s programming.
Most modern fluoroscopes allow the operator to select from a number of dose rate settings typically labeled low, medium or high. This control determines the radiation dose rate at the image receptor, which affects the amount of noise in the image. A task with inherently low contrast such as differentiating soft tissues requires a higher dose to the image receptor and less noise. One example would be evaluating tracheomalacia or collapse of tracheal cartilage on inspiration. For this task, a dose rate of medium or high should be selected. An examination with high inherent contrast, such as a bone biopsy, angiogram of a large vessel or upper GI with barium, is less affected by the dose to the image receptor and a low or medium dose rate should be selected.

The operator should select the dose rate level appropriate to the imaging task. The low dose setting is typically half of the medium setting, which is typically half of the high dose level setting. The first image contains more noise and less detail than the second image because the first image was obtained on the low setting at 25% of the dose used for the second image obtained on the high setting. The operator
should select the lowest dose level setting that provides adequate image quality for the clinical task. As noted earlier, the default setting at the beginning of the examination should be low.
How do the low, medium and high dose settings affect dose to the patient?

- Any change in the dose rate to the image receptor changes the child's radiation dose.

The dose rate control setting directly affects the radiation dose to the image receptor, which affects the child's radiation dose. Any change of the dose to the image receptor changes the child’s radiation dose. This image shows three buttons provided by one manufacturer at the table side of an interventional fluoroscope used to select the dose rate to the image receptor. The choice on the left produces an air kerma rate that is 25% of the choice on the far right.
Frame averaging is the process of averaging multiple fluoroscopic image frames together to produce a final image with less noise. When successive fluoroscopic images are added together, the level of noise in the processed image is reduced due to an averaging effect. While this reduces noise, temporal resolution, that is the ability to clearly see objects in motion across the image, is diminished. These three images illustrate this concept. The first image contains no frame averaging, and the tip of the moving guide wire is properly imaged. The second image is four frames averaged together; note that the tip of the moving guide wire is displayed with four different ends. The third image is the composite of 16 frames averaged together; the tip of the moving guide wire is not imaged. The first image is noisier than the last image. Frame averaging is most commonly found in mobile fluoroscopic systems.
How does frame averaging affect patient dose?

- Patient dose is reduced with frame averaging.
- The loss of temporal resolution in pediatric imaging due to frame averaging is typically unacceptable.
- The radiologic technologist should ensure that frame averaging settings are minimized or turned off for pediatric patients.

Frame averaging allows reduction of patient dose as illustrated in this graph. Sixteen and 4 averaged frames allow the dose to the image receptor to be reduced by a factor of four and two, respectively. Because frame averaging reduces the noise in the image, the radiation dose to the image receptor can be reduced without affecting the original image quality. While this is attractive with respect to patient dose management, the loss of temporal resolution in pediatric imaging due to frame averaging is typically unacceptable. When verifying default settings before a case begins, the radiologic technologist should ensure that frame averaging settings are minimized or turned off for pediatric cases.
What is the purpose of the automatic brightness control (ABS) or automatic exposure rate control (AERC) feature of the fluoroscope?

A feedback control loop called automatic brightness control or automatic exposure rate control allows the tube current, voltage, pulse width and/or added filtration in the beam to be automatically adjusted in response to patient thickness and attenuation changes. During a typical pediatric fluoroscopic examination, the path length of the x-rays through the patient continually changes. In addition, attenuation properties of lung, soft tissue and bone are dramatically different. The differing attenuation properties and patient thicknesses significantly change the number of x-rays required (air kerma rate) to penetrate the patient and maintain consistent image quality throughout the examination. In the two charts, the PMMA thickness on the horizontal axis is the thickness of phantom used during performance testing of the fluoroscope. The figures illustrate the change in tube voltage, filter thickness, pulse width and tube current that occurs in response to changing simulated patient thickness.
How does anatomical programming work?

- Organizes clinical examinations and pediatric size ranges into presets.
- A single selected preset automatically adjusts the tube current, voltage, pulse rate, pulse width, added filtration, focal spot size and other control parameters selected by the medical imaging team for that unique patient and examination.

Anatomical programming organizes the many types of clinical examinations and pediatric patient size ranges into presets. This figure illustrates typical presets found on an interventional fluoroscope configured for adults. These adult presets typically do not include examinations specific to pediatric imaging nor as a range of patient thickness. However, each program setting is given a unique name and includes the correct tube current, voltage, pulse rate, pulse width, added filter thicknesses, focal spot size and other control parameters as determined by the medical imaging team. A more appropriate pediatric preset, for example, a voiding cysto-urethrogram (VCUG), might be assigned 1 of 4 patient size ranges (e.g., 10–15, 15–20, 20–25 and 25–30 cm). All other types of exams would also be programmed for the four size ranges above. This is a valuable feature. If set up properly, anatomical programming takes the guesswork out of choosing the correct settings for various exams and different sized patients.
What is last image hold (LIH) and how should it be used?

- LIH retains the last image of a fluoroscopy sequence on the monitor after the fluoroscopic pedal is released.
- Allows for image inspection without any further irradiation of the patient.
- LIH helps reduce the patient’s total radiation dose from fluoroscopy.

Last image hold (LIH) is an equipment feature that retains the last image of a fluoroscopy sequence on the monitor after the fluoroscopic pedal is released. Prior to the introduction of LIH, fluoroscopic images only appeared on the display monitor while the fluoroscopy pedal was depressed and the patient was irradiated. LIH allows the operator to study the displayed static fluoroscopic image like the one here as long as necessary without further irradiation to the patient. Proper use of this feature reduces the patient’s total radiation dose from fluoroscopy.
Fluoro save (FS), sometimes called “fluoro-grab,” allows the operator to select the LIH image displayed on the monitor or ‘grab’ a fluoroscopic image during live fluoroscopy and store the image to the fluoroscope’s memory. This image is stored permanently with any radiographic images acquired for archival purposes. In the absence of FS, a digital radiographic image must be acquired to create an archived image. While the recorded digital radiographic image has significantly better image quality than the FS image, it also results in a radiation dose to the patient at least 10 times greater. If the archived FS image provides the necessary clinical information, the patient can be spared the radiation dose of the digital radiographic image.

This is an example of the difference in appearance of a fluoro save image (Image A) from an upper GI on an infant with congenital heart disease. The spot film (Image B) demonstrates greater anatomic detail but the radiation dose to the patient is approximately 10 times higher. If the radiologist does not need anatomic detail, then the lower dose fluoro save image should be used.
What is last fluoro loop replay (LFLR) and how should it be used?

- LFLR saves the last fluoroscopic sequence to memory when the fluoroscopic pedal is released.
- The image is stored with radiographic images for archival purposes.
- If the FS image provides necessary clinical information, the patient can be spared the radiation dose of the radiographic image.

Last fluoro loop replay (LFLR) allows the operator to save to memory the last fluoroscopic sequence by pushing a button when the fluoroscopic pedal is released. LFLR images are noisier than digital radiographic acquisitions. However, if they provide the necessary clinical information, the additional radiation dose associated with an acquired digital angiography sequence can be avoided. As with FS, the radiation dose to the patient from the LFLR sequence will be at least 10 times less than a digital angiographic sequence. This movie clip is representative of a LFLR sequence that can be replayed during the procedure.
Are image processing presets specifically designed for pediatric fluoroscopy available?

Manufacturers ship their units with image processing presets that typically work well for adult anatomy, which typically contains higher subject contrast and larger objects than a pediatric image. Image processing designed for pediatric patients may allow the acquisition of images with less radiation dose to the patient. All acquired digital images are mathematically manipulated prior to their presentation on the monitor. If the manufacturer has presets designed for image processing of pediatric images, the fluoroscope should be configured to use these presets. The radiation dose to the subject in the two images here is the same. Image B uses image processing designed to reduce the noise in the image, which should allow for the reduction of radiation dose and obtain clinically useful images. If the manufacturer does not have these types of presets available, the medical imaging team should explore whether the manufacturer has image processing presets other than their standard adult settings, which may be more suitable for pediatric fluoroscopy.
Why does the fluoroscope sometimes emit a continuous sound when the fluoroscopy foot pedal is depressed?

- The FDA requires that machines with high-dose mode capability emit an audible tone to alert the operator that the machine is operating in high level control mode.
- High-level control mode should not be used during fluoroscopy of pediatric patients unless the pediatric patient is much larger than an average sized adult.

All fluoroscopes have a normal mode of fluoroscopic operation; the maximum air kerma rate to the patient is limited by the FDA to 88 mGy/min (10 R/min). Some fluoroscopes also have a high dose mode, called high-level control mode, with a maximum air kerma rate of 176 mGy/min (20 R/min). When the fluoroscopy pedal is depressed in the high-level control mode, the FDA requires that the fluoroscope emit an audible tone during fluoroscopy to alert the operator that the machine is operating in high-level control mode. This mode should not be used during the examination unless the additional dose is essential; it is typically needed only in very large patients. High-level control mode should not be used during fluoroscopy of pediatric patients unless the pediatric patient is much larger than an average-sized adult. The tone you hear is typical of the continuous tone emitted by a fluoroscope when operated in the high-dose mode.
What is fluoroscopy time?

The total elapsed time during the examination when fluoroscopic x-rays are produced by the fluoroscope.

Fluoroscopy time is the total elapsed time during the examination when fluoroscopic x-rays are produced. The radiologic technologist should monitor the timer and alert the operator when agreed upon milestones of fluoroscopy time have elapsed. This image is a reproduction of the fluoroscope’s display at the control panel in the control room. In this case the total fluoroscopy time during the procedure was 7 minutes, 38 seconds.
Why is intermittent use of fluoroscopy important?
The patient's total radiation dose will be lower if the operator uses fluoroscopy intermittently and for the shortest time needed to make the required observations.

The continuous use of fluoroscopy maximizes the radiation dose to the patient. The patient's total radiation dose will be lower if the operator uses fluoroscopy intermittently and for the shortest time needed to make the required observations. An example of intermittently depressing the fluoroscopic footswitch is illustrated in the short movie clip.
Fluoroscopy time provides no information concerning the radiation dose the child received from recorded images acquired during the examination. In addition, the exposure rate to the child varies dramatically based upon the attenuation of the child’s tissues and the child’s thickness, as illustrated in the figure. Fluoroscopy time does not account for these variances.
After the examination begins, an image of the patient is always present on the fluoroscopy monitor, so how does a staff member in the procedure room know when fluoroscopy or image acquisition is taking place?

An amber-colored light indicates that radiation is being produced.

Within the procedure room, typically near the display monitors, an amber-colored indicator light is provided. When this light is on, radiation is being produced. The images show the amber light off and on respectively.
When the operator releases the fluoroscopy or x-ray exposure switch, how long does it take for the stray radiation in the procedure room to dissipate?

- Stray radiation dissipates immediately.
- X-rays travel at the speed of light.

Stray radiation dissipates immediately when the foot switch is released by the operator. X-rays travel at the speed of light, so while stray x-rays may be scattered several times within the walls of the procedure room before they are completely absorbed, it occurs almost instantly due to their high speed.
What is the source-to-skin distance (SSD), and why is a larger SSD important?

- The SSD is the distance between the focal spot within the x-ray tube and the entrance plane of the patient's body.
- Small increases in SSD result in significant decreases in radiation dose rates.
- Doubling the SSD decreases the radiation dose to the patient to 25% of its original value.

The source-to-skin distance (SSD) is indicated by the vertical arrow in the figure. SSD is the distance between the focal spot within the x-ray tube and the entrance plane of the patient's body, represented here with the stacked saline bags. The radiation delivered to the patient depends on how far the patient is located from the source of the x-rays (the SSD). The inverse square law states that as one moves away from the focal spot, the radiation decreases as $1/SSD^2$. This means that small increases in the SSD result in significant decreases in the radiation dose rates. For example, doubling the SSD results in a 25% decrease in the radiation dose rate to the patient.
How is a larger SSD achieved for different types of fluoroscopes?

- For mobile C-arm fluoroscopes, the focal spot should be placed as far away from the patient as the C-arm and image receptor will allow.
- Raising the patient table on an interventional fluoroscopy unit increases the SSD.

For mobile C-arm fluoroscopes, the focal spot should be placed as far away from the patient as the size of the C-arm and image receptor allow. Mobile C-arms typically have spacers that prevent the SSD from being less than 30 cm. For most general fluoroscopic units, the SSD is typically fixed at approximately 50 cm. If your general fluoroscopic table allows adjustment of SSD, perform all pediatric imaging at the largest available SSD. For interventional fluoroscopy units like the one shown in the illustration, the x-ray tube is typically located beneath the table, so the operator should raise the patient table when possible to move the patient farther away from the focal spot and close to the image receptor.
What is the source-to-image receptor distance (SID), and why is a smaller SID important?

- The SID is the distance between the focal spot of the fluoroscope and the entrance plane of the image receptor.
- Small decreases in SID result in a significant decrease in radiation output necessary to deliver the correct number of x-rays to the image receptor.

The source-to-image receptor (SID) is the distance between the focal spot of the fluoroscope and the entrance plane of the image receptor as illustrated by the vertical arrow in the figure. Since the inverse square law applies to SID as well as SSD, small decreases in the SID result in a significant decrease in the radiation output necessary to deliver the correct number of x-rays to the image receptor. Any decrease in the radiation output of the fluoroscope as a result of a smaller SID results in a smaller radiation dose to the patient provided the SSD has been properly maximized.
How should the patient be positioned relative to the focal spot and the image receptor?

- For mobile C-arm units, the patient should be positioned as close to the image receptor as possible.
- For general fluoroscopic units, the image receptor should be moved as close to the patient as possible.
- For an interventional C-arm fluoroscope, the table should be raised and the image receptor placed as close to the patient as possible.

For a mobile C-arm, the patient should be positioned as close to the image receptor as possible, since this increases the SSD on a fluoroscope with a fixed SID. For a general fluoroscopic system, such as a GI room, the SSD is typically fixed, so the image receptor should be moved as close to the patient as possible. For an interventional C-arm fluoroscope as shown in the figure, the table should be raised appropriately to maximize the SSD and then the image receptor should be moved as close to the patient as possible. For small children (and some claustrophobic adults) being adjacent to the image receptor may be scary. However, achieving this goal significantly decreases the patient’s radiation dose.
What does field of view (FoV) describe?

- FoV describes the size or area of the x-ray field at the entrance plane of the image receptor.
- As FoV decreases, the size of the area of the x-ray field on the surface of the image receptor decreases.
- As FoV decreases, the electronic magnification of the image on the monitor increases.

Field of view (FoV) describes the size or area of the x-ray field at the entrance plane of the image receptor. In the normal mode, there is no electronic magnification, and the x-ray beam irradiates the entire surface area of the image receptor as shown in the drawing on the left. Magnification modes (e.g., mag 1, mag 2, and mag 3) result in successively smaller area x-ray beams to the image receptor. The smaller FoV (area) is enlarged to completely fill the area of the display monitor of the fluoroscope as shown in the drawing on the right. As the FoV decreases, the electronic magnification of the image on the monitor increases.
Displayed images on the monitor are enlarged as illustrated in Figure B compared to Figure A and may be sharper when a smaller FoV is selected. For image intensifiers, the image sharpness and resolution always improve for smaller FoVs. On the small-format flat-panel detectors, those with a field of view less than 20 cm found in cardiac catheterization labs and on mobile fluoroscopes, the sharpness and resolution are unchanged as the FoV changes. However, details are somewhat easier to see with smaller FoVs because the patient anatomy is enlarged on the display monitor. Large-format flat-panel detectors, those with a field of view more than 20 cm found in interventional labs or on general fluoroscopic tables, perform similarly to the small-format detectors as the FoV is reduced with the added bonus of significantly improved sharpness and resolution when the FoV is decreased below 20 cm.
The radiation dose rate to the patient increases as smaller FoVs are selected. On older fluoroscopes, the patient radiation dose rate quadrupled when the selected FoV diameter was halved. However, on state-of-the-art fluoroscopes, the increase in patient dose rate is less pronounced. On these newer machines, as the size of the FoV is halved, the patient dose rate is typically doubled. The graph illustrates the relative dose rate increase as the dimension of the FoV decreases from its largest size.
What FoV is appropriate during pediatric fluoroscopy?

- The operator must weigh the need for better image quality against the cost of more radiation dose to the patient.
- The smallest FoV is typically used with small children to improve sharpness and resolution.
- If larger FoVs provide adequate image quality for some portions of the study, the operator should use them instead, with appropriate manual collimation.

When selecting the FoV, the operator must weigh the need for better image quality against the cost of more radiation dose to the patient. Organs of infants and toddlers are small and difficult to image. For this reason, small children are typically imaged using the smallest FoV to improve sharpness and resolution (e.g., a newborn child with subtle posterior urethral valves blocking outflow of urine from the bladder). If larger FoVs provide adequate image quality for some portions of the study, the operator should use them instead, with appropriate manual collimation. This image of a rabbit thorax, which is approximately the size of a newborn child’s, illustrates that the smallest FoV of the fluoroscope is still capable of imaging the entire thorax.
What is the correct default FoV at the start of a case?

- At the beginning of the examination, the largest FoV should be the default setting.
- To improve image quality, operators may select smaller FoVs.
- If the new FoV irradiates a larger area of the patient than necessary, the collimator should be adjusted.

At the beginning of the examination, the largest FoV should be the default setting (green arrow) because it reduces the radiation dose rate to the patient. The section of the control panel that allows this selection is shown in the figure. If this large FoV does not provide adequate image quality, the operator may select a smaller FoV. If the selected FoV with good image quality irradiates a larger area of the patient than necessary, the collimator should be closed part way to reduce the area of patient anatomy to only that required for the image. The indicator light that is lit (yellow arrow) indicates that the smallest FoV has been selected.
Recall that electronic magnification occurs when the operator selects a smaller FoV. Geometric magnification occurs when the patient is positioned closer to the focal spot than normal with a gap between the patient and the image receptor. For example, if the patient is located halfway between the focal spot and the image receptor (SID) as illustrated in the image by the blue arrow, the patient’s anatomy will be enlarged on the display monitor by a factor of approximately two. Geometric magnification occurs any time the image receptor is moved away from the patient.
Should geometric magnification be used during pediatric imaging to improve image quality?

- Geometric magnification is strongly discouraged for pediatric fluoroscopy.
- Geometric magnification reduces SSD and increases SID.
- Improvement in image quality from geometric magnification does not occur unless the focal spot size is smaller than the focal spots found on the majority of fluoroscopes.

From a practical standpoint, small amounts of geometric magnification may be unavoidable during pediatric fluoroscopy. If a sterile field must be maintained or the child is small relative to the size of the image receptor, an air gap between the patient and image receptor may be necessary, which will automatically result in some geometric magnification. This should be minimized, however. Geometric magnification is strongly discouraged for pediatric fluoroscopy. First, geometric magnification reduces the SSD and increases the SID. Recall that this causes patient dose rates to increase. Second, improvement in image quality from geometric magnification does not occur unless the focal spot size is smaller than the focal spots found on the majority of fluoroscopes. Typically, the patient should be positioned close to the image receptor as shown in this figure.
Collimation is the reduction of the area of the x-ray beam arriving at the patient by blocking the outer portions of the x-ray field with attenuating blades inside the collimator. State-of-the-art fluoroscopes provide a graphical display of the position of the edge of the collimator blade superimposed on an LIH image of the patient’s anatomy shown in the figure at the left. This allows the operator to reposition the collimator blades without subjecting the patient to additional radiation dose during the adjustment. All unnecessary regions of patient anatomy outside the area of interest should be collimated out of the image. Image B illustrates the result of subsequent fluoroscopy after the collimator blades are positioned as indicated by the graphical lines in image A.
Does collimation affect image quality?

When the volume of patient’s tissues irradiated is reduced by collimation, less scatter radiation is generated. Less scatter results in a slight improvement in subject contrast in the images. Image A was created with a collimated area significantly larger than the square object. Image B was created with a collimated field area slightly larger than the square object. Image B presents slightly better contrast, which improves delineation of rounded corner of the object due to the decreased scatter in the field of view.
A 12-year-old girl was born with one forearm longer than the other. The orthopedic surgeon fused the growth plate of the distal radius under fluoroscopic guidance. The patient's skin dose at the center of the x-ray field, the region of the patient's wrist, is unchanged by collimation. Because the radiographic technique factors are unchanged by collimation, the dose to the patient's wrist is unchanged. However, the radiation field should have been limited to the area of the box. Proper collimation would decrease patient dose to patient anatomy outside the box. In addition, the primary radiation dose to the surgeon's hands essentially would have been eliminated by proper collimation.
Does collimation indirectly affect the occupational dose of the operator and staff during the examination?

- Occupational exposure to the operator and staff is primarily from scatter emitted from the patient.
- Occupational exposure is reduced with proper beam collimation.
- Small-area image receptors typically found in cath labs generate lower scatter than large-format units in radiology, everything else being equal.

The occupational exposure that the operator and staff receive during a fluoroscopic procedure should be primarily determined by the amount of scatter radiation emitted from the patient. Therefore, everything else being equal, the occupational dose of the operator and staff will be reduced by proper collimation. The graph illustrates that a FoV with a 37-cm dimension (large FoV) will generate scatter radiation at a rate six times greater than the scatter radiation rate from the smallest FoV with a dimension of 15 cm. Please note that all other radiographic technique factors being equal, the small field of view image receptors to the left of the vertical dashed line, which are typically found in catheterization labs, generate scatter rates that are two to three times less than the large-format image receptors found in radiology interventional fluoroscopic labs.
If proper collimation is lacking during a fluoroscopy procedure, lack of collimation can result in the hands of the fluoroscopist being placed in the primary radiation beam. An infant had abdominal distention soon after birth resulting in a concern for bowel obstruction. This fluoroscopic image demonstrates two suboptimal practices in pediatric fluoroscopy: First, the image is not collimated to the area of interest. Only the region of the rectum should be included on the exam, which is indicated by the box. Second, the hands of the operator are included in the fluoroscopy beam, which would not occur with appropriate collimation.
The risk to the patient from ionizing radiation is believed to be proportional to the kerma area product. The kerma area product can be cut in half by either reducing the air kerma (patient dose) or the area of the x-ray beam by half. Tighter collimation that reduces the area of the x-ray beam to half of its original value reduces risk to the patient to the same degree as reducing the air kerma by half. While either tighter collimation or dose reduction can be used to reduce patient risk, tighter collimation avoids the increase in noise that occurs with dose reduction and also results in a small improvement to subject contrast in the image.

Image A on first pass may appear to be reasonably collimated. Image B is the same image with tighter collimation, but adequate anatomy is included. However, the area of the collimated beam in Image B is one-half the area of the image on Image A. The dimension of the collimated field only needs to be divided by 1.4 as opposed to 2 to cut the area of the beam in half. This illustrates that relatively small reductions in the dimension of the field can have a significant impact on reducing the risk to the patient.
How should the operator select the FoV and collimation during pediatric imaging?

- The operator should select the FoV that offers the necessary image quality.
- FoV choice manages dose rate to the patient.
- The operator should collimate the x-ray beam to reduce the kerma area product.

The operator should first select the FoV that offers the necessary image quality with the understanding that less image quality will be achieved with larger FoVs. Selecting the larger FoV reduces the radiation dose rate to the patient. This image suggests the operator reduced the patient dose rate by selecting the largest FoV for the study. For most pediatric cases, this large FoV will include patient anatomy in the image that is unnecessary. Next, the operator should collimate the x-ray beam to reduce the kerma area product. Unfortunately, instead of using this two-step process, many operators simply select a smaller FoV with better image quality. While this may result in a reasonable x-ray beam area for most children, the dose rate to the child will be unnecessarily high.
Can one collimate too aggressively during pediatric fluoroscopy? If so, what is the result? How can the operator know if this has occurred? How can this be avoided?

- If the area of the x-ray beam is smaller than the area of the automatic brightness control/automatic exposure rate control (ABS/AERC) feedback system more radiation may be delivered to the patient than necessary.
- Consult with the service representative or QMP to adjust the ABS/AERC sensor.

Due to the small size of children, proper collimation may result in an x-ray beam area at the image receptor less than 20 cm². The ABS/AERC feedback system, which is designed to respond to changes in thickness and attenuation of the patient, will not work properly if the area of the x-ray beam, the dimension of the square area in the figure is smaller than the diameter of the ABS/AERC's round sensor. When this occurs, the fluoroscope will incorrectly increase radiation production and deliver a higher radiation rate to the patient than necessary. This can be avoided by asking the service representative of the fluoroscope, in consultation with the QMP, to reduce the area of the ABS/AERC's small circular sensor. The figure illustrates the smallest collimated square x-ray field that can be used correctly with the circular area of the sensor.
When should the grid be removed from the radiation beam for the pediatric patient? How much does this reduce the dose rate to the pediatric patient? What is the disadvantage of removing the grid on larger patients?

The antiscatter grid used during adult fluoroscopy attenuates the majority of the scatter radiation before it reaches the image receptor. If the grid is not used for adults, the image quality is unacceptable because of the loss of subject contrast as illustrated in the image of the lateral lumbar spine of an adult patient on the left. The image on the right was produced using a good-quality grid designed for use with adult patients. The removal of the majority of scatter radiation dramatically improves the subject contrast in the image. Small children (and the distal extremities of adults) generate much less scatter radiation than adult trunks. For body part thicknesses less than 10 cm, the small amount of scatter radiation reaching the image receptor when a grid is not used does not significantly reduce subject contrast. The radiation dose rate without a grid is approximately 60% of the radiation dose rate with a grid for thicknesses less than 10 cm. Therefore, the antiscatter grid should be removed when imaging portions of the patient with thicknesses less than 10 cm. Note that grids on all general tilt table units and most interventional fluoroscopy units are designed to be removed by the operator, while most mobile C-arm fluoroscopes do not allow the operator to remove the grid.
Prior to the start of the examination, what other technique can the operator use to decrease radiation dose to the pediatric patient?

- The operator should position the detector over the area of anatomical interest prior to depressing the fluoroscopy pedal.
- Moving the detector to the area of interest while the fluoroscopy pedal is depressed is strongly discouraged.

The operator should position the detector over the area of anatomic interest prior to depressing the fluoroscopy pedal. For example, if an upper GI is being performed on an adolescent, the experienced user will avoid turning the x-ray beam on over the pelvis of the patient. There is no need to radiate the patient as the detector is moved from the pelvis to the esophagus. This practice is strongly discouraged.
Should the radiologic technologist inform the operator of patient dose during the examination?

- The technologist should notify the operator when agreed-upon milestones of the patient's cumulative air kerma have been reached.
- For an interventional procedure with an expected air kerma of 2,000 mGy, the technologist would notify the operator at 500-mGy intervals.
- Appropriate milestones should be established based on the complexity of the fluoroscopic examination, e.g., complex intervention, diagnostic, GI, GU, VCUG, etc.

Operators may better manage their patients' radiation dose during a procedure if they receive periodic notifications during the examination when agreed-upon milestones of the patient's cumulative air kerma have been reached. For example, the protocol within a department might be notification of the operator every time 25% of the total expected dose is reached during an examination. For example, if the total expected air kerma was 2,000 mGy for a given interventional procedure on a given sized patient, the radiologic technologist would notify the operator at 500-mGy intervals. The target total air kerma for a diagnostic or complex interventional case would probably be some multiple of 100 or 1,000 mGy, respectively. The total target air kerma for a routine GI or VCUG study would be some multiple of 10 or 1 mGy, respectively.
Learning Objectives:

1. Explain the basic operation of fluoroscopic equipment.
2. Identify areas of fluoroscopic practice that can reduce radiation dose to the pediatric patient during fluoroscopy.
3. List equipment configuration adjustments that affect dose to pediatric patients during fluoroscopy.
4. Discuss the relationship between fluoroscopic image quality and patient dose.

This concludes Image Gently: Steps To Manage Radiation Dose During the Examination. You should now be able to:

1) Explain the basic operation of fluoroscopic equipment.
2) Identify areas of fluoroscopic practice that can reduce radiation dose to the pediatric patient during fluoroscopy.
3) List equipment configuration adjustments that affect dose to pediatric patients during fluoroscopy.
4) Discuss the relationship between fluoroscopic image quality and patient dose.
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