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Fluoroscopy:
Image Quality and Analysis

American Society of Radiologic Technologists

Fluoroscopy: Image Quality and Analysis

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The diagnostic quality of radiographic images obtained during fluoroscopy studies depends on multiple factors, including patient positioning, selection of exposure technique, patient preparation, removal of artifacts and appropriate use of image processing equipment and software. Fluoroscopy operators, including radiographers and radiologist assistants, must be able to distinguish sources of error during image acquisition and determine ways to improve image production and quality. Radiology personnel should follow established departmental standards for image acceptance to prevent unnecessary repeat exposures and to provide the radiologist with the most useful images for interpretation.

After completing this article, readers should be able to:

- Describe the role of the radiographer and radiologist assistant in image quality and analysis.
- Identify the factors used to evaluate image quality.
- Summarize the importance of proper positioning.
- Discuss the effects of patient preparation on the resulting radiographic image.
- Differentiate between technical factors, procedural factors and equipment malfunctions that affect image quality.

Fluoroscopic imaging typically is used to demonstrate real-time, dynamic processes; however, fluoroscopy equipment also can acquire static images if necessary to capture a permanent record of an anatomical area or abnormality. Several types of image recording technologies are available for fluoroscopy, including spot film devices, automatic film changers, photofluorography, digital fluorography, cine fluorography and video recording. Each recording method has different characteristics that affect image quality in terms of spatial resolution, contrast and noise.[1]

Additionally, there are different fluoroscopy equipment configurations designed for specific uses, including standard radiography/fluoroscopy combination units, fixed C-arm units and portable C-arm equipment. Because each type of equipment has distinct limitations, imaging personnel should receive specific training for their fluoroscopy systems and the use of postprocessing tools to produce the best possible images.[1]

Despite the variety of fluoroscopy equipment, imaging standards have been developed to help ensure diagnostically useful studies are produced, regardless of the equipment configuration or image recording device used. Standards pertaining to medical image quality are necessary to optimize the diagnostic usefulness of radiographs and to minimize radiation exposure caused by repeat imaging examinations.[2] Each imaging facility has its own standards for acceptability; therefore, fluoroscopy operators must be aware of their individual organization's requirements for performing repeat examinations, even as they work to produce the best possible images.[3]

High-quality images demonstrate the following characteristics:

- Maximum recorded detail.
- Optimum patient positioning.
- Excellent penetration, contrast and density.
- No motion or removable artifacts.[3]

The radiographer or radiologist assistant (RA) should examine all images for quality before they are submitted to the radiologist for interpretation.

The Role of the Radiographer

Radiographers may perform noninterpretive fluoroscopic procedures and assist licensed practitioners with fluoroscopic and specialized interventional imaging procedures, when appropriate and in accordance with state statutes.[4] The American College of Radiology (ACR) suggests that technologists receive formal training in radiation management and complete a formal credentialing process administered by the facility for assisting with interventional procedures.[5] In the United Kingdom, radiographers frequently are trained to perform double contrast barium enema examinations, and research reports that radiographers produce studies that are comparable to radiologist-managed studies.[6]

According to the American Society of Radiologic Technologists (ASRT) Radiographer Scope of Practice, the technologist is responsible for the following parts of the medical imaging procedure:

- Reviewing the patient's clinical history to ensure the proper imaging procedure has been ordered.
- Preparing the patient for the procedure.
- Selecting the proper imaging equipment and associated accessories.
- Positioning patients to best demonstrate the anatomy of interest.
- Immobilizing patients as necessary.
- Preparing and administering medications, such as contrast agents, prescribed by a licensed practitioner.
- Determining the radiographic exposure technique, while applying principles of radiation protection to the patient and staff.[4]

Following image acquisition, the radiographer should evaluate the images before submitting them to the radiologist. Images should demonstrate proper patient positioning, appropriate anatomy and overall satisfactory image quality, and the technologist should determine if additional images might improve the overall diagnostic value of the procedure. If additional images are obtained, the technologist must record the justification for the repeated images. Radiographers also should develop and maintain a technique chart for imaging equipment, including fluoroscopy systems, to minimize repeats caused by exposure error.[4]

The Role of the Radiologist Assistant

The ASRT *Radiologist Assistant Practice Standards* defines an RA as, "an advanced-practice radiographer who practices under the supervision of a radiologist and enhances patient care in radiology service."[7] The RA exercises independent professional judgment when performing patient assessment, patient management and procedures in medical imaging and interventional radiology, including fluoroscopy.[7]

According to the American Registry of Radiologic Technologists (ARRT), a registered radiologist assistant (R.R.A.) is responsible for evaluating images for completeness and diagnostic quality, as well as recommending additional images when necessary, as long as they are obtained using the same modality. An RA also assesses images for diagnostic utility and reports clinical findings and initial observations to the supervising radiologist. If there are exceptions to the expected outcome of a procedure, the RA must document those exceptions in a timely, accurate and comprehensive manner and may be required to devise a new plan of action to reach the intended outcome. If the RA develops a revised action plan, the RA must share the plan with the appropriate radiology team members.[7]

Part of the RA's responsibility for ensuring image quality is to confirm that equipment performance and maintenance meets the manufacturer's specifications.[8] The RA may perform quality assurance activities to assess equipment performance and radiology department processes. RAs also may be required to document these activities and request equipment repair or maintenance.[8]

In the United Kingdom, the trend for advanced radiographers has been to interpret diagnostic imaging studies and report their impressions. One study found that radiographers reported results of film-screen radiography in 46% of hospitals and barium enemas in 45% of hospitals.[9] It is important to note that the ACR, the ARRT and the ASRT do not support this trend.[9]

The ACR maintains that the RA may make initial observations of diagnostic studies and forward those remarks only to the supervising radiologist,[5] but RAs may not perform interpretations of radiological exams.[10] RAs, however, can communicate the radiologist's findings to the referring physician.[9,10]

Image Analysis

Although the radiologist ultimately is responsible for the diagnostic accuracy of radiographic images, accuracy depends directly on the quality of the radiographs being interpreted. Thus, radiologists should only interpret images that are properly exposed and demonstrate correct positioning.[11] The ACR recommends that technologists and radiologists review underexposed radiographs to determine a comfortable level for diagnostic viewing and to set a standard for requiring repeat examinations.[12]

Before analyzing an image for diagnostic quality, it must be displayed properly. Spot films, as well as scout images and postprocedure images, may be reviewed on a view box if using a film-screen system or a monitor if using a digital system.[3] Table 1 lists globally accepted guidelines for how to display radiographs of different body parts, positions and projections.[3]

Image analysis requires careful assessment of several factors including proper patient identification, correct positioning and appropriate anatomical marker indicating the body part, collimation to the anatomy of interest, adequate contrast and density, presence of artifacts and evidence of blur. A systematic check of these factors helps determine image acceptability and ways to improve images for interpretation.[13]

An image analysis form or checklist can be an effective tool for evaluating positioning and technical accuracy. In addition to the facility's identification requirements, the correct marker and satisfactory visualization of the required anatomy, the technologist should assess whether the image displays unintentional distortion, whether it defines bony cortical outlines and soft tissue structures and whether collimation is optimal. The images also should reflect use of the smallest possible receptor size and the best possible density and contrast; there should be no preventable artifacts on the image. Finally, the acquired images should satisfy the ordered procedure and indications for the exam.[3]

Radiographic technique should be adequate to demonstrate the anatomy of interest. Technique selection is important not only for producing acceptable density and contrast, but also for maintaining the as low as reasonably achievable (ALARA) principle. Protective lead shielding should adequately cover radiosensitive tissues to minimize radiation exposure, but it should not obscure areas of interest. Types of shielding that may be used include breast, thyroid, gonadal and apron. The primary x-ray beam should be collimated so that only the tissues of diagnostic interest are irradiated.[13]

Geometric or motion blur may interfere with the ability to visualize detail. The radiographer or RA should evaluate whether fine detail is adequately visible and, if not, determine whether blur was caused by patient motion, an incorrect focal spot size or a faulty receptor.[3]

Any imaging study should include adequate information for the radiologist to make a complete imaging diagnosis. As a general rule, the minimum for a complete examination is at least 2 projections performed at right

Table 1

Guidelines for Displaying Radiographs[3]

Type of Image	Image Orientation
Torso, vertebral column, cranium, shoulder, hip	Display as if the patient were in an upright position
Finger, wrist, forearm	Display as if the patient were hanging from the finger tips
Elbow, humerus	Display as if hanging from the patient's shoulder
Toes, AP and oblique foot projections	Display as if the patient were hanging from the toes
Lateral foot, ankle, lower leg, knee, femur	Display as if hanging from the patient's hip
Decubitus chest and abdomen	Display with the side that was positioned upward in the upward position on the image
Axiolateral shoulder and hip	Display with the patient's posterior surface down
AP and oblique vertebral column, torso, cranium	Display with the right side of the patient's image to the viewer's left
PA upper extremity	Display so the thumb is positioned toward the same side as the viewer's
Lateral upper extremity	Display to reflect that the ulnar side was positioned against the image receptor

angles to one another. Kogan suggests using an overall film rating of 1 to 5 to designate poor to excellent imaging factors.[13]

The Imaging Procedure Order

A physician or other appropriately licensed health care provider must provide a written or electronic prescription or request for an imaging procedure before a technologist can image a patient. The order should include sufficient information to prove the procedure is medically necessary and to allow for proper interpretation of the examination.[5]

The request should document the patient's signs and symptoms or a relevant medical history that includes known diagnoses. Any additional information about the specific need for the examination can be helpful and is occasionally necessary to properly perform and interpret the examination.[5]

To prevent errors, the patient chart should be checked to verify the referring physician has ordered the correct imaging exam or interventional procedure for the correct patient. The Joint Commission advocates following a universal procedure to prevent wrong site, wrong procedure and wrong person surgery or invasive procedure. The Universal Protocol identifies 3 actions that should be performed before an invasive procedure: preprocedure verification, site marking and timeout. Preprocedure verification should occur before the patient enters the exam or procedure room. Any missing information or discrepancy in the patient chart should be resolved at this time. The patient chart should contain documentation of the patient's history and physical, signed consent forms, and nursing and preanesthesia assessments. Prior radiology or laboratory results also should be included.[14]

Before performing an examination, the RA may be responsible for reviewing the patient chart and updating any changes in symptoms, laboratory values, vital signs and significant abnormalities. The patient also should be interviewed to obtain, verify and update the medical history.[7]

According to the Centers for Medicare and Medicaid Services, an order from the treating physician to the testing facility may be placed via written communication, which may be hand delivered or faxed, by e-mail or by telephone. Orders may be modified if obvious errors occur, such as the request for the wrong body part to be imaged, or cancelled if the patient's physical condition prevents the completion of the examination.[15]

When the referring provider cannot be reached, additional radiology procedures may only be performed if certain criteria are met. In such cases, the imaging facility must have completed the diagnostic test that was initially ordered by the referring physician. In addition, the following conditions must exist:

- The radiologist must determine that an additional test is medically necessary because of abnormal results of the first test.
- A delay in the additional testing would have an adverse effect on the patient.
- The treating physician is notified of the test results and uses those results to treat the patient.
- The radiologist documents why the additional testing is necessary.[15]

Image Identification

According to the ARRT Standards of Ethics, radiologic technologists are responsible for obtaining pertinent information for the physician to aid in the diagnosis and treatment of the patient.[16] The accuracy of the radiologist's report depends upon transmission of accurate patient information. Basic details that should be included on the image are the patient's name, date of birth and sex.[13] The ACR recommends the following identifiers be included with any radiology report:

- Name of the facility where the study was performed.
- Name of the patient and another patient identifier, such as the date of birth or age.
- Name of the physician ordering the exam.
- Date of the exam and time, when relevant.[17]

A right or left anatomic marker should be visible and placed outside the anatomy of interest.[3,13] It is critical to use the correct marker to prevent treatment of the wrong body part. A right marker should be placed when the right side is imaged, and similarly, a left marker should be placed when the left side is imaged. For lateral projections, the side closer to the imaging receptor should be marked. The marker will appear accurately when placed faceup on the image receptor for anteroposterior (AP) projections of the torso, vertebrae and cranium. Likewise, the marker

should be placed facedown for posteroanterior (PA) and oblique projections, or else it will appear reversed when displayed. For extremity images, the marker should be placed faceup on the receptor before exposure to be displayed accurately.[3]

A repeat exposure should be taken if the marker is missing. When using film, if the anatomical marker is only faintly visible, the technologist may circle the marker and write the information next to it. If the technologist is using computed radiography (CR) and the marker is not placed completely within the collimated field, a right or left marker may be added digitally to the image. However, the digitally placed marker should not cover up the original. If the technologist's marker does not appear after processing, the image should be repeated.[3]

Positioning

The body part being imaged should appear centered and adequately positioned.[13] Fluoroscopy operators must be careful to include all of the anatomy requested by the ordering physician before releasing the patient from the examination room.

When positioning the patient for more than 1 projection on an imaging receptor, the patient's same anatomical structure should be located on the same end of the receptor for both positions. Otherwise, it may be difficult to display and view the image.[3]

C-arm fluoroscopy is advantageous in that it allows multiple images of an anatomical part to be taken without moving the patient. In 1 study, researchers used a portable miniature C-arm fluoroscope at the bedside rather than conventional radiography to evaluate postoperative fracture reduction in pediatric patients. The authors suggested that a benefit of using fluoroscopy was the ability to study fracture alignment in multiple planes to assess stability. They determined that the diagnostic quality of the printed AP and lateral fluoroscopic images were comparable to traditional radiographs.[18]

Anatomy of Interest

The fluoroscopy operator should be aware of all the anatomy to be included on each image. The anatomy of interest should be aligned with the center of the image receptor, and selected surrounding anatomy should be included, depending on the area of interest.[19] When correcting positioning during a repeat examination, the patient should first be positioned as he or she was during the initial exposure. Then the technologist should move the patient to compensate for the poorly positioned part.[3]

A collimated border should be present on all sides of the image. Proper collimation both reduces radiation dose and improves the visibility of recorded details and image contrast. Overcollimation and undercollimation may cause unnecessary repeats. When using CR, collimation also helps the reader identify the useful regions of the image for analysis. When imaging structures within the torso, the technologist should use palpable anatomical landmarks, such as the pubic symphysis and anterior superior iliac spine (ASIS), as a guide for collimation.[3]

Plane/Baseline Reference

To demonstrate anatomical structures optimally, accurate patient positioning is essential. The patient may be placed in a true AP/PA, lateral or specific oblique position by using an imaginary reference line that is oriented to the imaging receptor or imaging table.[3]

The midcoronal plane is the imaginary plane that passes through the body from side to side, dividing the body into equal anterior and posterior sections. Any other plane that divides the body into anterior and posterior sections is called a coronal plane. The midsagittal plane divides the body into equal right and left sections by passing through the body anteroposteriorly or posteroanteriorly. Sagittal planes are any other planes that divide the body into right and left sections.[19]

The long axis of the anatomical structure being imaged is referred to as the longitudinal or lengthwise axis. An image receptor that is placed lengthwise means that it has been placed with the receptor's longitudinal axis aligned with the patient's longitudinal axis. The transverse or crosswise plane refers to one that is perpendicular to the longitudinal axis of the anatomical part being imaged.[19]

Central Ray Angulation

Proper alignment of the central ray prevents unwanted shape distortion (elongation or foreshortening of the anatomical part) on the image. The central ray is at the middle of the diverged x-ray beam emitted from the x-ray tube's focal spot. The smallest amount of divergence occurs at the central ray; therefore, the least amount

of shape distortion takes place when the central beam passes through the anatomy of interest and is captured on the image receptor.[3]

Accurate alignment of the x-ray beam, body part and image receptor minimizes shape distortion. Proper alignment consists of keeping the anatomical part parallel to the image receptor and aligning the central ray to pass perpendicularly through them. However, depending on the location and angle of the anatomy of interest within the body, a distorted image may be ideal.[3] An example is the AP axial projection of the rectosigmoid area of the large intestine, when the central ray is angled to improve visualization of the sigmoid colon with less superimposition of overlying structures.[20]

Anatomical Variations

Fluoroscopy operators should be familiar with the normal appearance of anatomy being imaged, as well as how to compensate for anatomical variations and patient characteristics. For example, the location of abdominal organs may vary according to body habitus, posture and the amount of stomach or fecal contents. A case in point is the gallbladder, which is usually pear shaped and situated in an oblique plane in the upper right quadrant of the abdomen. However, it also is commonly found anywhere from the level of the eighth rib to the level of the iliac fossa and from the midsagittal plane to the lateral wall of the abdomen. The location of the gallbladder also depends on its exact attachment sites to the liver.[20]

A scout radiograph often is taken before performing a contrast study of specific organs. Preliminary scout images are helpful when the patient has skeletal abnormalities or situs anomalies.[21] The patient chart may include details that would aid in proper positioning.

Body Habitus

A patient's physical characteristics often affect patient positioning for PA/AP chest or abdominal images.[3]

The hypersthenic patient has a wide, short thorax and a broad peritoneal cavity. For hypersthenic patients, the stomach is positioned horizontally across the upper portion of the abdomen, well above the umbilicus. The large intestine is located around the periphery of the abdomen, and in these patients, it may be necessary to take several images to show the entire length of the large intestine.[22] To include all the anatomy of interest, the image receptor should be placed crosswise for the PA/AP chest examinations and 2 receptors should be used for an AP projection of the abdomen.[3] In hypersthenic patients, a PA axial projection may be used to better demonstrate the greater and lesser curvatures, antral portion of the stomach, pyloric canal and the duodenal bulb of the stomach.[20]

Sthenic patients make up about 50% of the population. The kidneys in sthenic patients are normally found between the level of the superior border of T12 and the level of the transverse processes of L3, slightly lower than in asthenic patients and higher than in hypersthenic patients. In between the sthenic and asthenic body habitus types is the hyposthenic group; these individuals make up about 35% of the population.[20]

In asthenic patients, the stomach is positioned vertically and is located low within the abdominal cavity and may extend below the transpyloric line. The large intestine is found low in the abdomen and bunched together in asthenic patients.[20] Patients with sthenic or asthenic body types may be imaged with the image receptor placed lengthwise for both chest and abdominal examinations.[3]

Pathology

Positioning and exposure technique should correspond to the clinical information about the patient's pathology. Alternative projections and technique adjustments may be necessary to evaluate specific pathology. For instance, a patient with severe osteoporosis may require a lower exposure technique to penetrate bony anatomy.

Contrast examinations of the upper gastrointestinal (GI) tract allow the radiologist to identify abnormalities such as masses, ulceration and diverticula. During GI contrast studies, it is important to show consistent filling defects so that the radiologist can interpret the pathology. A single image taken during the examination may demonstrate an area of spasm, peristaltic wave or the presence of food. Several images of the defect should be obtained for proper interpretation. During barium enema studies of the colon, the cecum is only entirely demonstrated if there is retrograde filling of the appendix or the terminal ileum. For patients who suffer from unexplained anemia, carcinoma of the cecum must be ruled out.[22]

When patients present with obesity, bowel obstructions, soft tissue masses or suspected ascites, AP images may appear underexposed because of the increased density of the soft tissue. Increasing the kilovolt peak (kVp) by 5% to 8% or the milliampere seconds (mAs) by 30% to 50% from the typical technique setting can prevent underexposure and the need for repeat exposure. Conversely, a decrease in kVp by 5% to 8% or a 30% to 50% decrease in mAs is required when there is decreased tissue density because the patient presents with a large amount of bowel gas.[22]

Positioning Aids

Certain anatomy may require the use of positioning devices to adequately visualize an area of interest. For example, compression sponges and paddles may be required to demonstrate portions of the digestive system. A contrast study of the pyloric end of the stomach might entail the use of a pneumatic paddle, positioned fluoroscopically under the pyloric sphincter and duodenal bulb. The paddle is inflated and deflated while serial images are acquired during filling and emptying of the duodenal bulb. Another example is the Wolf method, which is used to evaluate small, sliding gastroesophageal herniations. For this method, a semicylindrical radiolucent compression sponge is placed horizontally under the costal margin while the patient is in a right anterior oblique position. This positioning aid improves visualization of the relationship between the stomach and the diaphragm.[20]

Positioning sponges also help a patient maintain a specific position,[16] and sponges should be used when available in place of the hands of radiology personnel. When an oblique body position is required, a wedge-shaped sponge can assist the patient in holding obliquity. However, depending on the placement of the wedge and the thickness of the patient's soft tissue, the actual degree of obliquity may vary. For example, if a 45° sponge is placed too far under the patient, the actual degree of obliquity may be greater than 45°. Radiographers or RAs should always reference the plane of the patient's body to determine correct positioning.[3]

Special Positioning Concerns

Age

Pediatric patients range in age from birth to 15 years and require the use of age-appropriate communication to explain the imaging examination. Parents and guardians also should be informed about the procedure and told explicitly how to hold a child if they must assist with positioning. The procedure and expectations for cooperation should be explained to the child face to face in a soft tone of voice. Adolescent or older children may be more cooperative with the imaging staff if they are educated about the procedure and if their concern for privacy is respected.[16]

Geriatric patients are considered to be individuals older than 65 years. They must be assisted gently when positioned because their skin is more fragile than that of younger patients. Loss of hearing is also common with age, so imaging staff should be careful to clearly state instructions and check for understanding. Because elderly patients may have less muscular strength, radiologic technologists should offer these patients assistance when getting on and off the examination table.[16]

Patient Condition

Radiographers and RAs should assess different aspects of the patient's condition that could affect positioning. For example, trauma patients should be evaluated carefully to determine if they are mobile, alert and able to follow instructions before beginning the examination. A confused or upset patient should never be left alone in an imaging department. Depending on the patient's condition, alternative positioning strategies and positioning aids may be necessary; however, the central ray, body part and image receptor should be in the same alignment as if the patient were positioned in the standard manner.[3]

Another example is the patient who has recently undergone total joint arthroplasty. The radiographer, RA or other imaging staff who move or position the patient should carefully follow the surgeon's instructions regarding movement restrictions. Correct positioning is essential to prevent dislocating a new prosthesis.[16]

Immobilization devices may be used when a patient's safety is in question because of an inability to remain still during an examination. Immobilizers restrict freedom of movement and cannot be removed easily. They must be ordered by the physician in charge and should only be used after less restrictive methods have failed to protect the patient. Examples of when these devices may be required include controlling the movement of

an extremity during placement of a diagnostic catheter, keeping a sedated patient in a certain position and preventing an unconscious, delirious or cognitively impaired patient from falling off an examination table or gurney.[16]

Many lower GI tract conditions require the temporary or permanent placement of a stoma. A stoma is a loop of bowel that is brought to the surface of the skin of the abdomen to drain bowel contents. Patients with a stoma should never be placed in the prone position because this position could damage the ostomy site.[16]

Mobile Examinations

Mobile imaging may be required to check the placement of a feeding tube, peripherally inserted central catheter (PICC) line or other type of catheter. Images obtained with portable equipment should demonstrate accurate relationships among the anatomical structures for each projection and position imaged. The patient's discomfort should be minimized and the exam should not cause further injury.[3] When portable images must be obtained, the radiographer or RA must be aware of drainage tubes and intravenous lines that may be in place.[16]

During mobile trauma examinations, the radiographer or RA should review the requisition to determine which images are necessary and first obtain the images that give information about the most life-threatening condition. Then any remaining images requested should be acquired in an order that requires the least adjustment of the central ray. This approach improves the speed of the overall exam.[3]

A grid should be used if the anatomical part being imaged is more than 5 inches thick and the exposure requires more than 70 kVp. The central ray should be aligned with the center of the grid and angled to match the angle of the grid. The grid also should be level, and the source-to-image distance must be within the grid's focusing range.[3]

Patient Preparation

Contrast Agent

Radiographic imaging studies of the GI and genitourinary systems, as well as the gallbladder, pancreas, heart, brain, adrenal glands, arteries, veins and joints, frequently require the use of contrast agents. Contrast agents are considered drugs because they are absorbed into the systemic circulation, resulting in a physiologic response. Therefore, they require a prescription from a licensed health care provider. When selecting a contrast medium, the provider must consider the agent's viscosity, ability to mix with body fluids, ionic strength, persistence in the body, iodine content, osmolality and potential for toxicity.

The required volume of contrast varies according to patient size, anatomy and pathology. At any time during a study, the radiologist may order the administration of more contrast if he or she believes the initial amount was not sufficient for diagnosis.[21] The radiographer or RA must be aware of indications and contraindications for any contrast agent used, potential adverse reactions and how to safely administer the contrast material. Additionally, imaging personnel must be able to explain postprocedure instructions to patients.[16]

High-density barium and iodinated preparations are examples of positive contrast that attenuate the x-ray beam. Barium is a metal and is available as a white crystalline powder that is mixed with water. Administered by mouth for upper GI studies, by rectum for a lower GI series or by infusion of a thin suspension through a duodenal tube, barium has negligible toxic effects as long as it remains in the GI tract.

Serious complications can occur if a break in the gastric mucosa allows the barium to leak into the peritoneal cavity or bloodstream. Seepage into the peritoneal cavity may lead to peritonitis, fibrosis or formation of a barium granuloma. A leak into the venous circulation may cause an embolus, which could be fatal. An absorbable, water-soluble contrast medium, such as diatrizoate meglumine or diatrizoate sodium (Gastrografin), should be used any time perforation of the GI tract is suspected. The radiologist should be informed if the patient was nauseated during a previous administration of oral barium sulfate suspension. Vomiting of this contrast agent could result in aspiration pneumonia.[16]

Iodinated contrast agents can help demonstrate areas of the body where there is no natural contrast; iodine has a high atomic density and attenuates the ionizing radiation. These agents may be administered via oral, vaginal, intravenous, intra-arterial routes or directly into joints or body cavities. Nonionic contrast agents may be administered in the same ways and have a lower likelihood of causing adverse reactions.[16]

Air and carbon dioxide often are used as negative contrast media, which decrease organ density to produce contrast. Depending on the anatomical structure to be examined, negative contrast agents may be used alone or in combination with a positive contrast medium. If one of these negative contrast agents is injected into the bloodstream, an air embolus may occur.[16]

Before and After the Procedure

Before administering a contrast agent, the radiographer or RA must complete a patient assessment. The imaging professional must review any questionnaire the patient has completed concerning his or her overall health and alert the physician before the imaging study if there is a reason the procedure cannot be performed. Informed consent is required before most invasive procedures and a signed consent form should be kept on file.[16]

To optimize the diagnostic quality of GI studies, proper patient preparation is essential. The lumen should be clear of food and feces so that intraluminal masses can be visualized.[22] Although specific instructions vary depending on the facility and special patient needs, the patient generally is instructed to eat only foods that are low in residue for 2 to 3 days before the procedure. Additionally, the patient should drink less than 2 cups of milk per day and avoid strong cheeses to prevent gas in the bowel. The patient also should increase water intake 2 to 3 days before the examination to clear waste from the GI tract. A clear liquid diet, including at least five 8-ounce glasses of water, is usually ordered for the 24 hours before the procedure. The physician may prescribe laxatives to be administered both the afternoon and evening preceding the examination. Special instructions may be provided to patients with insulin-dependent and noninsulin-dependent diabetes mellitus.[16]

A cleansing enema usually is prescribed for the night before or early in the morning of the examination. The radiographer or RA may have to administer an additional cleansing enema in the imaging department if the patient is not adequately prepared.[16] In a study by Thompson and colleagues, the criteria used to determine the quality of barium enema examinations included feces in the lumen, feces on the mucosa, distention of the colon, ability to assess for diverticula and ability to assess for polyps.[23] In another study that examined the diagnostic quality of spot films obtained during upper GI and lower GI examinations, researchers found that adequate distention, lack of overlap, good mucosal coating and completeness of display were required for clarity of visualization.[24]

Contrast studies often are uncomfortable, and patients are likely to be distressed about undergoing these examinations. Imaging professionals can help alleviate patient anxiety by being calm and professional.[9] Because barium often causes constipation, patients may develop fecal impaction or bowel obstruction if they do not follow instructions after a GI procedure.[16]

Artifacts

An artifact is an undesirable structure or substance appearing on an image. Artifacts may be anatomical structures that compromise the ability to view an area of interest, external objects such as jewelry or other possessions, internal objects such as monitoring lines or feeding tubes or problems with the operator's use of the equipment.[3] The accuracy of diagnosis may be compromised when artifacts appear on medical images.[25]

A common anatomical artifact is the patient's hand or arm. For example, patients may rest their hands over the abdomen during AP abdominal imaging or under a sore hip during hip or pelvic imaging. Radiographers and RAs must help patients understand why it is important not to move before the exposure.[3]

External artifacts commonly include earrings, necklaces, bra hooks, gown snaps and dental fittings. Occasionally, imprinted designs on shirts and pants also appear.[3] Radiation exposure and exam time can be reduced by simply removing these objects before exposure.

Internal artifacts cannot be removed and are frequently associated with prostheses, chest tubes, pacemakers and central venous pressure lines. When an unexpected internal artifact appears on an image, the technologist should interview the patient and search for a possible external artifact that might have been missed. Occasionally objects are ingested or introduced into the body through an orifice. Any discoveries made by the technologist should be recorded on the patient's requisition.[3]

Because spot radiographs and postfluoroscopy static imaging often are necessary, it is important to recognize that both film-screen and digital systems can produce artifacts when the equipment breaks down or if there is

an error in use. Technologists should be familiar with their image system's characteristics to help identify the source of artifacts and how to correct them.[25]

Artifacts produced using CR systems may stem from problems with the imaging plate, plate reader, image processing software or laser printer or from operator error. A study by Cesar suggested a similar pattern of errors could occur regardless of the brand of imaging equipment.[25]

Artifacts caused by cracks in the imaging plate first appear near the edges of the plate, then closer to the central area as deterioration progresses. White artifacts may appear when debris block light emission. Because the storage phosphor in imaging plates is highly sensitive to scatter radiation, backscatter and scatter from objects behind the imaging plate also may cause artifacts.[25]

When the plate reader improperly erases the imaging plate after exposure, or when the imaging plate has not been manually erased after a period of several hours, artifacts may occur. It is also imperative to select the proper erasure setting when more than 1 erasure setting is available to prevent image artifacts.[25]

The probability of image processing artifacts is reduced when standardized processing parameters are used and when the level of spatial frequency processing is optimized according to the body part being imaged. Often images with artifacts caused by poor processing parameters do not have to be repeated, but rather just reprocessed.[25]

Operator errors can be prevented by following the manufacturer's instructions for storing and handling imaging plates. The CR cassettes should be stored correctly to reduce imaging plate exposure to scatter radiation. Also, an antiscatter grid must be selected carefully. When the lines of low line-rate grids are parallel to the reader's scan lines, a moiré pattern will appear. Cesar and colleagues recommend that new users of CR equipment familiarize themselves with the orientation of the receptor because artifacts appear when the cassette is placed upside down.[25]

Corrective Action

Equipment

Factors that affect image quality in film-screen or digital imaging systems include contrast, detail and noise, but methods to manage these factors vary between the different systems.[12]

Film-Screen

For film-screen systems, the kVp and mAs selections must simultaneously produce proper film darkening and maximum image contrast. The range of acceptable optical density is limited by the view box luminance. Although film-screen images can be digitized, the same limitations remain in the digital images, and film digitizers often introduce additional noise in the image. Therefore, films should not be digitized in an effort to improve poor film image quality.[12]

Digital

Digital detectors have much wider exposure latitudes and a greater ability to compensate for underexposure and overexposure with preprocessing and postprocessing capabilities.[12] Computer aided detection and diagnosis algorithms for image enhancement and analysis are available with digital systems. When using digital systems, the smallest possible image receptor should be selected for each examination because the size of the pixels in the image matrix is proportional to the size of the image receptor. The smaller the pixel size, the better the spatial resolution.[3]

According to the ACR, digital systems should be capable of recording the kVp, mA, exposure time, beam filtration and radiation exposure indicator on images. A record of these factors helps keep technique selection consistent for future comparative studies.[12]

To produce consistent image quality and maintain doses that are as low as reasonably achievable, all x-ray equipment should be validated and calibrated to ensure similar radiographic technique parameters produce the same exposure. Additionally, CR readers or direct radiography (DR) image receptors should provide images of uniform quality, and imaging monitors at workstations should be checked to ensure consistent appearance of displayed images.[12]

Fluoroscopy Units

Fluoroscopy unit configurations vary depending on the type of procedures for which they are primary used, and these systems may have either film-screen or digital receptors for spot radiographs. Digital fluoroscopy systems possess the same postprocessing benefits as digital radiography systems.

During fluoroscopic examinations, blurring often is

caused by patient movement or the high-speed motion of the patient's organs, such as the heart beat or breathing. Blurring significantly lowers image quality, especially when the objects in motion are small and move quickly. Motion blurring can be minimized by using short pulse widths. Also, noise-reduction algorithms used during image processing can produce images without artifacts and with reduced noise.[26]

Image resolution depends on the focal spot size and the pixel size of the detector. Resolution is particularly important when performing fluoroscopic imaging of pediatric patients. One processing approach to improve resolution is called the super-resolution technique, in which 2 or more medical images are translated, rotated and scaled against each other within the subpixel dimension and then are combined. This process resolves structures smaller than a single-detector pixel.[26]

Technical Factors

Optimal kVp selection produces ideal contrast for the anatomical part being imaged. When using film, too much or too little mAs creates an image that is too dark or too light. Following an established technique chart improves the likelihood of accurate exposure technique selection.[13] It is also important to remember that the operator may need to adjust the kVp and mAs, depending on the patient's condition or placement of an immobilizing device.[3]

Technical factors related to image quality include:

- Detection efficiency.
- Dynamic range.
- Spatial sampling.
- Spatial resolution.
- Noise.
- Contrast resolution.
- Detective quantum efficiency.[12]

Magnification, or size distortion, also should be minimized to reduce blurring of recorded detail.[3]

Detection efficiency is defined as the efficiency with which incident x-rays are absorbed. For both film-screen and digital systems, it is determined by the absorber's thickness, density and composition. Detection efficiency can be improved by increasing material density or absorber thickness.[12]

The ratio of the largest to smallest input intensities that can be imaged with a given imaging system is called the dynamic range, or exposure latitude when referring to film-screen systems. The level of intrinsic system noise determines the smallest useful intensity, whereas the receptor saturation determines the largest intensity. For a digital radiography system to create quality images, the receptor must be capable of producing good contrast over this range. In film-screen systems, the loss of contrast at low and high exposure levels, as determined by screen and film characteristics, defines the exposure latitude.[12]

Spatial sampling occurs when digital detectors sample the x-ray fluence at discrete input locations separated by an interval called the sampling pitch. The ability of a digital imaging system to image high frequency fluctuations in x-ray fluence is determined by the spatial frequency in which sampling occurs. The Nyquist frequency is the highest spatial frequency in the incident x-ray fluence that can be reliably imaged and is equal to one-half the sampling frequency. If information reaches the receptor at frequencies higher than the Nyquist frequency, false image signals can occur that produce large-scale artifacts in the image. This results in the loss of ability to see fine details.[12]

The ability of an imaging system to visualize 2 adjacent structures as separate entities is called spatial resolution. Losses in spatial resolution occur because of geometric blur, detector element effective aperture size and patient motion. With film-screen systems, the thickness of the screen is the primary factor determining geometric blur. With CR systems, scattering of the laser light beam during image plate readout causes most of the loss in spatial resolution. Two factors are primarily responsible for loss of spatial resolution in DR systems. For an indirect DR system, the spread of light photons during the x-ray-to-light conversion process results in blurring. Many manufacturers use structured converters to minimize this spread. The del size also affects spatial resolution in DR systems because anatomical structures that are smaller than the del size are smeared out and their contrast is reduced.[12]

Noise in imaging systems occurs when fluctuations in the image do not correspond to variations in the x-ray attenuation of the body part being imaged. All image receptors contain some degree of internal noise that can occur randomly within the receptor or at fixed locations. Examples of random noise include film granularity in film-screen systems and electronic noise in

CR and DR systems. Examples of sources of fixed-pattern noise include spatial variation in screen thickness in film-screen equipment, position-dependent light collection efficiency in CR plate readers and variations among preamplifier gains in DR systems. One benefit of DR systems is the ability to eliminate most fixed-pattern noise during digital postprocessing. Quantization noise is created during the digitization of the analog detector output voltage to discrete pixel values in digital systems.[12]

Scatter radiation causes a loss of subject contrast. Antiscatter grids should be used when patient thickness exceeds 10 cm or for cases in which scatter dominates. Operators should consider using grids with high-frequency grid strips to avoid aliasing patterns during mobile and lateral tabletop exposures. The mAs must be increased to compensate for decreased transmission of primary radiation when grids are used, with the amount of increase determined by the grid ratio and whether the system is film-screen or digital. Following the ALARA principle is especially important when imaging pediatric patients, because they are up to 10 times more sensitive to ionizing radiation than adults. The use of an antiscatter grid requires an increase in radiation exposure and therefore patient size should be considered when using grids.[12]

Contrast resolution, also known as radiographic contrast, is described as the magnitude of the signal difference between the anatomy of interest and surrounding structures in the displayed image. Both subject contrast and receptor sensitivity influence the contrast resolution. Display parameters in digital systems may be used to alter the contrast of images.[12]

Detective quantum efficiency (DQE) describes image receptor performance and is based on detection efficiency, spatial resolution and noise. Systems with low DQE require more exposure for a given image quality than systems with a higher DQE.[12]

The selection of proper exposure techniques is critical for producing adequate image brightness and contrast. The appropriate selection of receptor speed class for film-screen systems, or exposure class for digital systems, produces images with the proper optical densities. Typical film speeds for film-screen systems are 100, 200 and 400. Digital systems usually operate with higher speed classes than film-screen systems, and displayed image brightness and contrast are not determined by the exposure used during acquisition. The level of noise increases with low patient exposure or decreases with high patient exposure. Because operators tend to increase dose to avoid image noise, a concept known as dose creep, imaging professionals should follow a validated technique chart based on patient size for all examinations.[12]

With film-screen systems, poor film-screen contact also can cause image blur. Cassettes that are damaged or that contain a foreign object between the image receptor and the screen will demonstrate blurring where contact is poor but will appear sharp everywhere else.[3]

Procedural Factors

Most modern radiography systems allow a small focal spot to be selected for high-radiation exposures. Magnification can be minimized by always placing the anatomy of interest as close to the imaging receptor as possible.[3]

When an examination of the torso is performed using automatic exposure control, the mA set by the system is low and the exposure time is long to obtain the density required to visualize the torso structures. The radiographer or RA must weigh the possibility of motion blur because of increased exposure time against the expected advantages of using the small focal spot. A large focal spot and a high mA setting should be selected when the patient has a large thickness measurement or when the patient cannot remain still.[3]

Blur may be caused by voluntary or involuntary patient movement during the examination. Voluntary motion includes patient breathing or any movement the patient can control. Involuntary motion includes peristaltic activity of the stomach and intestines, shivering or any other movement the patient cannot control at the time. Motion blur can be identified on an image by looking at the cortical outlines of bony anatomy. If 1 outline of an anatomical structure appears to the side or above the outline of another, then the patient moved during the exposure. A double-exposed image may look like a blurry image but is distinguished by having 2 outlines around the structure of interest because the patient was in a slightly different position.[3]

The diagnostic quality of GI contrast studies depends on factors such as the quality of barium coating of the bowel, the density and contrast within the images and

adequate demonstration of the correct anatomy when double contrast is used.[6] (See Figure 1.) The patient should be positioned in time to capture the air or barium in the portion of the digestive tract of interest. Proper drainage of barium is important to prevent pools of contrast from obscuring visualization of pathology. (See Figure 2). During upper GI contrast studies, the position of the patient and projection of the image may be determined by examining the appearance of the spine and the presence of air or contrast in the fundus of the stomach.[22] For example, when the pedicles are displayed on both sides of the spinous processes and there is air in the fundus, the patient is in the prone position and the projection is PA.[22]

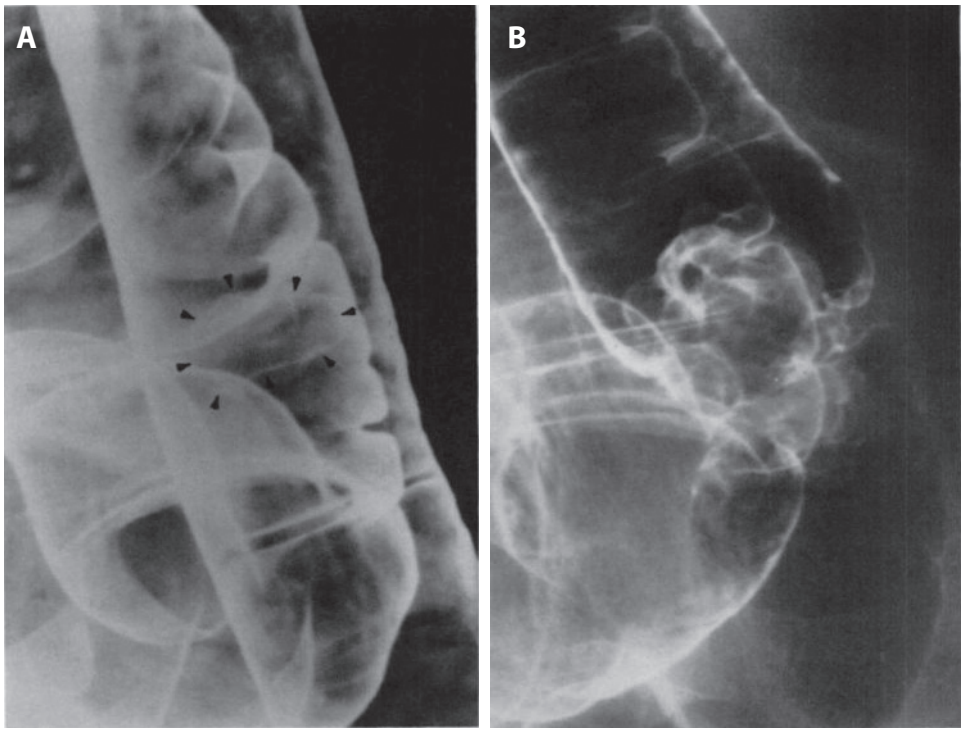

Fig 1. *Carcinoma of the descending colon. A. Polypoid mass (arrowheads) poorly coated with barium. Flocculated barium in upper part of radiograph is further evidence of poor mucosal coating. B. 2 years later. Larger lobulated mass in the same location is clearly visible. (Reprinted with permission from Kelvin FM, Gardiner R, Vas W, Stevenson GW. Colorectal carcinoma missed on double contrast barium enema study: a problem in perception.* AJR Am J Roentgenol. *1981;137(2):307-313.)*

Chest or abdominal images of a small patient should have a collimated border within 0.5 inch of the patient's skin line. The collimator head on some imaging equipment may be rotated to better collimate to the anatomy of interest, but severe rotation on CR systems should be avoided because it may alter the exposure field recognition process.[3]

Overcollimation or poor central ray placement can make anatomical structures appear clipped. Because x-ray beam divergence causes magnification of structures that are not placed directly on the imaging receptor, the shadow of the object projected from the collimator light onto the image receptor may be used to guide collimation margins. Accurate placement of the central ray may be determined by connecting the corners of the collimated border to form an imaginary X. The entrance point for the central ray is at the center of the X.[3]

The rotation and tilt of a patient during PA/AP chest imaging may be evaluated by checking for asymmetry and alignment of the shadows of the clavicles and the amount of lung field displayed superior to the clavicles. If the clavicles appear to lie in the vertical rather than the horizontal plane, then the patient was tilted forward during the PA projection.[19] If the patient is rotated, the mediastinum and heart appear enlarged and distorted because they are imaged in the oblique position.[19,22] Rotation on a lateral chest image may be detected by measuring the degree of posterior rib and anterior rib superimposition. If the patient is rotated, there will be more than 0.5 inch of space between the ribs and portions of the lung field appear distorted.[19]

Rotation on an abdominal image may be determined by rotation of the vertebrae. On an AP abdominal image, the distance from the pedicles to the spinous processes on each side of the vertebral body should be equal.[19] The side with the larger distance between the spinous process and the pedicle is the side positioned closer to

the tabletop.[22] Patients with scoliosis may appear to be rotated on AP images of the chest and abdomen; however, the sternoclavicular joints are routinely equidistant from the vertebral column in patients with scoliosis, whereas the distance is not equal when a patient is rotated.[19] Similarly, on AP images of the abdomen, scoliosis appears as a rotated section with lateral deviation on an otherwise straight vertebral column. Being familiar with the difference in appearance of a rotated vertebral column vs a scoliotic one helps to prevent unnecessary repeat examinations.[19]

Protective shielding should be used when the radiosensitive cells of the eyes, thyroid, breasts and gonads lie within 2 inches of the primary beam and if the shield does not cover the anatomy of interest. The use of gonadal shields can reduce the radiation exposure to the female gonads by 50% and to the male gonads by 90%. For the AP position, the female gonads are protected with a flat, 1-mm thick lead contact shield cut into the shape of the pelvic inlet. Several sizes of shields should be available to compensate for the amount of magnification due to the object-to-image distance and for variations in patient size. The female shield should be placed just superior to the symphysis pubis, with the sides of the shield equidistant from a margin the width of the index finger medial to the ASIS.[3]

The testes are protected with a flat, 1-mm thick lead contact shield cut into the shape of a right triangle in which the 90° angle is rounded. For the AP position, the rounded corner should be placed about 1 to 1.5 inches inferior to the palpable symphysis pubis.[3]

For lateral projections of the vertebrae, sacrum or coccyx, the straight edge of a lead apron may be used to shield both female and male patients. It should be placed just anterior to an imaginary line connecting the coccyx with a point 1 inch posterior to the ASIS.[3]

Artifacts

Although some artifacts such as processor marks, fingerprints or nail marks, fog and static electricity may be seen on the image, they should not obscure the anatomy of interest. It is important that glasses and jewelry be removed before the examination.[13] The technologist should ask patients to remove any items that are located around the area being imaged. Hospital devices such as monitoring leads should be shifted carefully so they overlap the least amount of anatomy possible. Usually, patient possessions and medical devices leave artifacts that are lighter density than the surrounding structures, whereas artifacts due to poor equipment use or handling errors have a darker density than the surrounding anatomical structures.[3]

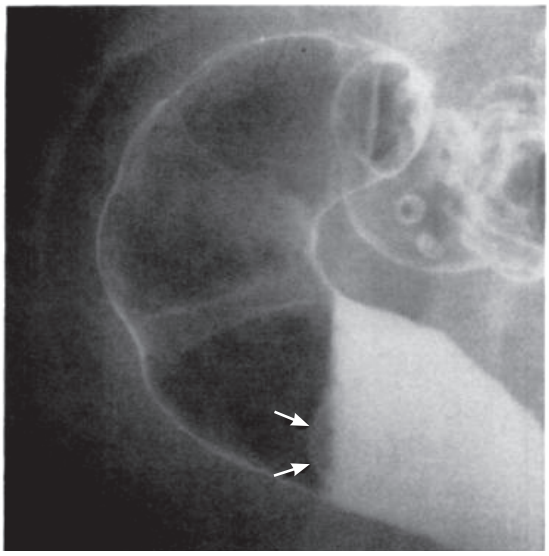

Fig 2. *Carcinoma of rectum (arrows) almost completely hidden by barium pool. Because of excessive, undrained barium, the lesion is not seen on other projections. (Reprinted with permission from Kelvin FM, Gardiner R, Vas W, Stevenson GW. Colorectal carcinoma missed on double contrast barium enema study: a problem in perception.* AJR Am J Roentgenol. *1981;137(2):307-313.)*

Conclusion

The quality and analysis of diagnostic images encompasses several factors. Standards of acceptability vary among radiology departments, but basic image analysis involves evaluation of the positioning and labeling of the anatomical part, exposure technique for desired contrast and density, collimation, evidence of protective lead shielding when appropriate and the presence of artifacts. Radiographers and radiologist assistants should be able to distinguish procedural and technical factors that affect image quality. They also should strive to reduce positioning, technique and equipment errors to prevent unnecessary repeat exposures and to provide the radiologist with optimal images for interpretation.

References

1. Geise RA. Fluoroscopy: recording of fluoroscopic images and automatic exposure control. *Radiographics*. 2001;21(1):227-236.
2. World Health Organization. Standardization of interpretation of chest radiographs for the diagnosis of pneumonia in children. World Health Organization website. www.who.int/vaccines-documents/DocsPDF01/www616.pdf. Published 2001. Accessed July 21, 2010.
3. McQuillen-Martensen K. *Radiographic Image Analysis*. 2nd ed. St Louis, MO: Elsevier Inc; 2006:1-52.
4. American Society of Radiologic Technologists. *The Practice Standards for Medical Imaging and Radiation Therapy. Radiography Practice Standards*. American Society of Radiologic Technologists website. www.asrt.org/media/pdf/practicestds/GR10_OPI_Strds_Rad_PS.pdf. Accessed October 5, 2010.
5. American College of Radiology. ACR Technical standard for management of the use of radiation in fluoroscopic procedures. American College of Radiology website. www.acr.org/SecondaryMainMenuCategories/quality_safety/RadSafety/RadiationSafety/standard-manage-radiation.aspx. Accessed August 10, 2010.
6. Nightingale J, Hogg P. The role of the GI radiographer: a United Kingdom perspective. *Radiol Technol*. 2007;78(4):284-290.
7. American Society of Radiologic Technologists. *The Practice Standards for Medical Imaging and Radiation Therapy. Radiologist Assistant Practice Standards*. American Society of Radiologic Technologists website. www.asrt.org/media/pdf/practicestds/GR10_OPI_RA_Strds_PS.pdf. Accessed August 7, 2010.
8. American Registry of Radiologic Technologists. Registered radiology assistant role delineation. American Registry of Radiologic Technologists website. http://arrtpdf1.s3.amazonaws.com/radasst/finalraroledelineation.pdf. Published 2005. Accessed July 26, 2010.
9. Berlin L. The Trojan horse once destroyed a nation, could it destroy the specialty of radiology? *Radiology*. 2008;248:8-11.
10. American College of Radiology. ACR ASRT joint policy statement – radiologist assistant: roles and responsibilities. American College of Radiology website. www.acr.org/SecondaryMainMenuCategories/quality_safety/RadiologistAssistant/ACRASRTJointPolicyStatementRadiologistAssistantRolesandResponsibilitiesDoc6.aspx. Published May 2003. Accessed July 13, 2010.
11. Berlin L. The importance of proper radiographic positioning and technique. *AJR Am J Roentgenol*. 1996;166(4):769-771.
12. American College of Radiology. ACR-AAPM-SIIM practice guideline for digital radiography. American College of Radiology website. www.acr.org/secondarymainmenucategories/quality_safety/guidelines/dx/digital_radiography.aspx. Published 2007. Accessed August 23, 2010.
13. Kogan PL, Lumsden R. How do you critique your radiographs. *J Can Chiropr Assoc*. 1993;37(4):230-232.
14. The Joint Commission: National Patient Safety Goals. http://www.jointcommission.org/NR/rdonlyres/868C9E07-037F-433D-8858-0D5FAA4322F2/0/July2010NPSGs_Scoring_HAP2.pdf . Published July 1, 2010. Accessed August 8, 2010
15. American College of Radiology. Clarification given by CMS on ordering of diagnostic tests rule, supervision rule and ICD-9 coding guidelines. *ACR Bulletin*. American College of Radiology website. www.acr.org/Hidden/Economics/FeaturedCategories/Pubs/coding_source/archives/NovDec07/Attachments/ACRBulletinNov01.aspx. Published November 2001. Accessed August 10, 2010.
16. Torres LS. *Basic Medical Techniques and Patient Care in Imaging Technology*. 6th ed. Baltimore, MD: Lippincott Williams & Wilkins; 2003.
17. American College of Radiology. ACR Practice guideline for communication of diagnostic imaging findings. American College of Radiology website. http://www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/dx/comm_diag_rad.aspx. Revised 2010. Accessed July 22, 2010.
18. Sharieff GQ, Kanegaye J, Wallace CD, McCaslin RI, Harley JR. Can portable bedside fluoroscopy replace standard, postreduction radiographs in the management of pediatric fractures? *Pediatr Emerg Care*. 1999;15(4):249-251.
19. McQuillen-Martensen K. *Radiographic Critique*. Philadelphia, PA: WB Saunders Co;1996:1-76.
20. Ballinger PW, Frank ED. *Merrill's Atlas of Radiographic Positions and Radiographic Procedures*. Vol 2. 9th ed. St Louis, MO: Mosby Inc;1999:33-230.
21. American College of Radiology. ACR-SPR practice guideline for the performance of pediatric contrast examinations of the small bowel. American College of Radiology website. www.acr.org/SecondaryMainMenuCategories/quality_safety/guidelines/pediatric/ped_contrast_small_bowel.aspx. Revised 2008. Accessed August 1, 2010.
22. Novelline RA. *Squire's Fundamentals of Radiology*. 6th ed. Cambridge, MA: Harvard University Press; 2004.
23. Thompson WM, Foster WL, Paulson EK, et al. Comparison of radiologists and technologists in the performance of air-contrast barium enemas. *AJR Am J Roentgenol*. 2006;187(3):706-709.
24. Schreiber MH, vanSonnenberg E, Wittich GR. Technical adequacy of fluoroscopic spot films of the gastrointestinal tract: comparison of residents and technologists. *AJR Am J Roentgenol*. 1996;166(4):795-797.

25. Cesar LJ, Schueler BA, Zink FE, Daly TR, Taubel JP, Jorgenson LL. Artifacts found in computed radiography. *Br J Radiol*. 2001;74(878):195-202.
26. Bernhardt P, Lendl M, Deinzer F. New technologies to reduce pediatric doses. *Pediatr Radiol*. 2006;36(Suppl 2):212-215.

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