Chapter 19

Image Evaluation

Learning Objectives

At the conclusion of this chapter, you will be able to

- Describe optimum conditions for viewing and evaluating radiographs
- Describe the correct orientation of images on a viewing monitor
- Demonstrate a systematic review of a radiograph for diagnostic, technical, and esthetic quality
- Recognize artifacts and technical errors on radiographs and state their causes
- Suggest appropriate changes in technique or procedure when film quality is less than optimal
- List appropriate criteria for determining whether a radiograph should be repeated

Key Terms

anatomic position

Much of the information in this chapter is not new. Facts from many chapters are brought together here and considered with respect to the evaluation of image quality.

Critical image review is an important contribution to your patients' care and to the physician who will interpret (read) the images. It is also essential to your continuing education as a limited operator. Image evaluation is the process by which you determine whether each projection is correctly identified and marked and whether it has sufficient diagnostic quality to meet the minimum requirements of the order or if it must be repeated. When a projection must be repeated, your review provides information to ensure that the new radiograph is satisfactory.

Up to this point, this text has dealt primarily with the science of radiography and the basic procedures involved in the application of that science. Radiography is also an art, and your ability to take consistently high-quality radiographs will develop only with time and practice. Every radiograph you take is an opportunity to learn; each image you review can teach you something that will improve your ability. Your skills will develop most rapidly if you pay close attention to the results of your work, always striving for excellence.

VIEWING RADIOGRAPHS

Viewing Conditions

You will be viewing images on a computer monitor. It is likely that your viewing monitor will have less resolution than the one used by the physician when interpreting the images you produce. If an image is of questionable quality on your monitor, it may still be acceptable on the physician's monitor. It is essential that you solicit feedback from the physician when he or she finds images to be unacceptable. That is an important component of improving your knowledge of appropriate image quality.

It is not necessary to view images in a fully darkened room, but a low light level in the viewing area is necessary. Too much light causes the pupils of the eyes to contract, admitting less light to the eye, and therefore causing radiographs to appear dark. A black frame, called a mask, usually surrounds each image, enhancing your ability to perceive its detail accurately. Inappropriately placed lights may cause an unacceptable glare on the monitor screen. If the area where you view images is brightly lit, that must be taken into account when you are judging image brightness. An image may appear dark to you but may be perfectly acceptable when it is viewed by the physician under an appropriately lower light level.

Image Orientation

Radiographs are generally viewed "right side up," with the most superior aspect of the anatomy at the top. Regardless of the patient's position when the image receptor (IR) is exposed, it is customary to view both anteroposterior (AP) and posteroanterior (PA) projections as if the patient were facing the viewer in the **anatomic position**. This is the position in which the patient is standing erect, with the face directed forward, arms extended by the sides with the palms facing forward, and the toes pointing anteriorly (Fig. 19.1). The patient's right side is toward the viewer's left. You will notice that radiographic markers will appear backward on PA projections because the image must be flipped, from left to right, for it to be oriented in anatomic position for viewing. Oblique projections are viewed using the same general rules. Lateral projections are usually viewed in the same position as they are taken; for example, a left lateral projection is oriented with the patient facing toward the viewer's right.

Exceptions to these general rules are made for examinations of the distal upper limb and the foot and for decubitus projections. Radiographs of the fingers, hand, wrist, forearm, and foot are usually viewed with the distal aspect pointing to the ceiling. Decubitus projections are often viewed horizontally, in the same position as they are taken.

The radiographs in this text are presented using these rules for viewing.

Some chiropractors and surgeons prefer to view AP and oblique spine projections from the same perspective used to examine the patient, as if the examiner were facing the patient's back. In this case, the radiograph is oriented so that the patient's left side is on the viewer's left.

SYSTEMATIC IMAGE REVIEW

With practice, you will learn to evaluate an image quite rapidly. However, it is important not to rush this process or significant details may be overlooked. An accurate assessment of image quality requires a systematic approach. You may find it helpful to use the acronym *I AM ExpERT*. These letters stand for *identification*, *anatomy*, *marking*, *exposure*, *esthetic considerations*, *radiation safety*, and *troubleshooting*.

- **Identification**. First, check the image identification. Is it clear and complete? Does it match the identification on the requisition?
- **Anatomy**. Is the pertinent anatomy included on the projection and clearly visible? Was the patient properly positioned? Look for missing anatomy, evidence of improper rotation, or superimposed structures that indicate improper position.
- **Marking**. Is the correct right or left side marker clearly visible and in the proper location? If your facility's protocol requires additional markers for images—such as flexion, weight bearing, or upright—check for placement and clear visibility of these additional markers as well.
- **Exposure**. Were the exposure factors appropriate? Are the essential features of the anatomy sharp and distinct? For a digital imaging system, is the exposure indicator number within the appropriate range?

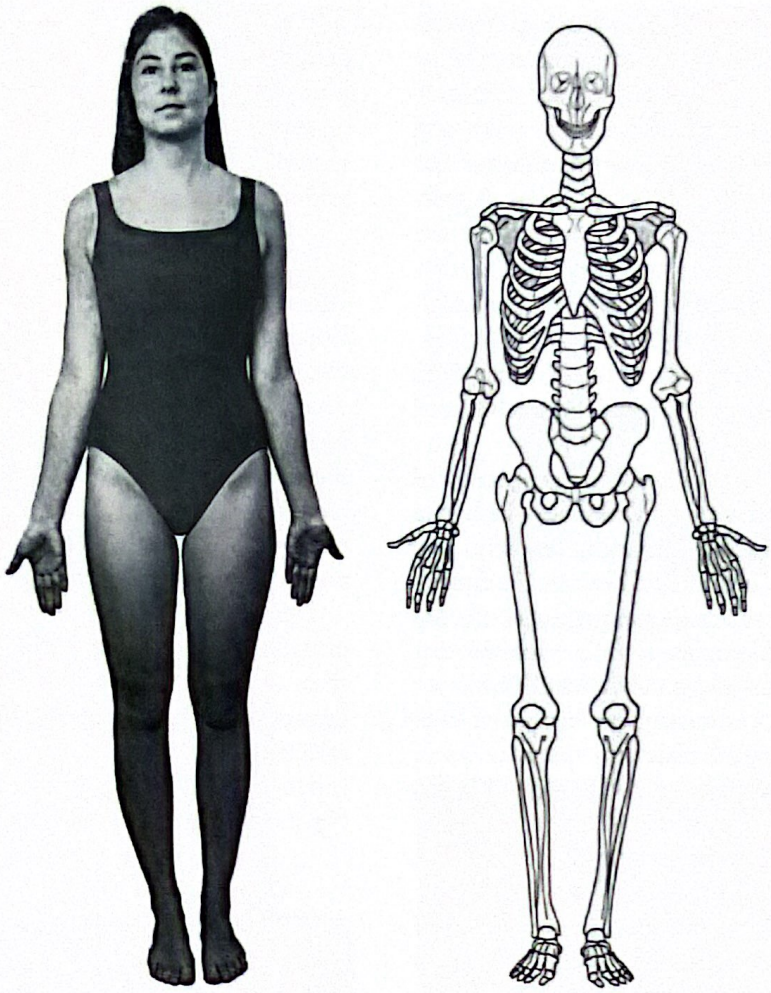

Fig. 19.1 Patient in the anatomic position. Most radiographs are displayed on the viewing monitor with the body part matching this position.

- **Esthetic considerations.** Does the image have artistic merit? Do artifacts, misalignments, or other features of the image detract from its general appearance?
- **Radiation safety.** Is there evidence of collimation on at least three margins of the image? Where appropriate, is shielding apparent and correctly placed?
- **Troubleshooting.** Identify the cause of any problems noted on the image. Are they so significant as to require the image to be repeated? If so, what changes are necessary for the repeat to be successful? Regardless of whether a repeat is required, what steps are necessary to improve image quality in the future?

Each of these aspects of image evaluation is discussed in greater detail later in this chapter.

IMAGE IDENTIFICATION AND MARKERS

The first thing to check when you are reviewing a radiograph is the patient's identification. This information must be complete and legible. Certainly it is a good practice to be aware of the need for accurate radiographic identification and to cultivate the habit of identifying images properly. However, errors sometimes occur. Your facility should have a policy regarding images that are not properly labeled and a method for rectifying the mistake.

Check to be certain that the correct right- or left-side marker (and any other required marker) is clearly visible and properly located. Correct marker placement is discussed in Chapter 12. All radiographic markers should be placed so that they are recorded on the image during the exposure. Although digital radiography systems allow the addition of "electronic markers," called *annotation*, during image review and postprocessing, this practice is not recommended. Although electronic marking may not be illegal, the practice is not considered the standard of care and can call into question the quality of the imaging process.

ANATOMY AND POSITIONING ERRORS

Exclusion of Significant Anatomy

Standard IR sizes, center points, and collimation sizes are used in radiography to ensure that the required anatomic structures will be included on the image. Even when these standards are followed, some significant anatomic details may be excluded because of inaccurate centering, collimation, or

variations in patient anatomy. During positioning, check to be certain that the outer margins of the structures to be included are within the IR margins and within the collimator light field. The image should include the surrounding soft tissues and the bony structures. It is helpful to remember that all radiographic images are magnified to some degree. Double check that the shadow of the outer margin of the part is seen within the collimator light field, because this shadow is magnified to approximately the same extent as the radiographic image. A small amount of light (about 1 inch) is customarily extended beyond the skin shadow to allow for slight variation between the location of the light field and the actual radiation field.

Fig. 19.2 shows incomplete anatomic demonstration of the scapula caused by excessive collimation, which is a light field too small to include all pertinent anatomy. The hand image in Fig. 19.3 is incomplete because the fingertips are not included. In both cases the projection should be repeated unless the physician is fully satisfied that the area of clinical interest is adequately shown. The lower leg radiograph in Fig. 19.4 is incomplete because it does not demonstrate the proximal tibia and the knee joint. Depending on the specific area of clinical interest, this examination may be sufficient. If not, the recommended approach is to take a separate projection of the knee area to include the proximal tibia.

Fig. 19.5 shows incomplete anatomic demonstration of the sacrum caused by poor alignment of the x-ray beam with the IR. There are three possible causes for this error: failure to secure the cassette in the Bucky tray, failure to push the Bucky tray all the way into the table or upright Bucky unit, and/or failure to align the x-ray tube to the center of the IR or grid. In this case it is apparent that grid alignment is not a problem because there is no evidence of grid cutoff (see Chapter 9).

Incorrect Positioning

Routine positions are established to ensure a comprehensive evaluation of the anatomy. Errors in diagnosis can occur when structures are not well visualized or when incorrect positioning prevents comparison with the usual normal radiographic appearance. If you cannot readily identify the errors on the radiographs in this section or on radiographs that you have taken, compare them with the normal radiographs illustrated in Chapters 13 through 17.

Figs. 19.6 and 19.7 illustrate common examples of incorrect limb positioning. In Fig. 19.6, the elbow joint space and associated anatomy are not well demonstrated because the radiographer failed to position the patient with the axilla at table level. Distortion of the anatomy results because the humerus is not parallel to the IR. In Fig. 19.7, visualization of the ankle joint is compromised

Fig. 19.2 Lateral scapula with incomplete anatomy demonstration resulting from improper collimation.

Fig. 19.3 Hand projection is incomplete because the fingertips are not included.

Fig. 19.4 Lower leg projection fails to demonstrate proximal tibia and knee joint. A separate projection of the knee may be required. Image brightness is insufficient to see the lateral malleolus.

because of part rotation. The sagittal plane of the ankle and lower leg was not parallel to the IR.

Figs. 19.8 and 19.9 are examples of the errors that occur in the AP projection of the upper cervical spine when the skull is positioned with incorrect neck flexion. Fig. 19.8 was taken with too much flexion of the neck, projecting the teeth over C1 and the dens. Fig. 19.9, on the other hand, is an example of too much neck extension, projecting the base of the occipital bone over C1 and the lower teeth over the upper portion of C2. Both of these radiographs are unsatisfactory and must be repeated.

Fig. 19.10 is a lateral lumbar spine radiograph that is unsatisfactory because the patient's arm is projected over the spine. In this case the limited operator failed to

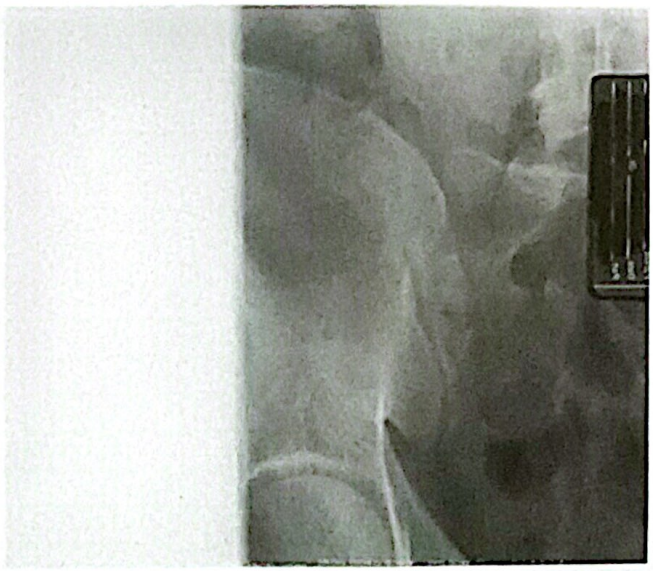

Fig. 19.5 This hip radiograph is incomplete because the IR was not centered to the x-ray beam. This may occur when the IR is loose in the Bucky tray or the tray is not fully inserted in the table.

Fig. 19.6 Visualization of elbow joint and distal humeral condyles is compromised by improper position. The humerus was not parallel to the IR.

Fig. 19.7 Visualization of ankle joint is compromised by rotation of leg from the lateral position. The sagittal plane of the leg was not parallel to the IR.

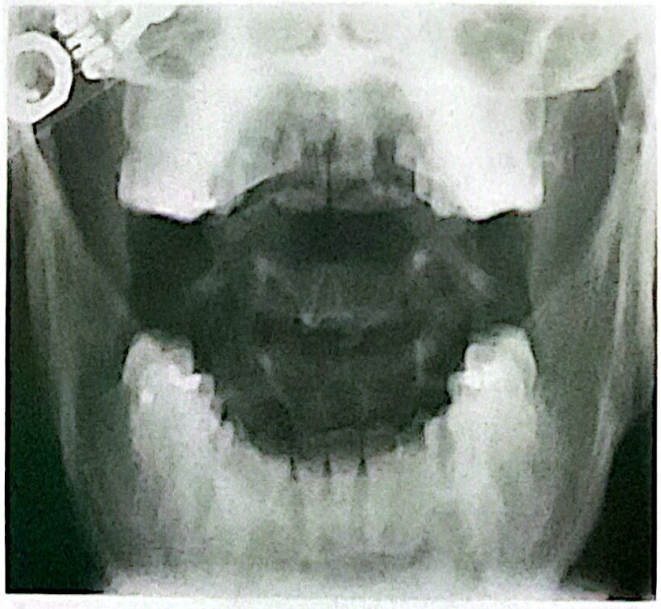

Fig. 19.8 Teeth obscure the atlas and the dens because of excessive neck flexion.

consider the location of the patient's arms when positioning. The arms should be positioned across the chest with the hands resting on opposite shoulders or supported anterior to the body and out of the radiation field.

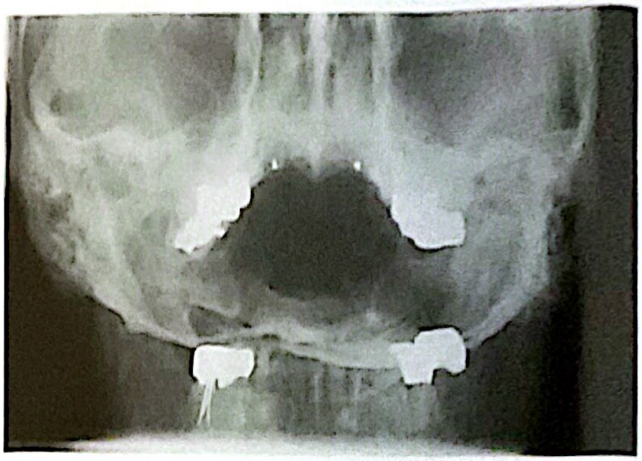

Fig. 19.9 Occipital bone obscures the atlas and the dens, and lower teeth obscure the upper body of C2 because of excessive neck extension.

Fig. 19.10 Poor attention to positioning details resulted in an arm being projected over lumbar vertebrae. Image brightness is low; it is a film-screen image.

Fig. 19.11 illustrates two common errors in positioning for the PA projection of the chest. First, the patient's torso is slightly rotated. The coronal plane of the body is not parallel to the IR. When the position is correct, the medial ends of the clavicles will appear equidistant from the

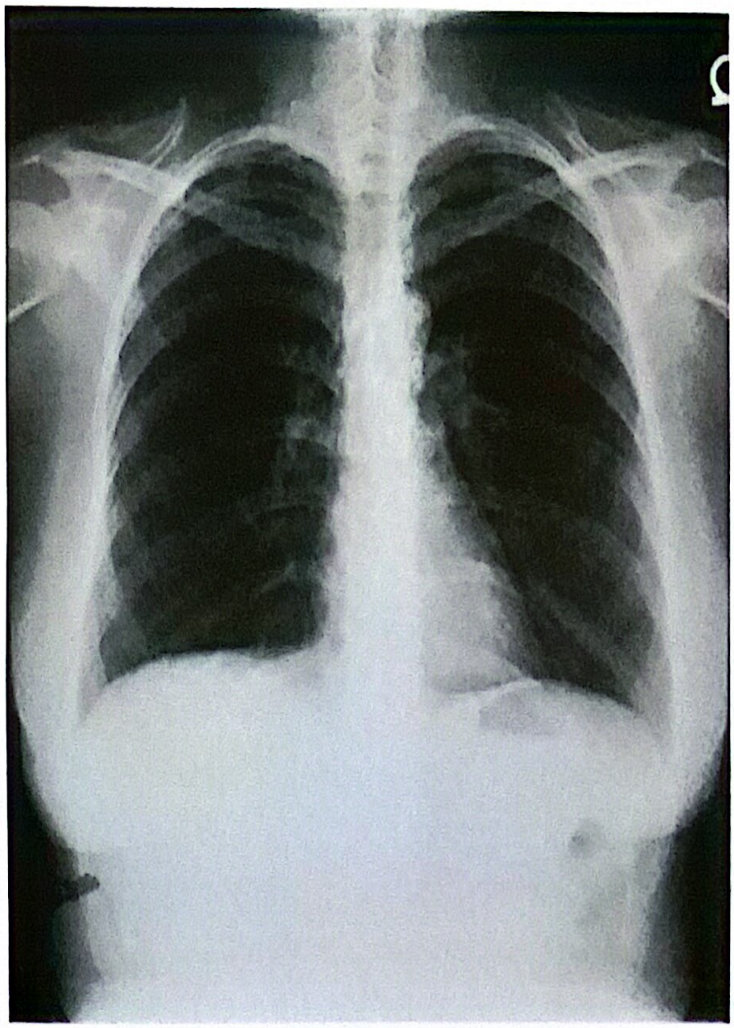

Fig. 19.11 PA projection chest radiograph shows slight rotation of the thorax because the medial ends of the clavicles are not equidistant from the midline. The medial portions of the scapulae are projected over the lateral lung fields, indicating that the patient's shoulders were not sufficiently rolled forward toward the IR.

center of the thoracic vertebra. In addition, the scapulae are superimposed on the lateral lung fields because of inadequate anterior rotation of the patient's shoulders during positioning.

Fig. 19.12 illustrates poor positioning caused by rotation of the skull for the PA projection. Note that the right and left halves of the image are not symmetric. When the skull is properly positioned, any lack of symmetry of cranial structures is an important diagnostic sign. When the position is rotated, cranial symmetry cannot be adequately evaluated and a significant aspect of diagnostic quality is lost. For PA projections, there are few visual clues to assist in determining whether the skull is rotated, so the ability to *feel* whether the alignment is correct is an essential positioning skill.

Some patients cannot assume routine positions for radiography. Compromise is required when deformity, injury, or discomfort prevents patients from maintaining the usual position. The positioning sections of Chapters 13 to 17 provide some alternative positions for common situations in which patients may be unable to comply with routine positioning. For example, the PA thumb projection may be substituted for the AP projection when the patient is unable to assume a satisfactory position to achieve the AP projection. Trauma projections of the shoulder and upper humerus may be used when the patient is unable to rotate the arm for a routine shoulder or humerus examination. When no standard position can be used, the limited operator should strive to obtain at least two different projections of the area of interest that are as close to standard as possible. All limb examinations must include at least one joint, and the same joint should appear on all images. Radiographs taken in nonstandard positions should be shown to the physician before concluding that the examination is complete.

EXPOSURE FACTORS

The *exposure* term in the I AM ExpERT acronym is a reminder to consider the image quality factors: image brightness, radiographic contrast, spatial resolution, and distortion. With digital radiography systems, image brightness is not related to the amount of radiation

Fig. 19.12 PA projection of skull demonstrating asymmetry because of rotation. The lateral orbital margins are not equidistant from the lateral surfaces of the skull.

exposure but rather is the result of image display algorithms or digital processing functions.

Image Brightness Problems

With digital radiography systems, whether CR or DR, there is rarely a visual cue to inappropriate exposure settings because the relationship between image brightness and amount of radiation exposure is evident on the image only when the anatomy of interest contains areas of significantly different tissue thickness. Fig. 19.13 illustrates one of the few situations where differences in image brightness are evident. For this reason, the visual quality check for proper radiation exposure in digital radiography systems is checking the Exposure Indicator number. The names and number ranges for these exposure indicators are specific to each manufacturer, so there is no current standard. The limited x-ray machine operator (LXMO) must become familiar with the proper exposure indicator numbers for the system in use and must check this number for each image during image evaluation.

Radiographic Contrast Problems

Radiographic contrast problems do occur with digital radiography systems but are infrequent. Under most

Fig. 19.13 Significant variation of image brightness, with the superior portion of the thoracic spine much darker than the inferior portion. This appearance can occur with large differences in tissue density. The image could be improved by using the anode heel effect or a compensating filter.

circumstances, digital processing will compensate for errors that would result in poor contrast on screen-film radiographs. Poor contrast on digital radiographs is subtle and will likely occur only with selection of a kVp value that is significantly outside the appropriate range for a specific body part or improper decision regarding whether a grid is needed. Inappropriate use of large radiation fields (undercollimation) can result in excessive scatter radiation, which can also reduce radiographic contrast. Fig. 19.14 illustrates poor and appropriate radiographic contrast.

Lack of Spatial Resolution (Detail)

When you are evaluating resolution on the radiograph, note whether the margins and fine lines of the image are sharp and clear. Chapter 7 explains the factors that affect spatial resolution (detail), which include film-screen speed, source–image receptor distance (SID), object–image receptor distance (OID), focal spot size, and motion

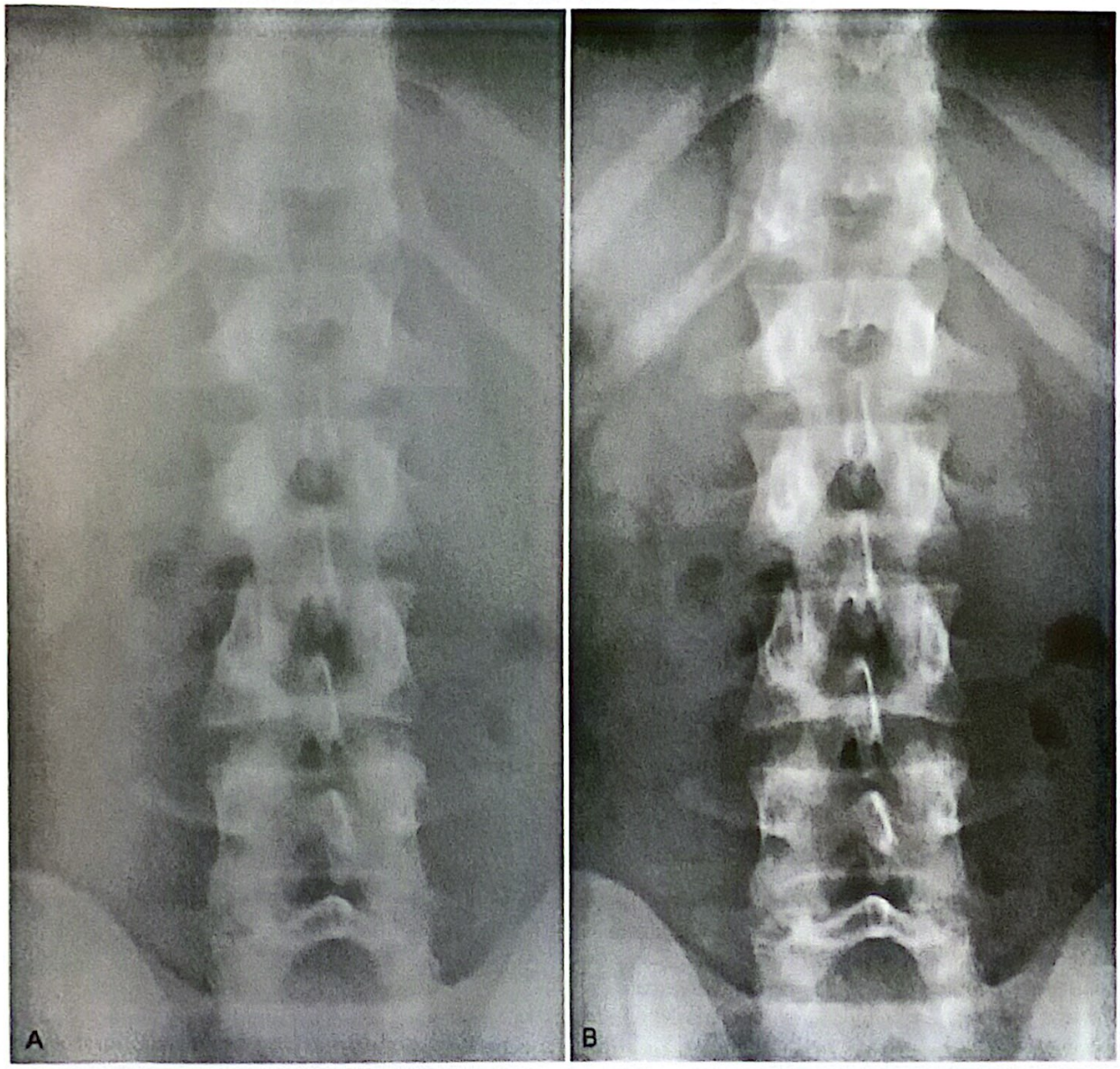

Fig. 19.14 (A) AP lumbar spine image demonstrating poor (low) radiographic contrast. (B) This image demonstrates appropriate radiographic contrast.

Fig. 19.15 illustrates a lateral cervical spine radiograph that was taken at a 40-inch SID using the large focal spot. For these reasons, the film exhibits magnification distortion and poor definition. Because of the large OID involved in lateral cervical spine radiography, a 72-inch SID and the small focal spot should be used. This radiograph also shows that the patient's shoulders were not depressed, which resulted in failure to properly demonstrate the C6 and C7 vertebrae. Failure to remove the patient's glasses degraded image quality with distracting artifacts. This radiograph must be repeated to correct all of these errors.

Because film-screen speed, SID, and focal spot size are usually established in advance to provide the required degree of resolution, blurring or unsharpness is most likely caused by patient motion during the exposure. Fig. 19.16 is an example of a blurred image resulting from patient motion. In this case, breathing technique (see Chapter 12) was used in the hope of blurring only the ribs and lung markings, but the patient was unable to avoid movement of the entire torso. If a radiograph must be repeated because of motion, take care that the patient's position is stable and secure. Provide clear instructions and adequate time for the patient to comply. Use sandbags, sponges, or other devices to aid in immobilization, if necessary. Use the highest possible milliamperes (mA) setting and the shortest exposure time that will provide the desired mAs (see Chapter 10).

ESTHETIC QUALITY

The term *esthetic quality* refers to the visual appeal of the radiograph. Esthetic quality is sometimes called *artistic*

Fig. 19.15 Lateral cervical spine radiograph taken at a 40-inch SID using the large focal spot has poor spatial resolution. Poor positioning (depress shoulders) and artifacts (eyeglasses) also need to be corrected when this radiograph is repeated at a 72-inch SID with the small focal spot.

Fig. 19.16 Lateral radiograph of the thoracic spine exhibits motion blur. If the patient is unable to remain still during the exposure, a higher mA and shorter exposure time should be used for the repeat exposure.

merit, a value that is placed on the excellence of the general appearance of the anatomy.

Radiographs that lack esthetic quality have a careless or sloppy appearance, even though they may meet the standards required for diagnosis. *Esthetic quality may also have diagnostic significance*. Informal research studies have shown that radiographs with a high degree of artistic merit are more likely to be interpreted accurately than diagnostic images with poor esthetic quality. Lack of attention to detail in the production of a radiograph may cause the physician to lack confidence in the information it provides. Artifacts and irregularities in the image may distract the viewer, affecting ability to focus on the significant details.

Although esthetic considerations alone seldom require repeat exposures, it is important for the limited operator to assess the esthetic quality of radiographs and, when artistic merit is absent, to strive for improvement at the next opportunity.

What is the first thing you notice when you look at the radiograph in Fig. 19.17? Patient preparation for radiography involves removing outer clothing, jewelry, and other artifacts from the area that will be included on the image. The radiographic images of jewelry, eyeglasses, hearing aids, snaps, buttons, and pocket change detract from the image and, equally important, may obscure important anatomic details. Artifacts such as images of safety pins or coins projected over the abdomen may raise a question as to whether the item has been swallowed or is instead outside the body. Note also the patient's hair. Although hair is not normally seen on radiographs, heavy locks of wet hair, braids, or dense masses of hair may be seen on the image and may mimic pathology or obscure relevant anatomy. Fig. 19.18 shows a hair artifact that was originally suspected to be a soft tissue mass in the patient's neck.

Another aspect of esthetic quality is the alignment and centering of the image. Studies of long bones are sometimes done with the anatomy placed diagonally on the film. However, standard practice is to align the long axis of the anatomy with the long axis of the IR. Inattention to alignment and centering produces images with a careless, sloppy appearance. Careful centering ensures that the

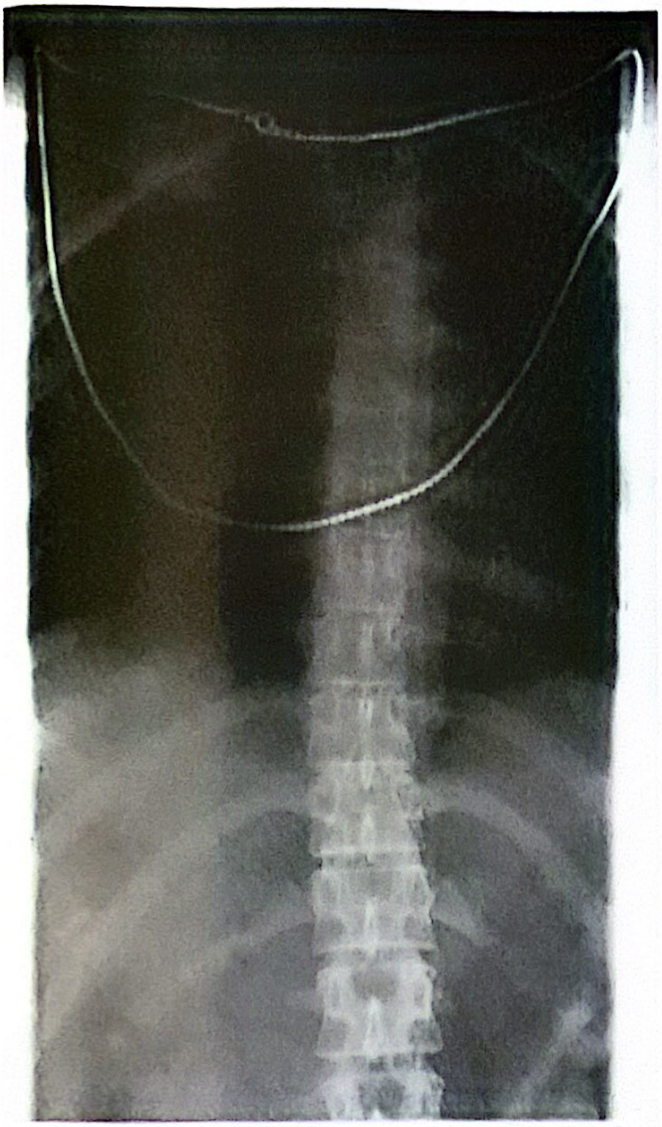

Fig. 19.17 Artifacts are distracting and may obscure significant anatomic detail. Note jewelry around the patient's neck.

collimation will show equal margins on each side and on the top and bottom of the image, which gives it an orderly appearance.

RADIATION SAFETY FACTORS

Although radiation safety involves many considerations, only two can be assessed by visually evaluating radiographs. These are collimation and shielding. Both are typically reviewed by radiation control officers when inspecting x-ray facilities for safety. This awareness should motivate limited operators to ensure that images demonstrate respect for radiation safety regulations.

Collimation

The need for proper collimation applies to all radiographs. Appropriate radiation field limitation minimizes patient dose and also improves radiographic quality. Regulations usually require that the field size be limited,

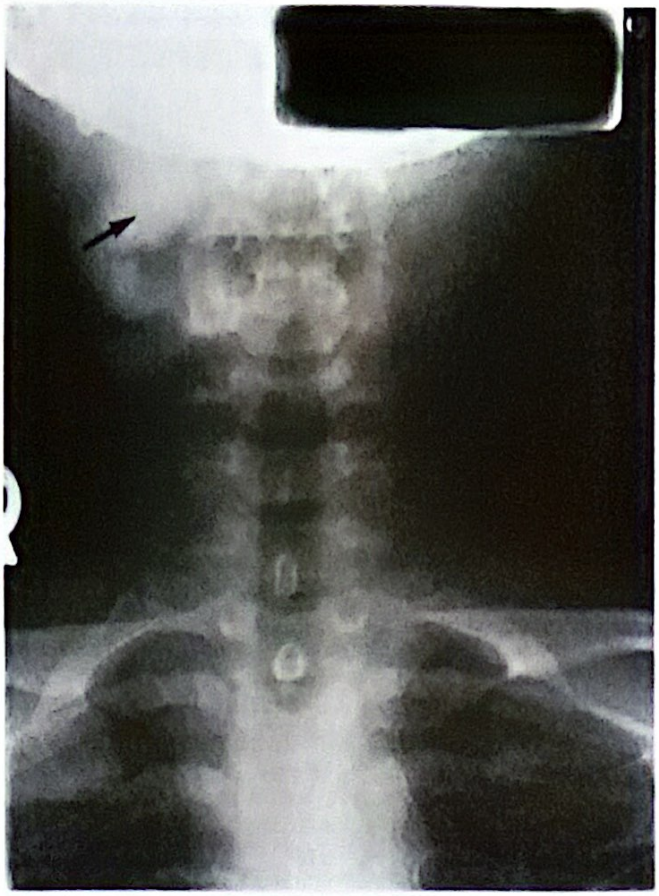

Fig. 19.18 AP projection cervical spine radiograph with hair artifact (*arrow*).

not only to the IR size but to the area of clinical interest. Radiation control officers usually judge that these requirements have been met when collimation is evident on three sides of a radiograph. However, the limited operator's goal is to show evidence of collimation on all four sides of the image and to narrow the field further, when possible, so that nonessential anatomy is excluded from the field.

The radiation field light indicator does not always indicate the radiation field precisely. Technically, there may be as much as a 0.75-inch difference between the light field margin and the radiation field margin. For this reason, it is wise not to collimate too closely, which raises the possibility of excluding an essential aspect of the anatomy and requiring a repeat examination. This is the reason for the recommendation of 1 inch of field light beyond all pertinent anatomy.

Shielding

As stated in Chapter 11, gonad shielding is required on patients under age 55 when the gonads are within 5 cm of the radiation field and a shield will not interfere with the purpose of the examination. Some states require special labeling of radiographs for which shielding is omitted because it would interfere with the examination's purpose. When reviewing radiographs for quality, check to be certain that shielding is apparent where required and that the shield is properly positioned.

TROUBLESHOOTING

The final step in image evaluation is to determine the causes of any problems identified to decide whether the radiograph should be repeated and, if so, what steps should be taken to ensure success. This process has been addressed specifically in the preceding sections. At this point it is important to emphasize that causes of image quality problems should always be accurately identified, whether a repeat is required or not. Understanding the reason for a problem is essential to preventing its recurrence.

When the cause of a problem is not immediately apparent, continue to investigate. Review the pertinent sections of this chapter and the chapters to which they refer. When the opportunity arises, show puzzling images to more experienced radiographers and seek their advice. The local technical representative of the company that manufactures your equipment may be willing to assist and can often help solve other technical problems as well. If you are not already acquainted with your equipment company's technical representative, contact can be made through the equipment dealer.

REPEATING RADIOGRAPHS

Few radiographs can accurately be described as perfect. Although some may be excellent, some are so poor that they must be repeated without question. Others may be marginal, acceptable to some physicians and unacceptable to others. Deciding whether or not to repeat a radiograph is a subjective judgment. Some limited operators might be inclined to take images over and over, striving for a perfect radiograph every time. Unnecessarily repeating radiographs wastes time and causes unnecessary radiation exposure to patients. On the other hand, some limited operators are very reluctant to repeat images, preferring to submit sloppy or substandard work rather than having to tell the patient that a repeat radiograph is required. *If the image is worth taking in the first place, it is worth taking well, even if success requires one or more repeat exposures.* Radiation safety should not be used as an excuse to avoid repeating the radiograph if an image is unsatisfactory. A reasonable standard is established by asking the question, "Does this image have sufficient quality to reveal or rule out any pathologic condition that may be present?"

The positioning sections of Chapters 13 through 17 provide general guidelines to assist you in determining whether the pertinent anatomy has been included on the image. The normal radiographs in the positioning sections generally represent an acceptable standard of positioning and technique. The pathology sections reveal some of the radiographic findings that should be seen, if present. A thorough study of these chapters will aid in determining whether your radiographs are acceptable. General guidelines for acceptable standards should be established in consultation with the physician who interprets the radiographs. In the beginning, you may need to consult the physician or your supervisor for help in deciding whether a repeat is required. With experience, you will learn to anticipate their opinions and to trust your own judgment.

It is useful to keep a record or log of all repeat exposures. A simple notebook with columns can be used to list the type of examination, the position or projection that was repeated, the problem that required a repeat exposure, and comments about the cause of the problem, including any steps taken to prevent the problem in the future. Review the record periodically to see if the same mistakes are recurring. For example, if repeat exposures are often necessary on cervical spine procedures because of positioning errors, you should review your procedure for these positions.

It is also useful to note the percentage of the radiographs you take that must be repeated. If your repeat rate is less than 1%, you could be an exceptional limited operator. More than likely, however, you are failing to repeat radiographs that should be redone. If your repeat rate is higher than 10%, consider whether you are repeating images unnecessarily or are making the same mistakes over and over. Most experienced limited operators have a repeat rate that is less than 4%. The number will vary with the types of patients seen and the types of examinations performed. A reduction in your repeat rate with no reduction in quality standards indicates that your skills are improving.

SUMMARY

Image evaluation is a critical review of all aspects of a radiograph and is an essential skill for all radiographers. This process is required to determine when repeat exposures are necessary and how they should be done. It also aids the limited operator in developing skills and improving performance.

A systematic review process ensures that important details are not missed. It should include attention to each of the following factors: image identification and labeling, anatomy and positioning, radiographic image quality, artistic quality, collimation, and shielding. The causes of any problems should be determined and steps taken to correct them.

The decision to repeat an image should be based on reasonable diagnostic standards developed in consultation with the physician who interprets the images. A log of repeated radiographs aids the limited operator in solving problems and assessing progress toward excellence.

REVIEW

Using the guidelines provided in this chapter, evaluate the radiographs in Figs. 19.19 through 19.24. List the errors

Fig. 19.19 Review image no. 1.

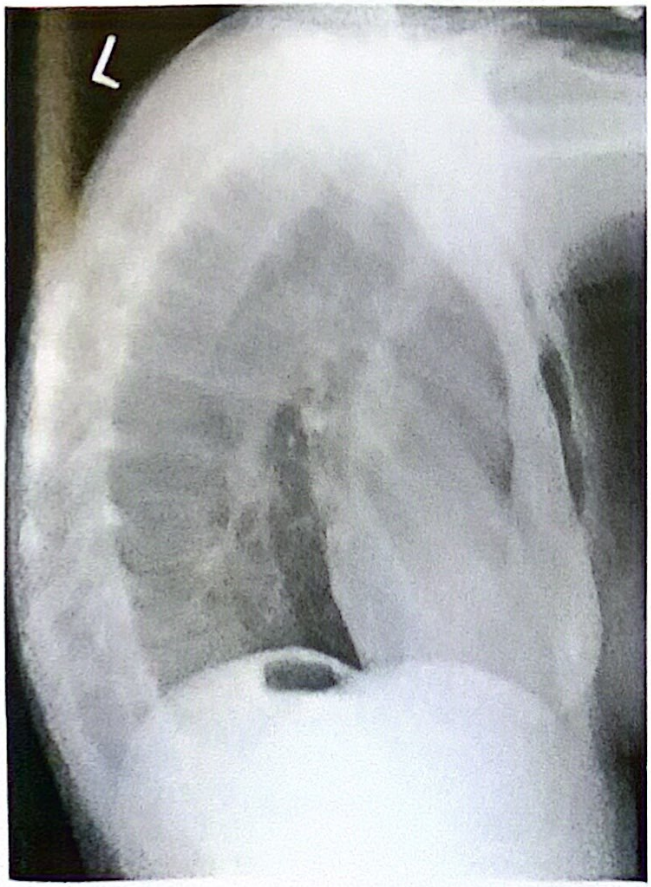

Fig. 19.20 Review image no. 2.

Fig. 19.21 Review image no. 3.

Fig. 19.22 Review image no. 4.

Fig. 19.23 Review image no. 5.

Fig. 19.24 Review image no. 6.

you identify and your suggestions for correcting them. Compare your list with the evaluations of these radiographs in Appendix I.

Note that image quality and detail are always compromised when radiographs are reproduced in books, so it is also important for you to practice your image critiquing skills on actual radiographs.