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EMERGENCY RADIOLOGY

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To all physicians who are dedicated to
the care of the acutely ill and injured patient.

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PREFACE

Over three decades ago, emergency medicine emerged as an organized discipline. With more than 100 residency training programs now in existence, emergency medicine has evolved into a sophisticated and broad-based arena of medical practice. The radiograph is an important tool for the evaluation of many acutely ill or injured patients, and understanding the use and interpretation of radiographic studies is an essential skill of the emergency physician. In addition, advanced imaging modalities such as computed tomography and ultrasonography are frequently used in the care of emergency department patients.

This text was developed to teach emergency radiology from the vantage point of the clinical emergency physician. The book is intended to serve as an instructional guide for the emergency medicine resident, practicing clinician, and medical student, as well as a reference text in the busy emergency department. Most chapters follow a similar format. The chapters begin with a discussion on *clinical decision making*—reviewing the indications for radiographic studies. This is followed by a discussion of *anatomy and physiology*, including the biomechanics needed to understand radiographic patterns of injury. The *radiographic technique* section illustrates the standard and supplementary radiographic views for each anatomical region and describes how these views are obtained. The core section of each chapter is entitled *radiographic analysis*. In this section, we present a step-by-step approach to interpreting the radiographs. This information is presented in a table and in drawings of each standard radiographic view. *Common abnormalities* reviews those injuries and pathologic conditions that are most frequently encountered in the emergency department, as well as those that have substantial associated morbidity. *Errors in interpretation* focuses attention on injuries that are easily missed. *Common variants* discusses anatomical variants such as accessory bones that can cause difficulty in radiographic interpretation. The *controversies* section addresses issues that are currently being debated or represent evolving practice patterns in emergency medicine.

Highlighting the text are illustrations and tables that reinforce key points. A figure appearing in most chapters focuses attention on *sites prone to injury and easily missed injuries*. These figures provide rapid visual cues to radiograph interpretation. A corresponding table summarizes a systematic way to review the radiographs. Each standard radiographic view is shown with an accompanying line drawing that details the radiographic anatomy. An additional table describes all of the standard and supplementary views. Finally, examples of both obvious and subtle radiographic abnormalities are illustrated. Where applicable, tables describing injury patterns and radiographic findings are included.

Key concepts in the use of the radiography as a diagnostic tool for the emergency physician are presented in Chapters 1 and 2—Introduction to Emergency Radiology and Fundamentals of Skeletal Radiology. These chapters provide an introduction to the principles of radiographic analysis that are used throughout the book. Chapters 3 through 12 address the skeletal radiology of the extremities and pelvis. Chapter 13 is an extensive review of the cervical spine, while Chapter 14 continues with a discussion of the thoracolumbar spine. Facial imaging (plain film and CT) is covered in Chapter 15. An introduction to cranial CT appears in Chapter 16. Chapters 17 and 18 are devoted to pulmonary and cardiovascular radiography. Chapter 19 discusses abdominal radiography, including plain film interpretation and advanced imaging studies such as computed tomography, enteric contrast studies, and ultrasonography. The radiographic evaluation of the trauma victim is covered in Chapter 20. An introductory overview of emergency department ultrasonography is provided in Chapter 21. Pediatric considerations, including the developing skeleton, abdominal and respiratory tract emergencies, and the radiology of child abuse, are reviewed in Chapter 22. Chapter 23 addresses the role of radiology in the evaluation of the poisoned patient, a topic unique to emergency medicine. Finally, a discussion of quality improvement completes the text.

It is our hope that this book will assist physicians dedicated to the care of the acutely ill and injured patient.

David T. Schwartz, MD, FACEP
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I would also like to thank my colleagues in the Michigan State University Department of Emergency Medicine and the emergency medicine residents for their understanding. A project of this enormity diverted resources and energies away from their specific interests. (EJR)

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INTRODUCTION TO EMERGENCY RADIOLOGY

EARL J. REISDORFF / DAVID T. SCHWARTZ

In 1895, Wilhelm Conrad Roentgen discovered x-rays, revolutionizing medicine. Although many modifications of diagnostic imaging have since developed [e.g., computed tomography (CT)], plain radiography remains the cornerstone of diagnostic radiology for emergency medicine. Of all patients seen in the emergency department (ED), 35 to 61% undergo radiographic evaluation.[1–3] Of one hospital's radiologic evaluations in ED patients, 89% were plain film studies and 11% were advanced studies (e.g., contrast study, CT) (Table 1-1).[2] Moreover, 22% of patients required multiple studies. The ED is a significant source of activity for the radiology department. Of all plain film studies done in the radiology department, 44% are ordered through the ED.[2]

CLINICAL DECISION MAKING IN EMERGENCY RADIOLOGY

The emergency physician must understand the clinical indications for various diagnostic radiographic studies. For example, the inability to walk, or localized tenderness over the posterior aspect of the distal fibula, is an indication to obtain ankle radiographs. A mild, isolated antalgic gait (limp) without bony tenderness probably does not constitute a clinical indication to obtain radiographs. However, the decision to obtain radiographic evaluation must consider the patient's age and other clinical factors, such as the history of the injurious event. The patient's expectation can also modify the physician's approach to ordering radiographs.

TABLE 1-1

Radiologic Evaluation of Emergency Department Patients*

Total patients	315
Patients receiving a study	192 (61%)
Patients with no radiologic evaluation	123 (39%)
Total number of studies performed	254
Plain radiographs	227
Advanced studies†	27
Patients receiving multiple studies	43
Patients receiving single studies	149

*Random sample of 315 ED patients seen during January 1996 at Ingham Regional Medical Center, Lansing, MI.
†Advanced studies include CT of the head (13), CT of the abdomen (3), intravenous pyelogram (5), ultrasound of the abdomen (1), leg Doppler studies for deep venous thrombosis (4), and ventilation/perfusion scan (1).

Ideally, radiographs should provide clinically relevant information that helps to direct the patient's care. The radiograph usually provides an extraordinary measure of information for both defining the presence of disease and excluding disease. For some situations, radiographic findings have an extremely high positive predictive value (e.g., tibial shaft fracture, lobar pneumonia). In other conditions, radiographic findings correlate poorly with the final diagnosis and add little to the patient's care (e.g., abdominal radiographs for appendicitis). Once radiographic information is obtained, the physician must revisit the differential diagnosis and decide whether any additional imaging studies would be of benefit.

The timing of diagnostic studies must also be considered. At times, stabilization of the patient requires that the diagnostic evaluation be deferred until a therapeutic action is complete.[4] For example, in the case of a tension pneumothorax, the need for a tube thoracostomy (therapeutic) outweighs the importance of getting a chest radiograph (diagnostic) to document the condition. Delaying treatment is not justified by the desire to obtain diagnostic information.

Emergency physicians must insist on receiving quality radiographs. However, it is not always necessary that the emergency physician obtain "perfect" radiographs in every setting. Nonetheless, the images must be adequate for the diagnosis in question. For example, it is of little consequence if, on a chest film, the lung apex is "cut off" on the side of a large pneumothorax. At times the patient cannot be positioned perfectly or must be imaged through an immobilization backboard. However, the emergency physician should never accept a film that does not completely visualize all critical areas. For example, the patient's nameplate must not be placed over the fifth metatarsal on an ankle film.

There is great variation among physicians in their approaches to ordering radiographs.[5–9] As compared with generalists, specialists order more radiographs. With the acquisition of experience, physicians tend to order fewer radiographs.[5,7] In addition to addressing a specific diagnostic concern, radiographs are obtained for "baseline screening," medicolegal reasons, patient reassurance, and patient demands. The number of ED radiographs ordered for medicolegal "protection" ranges from 10 to 46%.[7,8]

EMERGENCY PHYSICIANS AND RADIOGRAPH INTERPRETATION

The emergency physician must have expertise in the interpretation of radiographs. In fact, experienced emergency physicians have high levels of agreement with radiologists (83 to 99.6%) in radiographic interpretation.[3,10–18] In one study of 1417 patients, there were 102 (7.2%) discordant readings, yet only 38 (2.7% of patients) required any change in their treatment.[1] In another study, emergency physicians correctly interpreted 99.2% of radiographs.[19] Less than half (46%) of misread films warranted any change of therapy. Therefore, only 4 patients per 1000 required a change in treatment.[19] Among emergency medicine residents, accuracy in interpretation is related to their experience. As compared with senior-level residents, more inexperienced residents tend to overread radiographs.[20]

Errors in radiograph interpretation tend to occur in specific anatomic areas. One study found the highest error rate (12%) in studies involving the face.[3] Another study found that most missed fractures involved the ribs, elbow, and periarticular region of the phalanges. These three regions accounted for 72 of 162 missed fractures (44%).[21] A high rate of discordance also occurs in the interpretation of skull radiographs.[1,18]

At most hospitals, emergency physicians and radiologists share responsibility for the primary interpretation of radiographs. At some hospitals, radiologists interpret all films (12 to 21%).[22] At other hospitals, emergency physicians interpret all radiographs first (12 to 26%). In most settings, radiologists provide first-reading services during daytime hours; emergency physicians interpret all radiographs during the evening and overnight (62 to 67%). The in-hospital presence of a radiologist is variable in hospitals throughout the country. Nonetheless, it is essential to have radiologic consultation available on a 24-hour basis. The absence of an on-site radiologist means that the emergency physician must have substantial expertise in interpreting radiographs.

MALPRACTICE

The emergency physician must use the knowledge and skill that a reasonable clinician would employ under similar circumstances. Failure to obtain a radiologic consultation can also result in liability. The clinical reasons for ordering or not ordering radiographs should be documented. One is liable for negligence when the accepted standards of professional care are not maintained and, as a result, the patient is directly harmed.

Approximately 12% of all malpractice is radiology-related.[23] The most common causes are missed fractures and dislocations. Excellent radiographic technique and careful interpretation of the radiographs are the best safeguards against error. In one study, 20% of malpractice suits (Pennsylvania Hospital Insurance Company) from 1977 to 1981 involved the ED. Of these 200 cases involving the ED, 38 (19%) were due to failure to interpret radiographs correctly.[24] The Physician Insurance Association of American (PIAA) identified claims involving myocardial infarction and fractures of the cervical vertebrae as representing the largest dollar amounts paid in emergency malpractice medicine cases. The greatest *number* of claims in the PIAA data involved missed fractures.

Fractures and orthopedic injuries represented the third largest segment of malpractice costs (14% of all monies paid) in a study by the American College of Emergency Physicians.[25] Of these fractures, 44% were vertebral or pelvic and 22% involved the extremities.

As many as 46% of all radiographic studies are obtained because of physician concern for potential malpractice.[7,8,26] The use of clinical decision rules can provide protection for clinicians as well as guidance in clinical decision making. These are being developed for the evaluation of the cervical spine, knee, and ankle.[27–29] Similar criteria have also been developed for skull radiography.[30]

BIOLOGICAL EFFECTS OF X-RAYS

The primary risk to patients undergoing x-ray evaluation is radiation-induced malignancy, such as leukemia, thyroid cancer, breast cancer, lung cancer, and gastrointestinal cancer. Radiation exposure to the gonads has a risk of inducing genetic alteration in offspring. In addition, x-rays can cause teratogenic defects in the developing fetus and can predispose to the future development of certain malignancies after birth.

Radiation exposure to patients should be minimized. This is most easily accomplished by limiting the number of examinations. Obtaining good-quality images initially eliminates the need to retake views. Restricting the x-ray beam to those areas requiring study also reduces exposure. The gonadal areas should be shielded with a lead apron whenever they may be exposed to x-rays and do not lie in the field of interest.

TABLE 1-2

Irradiation Skin Exposures for Routine Studies

Examination	Skin exposure, mrads per projection
Chest (PA)	12–26
Skull (lateral)	105–240
Abdomen (AP)	375–698
Retrograde pyelogram	475–829
Cervical spine (AP)	35–165
Thoracic spine (AP)	295–485
Extremity	8–327
Dental (bitewing and apical)	227–425
Head and body CT (total images)	3400–5500*

*The skin exposure for the CT is reported as the total dose for the entire study, not for a single image.

SOURCE: Modified from *Merrill's Atlas of Radiology*, 7th ed. St. Louis: Mosby–Year Book, 1991. With permission.

TABLE 1-3

Approximate Gonadal Doses with Various Radiographic Examinations

	Gonadal dose, mrad	
Examination	Male	Female
Skull	<1	<1
Cervical spine	<1	<1
Full-mouth dental	<1	<1
Chest	<1	<1
Stomach and upper gastrointestinal	2	40
Gallbladder	1	20
Lumbar spine	175	400
Intravenous pyelogram	150	300
Abdomen	100	200
Pelvis	300	150
Upper extremity	<1	<1
Lower extremity	<1	8

SOURCE: From *Merrill's Atlas of Radiology*, 7th ed. St. Louis: Mosby–Year Book, 1991. With permission.

The standard unit of radiation exposure is the *rad* (radiation absorbed dose). This is the amount of radiation absorbed per volume of tissue. Another unit is the *rem* (radiation equivalent in man). For x-irradiation, the rad and the rem are equal. For other types of radiation (e.g., alpha-particle irradiation from a radioactive substance), the rad and the rem are not equal.

The quantity of radiation exposure to the patient is expressed in three different ways. One way is as the amount of radiation delivered to the area exposed—the *skin dose* (Table 1-2). Another way is the radiation exposure to the gonads (or fetus)—the *gonadal dose* (Table 1-3). The gonadal dose is calculated even if the pelvic region lies outside of the radiographic field, such as with a chest radiograph. This measure is used to assess the radiation exposure to the gonads for genetic or teratogenic effects. Finally, the *total-body radiation dose* is used to determine the risk of inducing such malignancies, as leukemia, or of causing bone marrow suppression (Table 1-4). This measure is usually used in the setting of exposure to radioactive materials.

TABLE 1-4

Estimated Whole-Body Radiation Doses from Common Diagnostic Procedures

Procedure	Whole-body dose, mrem
Dental	2
Chest	10
Skull	40
Cervical spine	50
Cholecystogram	70
Intravenous pyelogram	120
Lumbar spine	130
CT head	200
Thoracic spine	240
Kidneys, ureters, bladder (KUB)	450
Mammogram	450
Upper GI*	750
Barium enema*	1100

*Includes fluoroscopy.
SOURCE: From Juhl JH, Crummy AB: *Essentials of Radiologic Imaging*, 5th ed. Philadelphia: Lippincott, 1987. With permission.

The Pregnant Patient

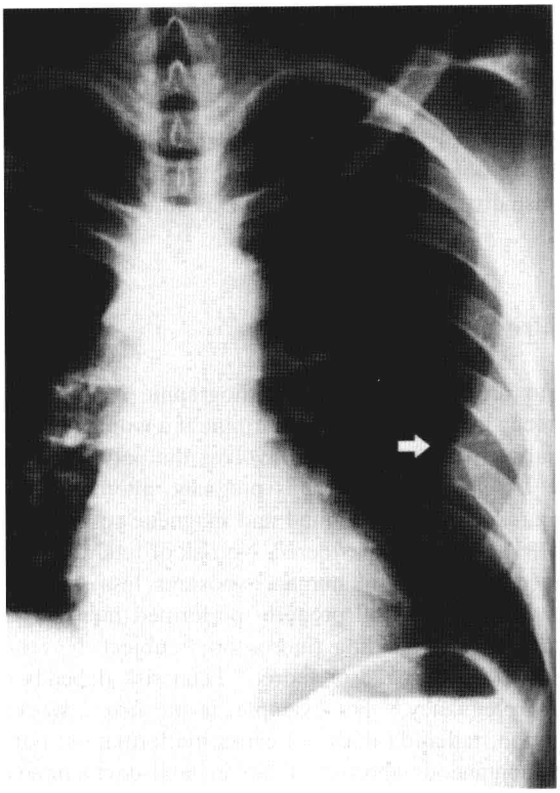
Prior to ordering an elective radiographic examination, the emergency physician should determine if a woman is pregnant, especially if the examination involves the pelvis or abdomen (Table 1-5). When a patient is pregnant, alternative imaging procedures such as ultrasound and magnetic resonance imaging (MRI) should be considered. No risk of fetal malformation has been implicated in human exposures less than 1 rad.[31] Fewer than 0.1% of all properly performed radiographic examinations (not including fluoroscopy) subject the fetus to a radiation dose of i rad or more.[32] Fetal risk depends on the stage of pregnancy.[33] For example, in the first 2 weeks after conception, radiation does not cause malformation, but it can cause spontaneous abortion. Later in fetal development risks include cancer, malformation, and mental retardation.

The National Council on Radiation Protection states that "the risk (to the fetus) is negligible at 5 rad or less when compared to the other risks of pregnancy, and the risk of malformation is significantly increased above control levels only at doses above 15 rad."[34] In nearly all forms of diagnostic radiology performed in the ED, fetal doses are below 5 rad. Even if the fetus is in the direct path of the x-ray beam, the fetal dose is typically between 1 and 4 rad, depending on the number of films. For doses lower than 5 rad, it is unlikely that an increase in fetal malformation is measurable in human populations.

TABLE 1-5

Guidelines for Radiating the Pregnant or Potentially Pregnant Patient

1. Do not iradiate the abdomen, pelvis, lumbar spine, or hips of a woman in the first trimester of pregnancy unless it is clearly medically indicated.
2. Whenever possible, defer the examination or choose an alternative imaging modality (e.g., ultrasound).
3. In evaluating a pregnant woman with modalities that use ionizing radiation, limit the number of images or views obtained to those required to ensure adequate care.
4. If the abdomen or pelvis of a pregnant patient is accidentally irradiated, the radiology department needs to be notified. The radiation safety officer can establish the radiation dose to the fetus, and this calculation can be used to determine the potential effects on the fetus.



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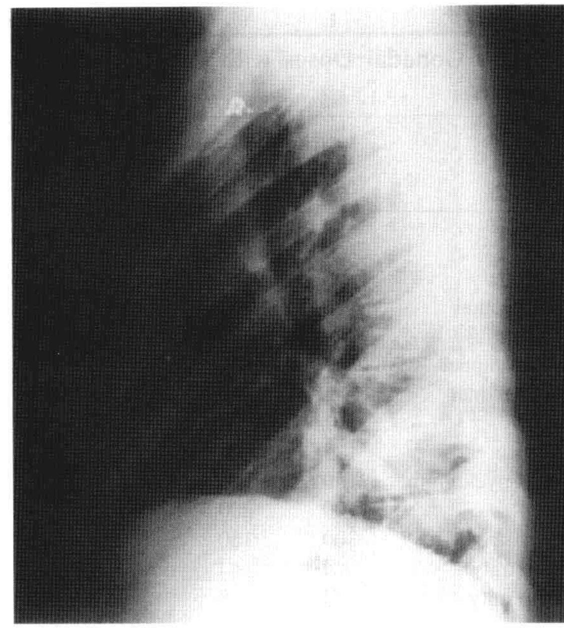

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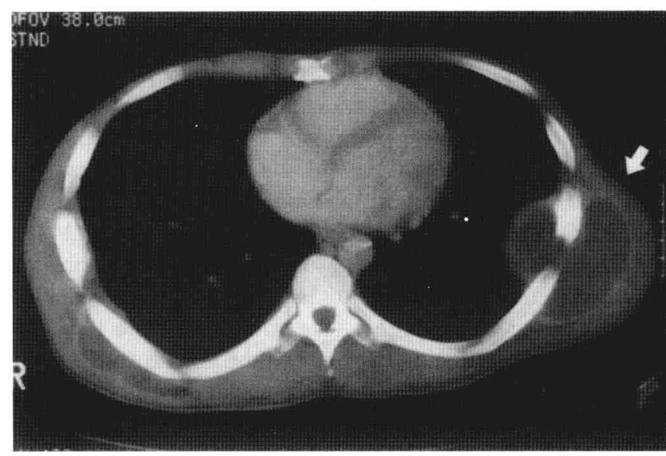

C

FIGURE 1-1. Without a well-defined border, an anatomical structure can be invisible. *A.* A pleural-based mass is easily seen on the PA radiograph because it has a distinct border with the adjacent air-filled lung (*arrow*). *B.* On the lateral radiograph, the pleural-based mass is invisible because its margins are indistinct. *C.* A CT scan clearly demonstrates the nature of the lesion. The pleural-based mass tapers gradually as it intersects with the chest wall. In addition, there is a contiguous mass on the outer surface of the chest wall (*arrow*). The lesion proved to be extrapulmonary tuberculosis. (Copyright David Schwartz, MD)

IMAGING MODALITIES

Conventional Plain-Film Radiography

Because of its ready availability, relatively low cost, and great diagnostic potential, plain-film radiography is the chief imaging modality in emergency medicine. Plain-film radiographic imaging depends on differences in radiographic density between air, soft tissues, bone, and metal. In addition, the shadow that an object makes on the radiographic film is a function of its thickness. Finally, an object is more apparent on the radiograph if its border is sharp and well-defined. If there is a gradual change in tissue density, the object casts an indistinct shadow on the radiograph and, in some instances, the object is "invisible" (Fig. 1-1). A nondisplaced fracture is radiographically obvious if the fracture line is parallel to the x-ray beam, whereas if the fracture lies at an angle to the x-ray beam, it will not be apparent (Fig. 1-2).

When examining a radiograph, it must be remembered that the radiograph is a two-dimensional image of a three-dimensional object. Overlapping structures are superimposed on the radiographic image. One must mentally subtract overlapping structures from the structures upon which they are superimposed (Fig. 1-3).

Standardized radiographic views have been devised for all regions of the body. These views are grouped into a radiographic series—e.g., a shoulder or abdominal series. The physician must be familiar with the positioning of the patient and the anatomy depicted on each of these radiographic views. The interpretation of a radiograph begins with the identification of the particular view and assessment of its technical adequacy.

Frontal radiographs are designated by the x-ray beam's direction as it passes through the patient, either from anterior to posterior (AP) or posterior to anterior (PA). For lateral radiographs, the direction of the x-ray beam is usually not specified. The terminology for oblique radiographs is variable. For extremities in which the frontal view is an AP view, such as the ankle or elbow, an internal (medial) oblique view is obtained when the x-ray beam is directed medially, from front to back. An external (lateral) oblique is obtained when the beam is directed laterally.

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