Radiology
in Emergency Medicine

Levy · Hawkins · Barsan

Radiology in Emergency Medicine

Richard C. Levy, M.D.
Professor and Chairman
Department of Emergency Medicine
University of Cincinnati College of Medicine
Cincinnati, Ohio

Hugh Hawkins, M.D.
Assistant Professor
Department of Radiology
University of Cincinnati College of Medicine
Cincinnati, Ohio

William G. Barsan, M.D.
Associate Professor
Department of Emergency Medicine
University of Cincinnati College of Medicine
Cincinnati, Ohio

With 561 illustrations

The C. V. Mosby Company
ST. LOUIS • WASHINGTON, D.C. • TORONTO 1986

MOSBY

A TRADITION OF PUBLISHING EXCELLENCE

Editor: Carol Trumbold
Assistant Editor: Anne Gunter
Editing, Design, and Production: CRACOM Corporation
Cover Design: John Rokusek

Printed in the United States of America

The C.V. Mosby Company
11830 Westline Industrial Drive, St. Louis, Missouri 63146

Library of Congress Cataloging-in-Publication Data

Levy, Richard C. (Richard Carl), 1947–
Radiology in emergency medicine.

Includes bibliographies and index.
1. Diagnosis, Radioscopic. 2. Emergency medicine.
I. Hawkins, Harold Hughes. II. Barsan, William G.
III. Title. [DNLM: 1. Emergencies. 2. Radiography.
WN 200 L668r]
RC78.L47 1986 616.07′57 86-12847
ISBN 0-8016-3144-0

C/MV/MV 9 8 7 6 5 4 3 2 1 12/A/221

Radiology in Emergency Medicine

Preface

The interpretation of radiologic images is essential in the practice of modern medicine. Plain radiographs, which once were the only type of radiologic image, have become just one of many different methods utilized to visualize the human body. As technologic innovations increase, the quality and types of images also increase. Unfortunately, the proliferation and specialization of radiologic techniques tend to distance the clinician who is ordering an examination from the radiologist who is interpreting it.

It is our perception that there is often a gap between radiologic imaging and clinical medicine. This book was written in an attempt to bridge that gap. We feel that this type of correlation would be beneficial to the radiologist as well as the practicing clinician. As imaging becomes more complex, clinicians are often at a loss when they try to determine when and what type of radiologic image to obtain. Similarly, radiologists may be unaware of the significance of a radiologic finding when they are not privy to the clinical context in which an image has been requested. Although this book will not substitute for dialogue between radiologists and clinicians, we hope that it will be of assistance when such discussions are not possible.

This book is a selective review of those subjects and their corresponding radiographs that are most commonly encountered by acute care physicians. It is not intended as a comprehensive reference source, nor does it include large numbers of normal variants. Furthermore, it is not an instructional manual designed to develop basic diagnostic skills in nonradiologists. Rather the purpose and primary emphasis is to present those conditions that threaten life or limb. Unexpected illnesses and sudden, severe trauma are the essence of this book. Diseases that are subtle or chronic in nature have been avoided. They, too, are of great importance, but the focus of this endeavor is on problems that must be diagnosed acutely. For example, a tumor may eventually consume an individual, rendering him lifeless, but the time course of the disease does not require a diagnosis within hours. This book concentrates on diseases such as aortic dissections and bony dislocations in which the outcomes may be improved if the diagnoses are rapidly established. To this end, various images have been selected and their corresponding clinical context discussed.

Although the majority of images presented in this book are plain radiographs, some are not. Increasingly, the acute care physician must seek more sophisticated imaging techniques to rapidly diagnose the disease at hand. Ultrasonography and computed tomography are no longer exotic tests. To the contrary, they are becoming commonplace in many locations. Likewise, radioisotope scanning and arteriography have specific indications in many acute diseases. They also must be part of the acute care physician's armamentarium. In short, the physician caring for critically ill patients must be conversant with all of the imaging techniques associated with the illnesses found in his or her practice. In those instances where plain films are inadequate for diagnosis, other studies are suggested and corresponding examples given.

This book is organized by anatomical sections. A rostral-caudal progression is followed using seven major body divisions: head, neck, chest, abdomen, pelvis and back, upper extremities, and lower extremities. Subject matter is further divided according to the etiologic presence of trauma. Each of the seven anatomical sections is subdivided into trauma and nontrauma sections, resulting in a total of fourteen chapters. Each chapter features a discussion of the specific disease entities unique to the particular trauma- or nontrauma-related body division. Major clinical and radiologic diagnostic points are reviewed. Correlation between diagnosis and treatment is given where appropriate. Each chapter also includes images that most graphically illustrate the diseases under discussion. Clinical relevance of the findings is combined with radiologic description.

Finally, each chapter has a table that summarizes the types of available images and the rationales for obtaining them. This table is meant to serve as a quick reference for those who are unfamiliar with the various imaging techniques available to them.

It is our hope that this book will be of value to our intended audience. The creation of this text involved an enthusiastic exchange between radiologic and clinical disciplines. This process was dynamic and exciting. It has been a delightful experience to produce the book, and we hope it is equally enjoyable to use.

Richard C. Levy
Hugh Hawkins, Jr.
William G. Barsan

Acknowledgments

We are indebted to a number of people who assisted in the creation of this book. Special thanks are due to Carol Trumbold, whose editorial vision and persistence were invaluable. Editorial assistance from Ginny Wharton and Anne Gunter brought the book to completion, and the contributions of the CRACOM Corporation during the production phase were appreciated. The book could not have been produced without the able efforts of our secretaries, Kris Taulbee and Carole Arend, nor could we have done without the technical support of Jeff Allen, John Gerace, Mike Brock, and Mike Meininger. Several radiologists contributed cases that were used for illustrations in the book: Diane Babcock of Cincinnati Children's Hospital, Michael Gelfand, Mariano Fernandez, and James Ball of the University of Cincinnati Hospital.

Thanks are extended to Jerome Wiot, Chairman of the Department of Radiology, for encouragement and for providing the opportunity to HHH to participate in the project. We appreciate the support of our fellow staff members during the period when part of our efforts were directed toward creating this book. In this regard, we are particularly appreciative of Donald Heimbrock, Ralph Shipley, and Harold Spitz.

Finally, we are grateful to Beth Levy, Poppy Hawkins, and Mary Barsan for their support and understanding. We could not have completed the book without them.

RCL, HHH, WGB

Collaborators

Michelle Biros, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Nontraumatic Pelvic and Back Disorders

Keith Burkhart, M.D.
St. Joseph's Hospital
United States Public Health Service
Buckhannon, West Virginia
Abdomen Trauma

Bryan Carducci, M.D.
Andrews Air Force Base
United States Air Force
Camp Springs, Maryland
Nontraumatic Skull and Facial Disorders

David Cash, M.D.
St. Joseph's Hospital
United States Public Health Service
Buckhannon, West Virginia
Skull and Facial Trauma

William Dalsey, M.D.
Lackland Air Force Base
United States Air Force
Lackland, Texas
Neck Trauma

Scott Davis, M.D.
Timken Mercy Medical Center
Canton, Ohio
Nontraumatic Chest Disorders

John Fowler, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Nontraumatic Lower Extremity Disorders

David Goltra, M.D.
Clermont County Hospital
Cincinnati, Ohio
Lower Extremity Trauma

J. Stephen Huff, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Nontraumatic Abdomen Disorders

James Hunter, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Nontraumatic Neck Disorders

Kevin Merigian, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Pelvic and Back Trauma

Phillip Oblinger, M.D.
Clermont County Hospital
Cincinnati, Ohio
Upper Extremity Trauma

David Ross, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Chest Trauma

Daniel Savitt, M.D.
University of Cincinnati Medical Center
Cincinnati, Ohio
Nontraumatic Upper Extremity Disorders

Contents

CHAPTER 1

Skull and Facial Trauma

Injuries to the head and face are among the most frequent injuries encountered by the emergency physician. In the United States 2 million patients per year seek medical attention because of head and facial injuries. Approximately 400,000 persons will require admission to the hospital for observation and treatment. In developed countries, motor vehicle accidents account for the vast majority of head injuries. One half of patients who require admission to the hospital because of head injuries have sustained their injuries in motor vehicle accidents. Approximately 75% of all injuries sustained in automobile accidents are related to head trauma. These injuries range from simple injuries, easily diagnosed and treated by the emergency physician, to severe injuries that are associated with high degrees of morbidity and mortality. Overall, head injuries account for 1% to 3% of all deaths, 25% of all trauma-related deaths, and 50% of all deaths related to automobile accidents.

It is at times easiest to separate head injuries into three separate groups: those that involve the face and related structures, those that involve the skull or cranial vault, and those that involve the intracranial components. Of the three groups, facial trauma is the easiest to diagnose because there is, in most cases, visible or palpable injury. On the other hand, intracranial injuries are difficult, if not impossible, to accurately diagnose without advanced radiologic techniques. The patient with injuries to the face and skull usually can be diagnosed by the combination of careful physical examination and appropriate radiologic studies. The human face is a very visible structure, allowing the physician to easily search for cardinal signs of significant injury: swelling, ecchymosis, deformity, crepitus, or point tenderness. Fortunately, the face is also an area that can be studied adequately, for the most part, by simple radiologic examinations. It is only rarely that the physician must resort to advanced radiologic techniques for diagnosis of facial and skull fractures. The availability of computed tomography (CT) has revolutionized the diagnosis of intracranial injuries. It is now standard trauma care for patients with severe head injury to undergo emergency CT.

NASAL FRACTURES

The nose is the most frequently fractured bony structure of the face. The combination of its prominent location and its size makes it vulnerable to injury. Its structural weakness, relative to other facial structures, also contributes to its high incidence of injury. Most nasal injuries are seen as a result of automobile accidents. Other common causes of injury include blows from an assailant's fists, falls, skiing, and snowmobile accidents.

Nasal fractures in children are a special cause for concern. Because of the small size of the nose and airway passages, it is difficult to evaluate the nasal septum for possible fracture. The failure to adequately diagnose a nasal fracture in a child may lead to permanent deformity or growth arrest. Chronic airway problems may develop from unrecognized nasal septal deviation.

The diagnosis of nasal fracture is usually made by an appropriate history and physical examination. The patient usually complains of pain in the nasal area. He may report excessive bleeding either from the external nose or into the nasopharynx and throat. The patient may complain of difficult breathing.

The physical examination begins by observation of the nasal area, with the examiner looking closely for swelling, ecchymosis, and deformity. Any bleeding or clear discharge should be noted as should periorbital hematomas or nasal lacerations. The nasal septum should be observed for any deformity or hematoma.

Radiologic studies are routinely obtained in cases where fracture of the nose is suspected. Routine radiographic evaluation of nasal fractures includes the anteroposterior (AP) and lateral views of the nose, Waters' view, and sinus films. Fractures of the nose, because of its structural weakness, have a tendency to comminute; because of the muscular attachments that keep their alignment relatively stable, the fragments seldom displace significantly. The lateral radiograph should be studied for alignment of the nose. Most simple nasal fractures are seen as a fracture line or comminution of the nasal bone on the lateral radiograph. The AP view of the nose should be inspected to note any deformity of normal "curve" of the nasal bridge and any deformity of the nasal septum. Fractures of the nasal spine usually result in nondisplaced or minimally displaced fracture segments.

Treatment of nasal fractures usually involves closed reduction and external splinting of the nose. In cases of extreme swelling and edema, reduction should be delayed 1 to 2 weeks to allow swelling to subside. Compound fractures of the nose are usually compounded internally into the septum and related structures. Injuries to the septal mucosa caused by displaced and comminuted fractures are generally left unsutured. Any septal hematoma should be drained. Antibiotics directed against *Staphylococcus aureus* and streptococcal organisms are usually administered.

ZYGOMATIC-MALAR FRACTURES

Fractures involving the zygoma and related structures are the second most common type of facial fractures. Usually the result of a blow to a localized area, these fractures can be limited to the arch of the zygoma or they can be extensive and involve the whole zygomatic-malar complex. Fractures to the zygomatic arch are most often caused by a direct blow just anterior to the ear. Pain in the area is usually accompanied by some displacement and depression in the cheek and malar region. If exterior swelling and hematoma are present, this depression may not be obvious. Point tenderness is uniformly present on palpation.

The submentovertex view is the best radiographic examination for detection of an arch fracture. Displaced fractures with facial deformity require an open reduction. The reduced fracture may require stabilization with wires to prevent slippage. Because of involvement of associated structures, fractures in the malar region are usually more serious than arch fractures. They have been labeled "tripod fractures," which is actually a misnomer. The zygomatic-malar complex has five components: the arch, the frontal bone, the medial maxilla at the orbital rim, the maxillary alveolus, and the greater wing of the sphenoid bone in the anterolateral orbit. The junction of the sphenoid and zygomatic arch is weak and easily fractured. A large portion of the lateral floor of the orbit and the lateral superior portion of the maxillary sinus are formed by the medial surface of the zygoma. It is therefore easy to see the propensity for associated maxillofacial injuries when this bone is fractured. The malar bone itself is rarely fractured; it is at the attachment sites to the facial bones where fractures and associated damage occur.

Practically all fractures of the malar complex occur as a result of a direct blow to the region. The blow is typically sustained during a motor vehicle accident or a physical altercation. The patient usually complains of pain in the area of the cheek and may have trismus, or difficulty in chewing. Hypesthesia or anesthesia may occur in the distribution of the inferior orbital nerve.

The physical examination begins with careful observation and inspection. Unless there is extensive hematoma or soft tissue swelling, a prominent depression of the cheek will be noticeable. If the orbital floor is involved, subconjunctival hematoma or periorbital ecchymosis may be present. Careful palpation of the orbital rim may reveal point tenderness or an obvious step-off. Inspection and palpation of the oral cavity may yield a buccal sulcus hematoma. The extraocular eye movements and eye position relative to the contralateral eye must be observed. A fracture through the orbital floor may cause entrapment and resultant gaze palsy. Finally, a careful sensory examination in the distribution of the infraorbital nerve should be carried out to detect any deficits.

The proper radiographic evaluation of zygomatic-malar fractures includes the Caldwell, Waters', and submentovertex views. The Caldwell view is excellent for detecting abnormalities at the zygomaticofrontal suture line. It clearly depicts the nasoethmoidal areas, enabling the examiner to inspect the ethmoid sinuses. Waters' view is perhaps the most helpful view to the physician. He can assess the maxillary sinuses, the lateral walls of the sinus, the orbital floor, and the inferior orbital rim. It also permits adequate viewing of the zygomaticotemporal suture. The physician should carefully outline the external wall of the maxillary sinus. The clarity of the maxillary sinus should be compared to that of the contralateral side. The sinus itself may be completely or partially filled with blood and intraorbital contents. A herniation of the orbital floor will produce a soft tissue mass "hanging" in the superior portion of the sinus. The submentovertex view is helpful for the zygomatic arch and may reveal a posterior displacement of the zygoma.

Initial treatment consists of adequate airway management and control of significant hemorrhage. Undisplaced fractures do not require definitive surgical care. If displacement of the orbital floor, enophthalmos, or diplopia persists, then open reduction and fixation with wire, pins, or other appliances are required.

MANDIBULAR FRACTURES

The mandible is the third most frequently injured structure of the face. It is subject to trauma from many different forces, resulting in a variety of fractures. The muscles of mastication insert on the mandible, and, when fractures occur, the strong pull of these muscles may result in displaced fracture fragments. As with other facial injuries, the most common causes are automobile accidents, blows from assailants, falls, and sports accidents. Since the mandible and skull form a ring, trauma very often causes two simultaneous mandibular fractures or a mandibular fracture with a condylar dislocation.

Patients with mandibular fractures typically complain of jaw pain or malocclusion of the teeth. If the mental nerve is damaged, numbness occurs in its sensory distribution. Trismus, or an inability to open the mouth, is common in mandibular injuries. Lacerations to the inside of the mouth are common patient complaints. Dislocations and fractures of the condyle may produce bleeding from the external ear canal.

Inspection and palpation of the mandible may reveal swelling, deformity, ecchymosis, point tenderness, and palpable deformity. The examiner's little fingers should be placed in the external auditory canals and the patient asked to open and close his mouth. Abnormal movements of the condyles should be noted. A sensory examination should be performed to evaluate damage to the mental nerves. Intraoral lacerations and fracture fragments as well as malocclusion may be present. All teeth should be grasped and palpated for abnormal movements or looseness.

The radiographic examination of the mandible includes posteroanterior (PA) and lateral oblique views. This basic examination allows the physician to obtain most of the necessary information. The PA view enables inspection of the symphysis, the ramus, and the angle of the mandible. The lateral oblique view allows the physician to visualize areas such as the body, condyle, and coronoid process, all of which are difficult to see on the PA film. Condyle fractures account for 35% of mandibular fractures, while body and alveolar ridge fractures make up 25% of fractures. Some facilities are equipped with a Panorex camera, a device that creates a radiographic image that closely approximates the mandibular anatomy. Since it shows the relationship of the mandible to the maxilla, the Panorex is more useful in diagnosis when malocclusions and bite deformities are the presenting complaints.

Initial treatment includes establishment of an airway, care of associated cardiopulmonary injuries, and clearance of the cervical spine. Most mandible fractures can be treated with "arch bars," which connect to the teeth and permit reduction and stabilization of the affected area. When arch bars fail, open reduction and fixation are employed.

ORBITAL FLOOR FRACTURES

Because of the inferior and superior orbital rims, the human eye is relatively well protected from trauma. However, if the size of the object striking the orbit is less than the distance between the rims, the rims may be ineffective in preventing significant damage. Since the globe is made almost entirely of gelatinous fluid, it compresses on impact, transmitting the impact pressure to weaker structures. The weakest structure in the orbit is the floor. If the force is sufficiently strong, the floor of the orbit may burst, or "blow out," inferiorly into the maxillary sinus. Along with the bony fragment, orbital fat herniates into the maxillary sinus, often incarcerating the inferior oblique and inferior rectus muscles. Muscle entrapment may result in diplopia.

As previously mentioned, the patient usually gives a history of a blow to the eye, generally as a result of an altercation. The patient may complain of numbness in the infraorbital area. The patient will also experience some degree of pain in the vicinity of the fracture.

Periorbital hematoma plus conjunctival hemorrhage is suggestive of an orbital floor fracture. Because of inferior oblique entrapment, the patient may be unable to adequately move the eye upward. If the inferior rectus is also entrapped, the patient has difficulty with downward movement of the eye. Palpation of the inferior rim may reveal a step-off or point tenderness. A careful neurosensory examination is done to evaluate the inferior orbital nerve. If entrapment of the inferior orbital nerve has occurred, the examination may reveal anesthesia of the adjacent eyelid, nose, and cheek.

The radiologic examination should include Caldwell and Waters' views in addition to a lateral view of the facial bones. Waters' view vividly demonstrates fluid and tissue accumulation in the maxillary sinus. If complete herniation has not occurred, a "teardrop" of orbital fat hanging into the maxillary sinus may appear. The Caldwell view is excellent for detecting fractures of the superior orbital rim. The lateral view may be helpful in detecting opacification of the maxillary sinus.

If an orbital floor fracture is suspected but routine radiographs are nonconfirmatory, advanced radiologic techniques can be employed. Facial tomograms are useful adjuncts to plain radiography. However, high-resolution CT has eclipsed the use of tomography in many hospitals.

Initial treatment consists of patient stabilization. Globe injuries should be assessed and cared for. Although less emergent, the orbital wall should be repaired if it is fractured. When entrapment occurs, surgical correction must occur within a few days.

CEREBRAL CONTUSION

Usually the result of a blow to the head, a contusion is a bruising or crushing of tissue, without any interruption of the physical continuity of the brain. The blow produces tiny areas of hemorrhage, but the amount of blood that escapes is usually not enough to cause a hematoma. Areas of contusion can occur alone or in multiple areas of brain tissue and may be found with another significant mass lesion. They can be found with or without associated skull fractures. In some circumstances the fracture is depressed. Contusions are approximately three times as likely in adults as in children.

Because of variation in location of the involved brain tissue and in the force producing the injury, the resulting neurologic pattern can vary greatly. A contusion is usually seen in the contra-coup–type injury, in which the brain tissue distant from the actual site of impact is damaged. In the wings of the sphenoid, the petrous process, the orbital surfaces, and frontal and occipital areas, bony processes bruise adjacent areas of brain tissue. The lesions usually present as focal neurologic deficits, such as aphonia, weakness, hemiplegia, and visual loss.

CT is the only noninvasive, rapidly available radiologic examination available for the diagnosis of cerebral contusion. The contusion appears as an area of higher heterogeneous density than that of surrounding tissue. The high density results from extravasated blood. Some edema is associated with a contusion; because the absorption coefficient of edema is lower than that of blood and surrounding normal tissue, a contusion with only minimal bleeding may not show on the CT scan. Particular attention should be given to the areas near the bony processes mentioned above. Plain skull films are usually not helpful in the patient with a cerebral contusion.

CRANIAL TRAUMA

Trauma to the cranial vault is commonly seen in accident victims. Before 1970 skull radiography was routinely obtained on all patients with trauma, regardless of the circumstances or the clinical presentation of the patient. Because of the enormous cost of these examinations, physicians in the early 1970s examined the utility of skull films and found that routine skull radiography contributed to patient care approximatey 2% of the time. These findings, together with rising concern over the cost of medical care, led to the recommendation that physicians adopt criteria as to the appropriate use of skull radiography.

In 1978 the U.S. Food and Drug Administration (FDA) recommended the use of "high-yield criteria," a collection of historic and clinical observations that increase the likelihood of discovering a skull fracture. The first of the historic criteria is established loss of consciousness. It is imperative that the physician undertake all means, including even interviewing any witnesses to the event, to establish the actual loss of consciousness. Any history of penetrating trauma, be it missile injury or penetration by any other instrument, demands radiographic examination. Patients who have had a previous craniotomy, especially if a cerebrospinal fluid (CSF) shunt is in place, deserve skull radiography if the cranial vault has been traumatized.

During the physical examination many findings necessitate a radiographic examination. Any bleeding from the ear canal or clear fluid from the ears or nose requires investigation with skull films. Blood in the middle ear cavity is usually a sign of a significant pathologic condition. "Raccoon eyes," or periorbital ecchymosis, is suggestive of basilar skull fracture. Battle's sign, or ecchymosis over the mastoid bone, may indicate fracture of that bone. Any palpable defect or depression in the cranial vault dictates the use of skull films. Until digital examination of the wound proves otherwise, clinicians should approach open cranial-scalp wounds as having underlying skull fractures. Depressed skull fractures require emergent neurologic consultation and, in most cases, also require CT to assess the extent of cerebral injury.

A carefully performed neurologic examination is required of all patients who have experienced cranial trauma. The presence of focal neurologic findings usually indicate brain dysfunction and must be investigated. Ultimately this is best accomplished by CT; if the physician does not have this tool available, then the investigation should proceed with routine skull radiography. Many physicians also argue that the presence of altered mental status following trauma is itself a focal neurologic sign and thus should be investigated by skull radiography and ultimately by CT. The patient who has incurred cranial trauma and who may be under the influence of alcohol poses a difficult problem. If the determination of blood alcohol levels is delayed or not immediately available, these patients usually deserve skull films. If the blood alcohol level does not correlate with the patient's mental status, CT is indicated.

SKULL FRACTURES

Fractures are classified as linear, depressed, diastatic, and comminuted. Depressed skull fractures seldom occur without some degree of comminution and vice versa. Compound skull fractures are demonstrated by a linear fracture traversing one of the sinuses of the skull, intracranial foreign material, or soft tissue defects seen in connection with a fracture line.

The physician who has determined a need for skull films should obtain the following radiologic views to ensure that the cranial structure is adequately examined: an AP view, a lateral view, a PA view, and a half axial AP projection (Towne view). These views supply the physician with the minimal basic examination, provided the patient is cooperative. If the clinical or radiographic examination calls for further studies, then other views can include stereoscopic evaluation, basal views, or upright views.

When viewing the skull radiograph, the examiner should recall that many normal structures may simulate a fracture. These are most commonly either vascular markings or suture lines and accessory ossicles. Vascular shadows or markings are more difficult to differentiate from a fracture line than are suture lines. Vascular shadows can be either venous or arterial in origin. Venous markings do not seem to cause as much confusion with fracture lines as do arterial markings. Venous channels usually occur in the diploic areas of the skull and are most pronounced in the parietal area, although they are frequently noted in the frontal and occipital areas. The venous markings are usually irregular in their course and have a tendency to join one another, which is unlike fracture lines. In the parietal area they may unite to form venous "lakes" of varying size.

Arterial grooves are usually straighter and have a more constant course than do venous channels. They bifurcate or trifurcate into branches, which is highly unusual for fractures. The most commonly noted arterial groove is that produced by the middle meningeal artery as it courses backward and superiorly toward the parietal area, where it usually branches. When the physician is in doubt as to whether a marking represents a fracture or vascular channel, stereoscopic films are helpful. Fractures usually extend through both tables of the skull whereas vascular markings do not. Fracture lines have sharp, jagged margins as opposed to the smooth margin of a vascular marking.

Normal sutures may occasionally resemble fractures. Sutures typically appear as zigzag lines or as interdigitating margins. Their edges are sclerotic. Fractures of the sutures themselves result in diastasis of the suture. Sutures in the occipital region of the skull give the physician the most problems, and the contralateral side should be inspected for a corresponding marking.

The majority of patients with basal skull fractures do not demonstrate radiologic evidence of the fracture. Even with basal and oblique views, the fracture is rarely demonstrated. A large proportion of suspected basal skull fractures involve intoxicated or uncooperative patients, further decreasing the yield of special views. More often than not, a suspected basal skull fracture may be suggested by an air-fluid level in the sphenoid sinus, best seen in films with the patient supine.

LINEAR FRACTURES

The forces applied determine the type of fracture generated. High-energy, high-velocity blows produce localized damage with perforation and depression. Low-velocity blows of the same energy level produce more widespread damage with production of stellate fractures and depressed segments encompassing a large area of skull. The instrument that imparts the blow influences the pattern of fracture.

Linear skull fractures are usually well visualized on plain radiographs. They have sharp margins, do not exceed 3 mm in width, and vary in length. They appear as lines of decreased density on plain films. The ends taper gradually to a point at which the line can no longer be demarcated.

Because of the irregularity of bones at the skull base, linear fractures in the basal area are difficult to diagnose on plain films. Fractures of the sutures, as noted before, are also difficult to interpret. Diastasis is usually coupled with a linear fracture line involving the surrounding bones. Occasionally a fracture of the sutures occurs with only diastasis. Traumatic diastasis is rare after 30 years of age. Linear fractures that cross vascular markings, especially the middle meningeal artery and vein, are frequently associated with epidural hematomas.

Since many of the patients seen are "repeat offenders," old fractures may be a difficult problem. Depending on the severity of the injury, fracture healing takes approximately 3 to 6 months in infants, 1 year in children, and 2 to 3 years in adults. A healing fracture becomes smooth along its margins and eventually become gray, as opposed to the black of a fresh fracture. As it heals further, it may take the appearance of a vascular shadow.

DEPRESSED-COMMINUTED FRACTURE

Usually the result of a high-energy blow, comminuted fractures occur predominantly in the cranial vault, particularly in the frontal and occipital areas, and rarely in the basal area of the skull. It is unusual to see a comminuted fracture without some degree of depression of one or more of its elements. In severe high-velocity blows or injuries, a segment of skull may actually burst, with some fracture fragments penetrating the brain tissue. Depressed fractures of the top of the head may impinge on the large dural sinuses with resultant hemorrhage or thrombosis. CT is often used to assess the actual degree of depression and damage to the underlying brain.

Depressed skull fractures show some comminution, except rarely in infants when the depressed segment is an intact plaque of bone. Also in infancy, the thin bones of the skull may actually "bend" inward, like other greenstick fractures seen in childhood. These latter fractures are difficult to ascertain on plain radiographs.

Depressed fractures appear as stellate or concentric defects. The depressed segment is often turned such that it appears to be of greater density than the surrounding skull. The fracture may appear as a linear fracture with a "double edge" overlap of bone. Tangential films are occasionally required to determine if and how much a fracture is depressed.

MID-FACE FRACTURES

Mid-face fractures are rare but devastating injuries that result from severe impact. The human maxilla is one of the most difficult bones to break. Its ability to absorb great force affords much protection to the intracranial contents. As with the nose and other membranous bones of the face, the deformity is the result of the original impact; there are no strong muscular attachments to produce distortion of bony fragments.

Mid-face fractures are usually the result of automobile accidents, in which the face strikes the steering wheel. The rigid steering wheel transmits tremendous force to the face, producing the "mid-face mash." Other causes include severe blows to the face from blunt objects, such as baseball bats or industrial tools.

Due to the tremendous impact on the brain, a large percentage of patients who have sustained mid-face fractures are unconscious when first seen or have altered sensorium. Those patients who are able to communicate verbally usually complain of pain in the facial region.

Obvious swelling about the mid face is routinely present. With severe fractures, a "deep dish" deformity occurs that is caused by the posterior displacement of the bones of the mid face. Rapid compromise of the airway as well as exsanguination can occur with these injuries. An immediate concern is the profuse bleeding that may accompany these fractures. There may be severe epistaxis, difficulty in breathing, or malocclusion. In 25% to 50% of cases, a CSF leak occurs, producing a clear discharge from the nose. Palpation of the face usually reveals a mobile maxilla. Uncommonly there is little malocclusion or mobility. In some cases a fracture traverses the maxillary alveolar ridge. An open fracture of the maxillary alveolar ridge may be obvious.

By inflicting massive trauma to the faces of cadavers, Rene Le Fort, a French physician of the 1900s, found that the fracture complex usually fell into one of three configurations. These were later described as Le Fort types I, II, and III. Actual categorization is rarely simple or exact.

Le Fort I Fracture

A Le Fort I fracture involves the maxillary alveolus and usually results in complete separation of the maxillary alveolus from the upper facial skeleton. The fracture line runs through the maxillary alveolus, involving just the inferior portion of the nasal aperture. It extends posteriorly through the pterygoid plates such that the fracture fragment contains the teeth, hard palate, anterolateral wall of the maxillary sinus, and the lower portion of the pterygoid process. Maxillary mobility is present unless the fracture segment is severely impacted.

Le Fort II Fracture

A Le Fort II fracture involves all the structures of a Le Fort I fracture but extends superiorly to involve the nasal area. The fracture line extends through the nasal bridge posteriorly and the pterygoid process inferiorly. Thus the fracture includes the lacrimal bones, inferior rims of the orbit, and junctions of the zygomatic-malar suture line. This fracture produces a widening of the medial canthus of the eyes and a pyramid-shaped nasomaxillary segment.

Le Fort III Fracture

The Le Fort III fracture is a severe injury that separates the maxilla, nasal bone, and zygomatic complex as a unit from their cranial attachments. The fracture line separates the facial bones from the cranial bones through the zygomaticofrontal junction, the orbital floors, and the nasoethmoidal areas. Le Fort III fractures rarely exist as a single entity but are more commonly a mixture of comminuted fractures of other Le Fort segments. The injury is usually more severe on one side, such that a Le Fort III fracture may coexist with a Le Fort II fracture on the contralateral side. Maxillary mobility is caused by a Le Fort I or II fracture bearing the maxillary dentition. Since Le Fort III fractures often involve multiple injuries within the fracture segment, severe elongation of the face may result if these are improperly handled.

The fracture is often difficult to evaluate radiographically, particularly using plain radiographs. The definitive determination of where the fracture lines actually exist is made by using plain tomography and CT. Nevertheless, the evaluation begins by obtaining Waters', Caldwell, and lateral radiographs of the facial bones. Waters' view is perhaps the best view for visualizing the fractures. Fractures may produce heavy bleeding into the maxillary sinus, with opacification of the antrum. In Le Fort I fractures, a line traversing the maxillary alveolus is associated with downward displacement of the fracture segment. Inspection of the inferior orbital rim and zygomaticofrontal areas may reveal the fracture lines of the Le Fort II and III complexes. If a communication exists between the ethmoid sinus and the orbit, air may be present in the orbits. The Caldwell view is helpful for visualizing the orbital rims. On the lateral view, the pterygoids may be seen. Treatment consists of emergency airway management. If the fracture is impacted posteriorly, the airway may be compromised by bone fragments, edema, and bleeding. The physician may attempt emergency reduction by gripping the posterior soft palate and pulling forward; this maneuver is important if airway obstruction exists. Definitive airway management consists of oral endotracheal intubation or emergency cricothyreotomy. After a definitive airway has been established, control of hemorrhage can be addressed.

A posterior nasal pack saturated with antibiotic may be employed. Alternatively, a rubber catheter with inflatable balloon tip may be inserted into the nasopharynx. Severe hemorrhage unresponsive to the above attempts may necessitate ligation of the external carotid artery. After airway control and adequate hemostasis have been secured, the definitive care of these injuries is the responsibility of the maxillofacial specialist. These injuries usually require open surgical reduction and fixation in order to reestablish proper dental occlusion and to preserve the appearance of the face.

SUBDURAL HEMATOMA

Subdural hematomas are classified by age as either acute, subacute, or chronic. An acute subdural hematoma is 3 days old or less. A subacute subdural hematoma is 4 to 15 days old. A chronic subdural hematoma is one that is present after 15 days. The designation of acute, subacute, or chronic implies changes in the pathologic course and the radiologic appearance of the blood collection.

Acute Subdural Hematoma

An acute subdural hematoma is one of the most feared complications of head injury. Its true incidence is unknown, but it is usually found in cases of severe head injury sustained in automobile accidents and in motorcycle accidents that involve helmetless riders. Subdural hematoma has an extremely high morbidity and mortality that are difficult to estimate, since many other extracranial injuries are associated with it that may cause the patient's death.

An acute subdural hematoma is hemorrhage of blood into the small space or potential space between the dura mater and the arachnoid covering of the brain. The site of hemorrhage is usually the bridging cerebral veins. Although most injuries tend to be severe head injuries, subdural hematomas can occur with little history of trauma. Certain groups of patients are at increased risk for acute subdural hematoma: patients with blood dyscrasia; alcoholics with frequent falls; elderly patients with cerebral atrophy that causes increased stress on the bridging cerebral veins; and infants and newborns.

As with other mass lesions, the clinical presentation of subdural hematoma can vary greatly. The patient may be alert and oriented with few or no complaints or may be completely unresponsive. Altered vital signs result from swelling and shifting of cerebral structures that compromise vital centers in the brain stem. The patient usually has some change in mental status with or without focal neurologic findings. Evidence of increased intracranial pressure may be present.

Subacute and Chronic Subdural Hematomas

Subdural hematomas undergo evolution as they age. Although some spontaneously resolve, others may calcify and become organized. With liquefaction of the clot, a membrane usually forms. Also, as the clot ages, it may become more convex along its inner margin. The membrane becomes hypervascular and may rebleed without significant trauma. This is why many alcoholics with altered mental status have no recent history of trauma and appear to have a new subdural hematoma.

Radiologic Findings of Subdural Hematoma.

The best radiologic tool for the diagnosis of subdural hematoma is CT. However, in rare cases, plain skull films may be of some aid. Skull fractures are rarely seen in association with subdural hematomas. Even when a skull fracture is present, the subdural hematoma may be on the opposite side of the cranial vault. In infancy, widening of the sutures may be seen. In older patients the calcified pineal gland may be shifted, indicating a midline shift of the contents to make room for the expanding hematoma. The gland is usually displaced laterally and downward. In a chronic, organized subdural hematoma, an area of unusual calcification may be noted and represents calcium in the organized clot.

Acute subdural hematoma appears as a spindle-shaped, extracerebral collection of blood. Since dissection by blood is not limited by the dura mater, the collection takes the appearance of a crescent. If the subdural hematoma has an arterial bleeding component, the resultant collection may assume a biconvex shape. Arterial bleeding usually produces a collection of blood that is larger and wider than that produced by venous bleeding. A subdural hematoma has an irregular inner border because it impinges on the irregular surface of the brain. It does not cross the falx or tentorium. Unless the patient is suffering from anemia or has significant mixing of cerebrospinal fluid and blood, acute subdural hematomas are high-density lesions on CT. They may be unilateral or bilateral; if bilateral, the hematomas may be of different ages. There may be significant compression of the adjacent lateral ventricle and shift of the midline structures to the opposite side.

As the clot ages, its CT density decreases, becoming isodense and then hypodense in relation to the cortex. During this period, a contrast-enhanced study may delineate the cortex vessels and the hypervascular membrane of the subdural hematoma. Contrast itself may enter the clot. These findings enable the physician to identify an isodense clot.

EPIDURAL HEMATOMA

Epidural hematoma (EDH) is a collection of blood that results from bleeding into the space that exists between the inner table of the skull and the dura mater. It is most commonly found in the frontal, temporal, or occipital area. The bleeding is usually caused by injury of an artery, dural veins, or diploic veins. Approximately 15% of blunt head trauma patients have an EDH; 22% have an associated skull fracture.

The clinical presentation is usually that of a severe head injury with an asymptomatic interval. The interval may be hours to days, but it is less than 24 hours in most cases. Following the lucid period, the patient has a period of abrupt neurologic deterioration, the rate of which depends on whether the bleeding is arterial or venous. Arterial bleeding produces a rapid change, whereas venous bleeding may produce a slower change in mental status. The physical examination usually reveals coma or decreased mental status. Focal neurologic findings are common.

Plain radiologic films are of limited value in the diagnosis of EDH. A fracture across the middle meningeal artery is suggestive of EDH, especially if the patients' mental status is deteriorating. If the calcified pineal gland is present, it may be shifted across the midline.

CT is the best radiologic tool for the evaluation of EDH. The majority of epidural hematomas appear as biconvex, high-density lesions. Approximately 15% of subdural hematomas are found in configurations that resemble EDHs. The latter usually are wider compared to the smaller width of a subdural hematoma. The inner margin is usually smooth and regular as it abuts the dura mater. In the presence of anemia or mixture with cerebrospinal fluid, the EDH may be less dense or isodense compared to surrounding brain tissue. Administration of contrast usually highlights the EDH to show its presence. As opposed to a subdural hematoma, EDH may extend across the midline.

As with subdural hematoma, an EDH may be in an acute, subacute, or chronic stage. As time elapses, the density of the EDH decreases, until it eventually becomes hypodense compared to surrounding brain tissue. During the isodense or hypodense phase, contrast agents may be necessary to reveal the existence of the clot. The EDH may undergo organization and may later calcify. EDH may occur in the posterior fossa with extension into the supratentorial area; likewise, a supratentorial lesion may extend into the posterior fossa. EDHs occurring in the posterior fossa are hard to diagnose via CT, since they are often confused with cerebellar hemorrhage. The use of contrast agents may help demonstrate displacement of the dura.

BIBLIOGRAPHY

Balasubramaniam, S.: Efficacy of skull radiography, Am. J. Surg. **142**:366, 1981.

Cordon, I.W.: Skull roentgenogram for patients with head trauma: the use of high yield criteria, Can. Med. Assoc. J. **124**:584, 1981.

Daffner, R.H., et al.: Lateral view of facial fractures: new observations, Am. J. Radiol. **141**:587, 1983.

Darmody, W.: Head injuries, J. Am. Coll. Emerg. Phys. **8**: 3, 1979.

Gennarelli, J.A.: Emergency department management of head injuries, Emerg. Med. Clin. North Am. **4**:749, 1984.

Hammerschlag, S.B., et al.: Another look at blow out fractures of the orbit, Am. J. Radiol. **139**:133, 1982.

Manson, P.N.: Maxillofacial injuries, Emerg. Med. Clin. North Am. **4**:761, 1984.

Marshall, F.F., et al.: Head injuries: rapid evaluation, acute resuscitation and cost effective diagnosis, Emerg. Med. Rep. **11**:771, 1984.

Taveras, J. and Wood, E.: Diagnostic neuroradiology, Baltimore, 1976, Williams & Wilkins Co.

Rosen, P., et al., editors: Emergency medicine: concepts and clinical practice, St. Louis, 1983, The C.V. Mosby Co.

Rosman, N.P., et al.: Emergency management of pediatric head injuries, Emerg. Med. Clin. North Am. **1**:141, 1983.

Woyek, A.M., et al.: Contemporary radiologic evaluation in maxillofacial trauma, Otolaryngol. Clin. North Am. **3**:473, 1983.

Zizmor, J., et al.: Fractures of the paranasal sinuses, Otolaryngol. Clin. North Am. **6**:473, 1973.

Zuidema, G.D., editor: The management of trauma, Philadelphia, 1979, W.B. Saunders Co.