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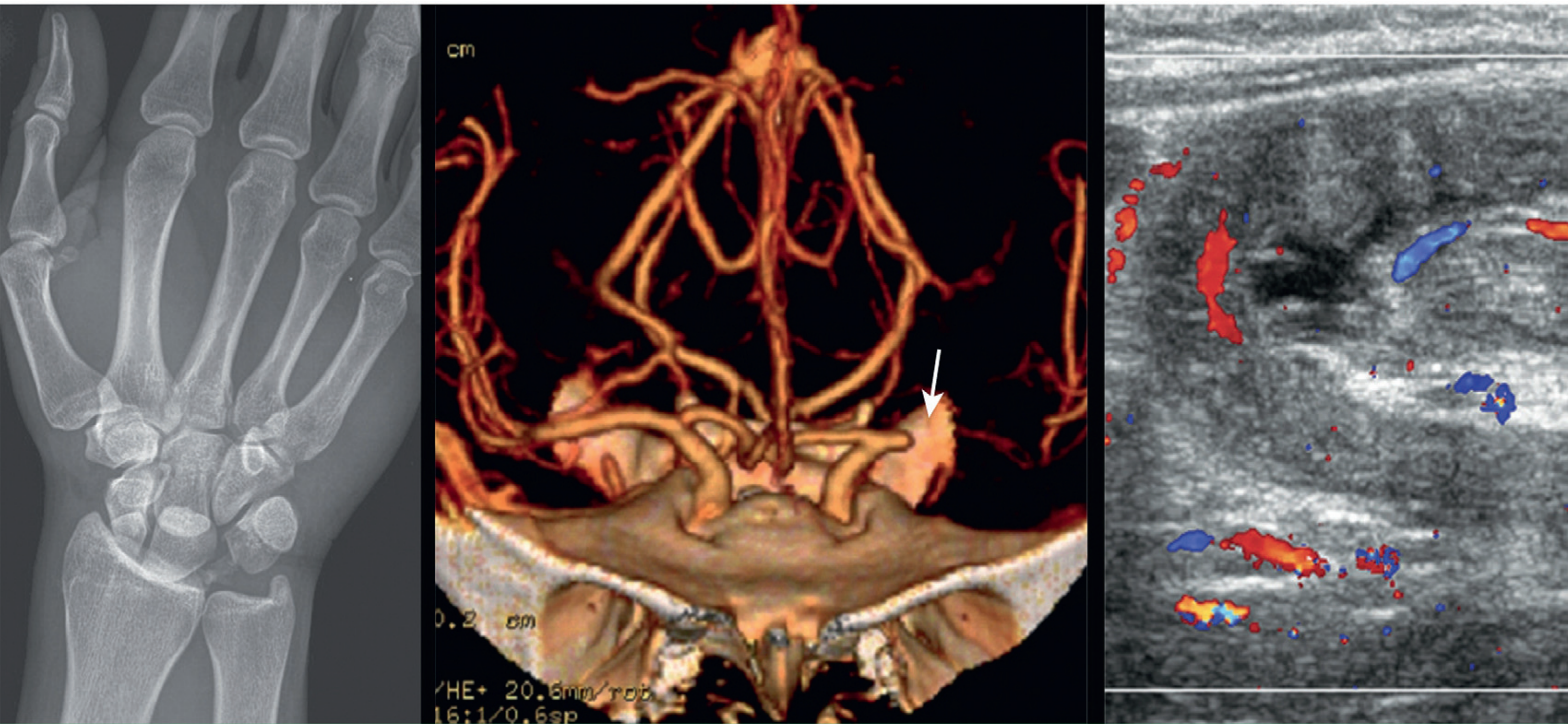
EMERGENCY RADIOLOGY



THE REQUISITES

2nd EDITION

ELSEVIER

THE REQUISITES

Emergency Radiology

SERIES EDITOR

James H. Thrall, MD
Radiologist-in-Chief Emeritus
Department of Radiology
Massachusetts General Hospital
Distinguished Juan M. Taveras Professor of Radiology
Harvard Medical School
Boston, Massachusetts

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THE REQUISITES

Emergency Radiology

SECOND EDITION

Jorge A. Soto, MD
Professor of Radiology
Department of Radiology
Boston University School of Medicine;
Vice Chairman
Department of Radiology
Boston Medical Center
Boston, Massachusetts

Brian C. Lucey, MD
Associate Professor
Department of Radiology
Boston University School of Medicine
Boston, Massachusetts;
Clinical Director
Department of Radiology
The Galway Clinic
Doughiska, County Galway, Ireland

ELSEVIER

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1600 John F. Kennedy Blvd.
Ste 1800
Philadelphia, PA 19103-2899

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To my parents, Jorge Sr. and Socorro, for their example and guidance, and to my wife, Ana, and children, Andrea and Alejandro, for their sustained support and patience as I devote my time to academic radiology.

J.A.S.

To my parents, James and Anne; sister, Suzanne; wife, Ciara; and son, James. Thanks for the unconditional support.

B.C.L.

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Contributors

Carlos A. Anaya, MD
Medical Director
Cardiovascular Interventional Institute
Department of Radiology
Manati Medical Center
Manati, Puerto Rico

Stephan W. Anderson, MD
Associate Professor of Radiology
Boston University Medical Center
Boston, Massachusetts

Laura L. Avery, MD
Assistant Professor
Massachusetts General Hospital
Harvard Medical School
Boston, Massachusetts

Glenn D. Barest, MD
Assistant Professor of Radiology
Boston Medical Center
Boston, Massachusetts

Sarah D. Bixby, MD
Assistant Professor of Radiology
Harvard Medical School;
Pediatric Radiologist
Department of Radiology
Boston Children's Hospital
Boston, Massachusetts

Anna K. Chacko, MD
Adjunct Professor of Radiology
Boston University
Boston, Massachusetts;
Professor of Telemedicine
John A. Burns School of Medicine
University of Hawaii
Honolulu, Hawaii

Margaret N. Chapman, MD
Chief of Neuroradiology
Boston VA Healthcare System;
Assistant Professor of Radiology
Boston Medical Center
Boston University School of Medicine
Boston, Massachusetts

Luis E. Diaz, MD
Associate Chief of Radiology
VA Boston Health Care System;
Associate Professor of Radiology
Boston University
Boston, Massachusetts

Alejandra Duran-Mendicuti, MD
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts

Ana Maria Gomez, MD
Department of Radiology
Manati Medical Center
Manati, Puerto Rico

Rathachai Kaewlai, MD
Instructor
Division of Emergency Radiology
Department of Diagnostic and Therapeutic Radiology
Ramathibodi Hospital
Faculty of Medicine
Mahidol University
Bangkok, Thailand

Russ Kuker, MD
Department of Radiology
University of Miami Hospital
Miami, Florida

Christina A. LeBedis, MD
Assistant Professor
Boston University Medical Center
Boston, Massachusetts

Brian C. Lucey, MD
Associate Professor
Department of Radiology
Boston University School of Medicine
Boston, Massachusetts;
Clinical Director
Department of Radiology
The Galway Clinic
Doughiska, County Galway, Ireland

Asim Z. Mian, MD
Assistant Professor of Radiology
Boston Medical Center
Boston University
Boston, Massachusetts

Sarah S. Milla, MD
Associate Professor
Department of Radiology and Imaging Sciences
Emory University;
Attending Pediatric Radiologist and Neuroradiologist
Children's Healthcare of Atlanta
Egleston Hospital
Atlanta, Georgia

Felipe Munera, MD
Department of Radiology
University of Miami Hospital
Miami, Florida

Rohini N. Nadgir, MD
Assistant Professor of Radiology and Radiological Science
Johns Hopkins Medical Institutions
Baltimore, Maryland

Osamu Sakai, MD, PhD
Chief of Neuroradiology
Professor of Radiology, Otolaryngology–Head and Neck Surgery and Radiation Oncology
Boston Medical Center
Boston University School of Medicine
Boston, Massachusetts

Rashmikant B. Shah, MD
Diagnostic Radiology
St. James Healthcare
Butte, Montana

Ajay Singh, MD
Department of Radiology
Massachusetts General Hospital
Boston, Massachusetts

Aaron D. Sodickson, MD, PhD
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts

Jorge A. Soto, MD
Professor of Radiology
Department of Radiology
Boston University School of Medicine;
Vice Chairman
Department of Radiology
Boston Medical Center
Boston, Massachusetts

Michael Stella, MD
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts

Joshua W. Stuhlfaut, MD
Beth Israel Deaconess Hospital
Plymouth, Massachusetts

Jennifer C. Talmadge, MD
Department of Radiology
Children's Hospital Boston
Boston, Massachusetts

Salvatore G. Viscomi, MD
Clinical Instructor
Harvard Medical School;
Attending Radiologist
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts;
Chairman
Department of Radiology
Cape Cod Hospital
Hyannis, Massachusetts

Scott White, MD
Department of Radiology
Brigham and Women's Hospital
Boston, Massachusetts

Ryan T. Whitesell, MD
St. Paul Radiology
Regions Hospital
St. Paul, Minnesota

Foreword

Time passes quickly, and it is now time to introduce the second edition of *Emergency Radiology:* THE REQUISITES. Drs. Soto and Lucey, along with their coauthors, have once again created an excellent text that captures the fundamental building blocks of emergency radiology practice.

Drs. Soto and Lucey have maintained the logical division of their book by both body part and indication—trauma versus nontrauma with separate chapters for special considerations in children and for nuclear medicine applications. This allows the reader of *Emergency Radiology:* THE REQUISITES to go immediately to the material of interest. As a side note, only two or so decades ago, nontrauma emergency patients were not imaged nearly as often as they are today. Today, emergency applications for the nontrauma patient are just as important as the historic role of imaging in trauma. Imaging is truly the "guiding hand" of medical practice, making possible rapid diagnosis, triage, and disposition, which are vitally important given the time and resource constraints faced by busy emergency departments.

In the years between the preparation of the first edition and the current work, much has happened to enhance the role of radiology in the emergency department and to reshape our thinking. These changes affect every area of application and include, among many others, optimization of computed tomographic (CT) protocols in every organ system for lower radiation exposure, taking advantage of fast CT scanning capabilities to reduce contrast usage and an increasing appreciation for the potential roles of MRI for both traumatic and nontraumatic indications. Conventional radiography continues to play an important role, especially for extremity trauma and some thoracic imaging applications such as pneumonia and congestive heart failure. However, for most applications, radiography is being inexorably replaced by cross-sectional imaging.

Drs. Soto and Lucey have again assembled an outstanding team of coauthors to help ensure that *Emergency Radiology:* THE REQUISITES is as up to date as possible. Thanks to all the authors for their contributions.

Each chapter presents a different challenge in presenting material. All share a rich opportunity for illustrations, and *Emergency Radiology:* THE REQUISITES is extremely well illustrated. Otherwise the use of outline lists, boxes, and tables has been dictated by the material requiring presentation.

THE REQUISITES books have become old friends to imagers for over 25 years. We have tried to remain true to the original philosophy of the series, which was to provide residents, fellows, and practicing radiologists with a text that might be read within several days. From feedback I have received, many residents do exactly that at the beginning of each rotation. During first rotations this allows them to acquire enough knowledge to really benefit from their day-to-day exposure to clinical material and the conditions about which they have just read. During subsequent rotations, a rereading imprints the knowledge they will need subsequently for upcoming certification exams. For the practicing radiologist, it serves as a useful refresher, like a booster shot. At the workstation, the books in THE REQUISITES series are useful as a first reference source and guide to differential diagnosis.

THE REQUISITES books are not intended to be exhaustive. There are other large reference books to catalog rare and unusual cases and to present different sides of controversies. Rather, THE REQUISITES books are intended to provide information on the vast majority of conditions that radiologists see every day, the ones that are at the core of radiology practice. In fact, one of the requests to authors is to not look up anything they do not know but to put in the book what they teach their own residents at the workstation. Since the authors are experienced experts in their respective areas, this is predictably the most important material.

Drs. Soto and Lucey and their coauthors have again done an outstanding job in sustaining the philosophy and excellence of THE REQUISITES series and deserve congratulations. Their book reflects the contemporary practice of emergency imaging and should serve radiologists, emergency medicine specialists, and other physicians who deal with emergencies as a concise and useful foundation for understanding the indications for imaging and the significance of imaging findings in the emergency setting.

James H. Thrall, MD
Chairman Emeritus
Department of Radiology
Massachusetts General Hospital
Distinguished Taveras Professor of Radiology
Harvard Medical School

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Preface

Emergency Radiology is a unique title in THE REQUISITES series. Although both the organ system–based and modality-based divisions of radiology have existed for some time, this REQUISITES title is the first to embrace a multimodality, multisystem approach to radiology. There is an ongoing paradigm shift in medical management over the past 25 years or so, away from inpatient-oriented health care toward an increasingly outpatient-based system. Nowhere is this more apparent than in emergency departments across the United States and around the world. The reliance on imaging for diagnosis and guiding management decisions throughout medicine has been increasing, and this is exemplified in the emergency setting. All imaging modalities are available to the emergency physician. More than in any other modality, the massive increase in the use of computed tomograpy (CT) has led to the development and growth of the specialty of emergency radiology. The value of CT in the setting of trauma, investigation of severe headache, abdominal pain, and the evaluation of patients with suspected pulmonary embolus forms the bedrock of emergency imaging, although there is an increasing role for MR and ultrasound imaging in the emergency setting, particularly for the rapid evaluation of musculoskeletal injury and emergent neurologic evaluation. The book is an attempt to collate all the radiology information required in today's emergency department setting into one succinct, practical, and current text that can be used by both residents in training and general radiologists in practice, as well as emergency department physicians and trauma surgeons.

The goal of this revision is to provide updates to address the rapid changes in emergency imaging requirements, including CT angiography in the emergency department for coronary, aorta, brain/neck, visceral, and extremity arteries, updated CT protocols in trauma and nontraumatic emergencies, and new and better quality images obtained with the latest imaging technology. Stepping away from the organ- and modality-based divisions, we acknowledge that there is potential for overlap among this text and others in THE REQUISITES series. However, to avoid this, we have endeavored to confine the text to medical and surgical conditions that commonly present through the emergency department rather than including every imaging possibility that may present. We apologize in advance if any overlap is identified—it was included for completeness—or for any deficiencies; some rare entities may have been omitted for the sake of brevity. The fundamental division of the book is in two parts, one dealing with acute trauma and the other with nontraumatic acute processes, and the division of the chapters reflects this. This makes it possible to easily select those chapters relevant to an individual radiology practice. Some departments, especially large academic departments with residency programs, will have trauma units, whereas some community practices may run an emergency department without dealing with acute trauma.

We are pleased with how this revision has developed from an abstract concept into reality and built upon the first edition. It has taken substantial effort, and we fully appreciate the contributions from the authors, all of whom have considerable experience in emergency imaging. We hope that the revision will be as well received as the first edition and will act as an integral resource for all radiology departments and training programs.

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We would like to thank many people who helped transform the concept of this book into a reality. First, we owe thanks to innumerable individuals (staff, residents, fellows, technologists, and nurses) at the Boston University Medical Center who helped us and our colleagues build multidisciplinary groups for the care of the acutely ill patient. This was the principal driving force behind our growing interest in the field of emergency radiology. We would also like to thank Dr. James Thrall for insisting on the timeliness and necessity of this text to add to THE REQUISITES series. We would also like to extend a sincere thank you to the contributing authors, all of whom are experienced radiologists with extensive knowledge in the various aspects of emergency radiology. Each author has added his or her own subspecialty expertise to the chapters, which has resulted in the final product, a textbook that we believe they should all be proud of. Finally, thanks to all the staff at Elsevier, especially Amy Meros and Robin Carter, who waited patiently for us to deliver the various parts of the book, sometimes at a slower-than-hoped-for pace.

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THE REQUISITES

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Chapter 1

Traumatic and Nontraumatic Emergencies of the Brain, Head, and Neck

Glenn D. Barest, Asim Z. Mian, Rohini N. Nadgir, and Osamu Sakai

Imagine you are asked to create a list of the disorders of the brain, head, and neck that one might commonly expect to encounter at an emergency department (ED) and describe the typical imaging features. At first, this challenge seems straightforward enough. However, upon beginning the task, it soon becomes clear that almost every disorder within the realm of neuroradiology/head and neck radiology might at one time or another present as an acute emergency. Inclusion of certain diagnoses such as stroke, fractures, and epiglottitis is a must. Other diagnoses, such as oligodendroglioma or perhaps a slowly growing lesion, might seem less clear-cut. Ultimately, it is important to realize that a wide variety of processes will result in an alteration in mental status leading to an ED visit, with imaging playing a key role in diagnosis and appropriate management.

Upon admission, inpatient workups now occur on a 24/7 basis, with many complex examinations completed during the night shift. On-call radiologists (often residents or fellows) are expected to provide "wet readings" or complete interpretations for complex cases covering the full spectrum of medicine, pediatrics, surgery, and related subspecialties. It was not that many years ago that the radiologist was faced with a seemingly never-ending stack of plain films from the ED, inpatient wards, and intensive care units requiring rapid interpretations. This work was interrupted by an occasional computed tomography (CT) scan. In this new millennium, during a typical shift the radiologist must maintain a rapid pace to review thousands of cross-sectional CT and magnetic resonance images (MRI) with two-dimensional (2D) and three-dimensional (3D) reformats. For this reason, the majority of the discussion and most of the examples in this chapter are based on these modalities and the latest techniques.

The most daunting part of preparing this chapter was to boil down all of the disorders and details to a set of requisites. Division of this chapter into sections is not quite as neat as one might think. For example, it is not possible to separate the vascular system from discussion of the brain, head and neck, or spine, and the imaging methods applied to the extracranial vessels in the setting of stroke are similar to those used for blunt or penetrating trauma to the neck. One may therefore notice mention of similar techniques and findings in several places with examples appropriate to the context. All readers would do well to study the other volumes in the Requisites series (especially Neuroradiology, Musculoskeletal Imaging, and Pediatric Radiology), which cover this material in great detail. In this attempt at condensing so much material into one useful volume, important topics inevitably have been neglected. We hope that this volume can serve as a starting point for further study and become a valuable reference to on-call radiologists, emergency department physicians, and residents of both specialties.

INTRACRANIAL HEMORRHAGE AND TRAUMATIC BRAIN INJURY

Whether in the setting of head trauma, spontaneous development of headache, or alteration of mental status, the ability to diagnose intracranial hemorrhage (ICH) is of primary importance for all practitioners. These presentations are some of the most common indications for brain imaging in the emergency setting. Almost invariably, the requisition will read, "Rule out bleed." An understanding of traumatic and nontraumatic causes of ICH, the usual workup, and recognition of ICH is therefore important and seems like a natural starting point. A discussion of the important types of mass effect resulting from ICH and traumatic brain injury is also included in this section. An understanding of hemorrhage and herniation syndromes is central to the discussion of other topics that follow, such as stroke and neoplasms.

The word ***hemorrhage*** has Greek origins: the prefix *haima-,* meaning "blood," and the suffix *-rrhage,* meaning "to gush or burst forth." Incidence of ICH is approximately 25 to 30 per 100,000 adults in the United States, with a higher incidence in elderly hypertensive patients. ICH is typically more common in the African American and Asian populations. Bleeding may take place within the substance of the brain (intraaxial) or along the surface of the brain (extraaxial). Intraaxial hemorrhage implies parenchymal hemorrhage located in the cerebrum, cerebellum, or brainstem. Extraaxial hemorrhages include epidural, subdural, and subarachnoid hemorrhages, and intraventricular hemorrhage can be considered in this group as well. Hemorrhages can lead to different types of brain herniation, from direct mass effect and associated edema or development of hydrocephalus, causing significant morbidity and mortality.

TABLE 1-1 Usual Magnetic Resonance Signal Characteristics of Hemorrhage

Stage	Time	Component	T1	T2
Hyperacute	(0-12 h)	Oxyhemoglobin	Isointense	Hyperintense
Acute	(12 h-3 days)	Deoxyhemoglobin	Isointense	Hypointense
Early subacute	(3-7 days)	Methemoglobin (intracellular)	Hyperintense	Hypointense
Late subacute	(1 wk-1 mo)	Methemoglobin (extracellular)	Hyperintense	Hyperintense
Chronic	(>1 mo)	Hemosiderin	Hypointense	Hypointense

General Imaging Characteristics of Hemorrhage

The appearance of ICH on a CT scan can vary depending on the age of the hemorrhage and the hemoglobin level. The attenuation of blood is typically based on the protein content, of which hemoglobin contributes a major portion. Therefore the appearance of hyperacute/acute blood is easily detected on a CT scan in patients with normal hemoglobin levels (approximately 15 g/dL) and typically appears as a hyperattenuating mass. This appearance is typical because, immediately after extravasation, clot formation occurs with a progressive increase in attenuation over 72 hours as a result of increased hemoglobin concentration and separation of low-density serum. On the other hand, in anemic patients with a hemoglobin level less than 10 g/dL, acute hemorrhage can appear isoattenuating to the brain and can make detection difficult. Subsequently, after breakdown and hemolysis, the attenuation of the clot decreases until it becomes nearly isoattenuating to cerebrospinal fluid (CSF) by approximately 2 months. In the emergency setting, one should be aware of the “swirl” sign with an unretracted clot that appears to be hypoattenuating and resembles a whirlpool; this sign may indicate active bleeding and typically occurs in a posttraumatic setting. It is important to recognize this sign, because prompt surgical evacuation may be required. The amount of mass effect on nearby tissues will depend on the size and location of the hemorrhage, as well as the amount of secondary vasogenic edema that develops.

Use of an intravenous contrast agent usually is not necessary for CT detection of ICH. If a contrast agent is used, an intraaxial hemorrhage can demonstrate an enhancing ring that is usually due to reactive changes and formation of a vascularized capsule, which typically occurs 5 to 7 days after the event and can last up to 6 months. Subacute and chronic extraaxial hematomas also can demonstrate peripheral enhancement, usually because of reactive changes and formation of granulation tissue. Unexpected areas of enhancement should raise concern, because active bleeding can appear as contrast pooling. Refer to the section on aneurysms and vascular malformations in this chapter for a discussion of CT angiography in the setting of acute ICH.

MRI has greatly revolutionized the evaluation of ICH. The evolution of hemorrhage from the hyperacute to the chronic stage will have corresponding signal changes on T1-weighted images (T1WIs), T2-weighted images (T2WIs), fluid-attenuated inversion recovery (FLAIR) images, and gradient-echo sequences. These properties can assist in detection and understanding of the time course of the injury. Although it is beyond the scope of this chapter, a description of the physics of the signal characteristics of blood products on MRI is generally based on the paramagnetic effects of iron and the diamagnetic effects of protein in the hemoglobin molecule. The usual signal characteristics of hemorrhage and the general time course over which hemorrhages evolve are summarized in Table 1-1.

EXTRAAXIAL HEMORRHAGE

Extraaxial hemorrhage occurs within the cranial vault but outside of brain tissue. Hemorrhage can collect in the epidural, subdural, or subarachnoid spaces and may be traumatic or spontaneous. It is important to recognize these entities because of their potential for significant morbidity and mortality. Poor clinical outcomes are usually the result of mass effect from the hemorrhage, which can lead to herniation, increased intracranial pressure, and ischemia. Intraventricular hemorrhage will be considered with these other types of extracerebral hemorrhage.

Epidural Hemorrhage

Epidural hematoma is the term generally applied to a hemorrhage that forms between the inner table of the calvarium and the outer layer of the dura because of its masslike behavior. More than 90% of epidural hematomas are associated with fractures in the temporoparietal, frontal, and parieto-occipital regions. CT is usually the most efficient method for evaluation of this type of hemorrhage. An epidural hematoma typically has a hyperdense, biconvex appearance. It may cross the midline but generally does not cross sutures (because the dura has its attachment at the sutures), although this might not hold true if a fracture disrupts the suture. Epidural hematomas usually have an arterial source, commonly a tear of the middle meningeal artery, and much less commonly (in less than 10% of cases) a tear of the middle meningeal vein, diploic vein, or venous sinus (Figs. 1-1 and 1-2). The classic clinical presentation describes a patient with a “lucid” interval, although the incidence of this finding varies from 5% to 50% in the literature. Prompt identification of an epidural hematoma is critical, because evacuation or early reevaluation may be required. Management is based on clinical status, and therefore alert and oriented patients with small hematomas may be safely observed. The timing of follow-up CT depends on the patient’s condition, but generally the first follow-up CT scan may be obtained after 6 to 8 hours and, if the patient is stable, follow-up may be extended to 24 hours or more afterward.

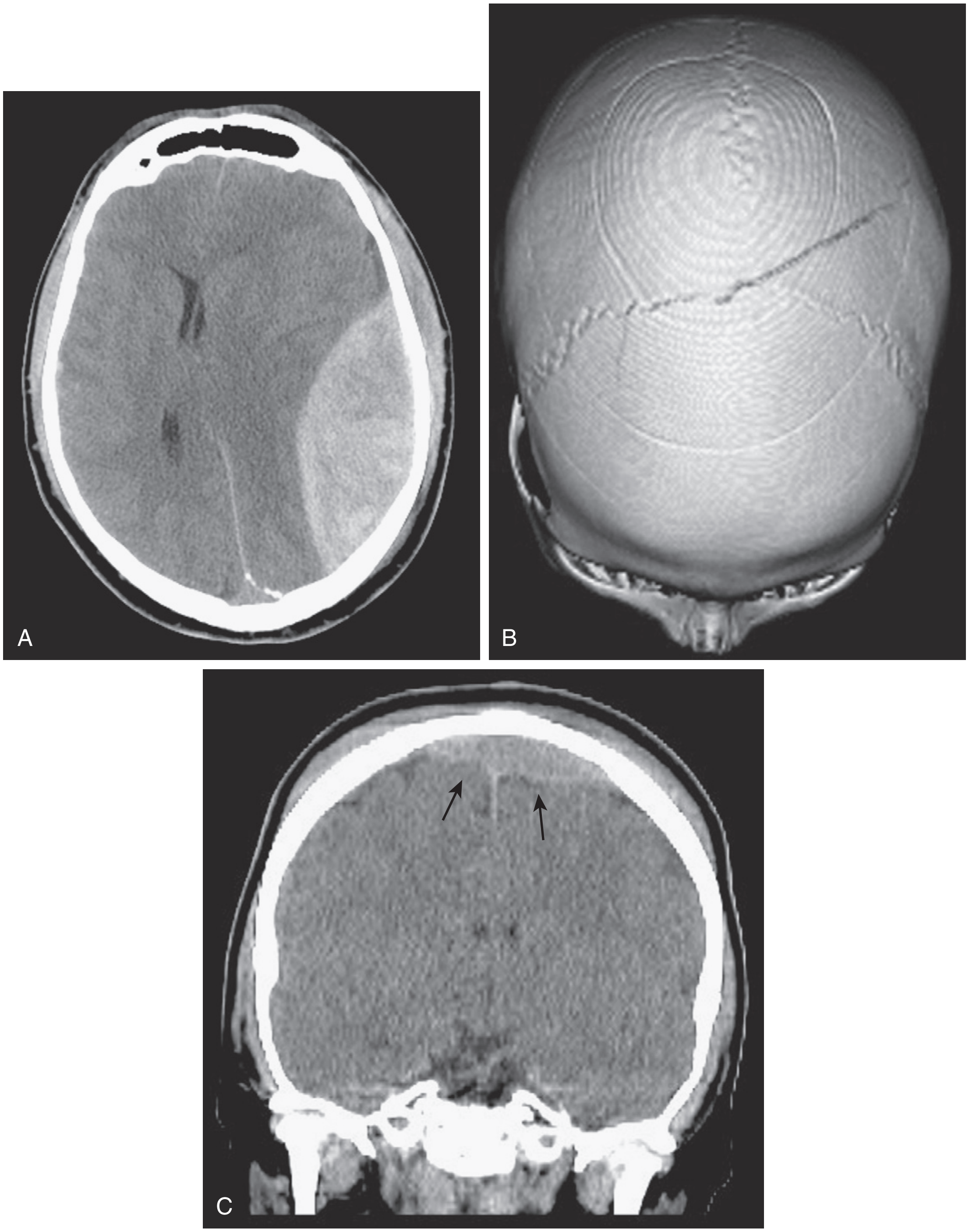

FIGURE 1-1 An epidural hematoma. **A,** Computed tomography (CT) shows a usual biconvex, hyperdense acute epidural hematoma causing effacement of sulci and lateral ventricles and shift of midline structures. **B,** A CT volume-rendered image shows a nondisplaced fracture at the vertex involving the coronal suture. **C,** Coronal multiplanar reconstruction shows a biconvex epidural hematoma crossing midline over the superior sagittal sinus *(arrows)*.

Subdural Collections

Subdural hematoma (SDH) is the term generally applied to a hemorrhage that collects in the potential space between the inner layer of the dura and the arachnoid membrane. It is typically the result of trauma (e.g., motor vehicle collisions [MVCs], assaults, and falls, with the latter especially occurring in the elderly population). An SDH causes a tear of the bridging vein(s) and has a hyperattenuating, crescentic appearance overlying the cerebral hemisphere (Fig. 1-3). These hemorrhages can cross sutures and may track along the falx and tentorium but do not cross the midline. Inward displacement of the cortical vessels may be noted on a contrast-enhanced scan. SDHs have a high association with subarachnoid hemorrhage. Acute SDHs thicker than 2 cm that occur with other parenchymal injuries are associated with greater than 50%

mortality. As the SDH evolves to the subacute stage (within 5 days to 3 weeks) and then to the chronic stage (after more than 3 weeks), it decreases in attenuation, becoming isodense to the brain and finally to CSF. A subacute SDH can have a layered appearance as a result of separation of formed elements from serum. Subacute hemorrhages may be relatively inconspicuous when they are isodense, and therefore it is especially important to recognize signs of mass effect, such as sulcal effacement, asymmetry of lateral ventricles, and shift of midline structures, as well as sulci that do not extend to the skull (Fig. 1-4). Bilateral isoattenuating SDHs can be especially challenging because findings are symmetric. One should beware of bilateral isoattenuating SDHs, particularly in elderly patients who do not have generous sulci and ventricles. At this stage, the SDH should be conspicuous on MRI, especially on FLAIR sequences. A subacute SDH also may be very conspicuous on T1WIs because of the hyperintensity of methemoglobin.

Chronic subdural hematomas are collections that have been present for more than 3 weeks. Even a chronic hematoma may present in the emergency setting, such as

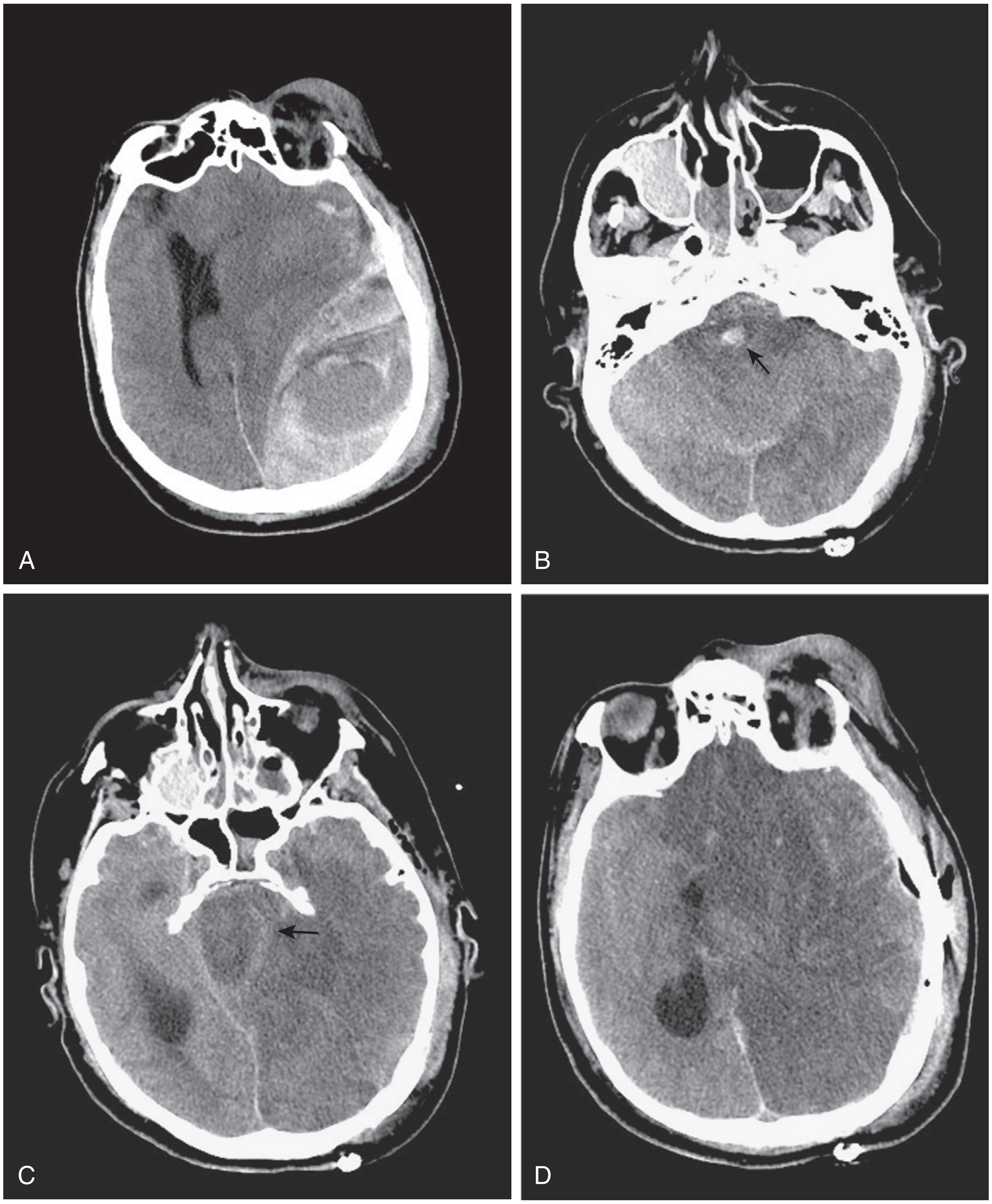

FIGURE 1-2 An epidural hematoma and complications demonstrate on noncontrast CT. **A,** The "swirl" sign in this large epidural hematoma suggests continued bleeding. **B,** A pontine (Duret) hemorrhage *(arrow)* and effacement of the basal cisterns as a result of downward herniation. **C,** Uncal herniation (the *arrow* shows the margin of the left temporal lobe) and a resultant left posterior cerebral artery territory infarct. The brainstem is distorted and also abnormally hypodense. **D,** Infarcts in bilateral anterior cerebral, left middle cerebral, and left posterior cerebral artery territories as a result of herniations.

in a patient prone to repeated falls who is brought in because of a change in mental status. On both CT and MRI, these collections typically have a crescentic shape and may demonstrate enhancing septations and membranes surrounding the collection after administration of a contrast agent. Calcification of chronic SDH can occur and may be quite extensive (Fig. 1-5). Areas of hyperdensity within a larger hypodense SDH may indicate an acute component due to recurrent bleeding, termed an "acute on chronic subdural hematoma." Mixed density collections also may be acute as a result of active bleeding or CSF accumulation as a result of tearing of the arachnoid membrane. A chronic SDH is usually isointense to CSF on both T1WIs and T2WIs, but the appearance can be variable depending on any recurrent bleeding within the collection. The FLAIR sequence is typically very sensitive for detection of chronic SDH as a result of hyperintensity based on protein content. Hemosiderin within the hematoma will cause a signal void because of the susceptibility effect, and "blooming" (i.e., the hematoma appears to be larger than its true size) will be noted on a gradient-echo sequence.

FIGURE 1-3 A subdural hematoma with a mixed density layered pattern due to recurrent hemorrhages. The image *(arrow)* shows one method of measuring midline shift.

A subdural hygroma is another type of collection that is commonly thought to be synonymous with a chronic subdural hematoma. The actual definition of a hygroma is an accumulation of fluid due to a tear in the arachnoid membrane, usually by some type of trauma or from rapid ventricular decompression with associated accumulation of CSF within the subdural space. Many persons still use this term interchangeably with chronic subdural hematoma. CT demonstrates a fluid collection isodense to CSF in the subdural space. MRI can be useful in differentiating CSF from a chronic hematoma based on the imaging characteristics of the fluid on all sequences. Occasionally hygromas are difficult to differentiate from the prominence of the extraaxial CSF space associated with cerebral atrophy. The position of the cortical veins can be a helpful clue. In the presence of atrophy, the cortical veins are visible traversing the subarachnoid space, whereas

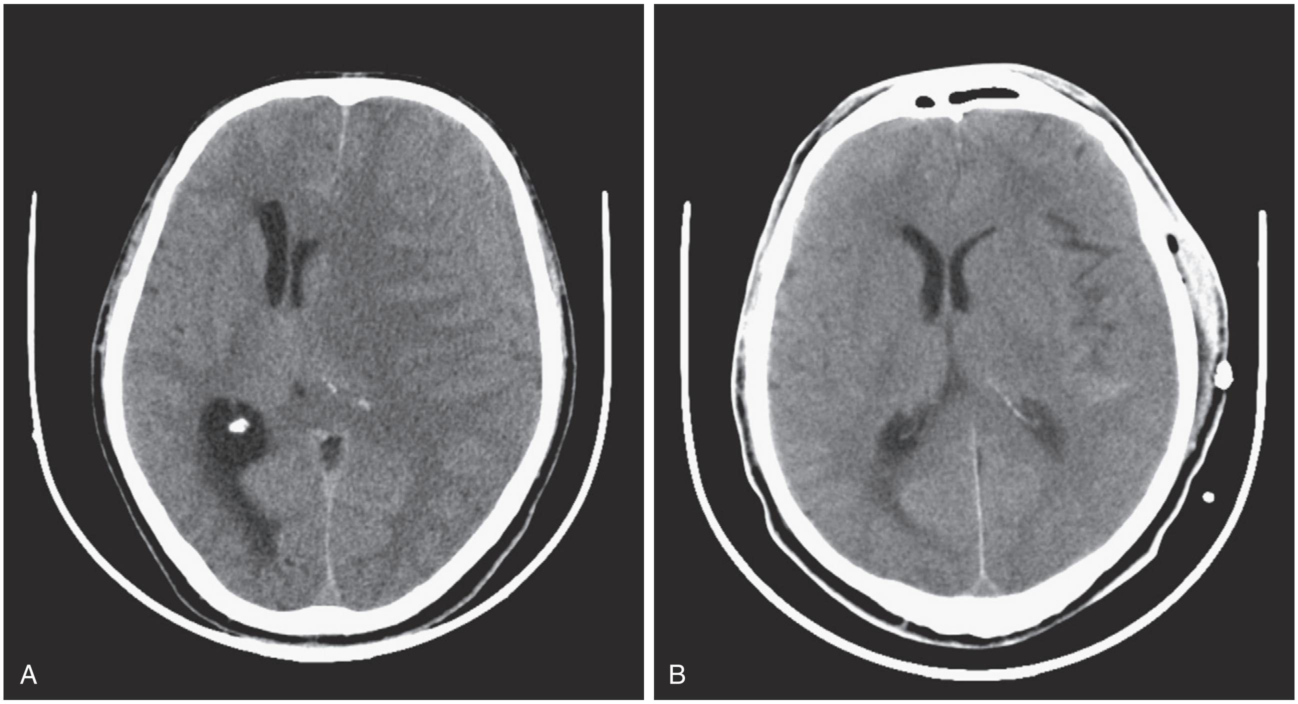

FIGURE 1-4 An isodense subdural hematoma. **A,** Sulcal effacement and a midline shift to the right are clues to the presence of a left-sided subdural hematoma. **B,** Reexpansion of the left Sylvian fissure and a reduction in midline shift after evacuation.