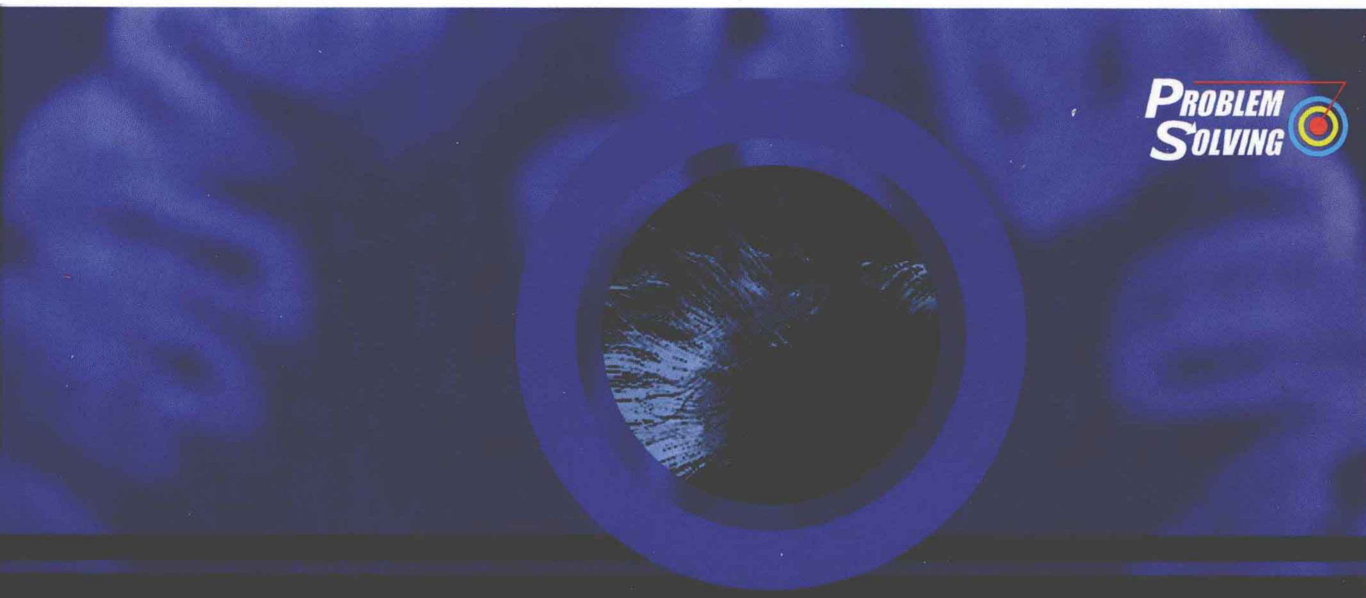

PROBLEM SOLVING

PROBLEM SOLVING IN RADIOLOGY

Problem Solving in Neuroradiology

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To my parents, Lawrence and Sue, for their love and inspiration

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To my wife, Judy, for her support and love

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To my dear wife, Michele Levin Naidich, whose love balances my life

TPN

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Foreword

In a departure from commonly constructed textbooks in radiology, three eminent leaders in the field of neuroradiology—Drs. Law, Som, and Naidich—have approached imaging in an original and highly educational manner. With separate sections (each with individual chapters) on advanced imaging, interventional procedures, specific diagnosis, and anatomic considerations, these authors, along with those who have coauthored chapters, bring their material to life with the Socratic method, posing critical questions throughout the book and then answering them.

There are none more qualified than these three primary authors to guide us through the many areas of neuroimaging. Their deep knowledge of the field and their love of teaching—imparting knowledge, combined with a firm foundation of the underlying anatomy of the brain, head and neck, and spine and the associated imaging techniques—results in a textbook that will appeal to all levels of radiologists, from trainee to attending physician. Who better than Tom Naidich to lead us through the intricacies of brain anatomy and to show us how important this knowledge is when applying advanced imaging protocols, or Peter Som to take the reader through the basics of head and neck imaging and address questions of a critical nature related to ENT radiology, or Meng Law to demonstrate the current state-of-the-art of neuroimaging. For years I have learned from them, and to this day I marvel at their command of the intricacies of neuroimaging.

Congratulations to Drs. Law, Som, and Naidich, not only for conceiving this new way of presenting diagnostic imaging but also for offering to the neuroradiology and neuroscience community a book that will provide new insights into diagnosis and intervention in neurological diseases.

Robert M. Quencer, MD

Preface

Neuroradiology is a subspecialty field that has seen exciting advances over the past few decades. The advent of MRI in the 1980s began an era of new techniques for studying the central nervous system. Neurological disorders are often complex, and to make a diagnosis requires knowledge of neuroanatomy, neuropathology, and neurophysiology, as well as knowledge of the tools enabling us to image these entities. As a result, we hope to provide a textbook that describes how to resolve many of the diagnostic problems facing the clinician and diagnostician in a systematic fashion.

We approached this textbook by dividing it into four distinct sections, based in part on the expertise of the editors. The first section provides a state-of-the-art review of advanced imaging modalities available for problem solving, which can help increase the sensitivity and specificity of neurodiagnosis. In this section we review multidetector CT, conventional MRI, advanced MRI (including MR spectroscopy, perfusion, and diffusion), and nuclear medicine, in particular positron emission tomography, as problem-solving tools.

The second section addresses some of the procedures performed in neuroradiology, including diagnostic angiography, interventional neuroradiology or endovascular neurosurgery, and, of course, spine interventional procedures. The third and largest section approaches problem solving in neuroradiology in a disease-based fashion, covering brain and spine neuroradiologic pathology. The fourth section was developed to approach diseases in different anatomic regions, in particular spinal as well as head and neck disorders.

We recognize that to provide a comprehensive textbook in neuroradiology would be a challenge. So rather than covering every aspect of neuroradiology, this textbook serves as a practical approach toward problem solving. Our hope is that this will serve as a reference textbook that will benefit a spectrum of readers, from medical students, radiology residents, and neuroradiology fellows, to the seasoned neuroradiologist. Residents studying for the radiology board certification and fellows preparing for the certificate of added qualification (CAQ) examinations will find the combination of general knowledge and case-based sections to be valuable in a problem-solving approach. It may also be of benefit for students, residents, and practitioners in neurology, neurologic surgery, and the neurosciences.

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TPN

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SECTION I

Advanced Modalities: Protocols and Optimization

CHAPTER 1

Multidetector Computed Tomography as a Problem-Solving Tool in Neuroradiology

Rajiv Gupta, Sunithi Mani, Amit Mehndiratta, Stuart Pomerantz, and Michael Lev

INTRODUCTION

The concept of x-ray computed tomography (CT) was pioneered by Sir Godfrey Hounsfield at EMI Central Research Laboratories (Middlesex, United Kingdom) and concurrently by Allan McLeod Cormack at Tufts University (Boston, MA, USA). Their main idea of using multiple projections to create tomographic images formed the basis of the EMI scanner, the first clinical brain scanner. Since the days of the first brain scan in the early 1970s, CT has come a long way. Multidetector computed tomography (MDCT) has seen a steady increase in the capabilities, availability, and dedicated protocols for neurologic applications. Although magnetic resonance imaging (MRI) clearly plays an important role in neuroradiology, CT is the main workhorse. Table 1-1 lists a compilation of the main advantages and disadvantages of MDCT and MRI in neurologic applications.

This chapter illustrates how the excellent technical capabilities of a modern MDCT scanner can be put to use for problem solving in neuroradiology. The exposition is example driven. The requirements for the CT protocols for each application domain are summarized and illustrated with the help of clinical examples. Many clinical pearls and pitfalls are presented and illustrated. Guidelines for image acquisition and interpretation are discussed.

MDCT IN THE EMERGENCY DEPARTMENT

After a patient has been stabilized in the emergency department, imaging is directed at providing a clearer picture of the extent of injury and information about potential treatments. The ability of CT to rapidly image traumatic conditions has made it invaluable in acute neurotrauma management. CT is the vital imaging modality for determining the full extent and effects of the brain injury. Lesions commonly seen on CT include calvarial fractures, acute intraaxial and extraaxial hemorrhage, hemorrhagic contusions, diffuse axonal injury, and spinal fractures.

For emergent management, the lesions can be broadly classified as traumatic or nontraumatic. MDCT is the main diagnostic tool for both of these conditions. The salient features, protocols, and pitfalls in the use of MDCT for a variety of conditions encountered in the emergency department are summarized here.

Fractures

CT is excellent for showing bony anatomy and far exceeds the capabilities of MRI. With the advent of fast scanning and multiplanar reconstructions, it now is feasible to demonstrate various types of skull fractures in exquisite detail. For example, the various types of Le Fort fractures now can be depicted quickly and easily. Three-dimensional (3-D) renderings of these different fractures are invaluable to ear, nose, and throat (ENT) and plastic surgeons for rendering appropriate therapy. Because of their low sensitivity, skull radiographs have been supplanted by CT, which now is a part of emergency workup in nearly all trauma centers.

The optimal protocol for detecting calvarial and maxillofacial fractures requires thin axial slices constructed using a sharp kernel (e.g., bone kernel for a GE scanner or H50 sharp kernel for a Siemens scanner). The axial slices must be at least 1.25 mm thick with about 50% overlap. These scans may be augmented by coronal, sagittal, multiplanar oblique, or 3-D views to aid in visualization. The reviewing radiologist requires multiplanar reconstructions to assess bony asymmetries and alignment as well as certain structures that are optimally visualized in the coronal or sagittal imaging planes. The referring physicians require 3-D reconstructions for preoperative planning and intraoperative guidance. Figure 1-1 shows selected images from the case of a 45-year-old man who presented after a fall from a 30-foot ladder. The axial CT slices show fractures of the frontal eminence and parietal bone. However, the interrelationship between the fracture fragments is much better appreciated on the 3-D surface-rendered views, which show the extent of fracture from frontal eminence to parietal bone. Use of 3-D views is not limited to trauma cases. Figure 1.2 shows the similar application of the 3-D surface-rendering technique to visualize a congenital cranial malformation.

Table 1-1 Comparison of MDCT and MRI for Neurologic Applications

MDCT	MRI
Fast, more available	Slower, less available
Few contraindications	Multiple contraindications
Radiation exposure	No radiation exposure
Good for acute hemorrhage	Excellent for phases of hemorrhage
Excellent for bone and air–tissue interfaces	Poor visualization of bone, air–tissue interfaces
Poor soft tissue contrast	Great for soft tissues
Higher chance of contrast reaction	Lower chance of contrast reaction
Nephrotoxic contrast	Nephrotoxic contrast (NSF)
Can only measure attenuation	Sensitive to different tissue properties
Excellent contrast-enhanced angiograms	Good contrast-enhanced angiograms
Need contrast for computed tomographic angiography	Noncontrast magnetic resonance angiography (based on flow)

MDCT, Multidetector computed tomography; *MRI,* magnetic resonance imaging; *NSF,* nephrogenic systemic fibrosis.

The most common pitfall in evaluating calvarial and skull base fractures is improper protocol. Evaluation of the bony anatomy on slices that are too thick or do not use a sharp kernel can be detrimental. Figure 1-3, which shows thin slices reconstructed using a sharp kernel, demonstrates a subtle right occipital fracture that extends into the skull base. This fracture was missed on the slices acquired at 2.5-mm thickness and standard kernel. Due to the subgaleal hematoma in the vicinity and a high clinical suspicion, retrospective reconstructions at 1.25-mm slice thickness using a sharp kernel demonstrated the nondisplaced fracture shown in the figure.

The scenario described exemplifies a separate but related feature of MDCT. When the projection data are acquired using a helical or spiral protocol, thinner image slices can be retrospectively reconstructed at any user-defined spacing and overlap. This can be done as long as the raw projection data are available. Therefore, operationally it is mandatory for the raw projection data to be saved, at least for a few days after the scanning, while the clinical questions during acute care are still being addressed.

Even though tomographic slices are more sensitive in detecting fractures, scout views sometimes can show linear fractures that may be missed on the tomographic data (Figure 1-4). It is a good practice to always examine the scout view with all CT data. It also is a good practice to review sagittal and coronal views, which can be easily reconstructed on the scanner console. Coronal views are especially helpful because they are more forgiving of side-to-side misregistration, allowing easier comparison between the left and right sides. It is useful to have an individualized checklist of frequent misses, such as fractures of the condylar head, zygoma, around the foramen magnum, pterygoid plates (Le Fort fractures), and nasal bones.

Figure 1-5 shows the case of an 18-year-old man with a history of impaling his face onto the branch of a tree who presented with facial paresthesias. CT scan images show a hypodense foreign body adjacent to the infraorbital nerve that extends into the anterior wall of the left maxillary sinus. Subcutaneous emphysema is present along the entrance track adjacent to the infraorbital foramen. The sagittal and coronal images also demonstrate the foreign body and mucosal thickening in the left maxillary sinus.

Figure 1-6 shows a common pitfall in CT scans of traumatic injury. A CT scan was performed on a 54-year-old man who fell from a tree and complained of irritation in the left eye. Axial CT scan demonstrated proptosis of the left globe with air in the extraconal post-septal region, along the lateral aspect of the orbit, extending posteriorly up to the orbital apex. This was presumed to be posttraumatic air, likely secondary to a fracture. However, a fracture was not identified. The patient returned 2 months later, when MRI scan showed persistent proptosis and extensive inflammatory and phlegmonous changes with enhancement. The central nonenhancing portion was thought to be the necrotic core of an abscess. The patient was emergently taken to the operating room, where a 2-cm wood chip was removed from the left orbit. The take-home point is that wood can have a variety of appearances on CT, with dry wood essentially resembling air in Hounsfield units (HU).

Intracranial Hemorrhage

Hemorrhage due to a direct mechanism, either penetrating or blunt, may be extraaxial (epidural or subdural), intraparenchymal, or associated with a brain contusion. All of these pathologies, with varying degrees of sensitivity and specificity, can be detected and characterized using MDCT. Rotational forces can lead to hemorrhagic shear and diffuse axonal injury at characteristic locations such as the corpus callosum and gray–white junction. CT has relatively low sensitivity for diffuse axonal injury, which is apparent on only 20% to 50% of initial CT scans. Diffuse axonal injury lesions that are visible are commonly found in the subcortical white matter, centrum semiovale, corpus callosum, basal ganglia, brainstem, and cerebellum.

The volume inside the calvaria is limited and fixed. This volume is composed of three components: cerebrospinal fluid, blood, and brain tissue. According to the Monro-Kellie hypothesis, intracranial pressure remains stable as long as the volume added to any one of these components is balanced by the volume displaced. Therefore, a sudden rise in the amount of any one of these components may cause the intracranial pressure to increase if the volume of the other two components remains constant. The greatest risk to a patient with any traumatic injury is a fast-growing intracranial hematoma leading to increased intracranial pressure and

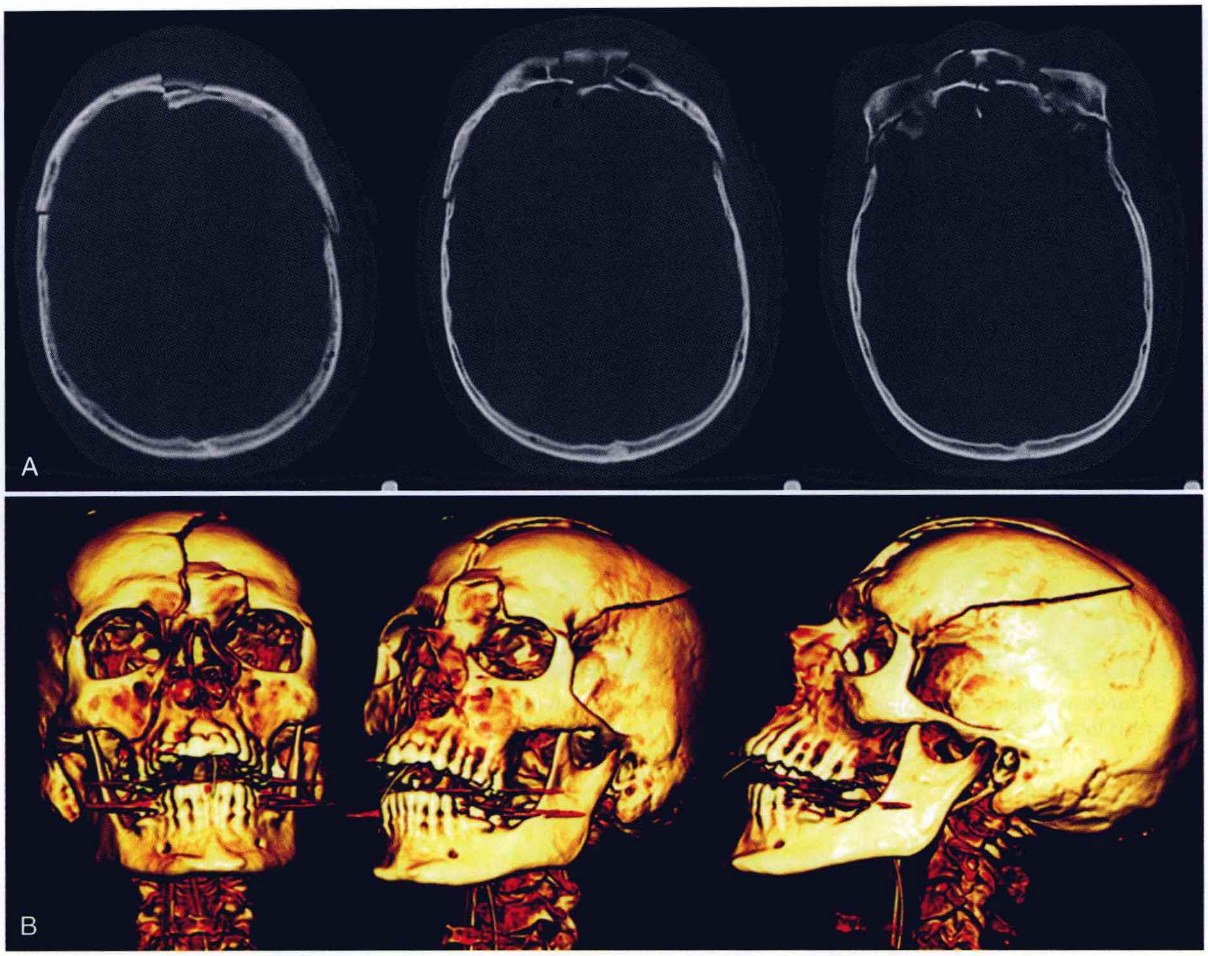

Figure 1-1 Noncontrast maxillofacial multidetector computed tomography of a 45-year-old man who presented with a history of a fall from a 30-foot ladder. **A:** Axial computed tomographic slices showing fracture through the frontal eminence and parietal bone. **B:** The extent of fracture from the frontal eminence to the left parietal bone and the relationship between the various fracture fragments are much better appreciated on these three-dimensional surface-rendered views.

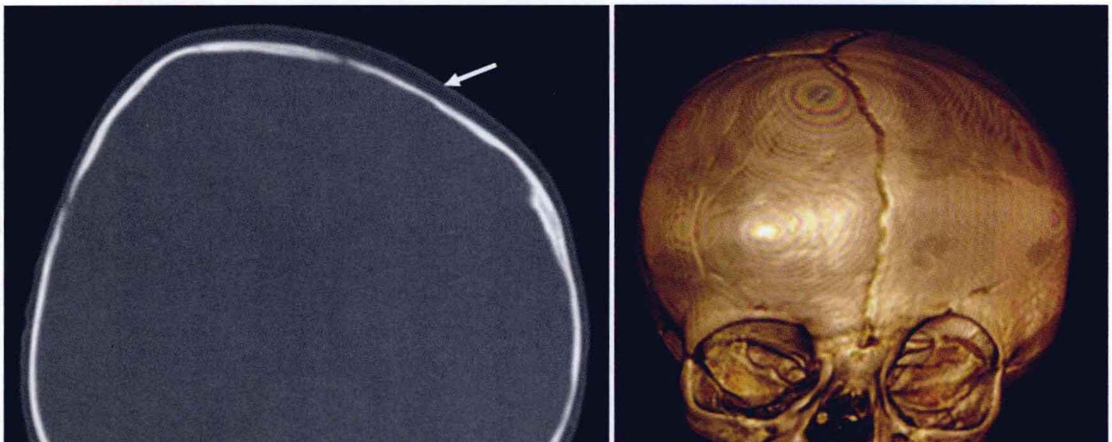

Figure 1-2 Congenital craniofacial malformations are better demonstrated using three-dimensional (3-D) surface-rendered views than routine axial views. Axial **(A)** and 3-D surfaced-rendered **(B)** views of plagiocephaly in a neonatal patient.

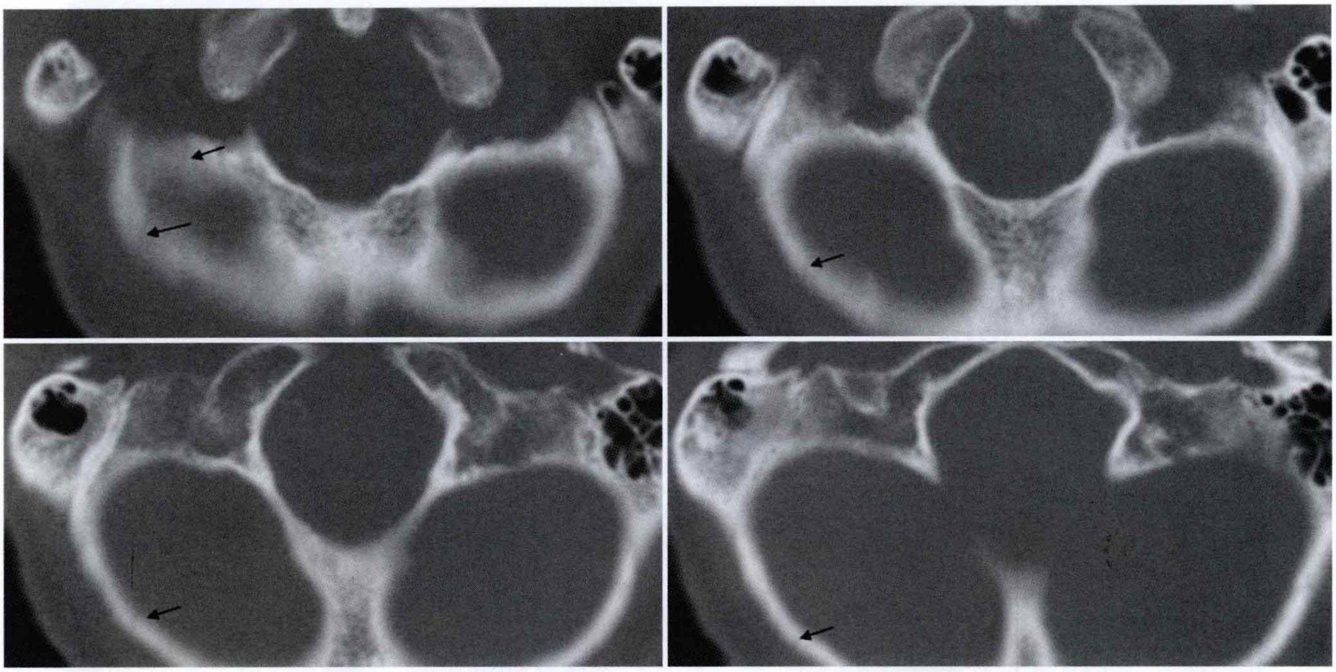

Figure 1-3 Subtle, nondisplaced fracture of the right occipital bone that was not visible on thicker slices. Adjacent subgaleal hematoma overlying the fracture is better seen on the soft tissue windows.

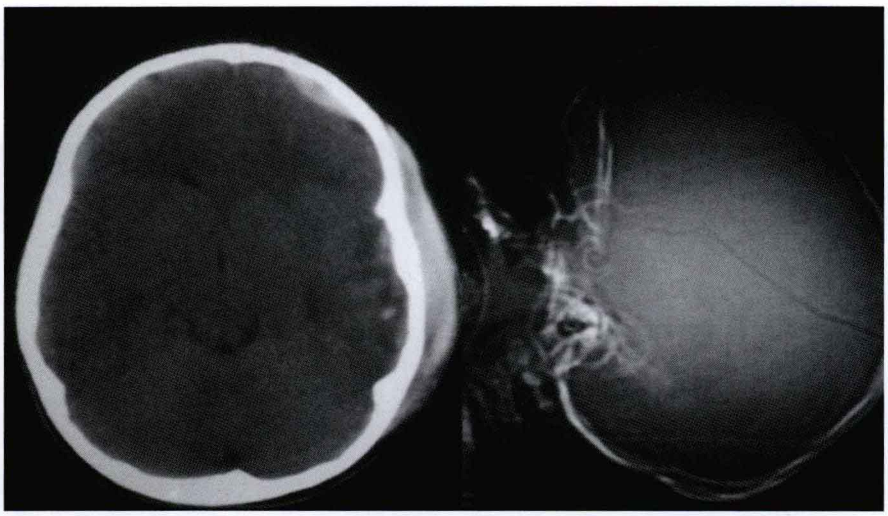

Figure 1-4 Left parietal fracture that is more easily visualized on the scout view.