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Authors
Shen, Peter
Dublin, Arthur
Bobinski, Matthew

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Basic Imaging of Skull Base Trauma

Matthew Bobinski[1] Peter Y. Shen[1] Arthur B. Dublin[1]

[1] Department of Radiology, University of California-Davis School of Medicine, Sacramento, California, United States

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Address for correspondence Matthew Bobinski, MD, PhD, Department of Radiology, University of California-Davis School of Medicine, 4860 Y Street, Suite 3100, Sacramento CA 95817, United States (e-mail: mbobinski@ucdavis.edu).

Abstract

Skull base fractures extend through the floor of the anterior, middle, or posterior cranial fossa. They are frequently associated with complex facial fractures and serious complications such as cranial nerve or vascular injury, cerebrospinal fluid leak, or meningitis. Several distinct patterns of skull base fractures have been recognized, each of them associated with different complications. Recognition of, often subtle, skull base fracture is essential to prevent or allow early treatment of these serious complications.

Keywords
- skull base
- trauma
- cerebrospinal fluid leak
- facial fracture

Introduction

Skull base fractures extend through the floor of the anterior, middle, and posterior cranial fossa and usually result from high-velocity blunt impact trauma such as motor vehicle collision, sport accidents (skiing, biking), and less frequently falls or assault. These injuries are frequently associated with facial fractures as well and their incidence with the number of facial fractures is: one facial fracture (21.0%), two facial fractures (30.4%), and three or more facial fractures (33.3%).[1] Temporal bone fractures are associated with 18 to 40% and frontal sinus fractures with 15 to 20% of complex skull base injuries.[2]

Anterior Cranial Fossa Fractures

Anterior skull base fractures frequently accompany severe trauma to the frontal region or midface. These frontobasal injuries lead to significant neurologic morbidity. Three distinct frontobasal fracture patterns have been recognized based on impact site and force.[3] Type I represents isolated linear anterior skull base fractures. They parallel the cribriform plate and extend to separate the anterior and middle fossa from the posterior fossa. Type II fractures are linear fractures of the frontal bone extending to the skull base, often involving the orbital roof, lateral wall, or orbital apex (►**Fig. 1**). Type III fractures are complex fractures that include comminution of the entire frontal bone along with comminution of the orbital roof (►**Fig. 2**).

Type III fractures and impure (mixed) type II fractures are frequently associated with significant complications, mostly cerebrospinal fluid (CSF) leaks and meningitis. They have to be managed carefully, especially if fractures are naso-orbitoethmoid. CSF rhinorrhea complicates 4 to 48% of frontobasal fractures and pneumocephalus is seen 10 to 50%.[4,5] Between 4 and 54% of patients with CSF rhinorrhea develop meningitis, but the risk is related to the duration of the CSF leak.[6–8] Meningitis develops in only 3% of patients if the leak lasts for less than 1 week, but it exceeds 50% if it persists for more than 2 weeks.[6,8]

Middle Cranial Fossa Fractures

The middle cranial fossa is frequently divided into the central skull base and lateral skull base. The former includes the sella and parasellar cavernous sinuses. The latter is composed of temporal bone including its petrous and mastoid segments. Most fractures of the central skull base are direct extensions of frontobasal fractures and less frequently fractures of the clivus or posterior cranial fossa. Most of these fractures have either an oblique or sagittal orientation and extend through the sella and sphenoid sinus (►**Fig. 3**).[9,10] An additional and frequently seen type is a transverse fracture orientated in a coronal plane resulting from a direct blow to the lateral skull and zygoma (►**Fig. 4**). Depending on the orientation of an impact, these injuries may be either pure transverse or oblique. All these

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Fig. 1 Type II frontobasal fracture. Axial CT demonstrates a linear fracture (arrow) extending from the lateral aspect of the frontal bone (A) into the cribriform plate (B).

fractures involve the sphenoid sinus and may extend through additional skull base structures. The more anterior fractures may involve the orbital apex, superior orbital fissure, and clinoid processes (►Fig. 5). The more posterior injuries often extend laterally through the temporal bone and also through the clivus.

Fractures of the central skull base, especially those orientated in a coronal plane, are frequently associated with significant cranial nerve and vascular injuries.[11,12] Fractures involving the internal carotid artery (ICA) may result in transection, dissection, aneurysm/pseudoaneurysm, carotid cavernous fistula, or vascular entrapment in the fracture line.[11–13] Similarly, fractures passing through neural foramina or canals may transect, lacerate, or stretch cranial nerves. Fractures extending through the clinoid processes or the superior orbital fissure may result in palsy of cranial nerves III, IV, V1, and VI. Those involving

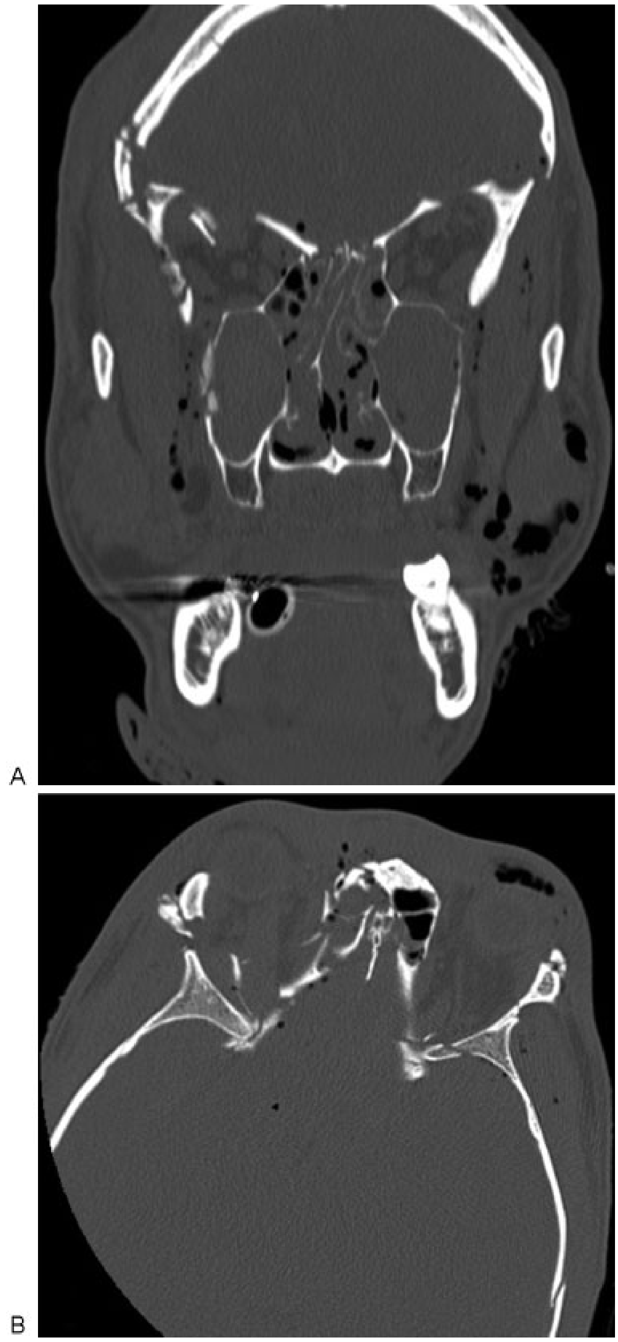

Fig. 2 Type III frontobasal fracture. Coronal (A) and axial (B) images show markedly comminuted and displaced fracture traversing through medial and lateral walls of both orbits with additional involvement of the ethmoid labyrinth and orbital roofs.

the orbital apex can cause impaired or loss of vision. Fractures extending through the cavernous sinus can cause palsy of cranial nerves III, IV, V1, V2 and VI.[14] Involvement of the sella often results in bitemporal hemianopia due to compression of the optic chiasm. Carotid dissection and, less likely fractures of the carotid canal, may contribute to a partial Horner syndrome, without anhidrosis, due

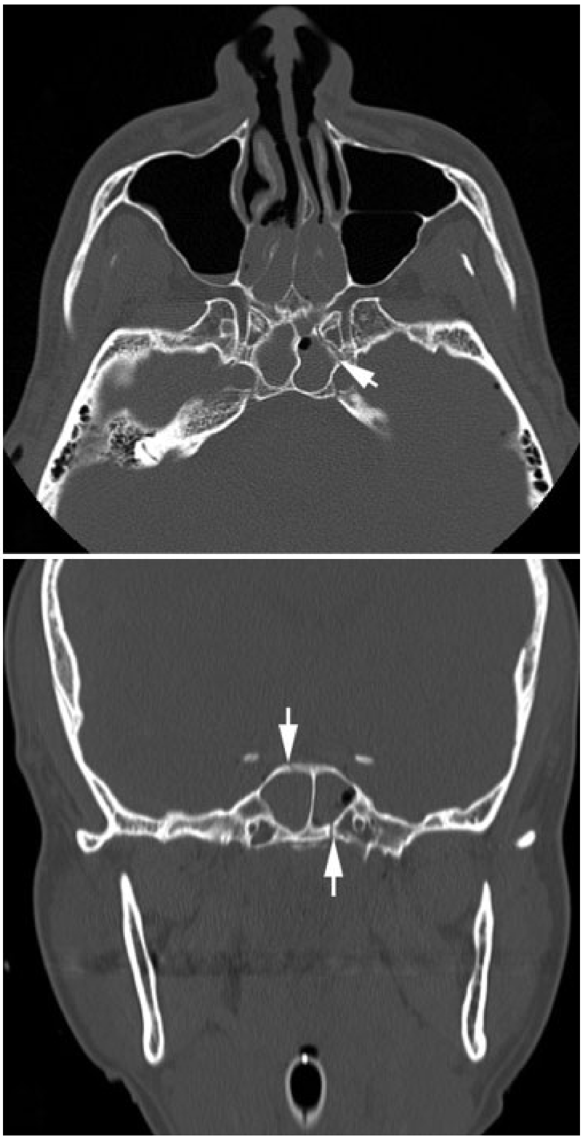

Fig. 3 Axial (A) and coronal (B) CT images demonstrate a linear fracture of the middle cranial fossa involving left carotid canal (arrow; A) and both sphenoid sinuses (arrows; B).

Fig. 4 Transverse fracture of the clivus in axial (A) and sagittal (B) planes involves the floor of the sella and both carotid canals (arrows).

to injury to sympathetic fibers surrounding the ICA (►**Fig. 6**).[15,16]

Fractures extending through the lateral part of the middle cranial fossa often involve the petrous and mastoid segments of the temporal bone. Ulrich's classification of temporal bone fractures, dividing them into longitudinal and transverse oriented, demonstrated poor clinical correlation mainly because most fractures are mixed in orientation. A new classification divides the temporal bone fractures into otic capsule sparing (91.5% of all temporal bone fractures) and otic capsule violating fractures (8.5%). This classification correlates better with radiologic and clinical signs.[2,17,18] Otic capsule violating fractures have a 5-fold increase in facial nerve injury, 25-fold increase in sensorineural hearing lost, and 8-fold increase in CSF leaks compared with otic capsule spearing fractures (►**Fig. 7**). Fractures that extend through the petrous ridge, and especially tegmen tympani, may be associated with CSF otorrhea and be further complicated by the development of meningitis and traumatic meningocele.[2]

Posterior Cranial Fossa Fractures

Fractures of the posterior fossa are uncommon and usually result from a direct blow to the occiput. They frequently involve the occipital bone and petrous segment of the

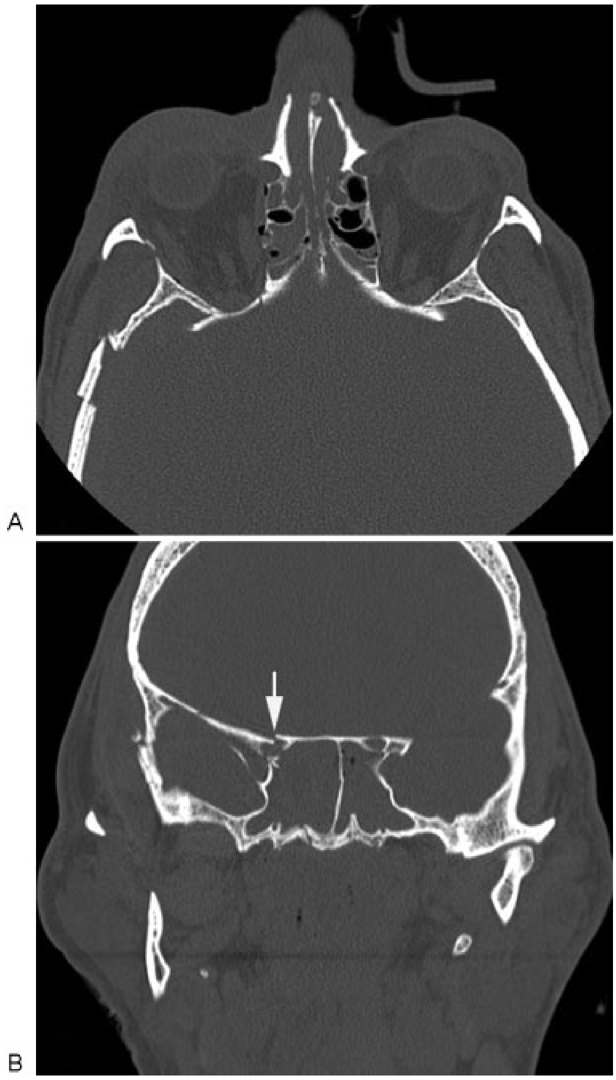

Fig. 5 Mildly displaced fracture extends through the right anterior clinoid and optic canal (arrow) in axial (A) and coronal (B) CT images.

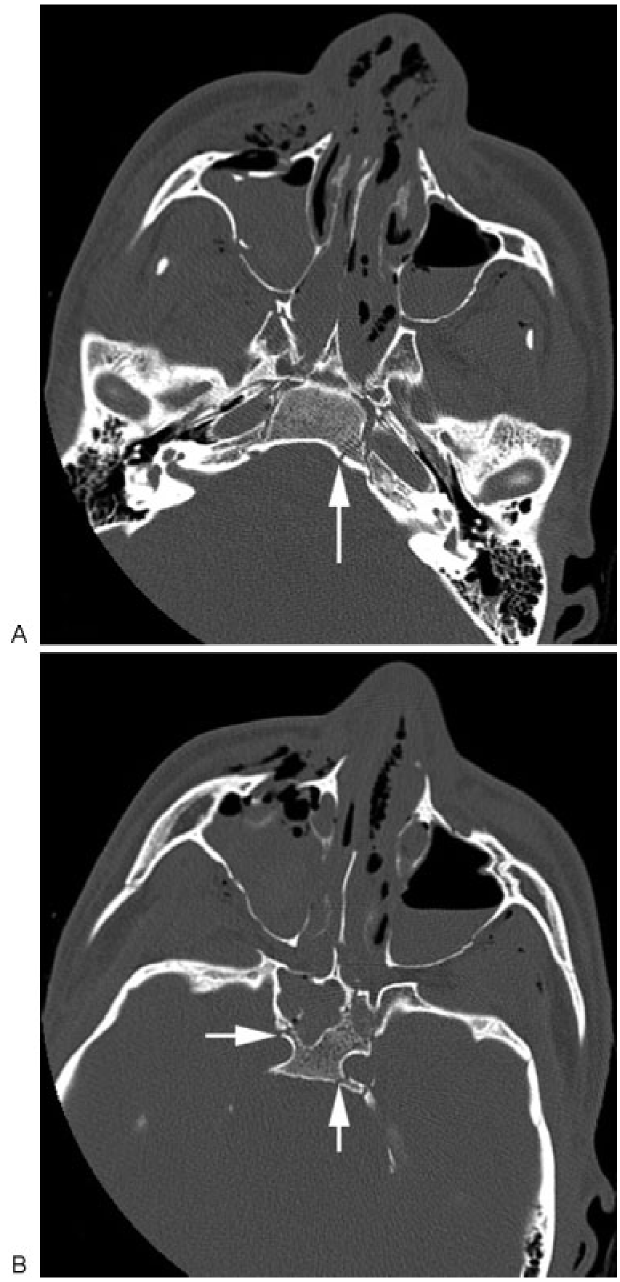

Fig. 6 Axial CT images demonstrate fracture of the middle cranial fossa in a sagittal plane involving the basisphenoid (A; arrow) and both carotid canals (B; arrows).

temporal bone. More severe impact may result in a clival fracture that is associated with high mortality rates (24–80%) due to injury to the basilar artery or brainstem.[19] Depending on the mechanism and direction of an impact, the fracture may extend in either a longitudinal or transverse direction.[19,20] The former is caused by axial loading and is often associated with significant injury to the brainstem and vertebrobasilar system.[21,22] Transverse fractures, on the other hand, are due to direct lateral blow or crushing injury and often result in ICA injury. Most clival fractures present with cranial nerve VI palsy due to involvement of the Dorello's canal.[23]

The most common traumatic lesion of the posterior fossa is epidural hematoma, often venous in origin, due to injury to the dural sinuses of jugular bulb (►**Fig. 8**).[24,25] These hematomas are usually clinically silent with nonspecific symptoms and are often associated with rapid clinical deterioration and a high mortality rate. Interval imaging is a prerequisite.[25] Fractures extending through dural sinuses or the jugular foramen may result in venous thrombosis and lead to hemorrhage or venous infarct[26] (►**Fig. 9**). In addition to venous thrombosis, fractures involving the jugular foramen injure cranial nerves IX, X, and XI and those through the hypoglossal canal damage cranial nerve XII.

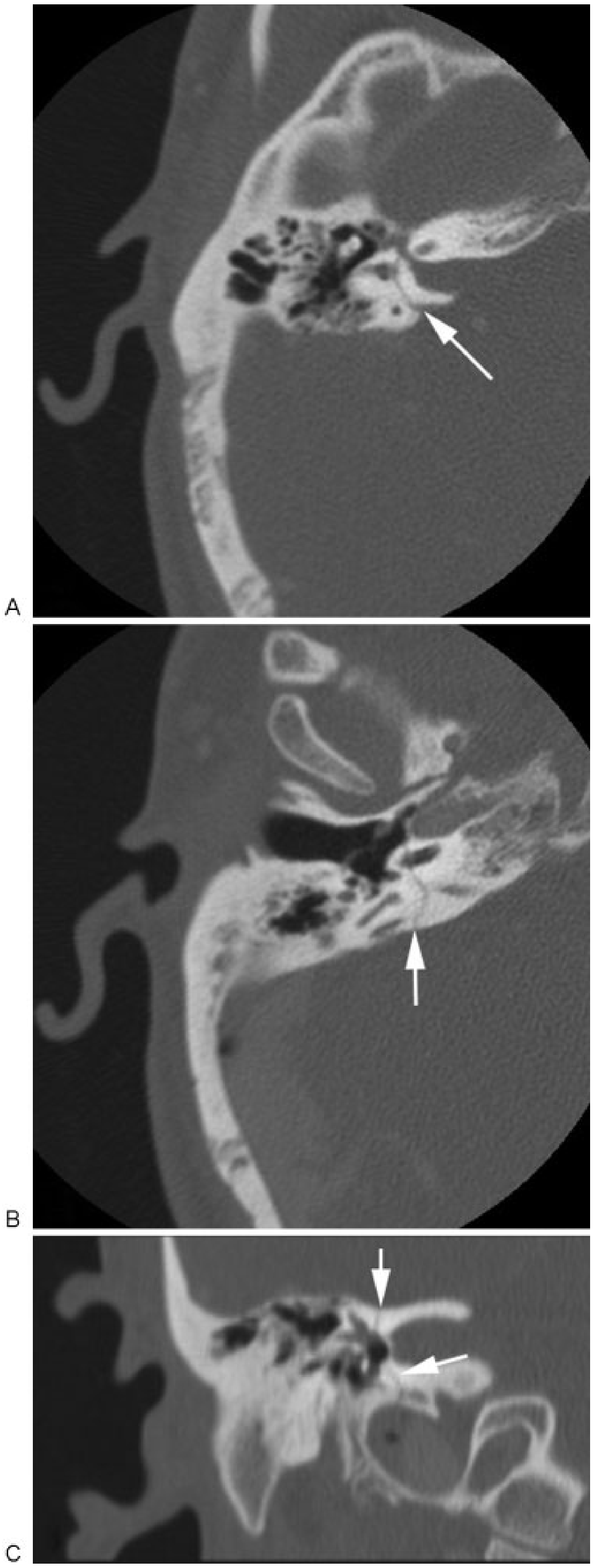

Fig. 7 Otic capsule violating fracture (arrow) in axial (A, B) and coronal planes (C) involving the basal turn of the cochlea (B) and the vestibule (C).

Fig. 8 Axial CT angiogram image demonstrates mildly displaced fracture of the occipital bone (arrow) and epidural hematoma (arrowhead) displacing the right sigmoid sinus medially.

Occipital condyle fractures are important because they may be associated with instability of the occipitoatlantoaxial joint and are invariably caused by high-energy trauma. The most widely used radiologic classification was described by Anderson and Montesano,[27] which divides fractures into three types: type I, comminuted impaction fracture due to axial loading; type II, skull base fracture that extends through the occipital condyle; and type III, avulsion fracture at the attachment of the alar ligament. While types I and II are stable fractures, a type III injury is potentially unstable due to possible disruption of the alar ligaments and tectorial membrane with resulting craniocervical dissociation.[28]

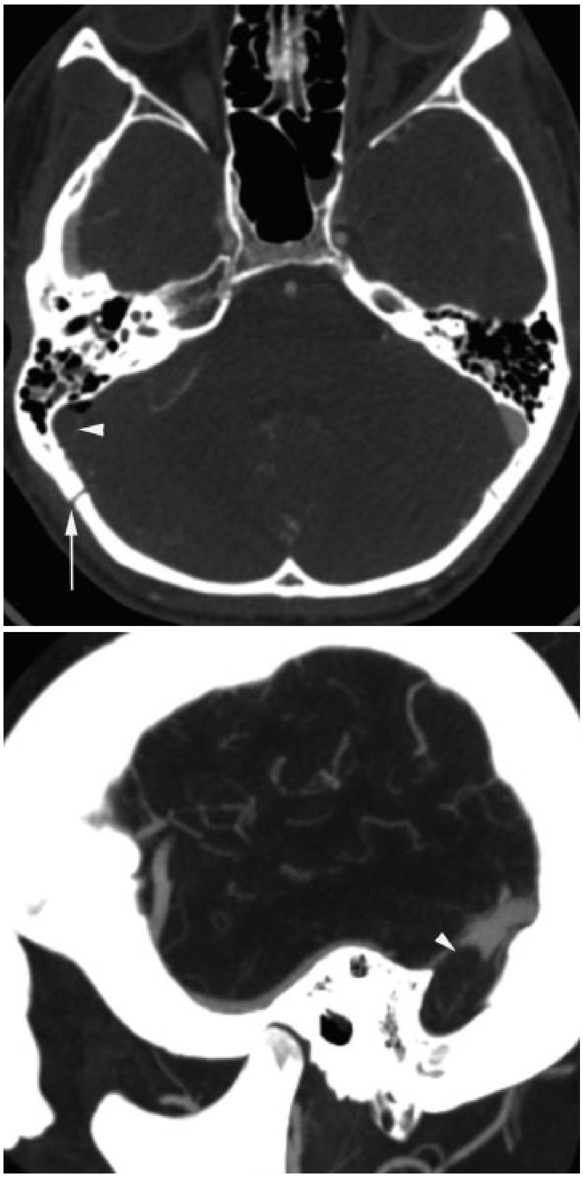

Fig. 9 Axial (A) and sagittal (B) images of the CT venogram that demonstrates an undisplaced fracture of the occipital bone and lack of opacification of the right sigmoid sinus consistent with thrombosis (arrowhead).

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