

# Skull Fractures

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## ETIOPATHOPHYSIOLOGY

- **direct impact to skull** → inbending or outbending of skull beyond its elastic tolerance.
- skull fracture - indicator of severe blow to head (increased chance of intracranial abnormality).  
*presence of fracture is not consistent with history of minor head injury!*
- skull fracture does not necessarily mean that brain is injured (but in many cases it is).

With increasing severity of head injury, likelihood of skull fracture increases; presence of skull fracture increases likelihood of brain injury 4-fold.

- skull fractures are detected in 5% mild head injuries.
- skull fractures are detected in ≈ 30% of all head injuries.

N.B. prognosis depends more on *BRAIN* damage than on *SKULL* injury!

Generated forces:

- walking into fixed obstruction (73 N force – enough to fracture skull!).
- 4.5-kg adult head falling 1 m on hard surface (510 N).
- falling from standing position (873 N).
- running into obstruction (1020 N).
- 10 times more force is required to fracture skull with overlying scalp than to fracture one without scalp cover.
- *skull thickness is not uniform* - force required to cause fracture depends on site of impact:
  - skull vault\*** is thinner than skull base (weakest parts of skull base → see *below*); skull vault diploë does not form (bone is thin) where skull is **covered with muscles\*** (esp. squamous temporal and parietal bones);
  - skull is thick - glabella, external occipital protuberance, mastoid processes, external angular process.

\*prone to fracture.

## CLASSIFICATION, CLINICAL FEATURES

Fracture type depends on **impact force** and **ratio of impact force to impact area**.

Communication with outside:

- CLOSED**
- OPEN (COMPOUND)** - torn pericranial tissues; patient is likely to have **severe brain damage**.
  - fracture that disrupts *paranasal sinuses* or *middle ear* is also considered open.

Location:

- Vault**
- Basilar**

Fracture form:

- Linear** (incl. sutural diastasis)
- Depressed**
- Comminuted**

Underlying cerebral substance damage:

- No injury** (UNCOMPLICATED FRACTURE)
- Compression** (by *depressed* fractures)
- Contusion**
- Laceration** (by *depressed* fractures)

### 1. **Linear fracture** (80%) - *single fracture line goes through entire skull thickness; no displacement.*

- **etiology** - low-energy blunt trauma over wide surface area of skull.
- starts at point of maximum impact → extends toward skull base.
- with multiple points of impact or repeated blows, fracture lines of subsequent injuries do not extend across prior fracture lines.
- when individual falls while awake → occipital impact; fall that follows loss of consciousness → frontal impact.
- **clinically** - just tender bump on head; skin may or may not be breached\* (most patients are asymptomatic, without loss of consciousness - it is often difficult to predict presence of skull fracture by clinical examination).  
\*scalp is mobile → possible nonalignment of fracture with scalp laceration
- **little significance** (except when runs over arterial groove, venous sinus groove, or suture → epidural hematoma, venous sinus thrombosis, sutural diastasis). *see below (COMPLICATIONS)*

**SUTURAL DIASTASIS (s. DIASTATIC FRACTURE)** - traumatic disruption of cranial suture.

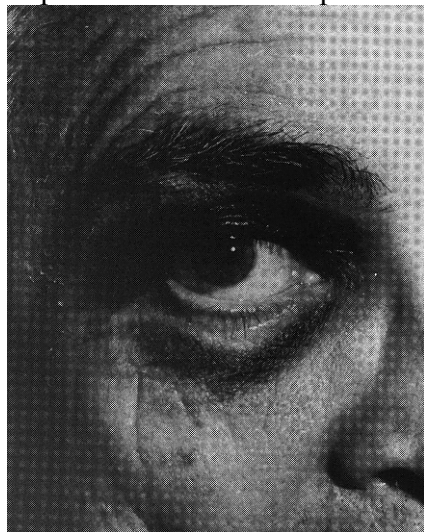
- usually occurs **when linear fracture extends into suture line**.
- usually affect infants (suture fusion has not yet happened); rare after sutures have undergone bony fusion.
- often involves *coronal* or *lamboid* sutures.

### 2. **Basilar fracture** (19-21%) - *linear fractures at skull base* (often are extensions of adjacent convexity fractures).

- basilar bones are thick – much more force required to fracture them!
- most basilar fractures occur at **specific locations**:
  - 1) most commonly (75%) - **temporal bone**. *see below*
  - 2) **occipital condylar region** (foramen magnum). *see below*
  - 3) along inner parts of sphenoid wings, sphenoid sinus, toward sella turcica and cribriform plate, roof of orbits.
  - 4) areas between mastoid and dural sinuses in posterior cranial fossa.  
N.B. **middle cranial fossa** is weakest part (thinnest + multiple foramina)
- **etiology** - impact to **occiput** or **sides of head** (rather than blow to vertex).
- difficult to detect at postmortem examination (require careful removal of tightly adherent dura).
- often associated with dural tears.
- **clinically**: ecchymoses (periorbital / retroauricular) distant from point of impact, cranial nerve palsies, CSF leaks, pneumocephalus, cavernous-carotid fistula. *see below (COMPLICATIONS)*

**ANTERIOR FOSSA:**

- 1) **periorbital ecchymosis** limited at edge of orbit ("raccoon eyes") - blood dissecting from disrupted skull cortex into periorbital soft tissue:

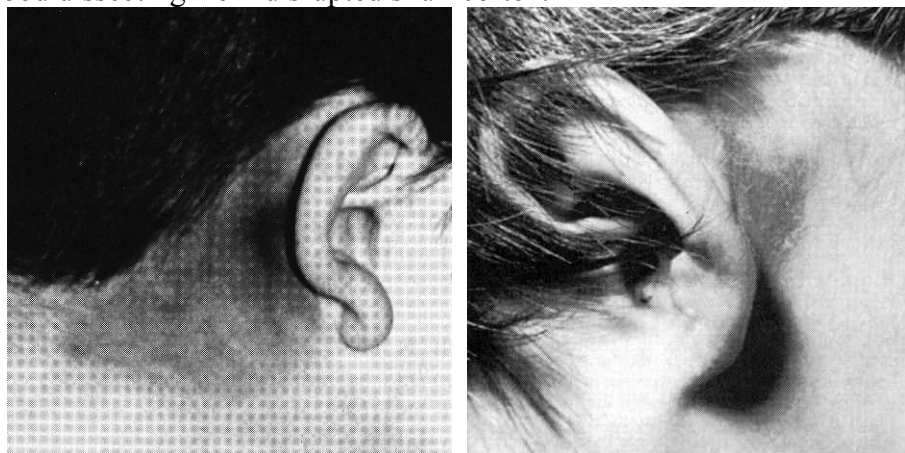


- 2) **CSF rhinorrhea** - CSF leak through cribriform plate or adjacent sinus.
- 3) **CN 1-2 damage**.

**MIDDLE FOSSA:**

**PETROUS PORTION OF TEMPORAL BONE:**

- 1) **retroauricular ecchymosis** - delayed ecchymosis over mastoid process (**Battle sign**) - blood dissecting from disrupted skull cortex:



- 2) **CSF otorrhea**.
- 3) **blood in ear canal** (more commonly due to local laceration of external canal)
- 4) **hemotympanum** (blood ± CSF behind tympanic membrane).
- 5) **CN7 palsy, hearing loss, vertigo**. see below (**TEMPORAL BONE FRACTURES**)

**SPHENOID, SELLAR FRACTURES:**

- 1) **air-fluid level** in sphenoid sinus
- 2) **CN2, 6-7 palsies**
- 3) **neuroendocrine dysfunction**.
- 4) **ICA pseudoaneurysms, carotico-cavernous fistulas**.

**POSTERIOR FOSSA:**

**CLIVUS FRACTURE** – **CN6 palsy, ganglion trigeminale lesion**.

**OCCIPITAL CONDYLAR FRACTURES** – **CN9-12 palsy**. see below (**OCCIPITAL CONDYLAR FRACTURES**)

3. **Depressed fracture (s. impressed fracture)** - **bony piece is driven** by direct traumatic impact\* **below plane of skull**.

\*usually small blunt objects (such as hammer or baseball bat)

- 75% frontoparietal (may involve frontal sinuses and orbits), ≈ 10% temporal, 5% occipital.
- most (75-90%) depressed fractures are open fractures.
- edges of depressed portion may become locked underneath adjacent intact bone and fail to rebound into previous position.
- in gunshot cases, bullet exit causes **EXPRESSED FRACTURE**.
- **clinically** – **depression** under generalized swelling (avoid driving bone fragment deeper!), depressed area may be several centimeters away (due to scalp mobility); **focal seizures** (from contusion underlying fracture).

**PING-PONG FRACTURES** (akin to greenstick fracture of long bones)

- occur in first few months of life.
- **etiology**:
  - 1) fall when skull hits edge of hard blunt object.
  - 2) birth trauma (newborn head was impinged against mother's sacral promontory during uterine contractions).
  - 3) birth trauma with forceps (rare).
- **clinically** - skull appears deformed, with shallow trench on skull surface.

4. **Comminuted fracture** - **multiple linear fractures** that radiate from impact site (≥ 2 bone fragments).

- suggests more severe blow (than in single linear fracture).
- portion of bone may be depressed.

**DIAGNOSIS**

Indications for **skull X-ray** → see p. TrH1 >>

- plain radiographs **may miss basal skull (esp. temporal bone) fractures** – only clues may be fluid levels (bleeding or CSF leakage) in sphenoid, frontal sinus or petromastoid air cells.
- **AIR within cranium**:
  - a) extradural - sharply defined, superficial, adjacent to midline or fractured sinus;
  - b) subdural - very extensive;
  - c) subarachnoid - diffuse air, in bubbles, or outlining brain;
  - d) within damaged brain;
  - e) intraventricular (can cause acute hydrocephalus).

X-ray differences between **linear fractures**, **normal sutures**, and **normal vascular markings**:

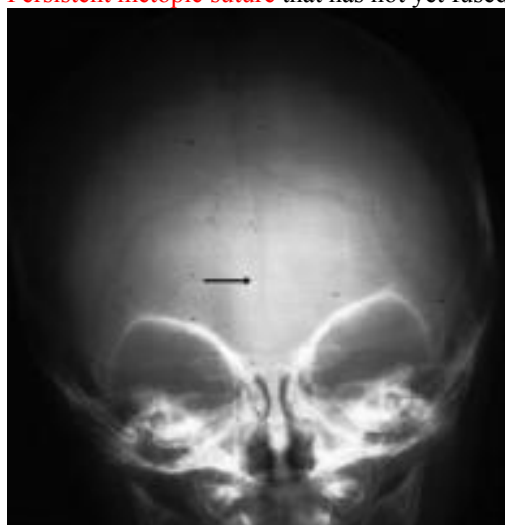
Fractures	Sutures	Vascular markings
– width > 3 mm.	– width < 2 mm.	– engrave inner table only.
– widest at center and narrow at ends.	– same width throughout.	– less translucent than fractures.
– runs through both outer and inner lamina of bone, hence appears darker.	– lighter on X-rays compared with fracture lines.	– ill-defined margins.
– usually over temporoparietal area.	– at specific anatomic sites.	– meningeal grooves taper as they run peripherally.
– runs in straight line with angular turns (sudden change in direction).	– does not run in straight line.	– symmetrical branching pattern.
– translucent line with sharp margins.	– curvaceous (serpiginous).	– diploic venous markings are wide.
	– symmetrical well-corticated sclerotic margins.	
	– symmetric suture line on opposite side.	

Skull fracture is indication for **CT!**

- CT with wide windows (1000-4000 HU) are needed to evaluate skull injuries.
- degree of skull depression is easily measured on CT.
- **CT may miss:**
  - 1) **small vertex fractures** (often, small streak artifact caused by misaligned fracture may be clue).
  - 2) **basilar skull fractures** (clues – pneumocephalus, air-fluid level in sphenoid sinus).

**MRI** easily misses skull fractures (low sensitivity and specificity)!

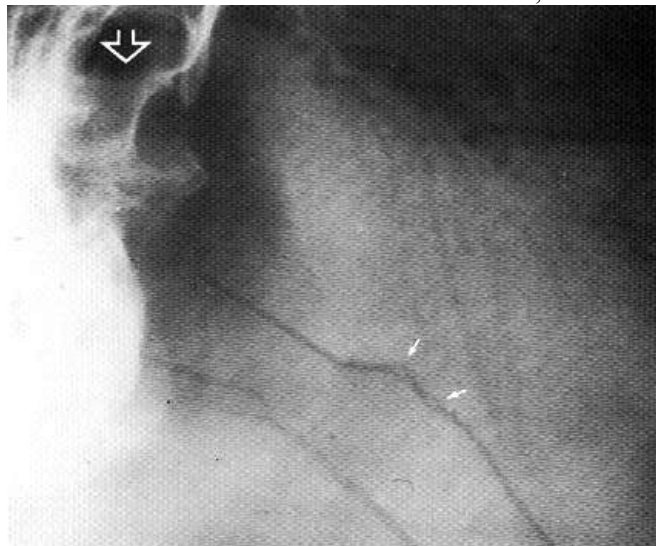
**Persistent metopic suture** that has not yet fused; this is not fracture:



**Importance of straight patient position for lateral imaging.** Because patient is slightly malpositioned, both coronal sutures are seen as separate entities (also applies to lambdoid sutures); because they are separated - could be mistaken for fracture:



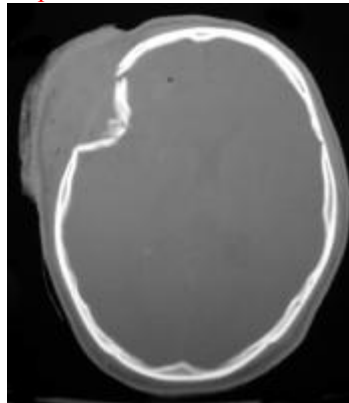
**Bilateral vault fracture** - fluid level in sphenoid sinus (open arrow); two fracture lines - more anterior (upper on this film) is better defined and is therefore on side nearer film; bone islands (small arrows) are typical:



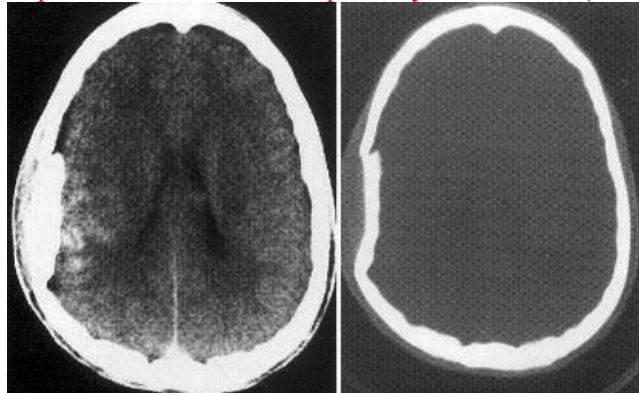
Lateral CT scanogram and axial bone-window CT - **ping-pong ball temporal fracture** - slight inward bulging of bone, but inner and outer tables are intact:



**Depressed skull fracture:**

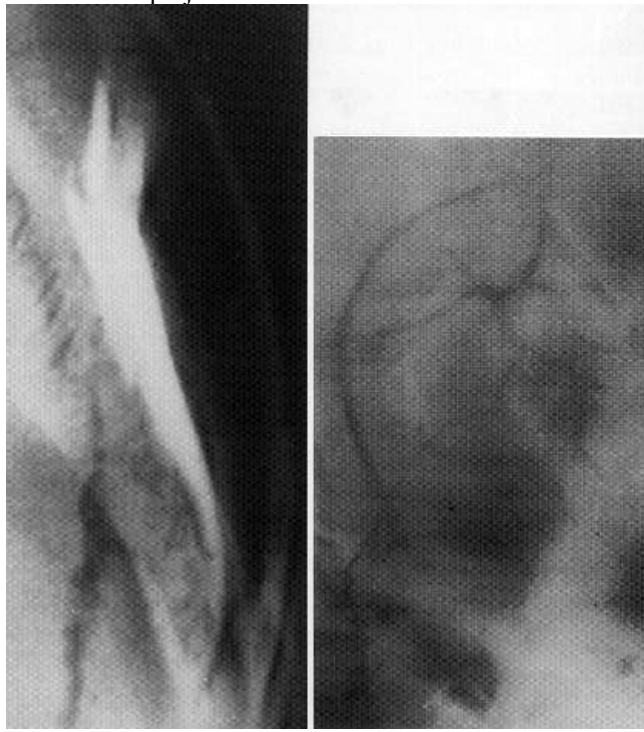


**Depressed skull fracture** with **parenchymal contusion** (CT 'brain and bone windows'):



**Stellate depressed fracture:**

- A. Lateral projection: typical appearance of dense flake deep to skull vault.  
 B. Half axial projection.



## TREATMENT

Prehospital management → see p. TrH1 >>

N.B. 15% patients with skull fractures have concomitant **cervical spine injury!**

**Linear fracture** – no special therapy.

- in *children*, skull fractures heal within 3-6 months; in *adults*, complete healing may take up to 3 years.

**Basilar fractures** – treat only complications (CSF leak, etc).

**Open fractures:**

- 1) **tetanus** toxoid vaccination
- 2) **antibiotic** prophylaxis for 5-10 days (only for obviously contaminated cases), e.g. **SULFISOXAZOLE**.
- 3) irrigation and **debridement**.
- 4) **CT** few times over next 2-3 months (to check for abscess formation).

**Depressed fractures**

1. Prophylactic **anticonvulsants**.
2. Most depressed fractures heal well and smooth out with time, without elevation; **surgical elevation** indicated:
  - a) **depth of depression thicker than calvaria** [i.e. > 3-10 mm inward displacement].
  - b) **focal neurologic deficit** (but focal deficits are caused by brain parenchyma damage more than by continuing compression by bone fragments; i.e. compression relief does not guarantee deficit disappearance).  
*depressed fracture over venous sinus: neurologically stable patient → observe (or primary wound debridement without elevation); neurologically unstable patient → urgent elevation.*
  - c) **cosmetic defect** (FRONTAL BONE is most important esthetically + it forms roof and portions of medial and lateral walls of orbit).
  - d) **open contaminated** fracture.
  - no proof that elevation of depressed fragments decreases epilepsy risk.
  - elevation of small depressed fractures need not be performed immediately (but before discharge); indications for immediate elevation: gross contamination, dural tear with pneumocephalus, underlying hematoma.
  - surgery details:
    - **lazy "S"** or **horseshoe**-shaped incision over depression; bicoronal incision is preferred for forehead depressions; in open fractures, scalp wound is incorporated into incision.
    - burr hole near impression → bony fragments are elevated → soaked in antibiotic and isotonic saline solution (if wound seems clean and occurred in < 48 hours).
    - dural tears are repaired.
    - bony fragments are reassembled (larger pieces may be wired together); **titanium mesh** is applied to cover larger skull defects; **methyl methacrylate** can be used as substitute for bone fragments (avoid in children; H: **absorbable bone plates and screws**).

## COMPLICATIONS

Skull fracture per se does not indicate trauma severity.

**Skull fracture importance** – risk of **intracranial infection and bleeding!**

**Clinically significant skull fractures** (prone to complications):

- 1) **extend into air sinuses** → infection.
- 2) **basal** → CSF leaks (→ infection), cranial nerve / vascular injuries.
- 3) **open** → infection.
- 4) **depressed** below level of inner table → underlying brain injury → posttraumatic epilepsy.
- 5) **overlie major dural venous sinus / middle meningeal artery** → bleeding.
- 6) linear fractures associated with **dural tear in young children** → leptomeningeal cyst.

N.B. basilar fractures are most serious - deserve closer monitoring than linear vault fractures!

**Bleeding**

- infants may bleed significantly intracranially from skull fractures (skull is very vascular – any fracture may cause venous epidural hematoma); check hematocrit q 12-24 h.
- **EPIDURAL HEMATOMA** is associated with skull fracture in ≈ 50% cases.
- **SUBDURAL HEMATOMA** is associated with skull fracture in ≈ 33% cases.

**Pneumocephalus** see p. TrH1 >>

**CSF leaks** - otorrhea and rhinorrhea (after **basilar skull fractures**). see p. S64 >>

**Meningitis** (via wound or CSF fistula); may extend into brain abscess.

**Cranial nerve palsies** (after **basilar skull fractures**). see p. TrH1 >>

**Posttraumatic epilepsy** (after **depressed skull fractures**) – risk factors: loss of consciousness for > 2 hours, associated dural tear, early seizures (within first week).

**Carotid-cavernous fistula** (after **sphenoid bone fracture**) see p. TrH9 >>

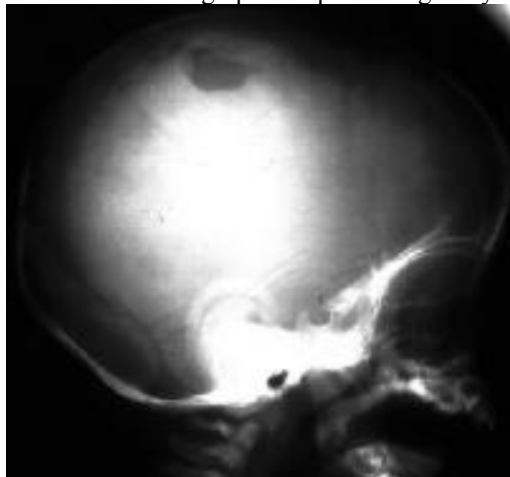
**Traumatic aneurysms** (e.g. after **sphenoid bone fracture**) see p. TrH1 >>

**Superior longitudinal sinus compression** (by depressed vertex fractures) → thrombosis.

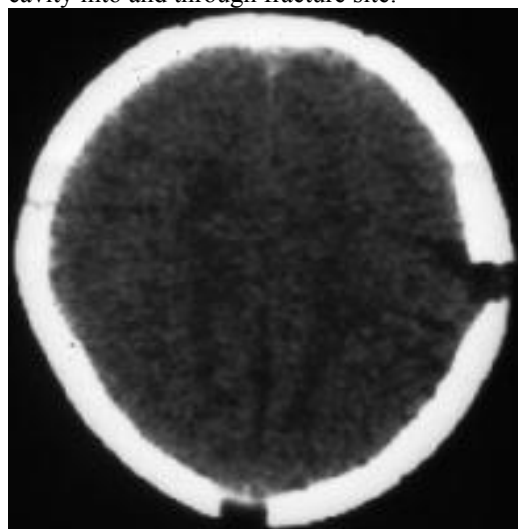
**Leptomeningeal cyst (s. growing fracture)** – extrusion (in form of cyst) of leptomeninges and brain tissue through dural defect.

- **etiopathology:** *skull fracture with separation of fracture edges* [depressed or diastatic skull fracture] **and dura laceration** → arachnoid and brain are caught between edges of fracture → brain pulsation forces CSF into cyst → skull erosion.  
N.B. seen almost exclusively in children < 3 yrs – such children with dural tear must be followed up closely for several months!!!
- most are located in calvarium (rare sites are basiocciput and orbital roof).
- underlying brain may herniate through skull defect.
- prominent porencephalic cyst or focal dilatation of lateral ventricle usually underlies fracture.
- **types:**  
Type I - leptomeningeal cyst herniating through skull defect into subgaleal space.  
Type II - damaged or gliotic brain.  
Type III - porencephalic cyst is seen.
- **clinically** (manifests several weeks ÷ months after fracture):  
1) **growing subgaleal mass** (slowly expanding pulsatile nontender swelling in area of previous skull fracture)  
2) convulsive **seizures** or **focal neurologic deficit**  
3) **mental retardation**  
4) **mass effect** with increased ICP.
- **diagnosis:** serial **X-ray** (sufficient for diagnosis\*) – enlarging **oval area of skull erosion** (progressive separation of long edges of seemingly benign linear skull fracture).  
\*but **CT** better defines exact pathology; intracranial hypoattenuating area may be encephalomalacia, arachnoid loculation, or cortical atrophy.
- tools for early diagnosis (→ early simpler surgical intervention → prevented long-term neurologic sequelae):  
1) **MRI** - depicts dural tears early.  
2) **ultrasound** (tool for assessing state of dura).
- **treatment:** **cyst excision** → **dural closure** → **cranioplasty**.  
– occasionally, shunt surgery is performed to decompress cyst and treat localized dilatation of ventricles.

Lateral skull radiograph of leptomeningeal cyst:



Axial CT of leptomeningeal cyst: widened fracture on left and fluid collection extending from intracranial cavity into and through fracture site:



**Dislocation of bones of auricular chain** (after *temporal bone fracture*). see below

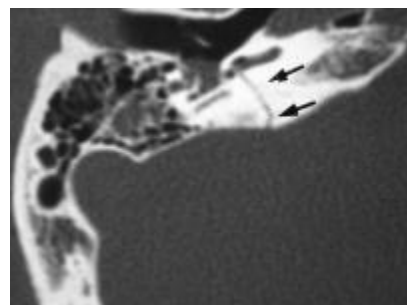
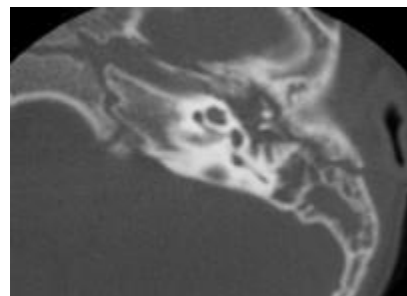
## SPECIAL SITUATIONS

### TEMPORAL BONE FRACTURES

- fractured in 15-48% of all skull fractures (75% of all skull base fractures).
- **clinical features:** Battle's sign, bleeding from ear (hemotympanum or from fracture line in ear canal), CN7 & 8 damage, ossicular chain & tympanic disruption, CSF otorrhea.

Subtypes (by Ulrich, 1926)

1. **Longitudinal** (70-90%) - parallel to petrous pyramid:
  - pars squamosa, posterosuperior wall of external auditory canal, tegmen tympani → **run either anterior or posterior to cochlea and labyrinthine capsule** → end in middle cranial fossa near foramen spinosum or in mastoid air cells, respectively.
  - caused by direct lateral force over mastoid or squamous bone or blow to mandible.
2. **Transverse** (5-30%) - perpendicular to petrous pyramid:
  - originate at foramen magnum → **extend through cochlea and labyrinth** → end in middle cranial fossa.
  - caused by frontal or parietal blow but may result from occipital blow.
  - pneumolabyrinth may be sign.
3. **MIXED** - components of both **LONGITUDINAL** and **TRANSVERSE** fractures.



**Complications:**

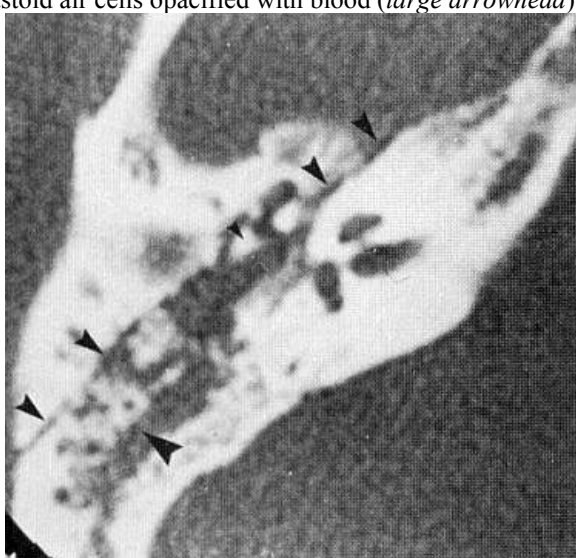
- 1) **facial nerve paralysis** (twice more common with transverse fracture):
  - a) **delayed-incomplete** – due to **neurapraxia** (10-20% longitudinal fractures); injury site is usually horizontal segment distal to geniculate ganglion; H: steroids.
  - b) **immediate-complete** – due to **nerve transection** (50% transverse fractures); injury site is anywhere from internal auditory canal to horizontal segment distal to geniculate ganglion; decompression surgery is not always indicated (use electroneuronography [ENOG] in decision making).
- 2) **hearing loss** (hemotympanum and mucosal edema in middle ear may cause temporary deafness - resolves within ≈ 3 weeks):
  - a) **conductive hearing loss** due to **hemotympanum**, **ossicular dislocation / fracture** or **tympanic rupture** (≈ 50% longitudinal fractures);
    - **incus** (relatively loose ligamentous attachments) is most frequently dislocated ossicle.
    - most tympanic membrane perforations and hemotympanum usually resolve in 3-4 weeks.
    - if conductive hearing loss is present at > 30 dB after 3 months → tympanoplasty with ossicular chain repair.
  - b) **sensory hearing loss** (≈ 80% transverse fractures); H: cochlear implants.
- 3) **vertigo** due to:
  - a) **fracture extending into vestibular apparatus** (e.g. with transverse fractures).
  - b) **labyrinth concussion** (e.g. with longitudinal fractures).
  - c) development of **perilymphatic fistula** (paroxysmal vertigo with fluctuating or progressive hearing loss); H: exploratory tympanotomy.
  - d) posttraumatic **benign paroxysmal positional vertigo**.

- 4) **CSF otorrhea** (in any subtype of fracture).
- 5) **unusual complications:**
  - **carotid injury.**
  - **CN6 paralysis** (recovery within 6 months is usual).
  - **CN5 damage.**
  - **sigmoid sinus thrombosis.**
  - **posttraumatic cholesteatoma** (can grow undetected for years).
  - **EAGLE syndrome** (classically follows tonsillectomy; fracture of ossified styloid and stylohyoid ligament can cause pressure on ECA or ICA → atypical pain referred to cheek or eye; treatment is surgical).
  - **sympathic cochleolabyrinthitis** (autoimmune inner ear damage - autoantibodies against inner ear proteins [as in polyarteritis nodosa]; H: immunosuppression).

**TRANSVERSE FRACTURES** nearly always produce *facial paralysis*, permanent *hearing loss*, severe ablative *vertigo*.

Diagnosis - high-resolution **CT** (axial and coronal images) with 1-mm slices and magnified views; bone windows alone are necessary.

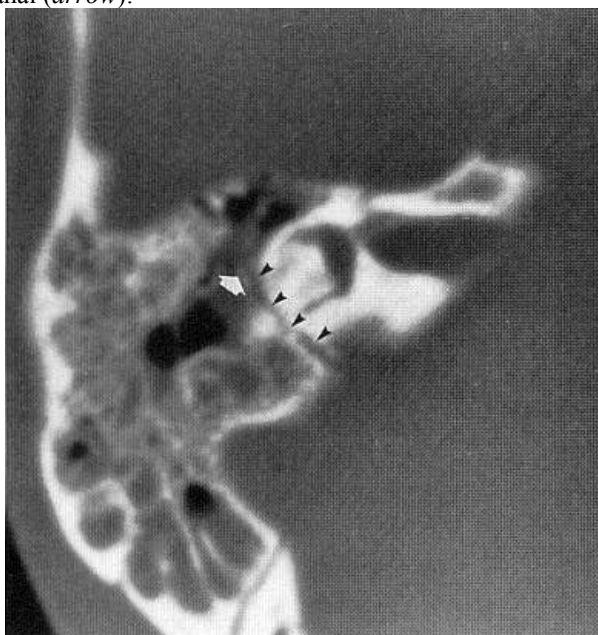
**Longitudinal fracture** of right temporal bone (axial CT) - fracture line follows long axis of temporal bone (medium arrowheads); incus is subluxed laterally (small arrowhead); mastoid air cells opacified with blood (*large arrowhead*):



**Longitudinal fracture** of right temporal bone (axial CT) - fracture line follows long axis of temporal bone (small arrowheads); fracture line is seen to cross area of geniculate ganglion of CN7 (*large arrowhead*):



**Transverse fracture** of temporal bone (axial CT) - fracture line (*arrowheads*) crosses petrous pyramid at level of posterior semicircular canal and posterior genu of CN7 canal (*arrow*):



### OCCIPITAL CONDYLAR FRACTURES

- very rare and serious injury.

**Type I fracture** – **stable\*** comminuted fracture of occipital condyle - due to axial compression injury.

**Type II fracture** – **stable\*** extensive fracture of basioccipital region - caused by direct blow.

\*preserved alar ligament and tectorial membrane.

**Type III fracture** – **unstable** avulsion injury - due to forced rotation and lateral bending.

- most patients are comatose and often have associated cervical spine injuries.

Complications: **CN9-12 palsy** (*Collet-Sicard syndrome*), **CN9-11 palsy** (*Vernet syndrome*).

Radiographically difficult to delineate.

Treatment:

**Types I-II** - neck stabilization with hard (Philadelphia) collar or halo traction.

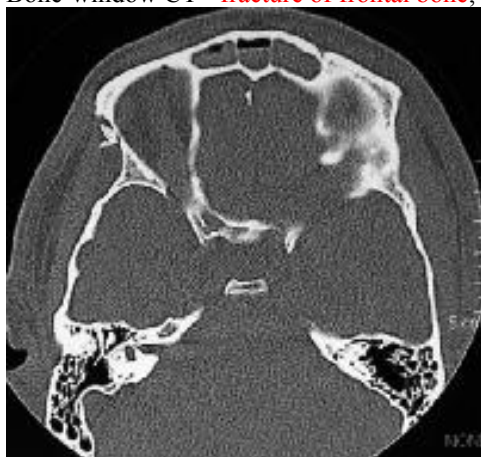
**Type III** - early surgical intervention (**atlantoaxial arthrodesis** with inside-outside fixation).

### FRONTAL FRACTURES that extend into paranasal sinuses

- treated as "open fractures" (because of communication with paranasal sinuses).

- usually back wall of frontal sinus is fractured.
- treatment:
  - open adequate scalp flap → craniectomy or craniotomy.
  - take cultures.
  - sinus is exenterated and occluded with muscle, fat, or Gelfoam soaked in antibiotic solution.
  - lacerated dura (thin in this region!) is closed or grafted with periosteum or fascia; graft may be performed on outer surface of dura, but it is frequently easier to perform it from inner surface after dura has been opened and frontal lobe retracted.
  - it may be necessary to ligate anterior extent of sagittal sinus if it has been injured.

Bone-window CT - **fracture of frontal bone**; fluid level in frontal sinus (clotted blood is layering out):



BIBLIOGRAPHY for ch. "Head Trauma" → follow this [LINK](#) >>

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Viktor's Notes<sup>SM</sup> for the Neurosurgery Resident  
Please visit website at [www.NeurosurgeryResident.net](http://www.NeurosurgeryResident.net)