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Radiological Perspectives on Emergency Head Trauma

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ASM Neuroradiology Head and Neck XXI

Makassar, 22-24 May 2025

OUTLINE

1. Definition
2. Imaging Modalities
3. Specific Skull Fractures
4. Intracranial Hemorrhage
5. Diffuse Axonal Injury
6. Take Home Message

Definition Head Trauma

Head trauma or head injury or traumatic brain injury (TBI):
→ any injury that results in trauma to the skull or brain.

Epidemiology of Traumatic Brain Injury

- In 2021: 20.8–27.16 million new TBI cases worldwide

Causes of Head trauma:

1. **Falls**: Leading cause, especially in children and older adults.
2. **Motor vehicle accidents**: High-impact collisions causing rapid acceleration/deceleration injuries.
3. **Assaults**: Blunt-force trauma or shaking (e.g., shaken baby syndrome).
4. **Sports injuries**: Contact sports (football, boxing) and recreational activities (cycling, skateboarding).
5. **Explosions**: Blast waves causing diffuse axonal injury (DAI) or hemorrhage

Yan et al. Global, regional, and national burdens of traumatic brain injury from 1990 to 2021.
Front. Public Health. Sec. Injury Prevention and Control 2025, 13.| doi: 10.3389/fpubh.2025.1556147

HEAD TRAUMA OR TRAUMATIC BRAIN INJURY

Primary Injury

Causes:

1. Contact → object collides with head or brain collides with the inside of the skull.

2. Acceleration and deceleration → unstopped head movement induces shear, tensile, and compressive strains

- Outcome:

1. Bone fractures
2. Intracranial hemorrhage
3. Vascular injury
4. Damage to cranial nerves & pituitary stalk.

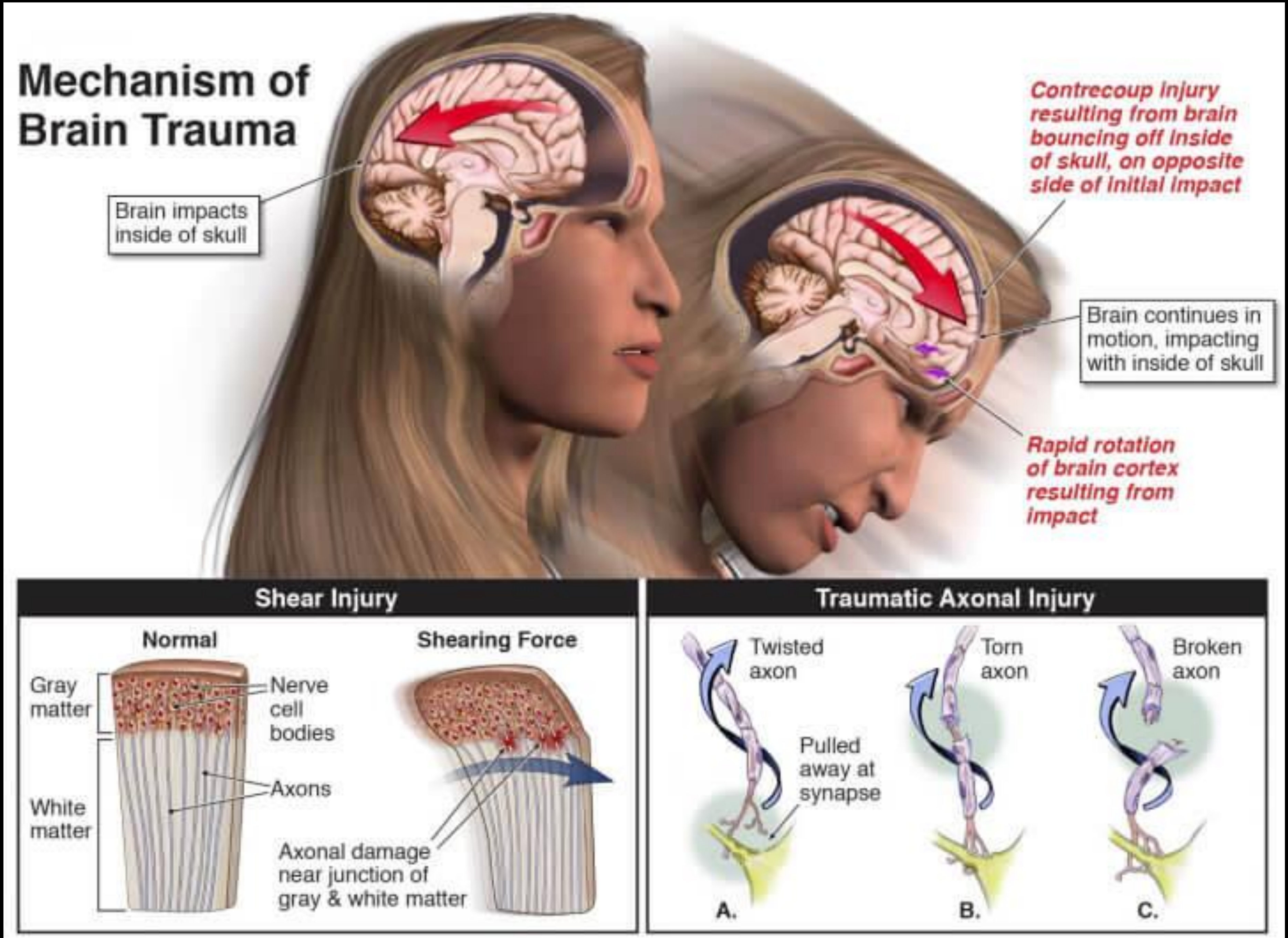
Secondary Injury

- After the initial hit and may add harm.

- Affecting:

1. Cerebral blood flow (hyper or hypoperfusion)
2. Reduced cerebrovascular autoregulation
3. Cerebral metabolic dysfunction
4. Impaired cerebral oxygenation.
5. Ischemia and edema.

Ravooru et al. Role of Imaging in Craniocerebral Trauma. A Narrative Review. *SBV Journal of Basic, Clinical and Applied Health Science 2022, 5(3*| *DOI:* 10.5005/jp-journals-10082-03158



Mechanism of Brain Trauma
Brain impacts inside of skull
Contrecoup injury resulting from brain bouncing off inside of skull, on opposite side of initial impact
Brain continues in motion, impacting with inside of skull
Rapid rotation of brain cortex resulting from impact
Shear Injury
Normal
Shearing Force
Gray matter
Nerve cell bodies
Axons
White matter
Axonal damage near junction of gray & white matter
Traumatic Axonal Injury
Twisted axon
Torn axon
Broken axon
Pulled away at synapse
A.
B.
C.

Types of Head Trauma

- Concussion: A mild form of TBI → cause temporary disruption in brain function.
- Cerebral Contusion: Bruising of the brain tissue.
- Penetrating Head Injury: An object pierces the skull and enters the brain.
- Skull Fractures: Breaks in the skull bone, which can be linear or depressed.

Imaging Modalities Overview

- CT Scan: First-line for acute trauma (speed, accessibility, fracture/hemorrhage detection)
- MRI: Superior for subtle injuries (e.g., diffuse axonal injury) but limited in acute settings
- X-ray: Limited utility; replaced by CT for skull fractures

Comparison CT vs MRI in Acute Head Trauma

Feature	CT	MRI
Speed	Seconds/minutes (emergency priority)	15–30 minutes (delayed utility)
Bone/Fractures	Superior (95% sensitivity)	Poor (misses 30–50% of fractures)
DAI/Subtle Injuries	Low sensitivity (e.g., 11% for DAI)	Superior (47% DAI detection)
Acute Hemorrhage	Hyperdense blood (immediate detection)	Variable signal (SWI/FLAIR for microbleeds)
Contusions	36% detection	57% detection
Subdural Hematoma	Detects 42% (vs. 58% on MRI)	Superior (small collections missed on CT)
Sensitivity Overall	63.4%	96.4% (acute trauma)

Types of Skull Fractures

1. Linear Fractures: Most common; CT detects discontinuity in bone.

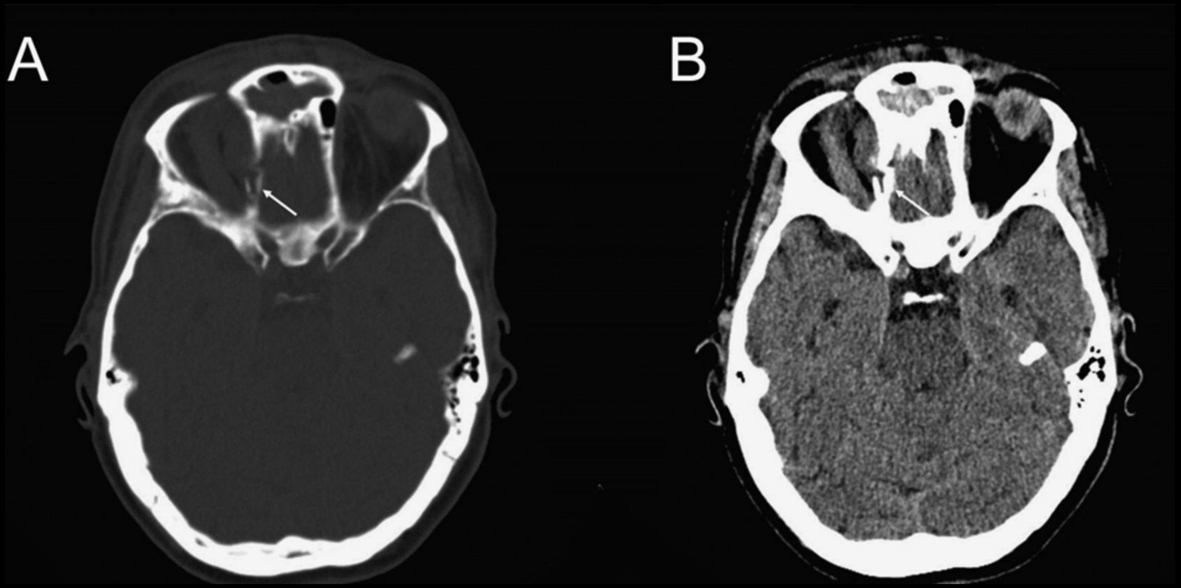
2. Depressed Fractures: Bone fragments displaced inward.

3. Basilar Fractures: Involve skull base; look for "raccoon eyes" or Battle’s sign.

4. Diastatic Fractures: Widened sutures (common in pediatric cases).

Specific Skull Fractures

1. Basilar Fracture



Comminuted fracture

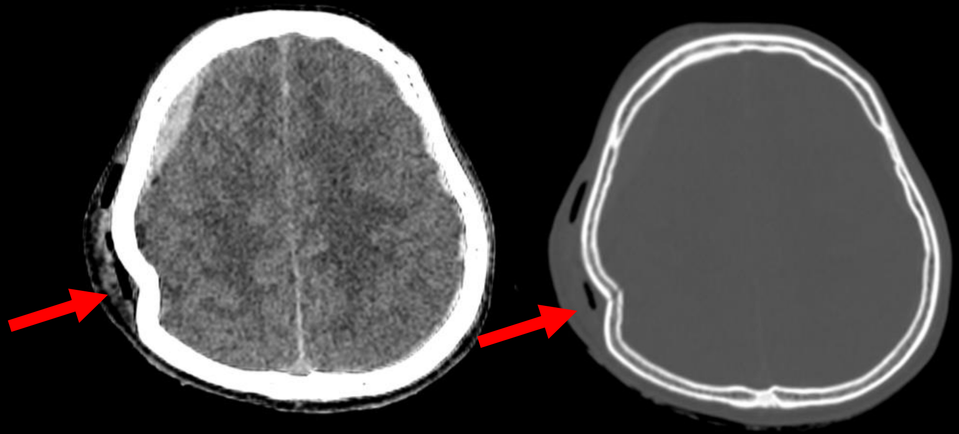
Raccoon/Panda eyes

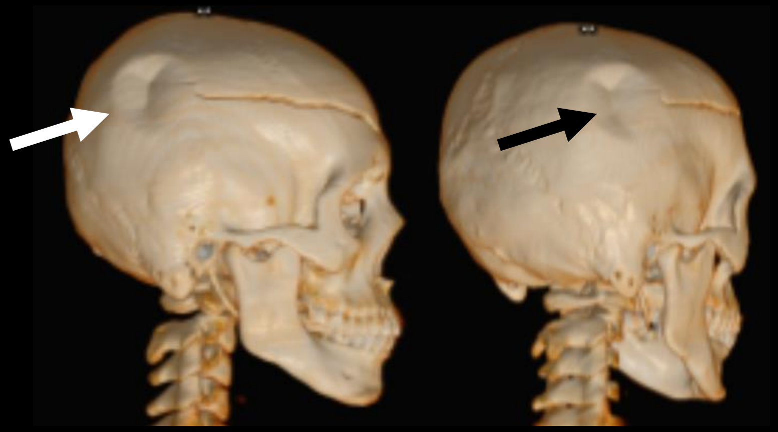
Battle’s sign

Classic Signs:

- Battle’s sign: retroauricular ecchymosis
- Raccoon eyes (periorbital ecchymosis)
- CSF rhinorrhea/otorrhea
- Hemotympanum

2. Depressed Fracture

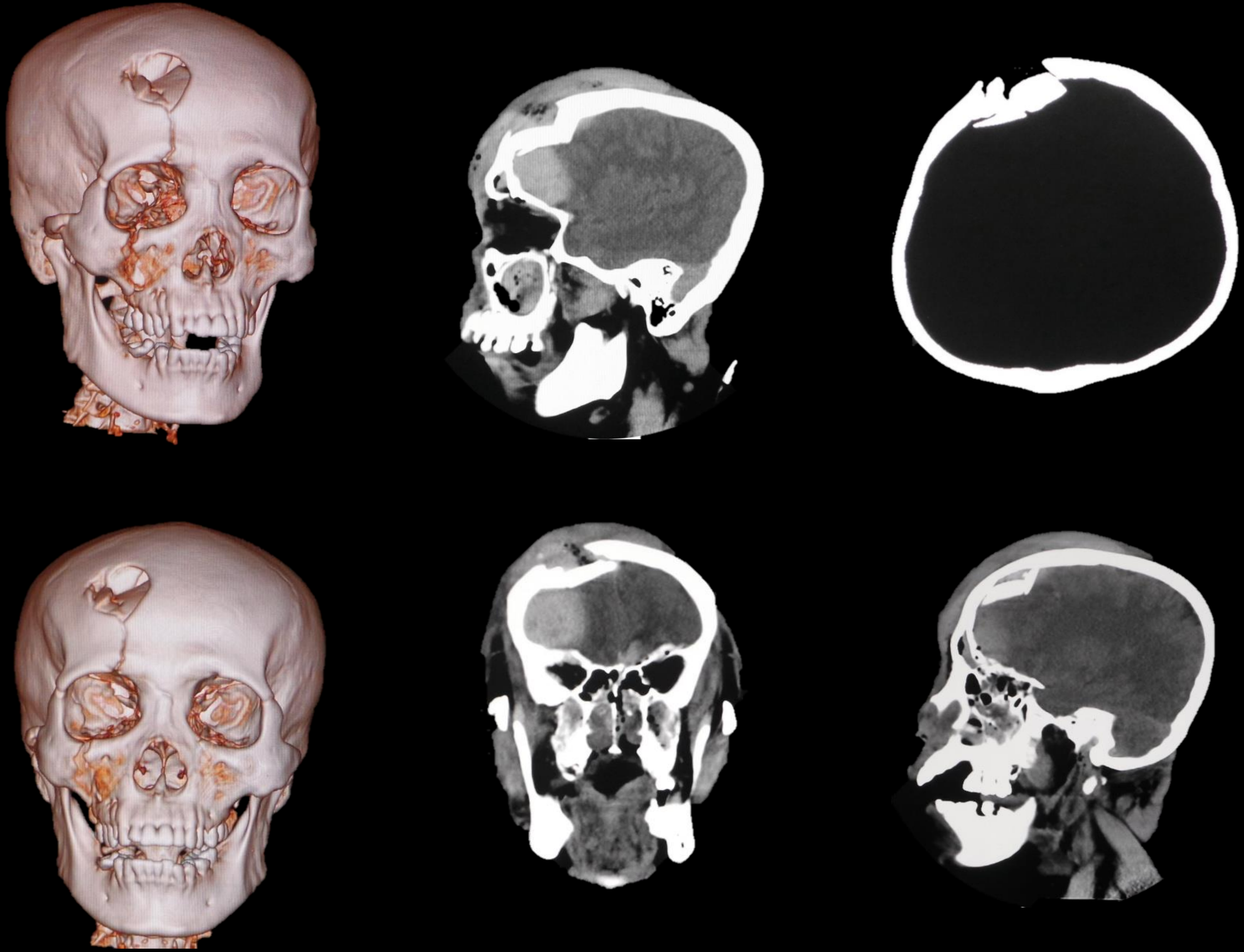


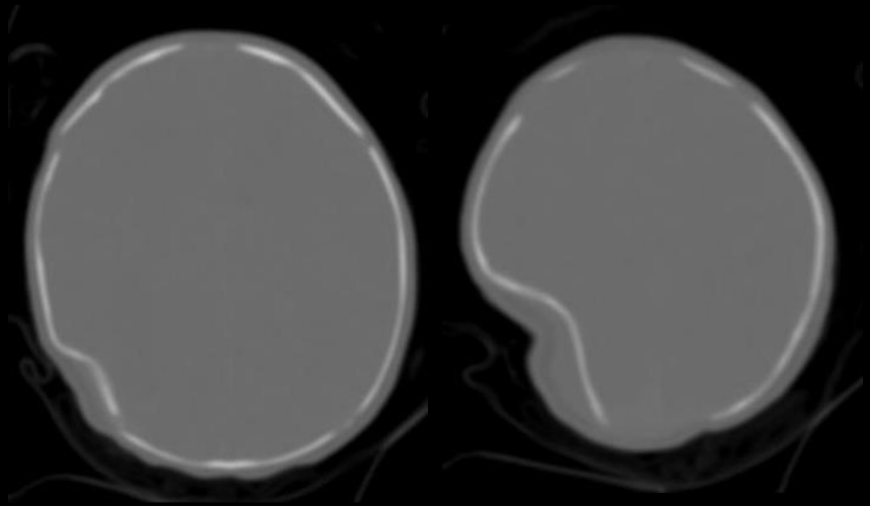


Depressed skull fractures:

- Displacement of the outer table of the skull to at least the level of the inner table
- 75% of cases in the frontoparietal region
- 75–90% are often opened

Depressed Fracture



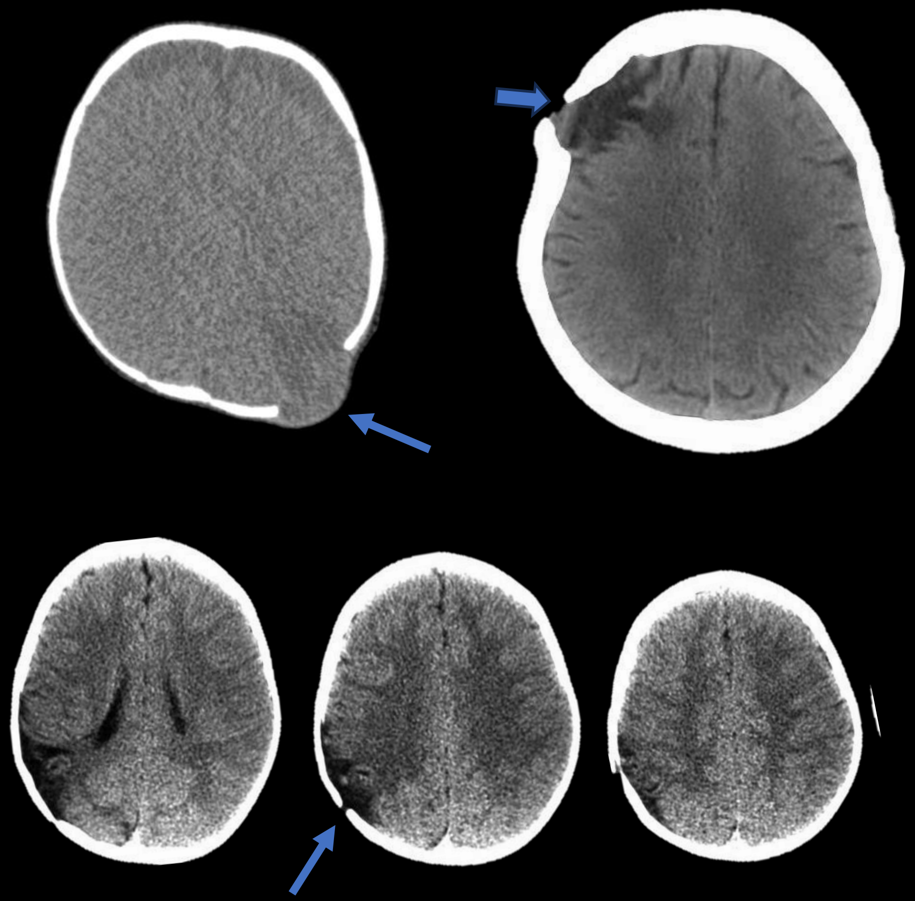


3. Ping pong skull fracture

- a depressed skull fracture of the infant by inner buckling of the calvarium.
- like greenstick fractures of long bones

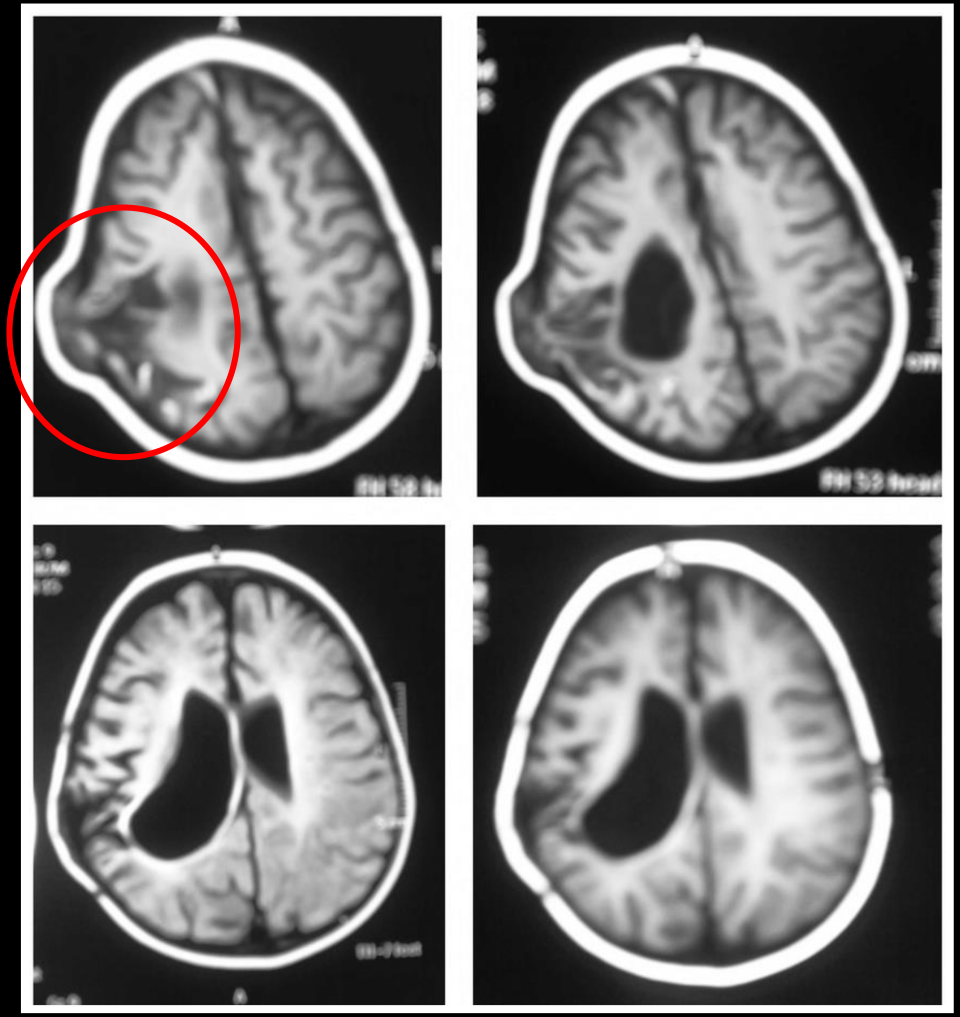
Imaging:
- smooth inward indentation of calvarium
- fracture line is not seen
- periosteum and dura are intact.

4. Growing Skull Fracture



Also described as:
- Traumatic ventricular cysts
- Craniocerebral erosions
- Cranial malacia
- Post traumatic bone absorption
- Leptomeningeal cysts

Characteristics:
- 90% occur in children under 3 years of age,
- Progressive diastatic enlargement of the fracture line.
- The most frequent location → parietal bone.
- It is usually seen a few months post trauma.
- It is not a true cyst, but focal herniation of an area of encephalomalacia, caused by trauma



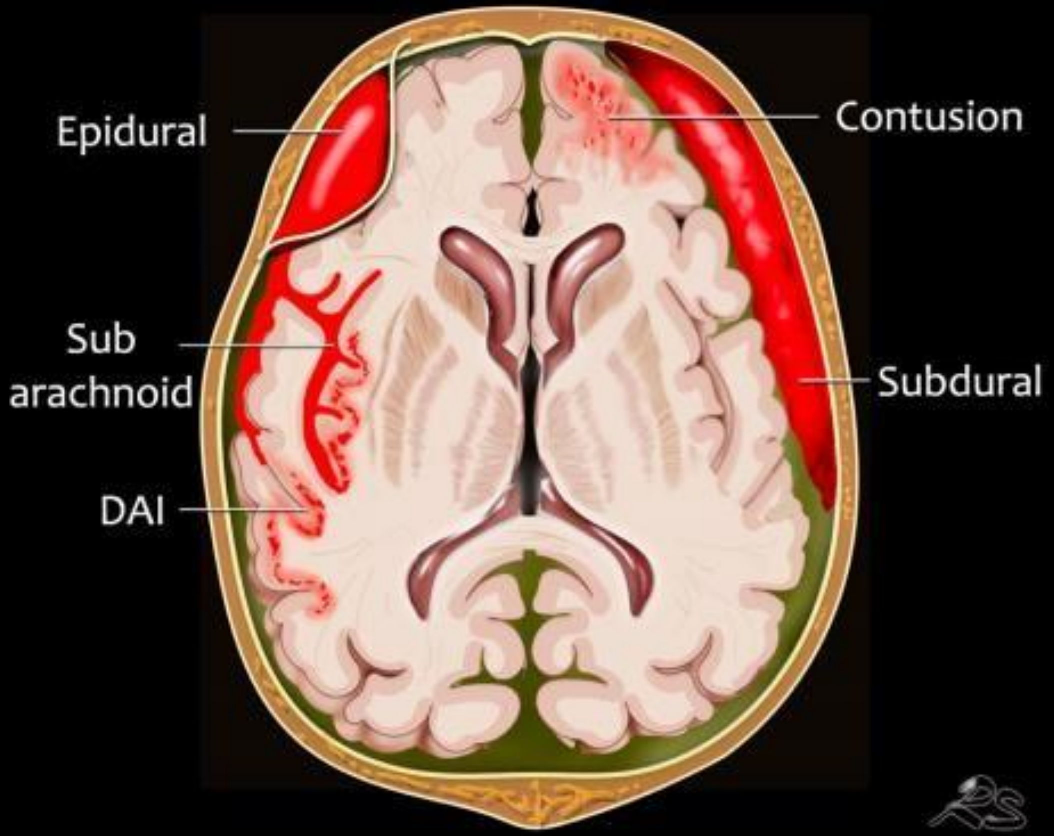
T1WI-MRI Brain → right parietal growing skull fracture.

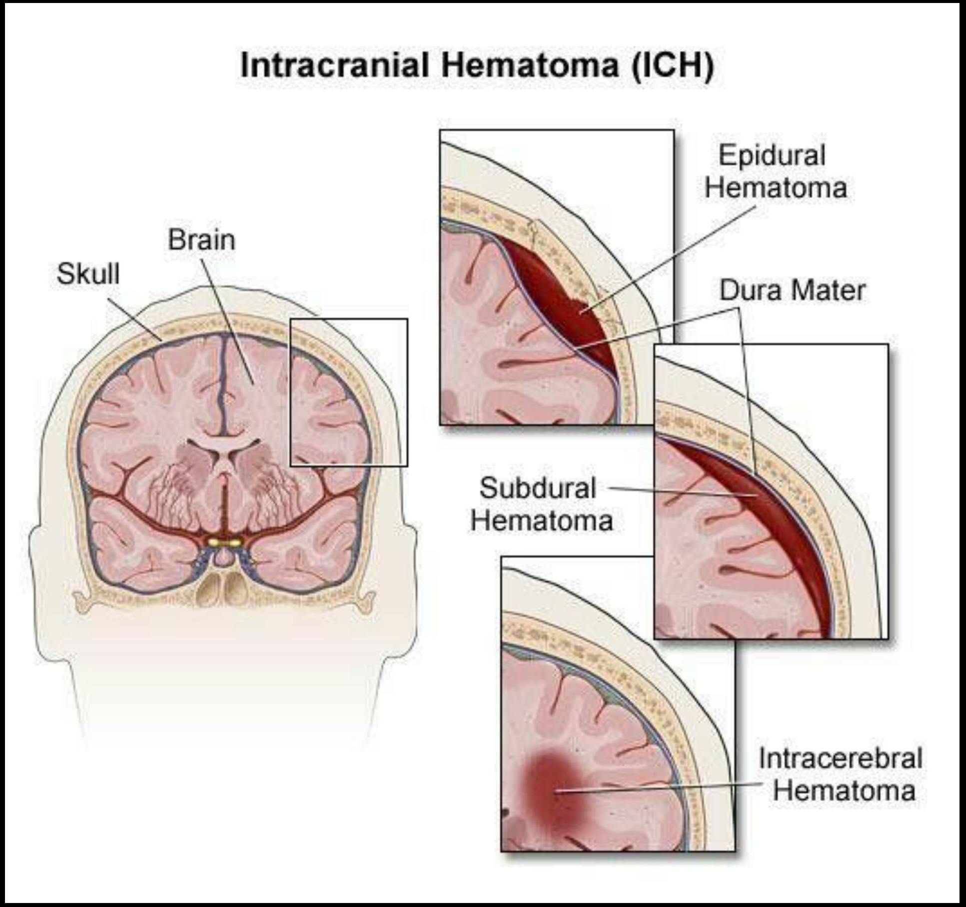
Elshafey et al. Growing Skull Fracture: A Clinical Study of 15 Children. Med. J. Cairo Univ., 2011; 79(2):39-42.

Traumatic Intracranial Hemorrhage

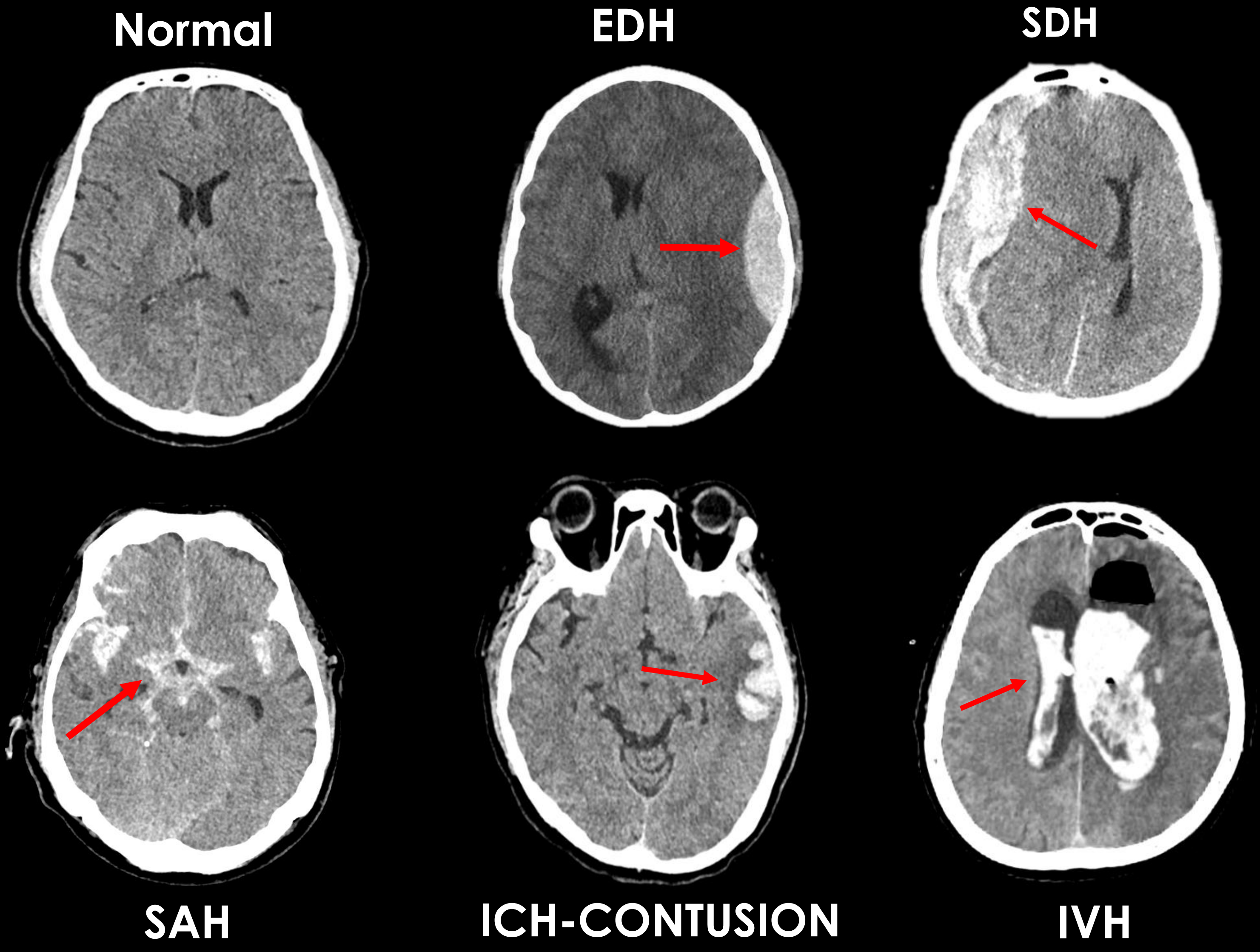
1. Epidural Hematoma (EDH): Lens-shaped, arterial bleed (middle meningeal artery).
2. Subdural Hematoma (SDH): Crescent-shaped, venous bleed
3. Subarachnoid Hematoma(SAH): Blood in CSF spaces; CT hyperdensity
4. Intracerebral Hematoma (ICH): Collection of blood within the brain parenchyma
5. Contusion hematoma: Localized collection of blood as a result of contusion
6. Diffuse Axonal Injury (DAI) hematoma: Small hemorrhagic lesions as part of DAI.

Intracranial Hemorrhage

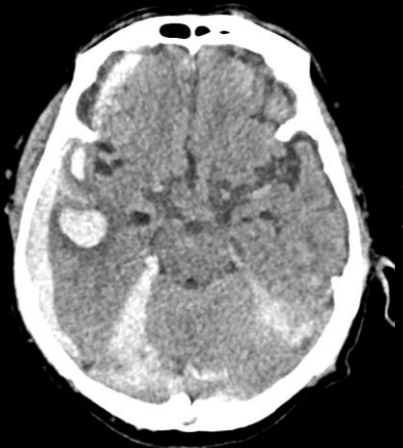




Types of Acute Traumatic Intracranial Hematoma on Brain CT



Multiple Acute Intracranial Hemorrhage



SDH-ICH
Tentorial

ICH

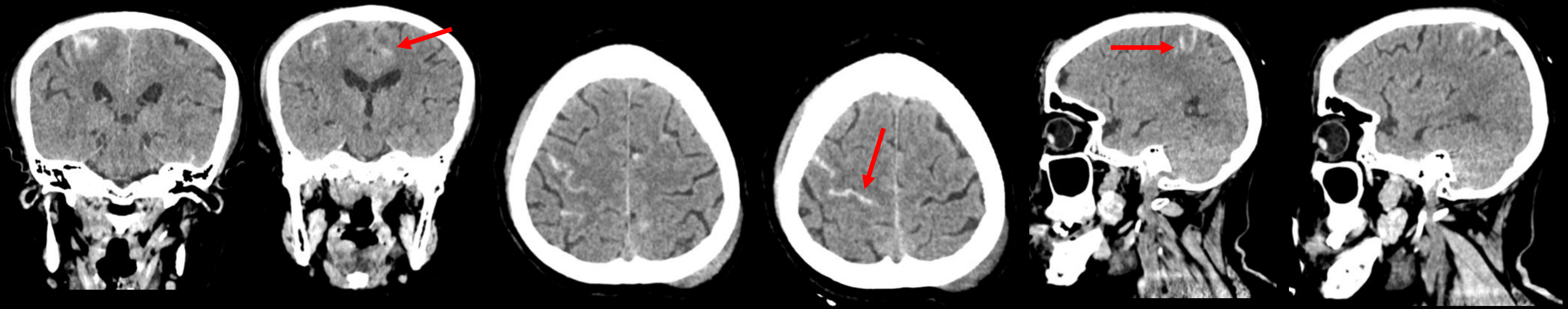
ICH + SAH

Tentorial

ICH-Tentorial

SDH-Tentorial

Multiple SAH in Head Trauma



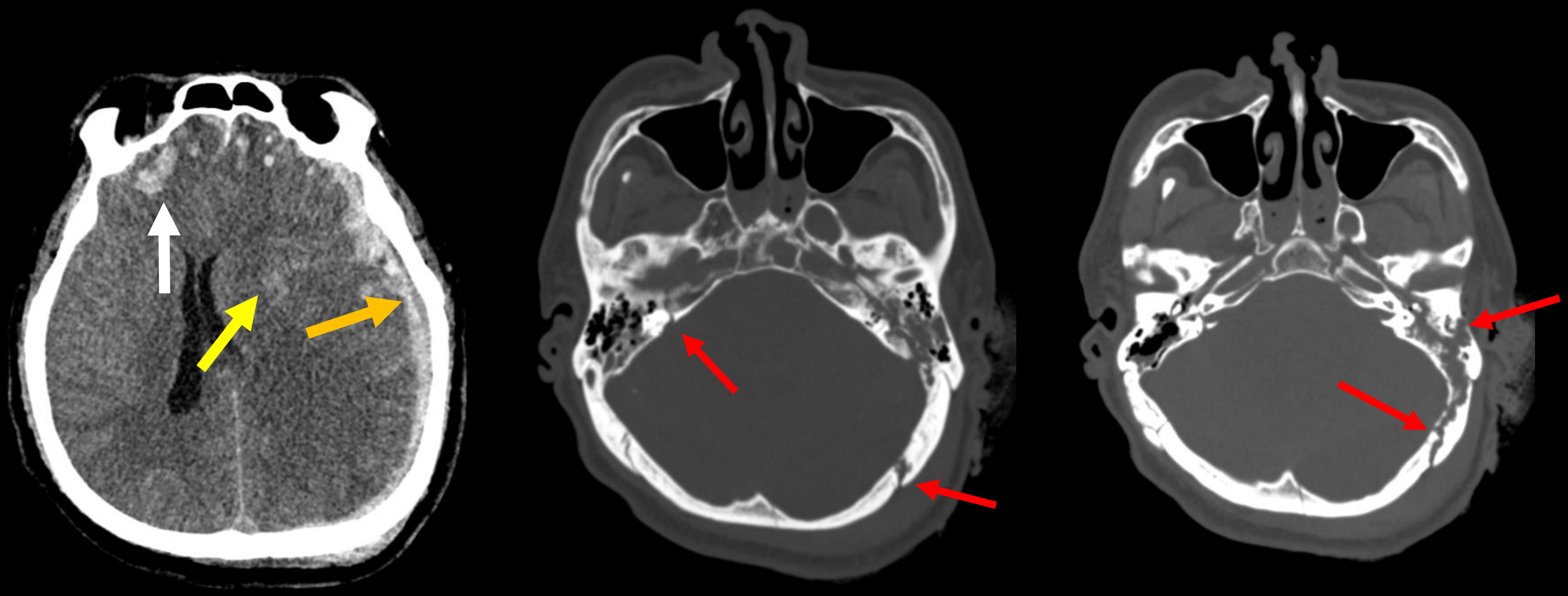
Acute SDH, ICH, IVH

Male, 24 yrs, head trauma in a traffic accident

CT scan:

- Crescentic hyperdense right frontotemporoparietal.
- Intracerebral hyperdense in the right temporoparietal with perifocal edema
- Intraventricular hemorrhage in lateral ventricles
- Shifting midline or mass effect

Acute Subdural Hematoma and Contusion Hemorrhage and Multiple Fractures



Male, 61 yrs, traffic accident, unconsciousness

CT scan:

- Acute SDH in the left frontotemporoparietal with shifting midline to the right side
- Contusion hemorrhage on both frontal lobes and perifocal edema.
- Multiple bone fractures: bilateral os petrosum and left occipital bone.

Diffuse Axonal Injury (DAI) or Traumatic Axonal Injury (TAI)

Diffuse axonal injury (DAI), or **traumatic axonal injury (TAI)**,

→ severe form of traumatic brain injury due to shearing forces.

Pathophysiology:

- The result of shearing forces, typically from rotational acceleration.
- Predilection: axons at the grey-white matter junction → due to the slightly different specific gravities of white and grey matter.
- Majority of cases these forces damage cells and result in edema.
- Complete tearing of the axons is only seen in severe cases → neurons degeneration.

Diagnosis:

The best → on MRI where it is characterized by several small regions of susceptibility artifact at the grey-white matter junction, in the corpus callosum and in more severe cases in the brainstem, surrounded by FLAIR hyperintensity.

Sharma. Diffuse axonal injury. Radiopaedia. Last revised on 26 Jan 2025

DAI – Grading System

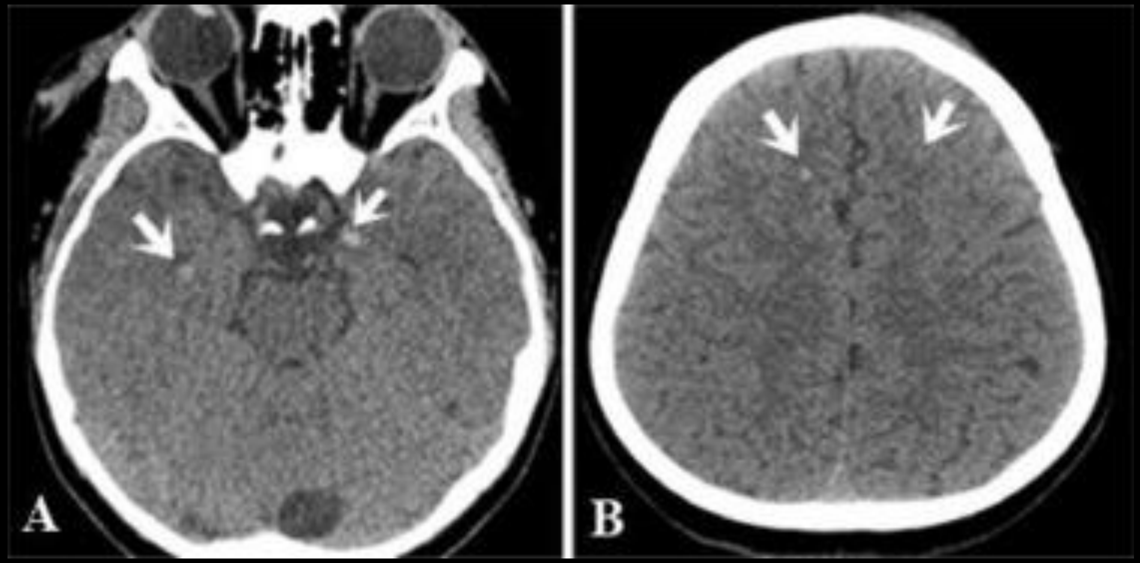
- Grade 1 (mild): Cortical gray-white matter junctions.
- Grade 2 (moderate): Corpus callosum (splenium)
- Grade 3 (severe): Brainstem

Comparison of CT Scan and MRI in DAI

Feature	CT Scan	MRI
Sensitivity	Detects 19% of non-hemorrhagic lesions 85-92% for hemorrhagic lesions	71-92% sensitivity for non-hemorrhagic lesions 91-92% for hemorrhagic lesions
Detected Lesions	Larger hemorrhagic foci (hyperdense) Edema-related hypodensity	Both hemorrhagic (hypointense on SWI/T2*) and non-hemorrhagic lesions (hyperintense on T2/FLAIR/DWI)
Common Findings	- Grey-white matter junction hyperdensities - Corpus callosum/bloodstem bleed - Traumatic SAH	- Multifocal white matter hyperintensities (T2/FLAIR) - Restricted diffusion (DWI) - Microbleeds (SWI) - Axonal disruption (DTI)
Advantages	- Rapid acquisition - Widely available - Better for acute hemorrhage	- Superior lesion detection - Identifies non-hemorrhagic injuries - Assesses white matter integrity (DTI)
Limitations	- Misses 81% of non-hemorrhagic injuries - Poor prognostic value	- Less accessible - Contraindicated in some patients (metallic implants) - Longer scan time

Diffuse Axonal Injury (DAI) on CT scan

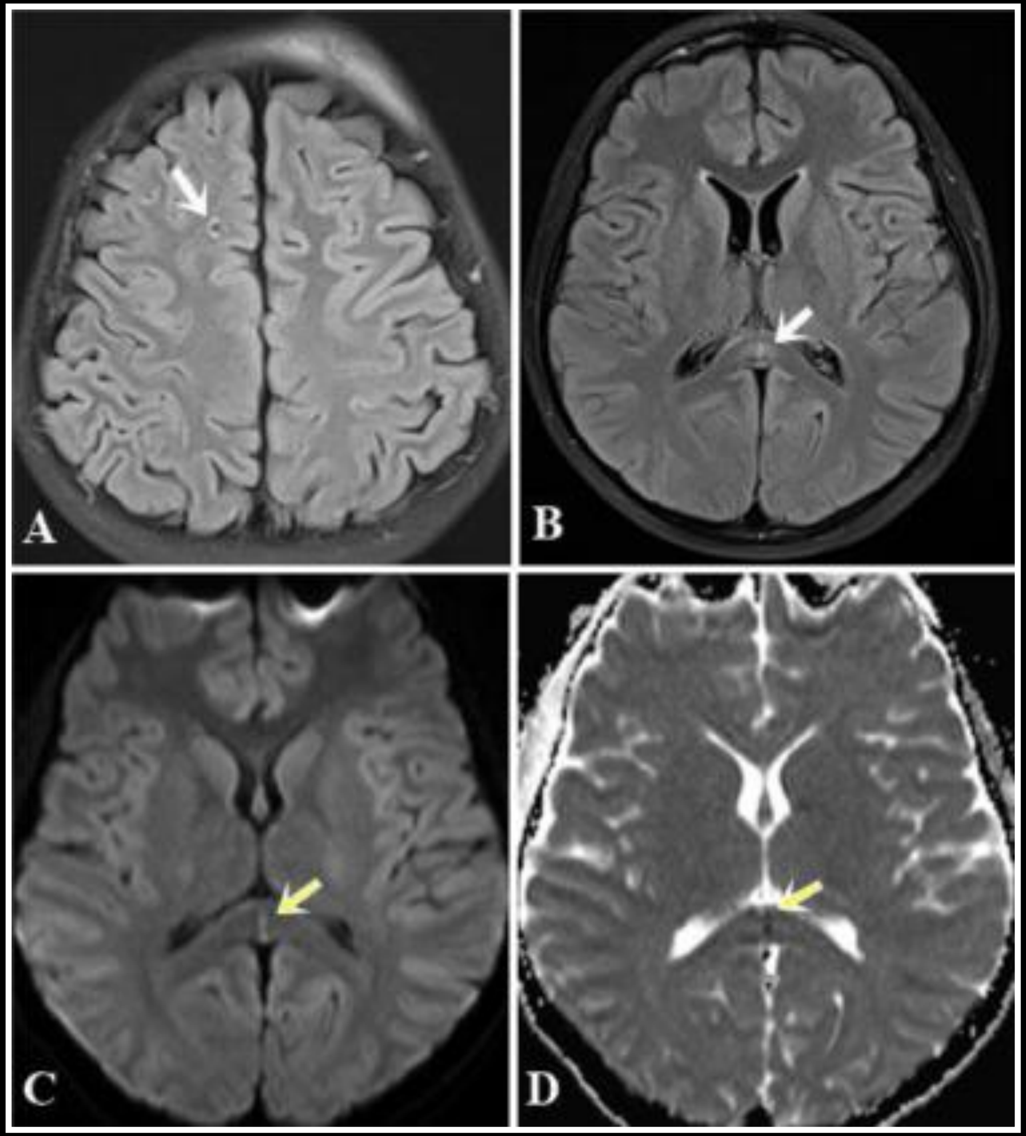
Temporal lobe



Frontal lobe

Multiple punctate hyperdense foci (microhemorrhage) at the gray-white matter junction

Vo et al. Diffuse axonal injury: a case report and MRI findings. Radiology Case Reports, 2022; 17(1):91-94.



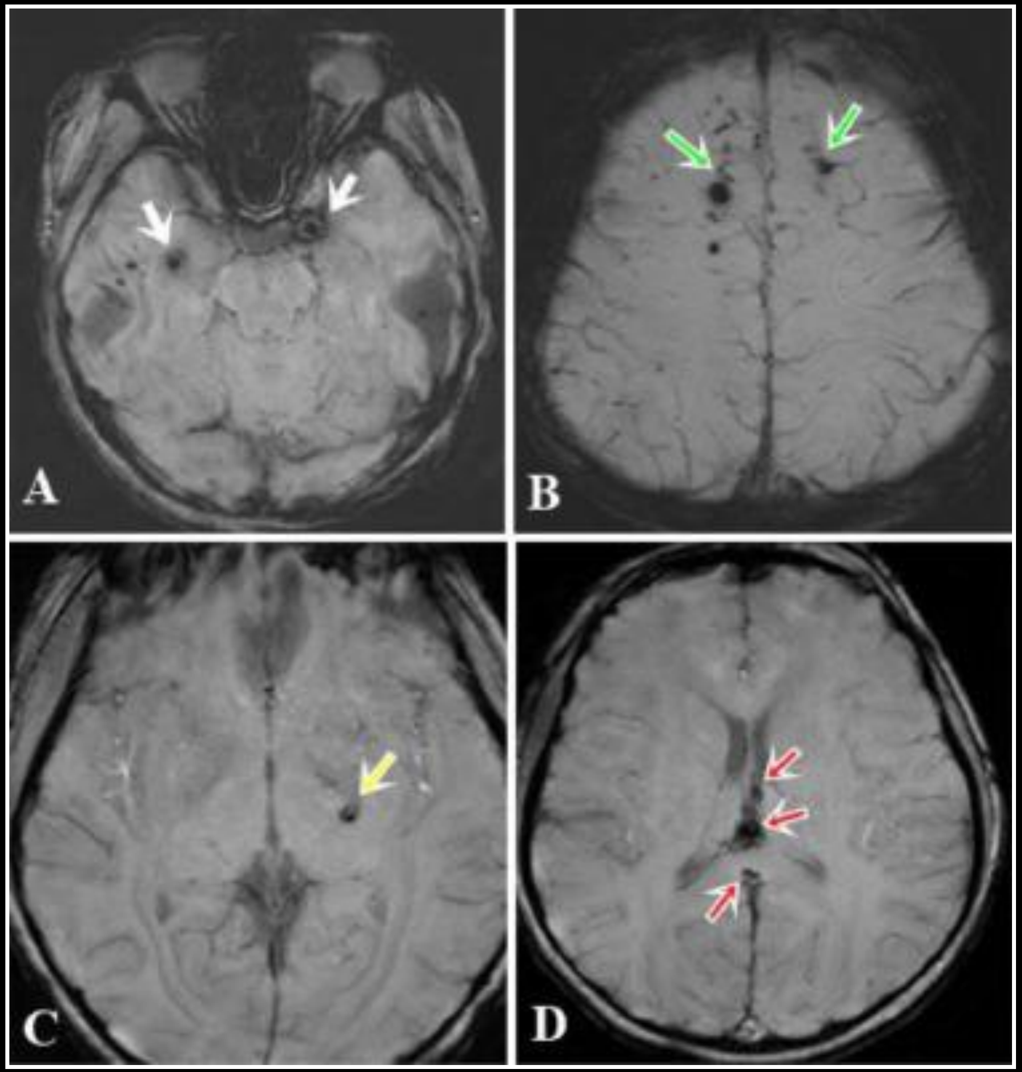
Axial FLAIR images.

(A) some punctate hyperintense foci in the subcortical white matter of the right frontal lobe (arrow)

(B) the splenium of the corpus callosum (white arrows).

DWI and ADC maps.

(C) & (D) → restricted diffusion within the splenium of the corpus callosum (yellow arrows).



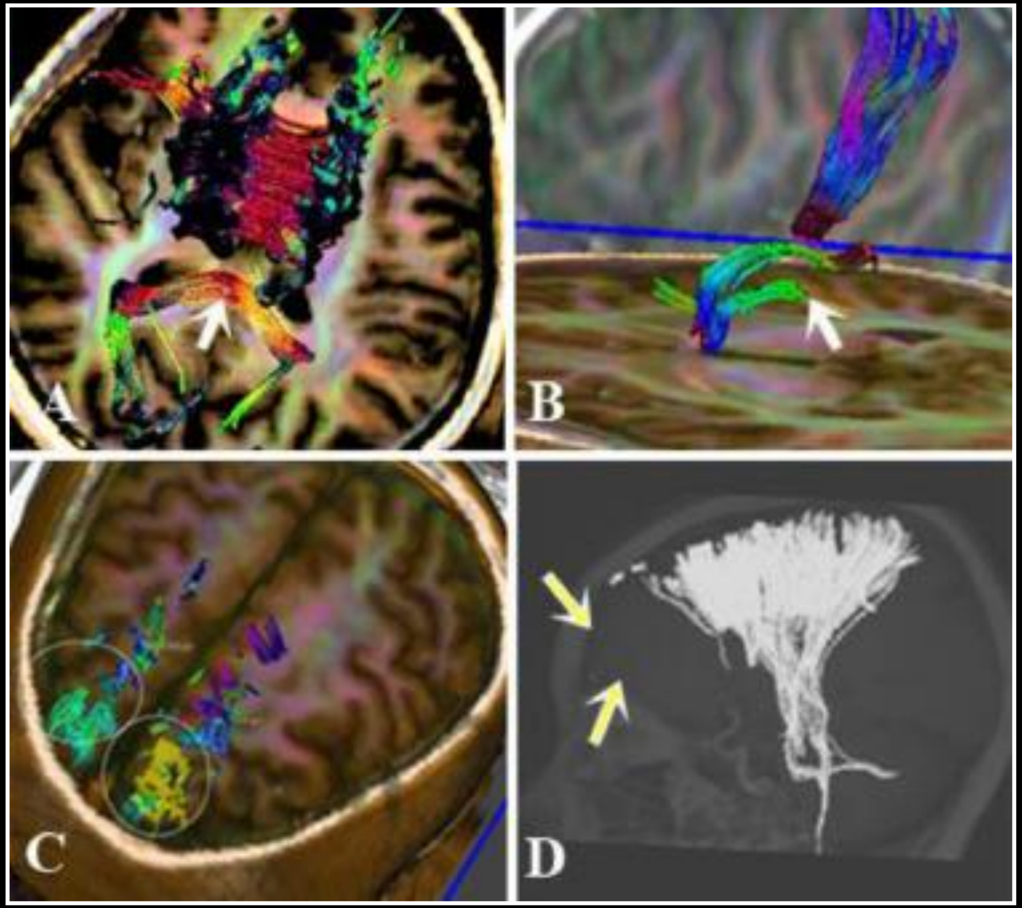
Axial SWI : Multiple hemorrhagic lesions.

A. Foci of hemorrhagic lesions at the grey-white matter junction of bilateral temporal lobes (white arrow),
B. Bilateral frontal lobes (green arrow),
C. Posterior limb of the left internal capsule (yellow arrow),
D. The fornix commissure, and the splenium of the corpus callosum (red arrows).

Diffusion Tensor Imaging with 3D-Fiber Tractography in DAI

Posteroinferior aspect of the splenium (arrow).

Left crus of the fornix (arrow)



Subcortical frontal tracts (circle)

Subcortical frontal tracts (arrow)

Disrupted white matter fibers

The Latest Advancement in Imaging DAI

1. Diffusion Tensor Imaging (DTI): → Maps white matter tracts by measuring water diffusion directionality in brain tissue.

2. Susceptibility Weighted Imaging (SWI): → detection microbleed/microhemorrhage.

3. Advanced MRI Sequences: High Definition Fiber Tracking (HDFT): → Visualizes individual axon bundles in 3D.

4. AI-Driven Analysis: → Automatic lesions detection

5. Emerging Technique:
   - 7T Ultra-High-Field MRI: Enhances resolution for tiny lesions.
   - PET-MRI Hybrids: Tracks neuroinflammation (e.g., TSPO tracers) post-DAI.

Take Home Message

- Head trauma may cause primary and secondary injury, including fractures, hemorrhages and brain damage.
- Rapid access to imaging technologies is critical to good outcomes in patients who have been significantly injured.
- CT is the imaging technique of choice in the setting of acute head trauma, accurate detection of fractures, extra- and intra-axial haemorrhage, mass effect.
- MRI is superior for detecting DAI, contusions, and small subdural hematomas, especially in mild TBI.
- Advanced MRI sequences (SWI, FLAIR, DTI) enhance detection of microbleeds and metabolic changes.


Thank You

Thank You

Merapi dan Merbabu – Yogyakarta, 2025

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