Tutorial 2: Imaging of Head Trauma

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Aims and Guidance for Tutors

In the emergency setting, accurate clinical assessment in combination with appropriate imaging is key to the identification of patients that would benefit from urgent surgical intervention. This chapter aims to familiarise students with the role of imaging for patients with head trauma. It is important that students understand the basic concepts and patterns of traumatic intracranial haemorrhage. After completion of this tutorial students should be able to describe the key CT appearances of traumatic intracranial haemorrhage and associated mass effect.

Introduction

- Traumatic brain injuries (TBI) are a major cause of morbidity and mortality in the injured patient.
- Injury occurs due to primary and secondary mechanisms.
- Primary injury occurs as direct mechanical consequence of the trauma.
  - Skull fracture, acute haemorrhage.
- Secondary injury occurs as a result of the pathological processes initiated by the initial traumatic insult.
  - Cerebral oedema, intracranial hypertension, cerebral hypoxia.
- In conjugation with clinical assessment, diagnostic imaging plays a fundamental role in the evaluation of patients with a suspected TBI in the emergency setting.

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- The Glasgow coma scale is the scoring system used to describe a patient's level of consciousness following head trauma
  - This is scored between 3 and 15. A score of 8 or less implies severe injury.
- All patients with severe head injury should be transferred to a dedicated neuro-surgical centre.
- Imaging also has an important role in the triage of patients sustaining minor head injuries to identify those who can safely be discharged.
- There is increasing evidence that for patients presenting with traumatic intracranial haemorrhage, features on the CT brain scan can predict long term outcome:
  - Findings such as haemorrhage site and size, presence of intraventricular haemorrhage, presence of mass effect.

Radiological Modalities Utilised

Non-contrast CT brain

- The initial investigation of choice. It is widely available and can be performed rapidly. It is a sensitive study for the identification of:
  - Acute intracranial haemorrhage
  - Evidence of mass effect
  - Bony injuries

  CT is also a useful study for the follow-up of patients with known TBI to assess response to treatment, haemorrhage stability and the development of complications. Imaging with CT will be the focus of this tutorial.
- We do not administer intravenous contrast media in patients with head trauma as contrast media is hyperdense and can look like haemorrhage.

MRI brain

- In comparison with CT, there are several practical reasons that MRI is less suited for use in the emergency setting:
  - Longer imaging time required
  - Sensitivity to patient motion
  - Possible incompatibilities with indwelling medical devices or foreign bodies
  - Not as widely available on-call
- MRI is superior to CT for the identification of non-haemorrhagic injuries of the brain parenchyma such as contusions, oedema and diffuse axonal injury. MRI can also detect acute ischemia associated with TBI.

Skull radiography

- The use of skull radiography for trauma has been largely replaced by CT. Of historical interest, before the advent of CT an abnormal position of the calcified pineal gland on frontal skull radiograph was used to diagnosis midline shift.

Indications for Imaging

- The need for imaging is dictated by clinical assessment.
- Patients who have sustained trauma and are considered at moderate or high risk for TBI require urgent CT brain.
- It can be more challenging in deciding which patients that have sustained a minor head trauma require imaging. For these patients clinical assessment will help decide if imaging is required. A number of criteria and guidelines have been published to assist clinicians in this decision. These criteria are based on clinical risk factors such as:
  - Glasgow coma scale
  - Vomiting
  - Anticoagulation treatment
  - Presence of amnesia
  - Dangerous mechanism of injury
  - Seizures

Radiologist's tips: Acute haemorrhage on CT

- Acute haemorrhage on CT is high in density/attenuation
  - It appears bright (between 50 and 70 Hounsfield units)
- Intracranial haemorrhage can be classified as extra-axial or intra-axial:
  - **Extra-axial haemorrhage** is blood inside the skull but outside the brain parenchyma. This includes extradural, subdural, subarachnoid and intra-ventricular haemorrhages.
  - **Intra-axial haemorrhage** is blood within the brain parenchyma
- If the patient's mechanism of injury is unclear, carefully examine the subcutaneous soft tissues overlying the skull on the CT. The presence small superficial haematoma often marks the point of impact.

Review of Relevant Radiological Anatomy: CT Brain

See Figs. 1, 2, and 3.

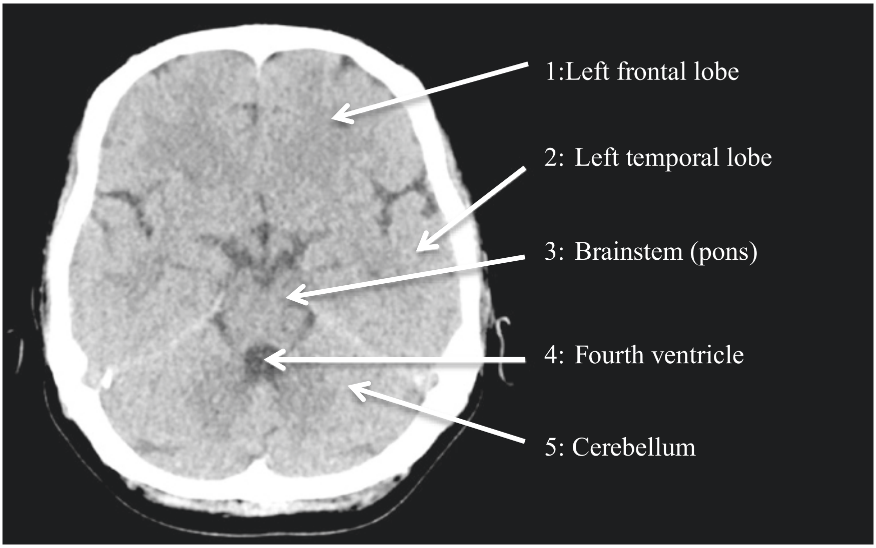

Fig. 1 Axial non-contrast CT brain

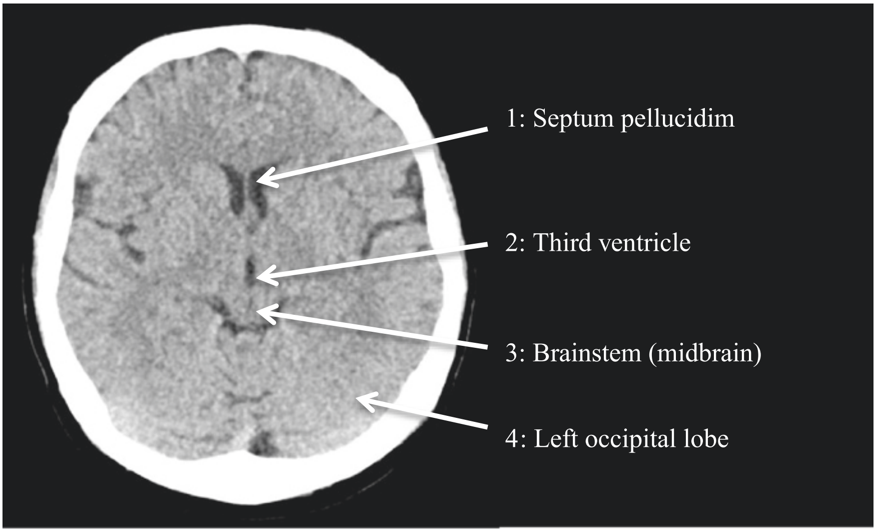

Fig. 2 Axial non-contrast CT brain

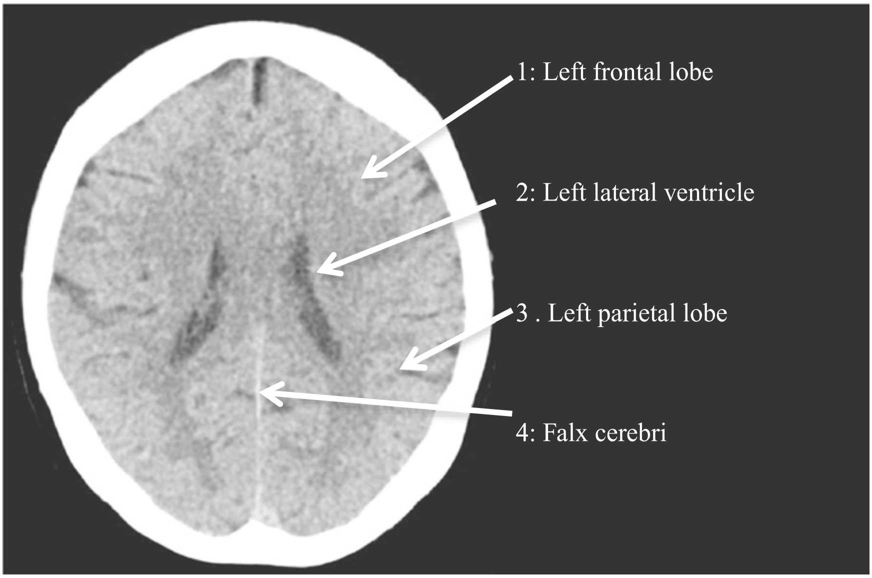

Fig. 3 Axial non-contrast CT brain

Extra-axial Lesions

Extradural haemorrhage

- Also known as epidural haemorrhage
- Involves blood located between the dura and the inner table of the skull. The site of haemorrhage usually occurs at the site of impact, in most cases this is in the temporal region and bleeding is due to laceration of the middle meningeal artery.
- Over 90% of cases have an overlying skull fracture.

Clinical features

- The classically described lucid interval followed by neurological deterioration is only present in a minority of patients with extradural haemorrhage.
- As the haematoma expands, patients develop features of herniation.

Key imaging appearances

– Hyperdense, biconvex (or lens-shaped) collection on CT
– The haemorrhage does not cross suture lines
– Underlying skull fracture (Fig. 4).

Subdural haemorrhage

- This is due to tearing of bridging cortical veins crossing the subdural space, usually as a result of acceleration/deceleration injuries.
- Subdural haemorrhages can be diagnosed at the acute, subacute or chronic stages. Chronic subdural haemorrhages are associated with anticoagulation use, alcoholism and epilepsy.

Clinical features

– Chronic subdural haemorrhages can have a vague/indolent clinical presentation and mimic other intracranial pathologies
– Consider chronic subdural haemorrhage as a cause of cognitive dysfunction in elderly patients (pseudodementia). Pay close attention to those on anticoagulant medication.

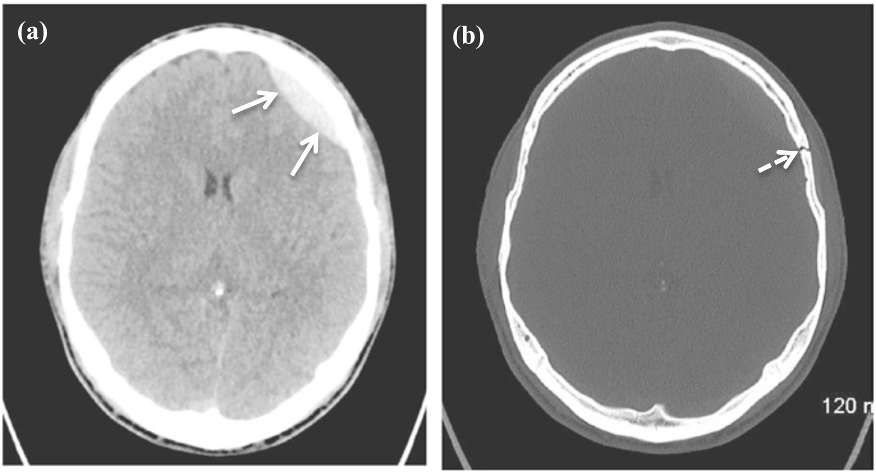

Fig. 4 A 30 year old man sustained a head injury after falling from a height. He complained of a headache on presentation (GCS 15) but after a short period became confused became drowsy (GCS 13). An emergency CT brain was performed. This demonstrates a biconvex hyperdense extra-axial collection adjacent to the left frontal lobe which obeys the suture lines **(a)**. This is an acute extradural haemorrhage. On the bone reconstruction image **(b)**, there is a non-displaced fracture of the left frontal bone. The patient underwent emergency surgical decompression of the haematoma

Key imaging appearances

– Crescentic collection spread diffusely over affected cerebral hemisphere
– Crosses suture lines
– The density of the haematoma on CT depicts the acuity:

  - Hyperdense: Acute (<1 week)
  - Isodense: Subacute (1 week to 1 month)
  - Hypodense: Chronic (>1 month) (Fig. 5).

Subarachnoid haemorrhage

- Haemorrhage in the subarachnoid space which can be traumatic or non-traumatic in origin (trauma being more common)
- CT has a very high sensitivity if performed within 6 hours of trauma.
- The main non-traumatic causes are ruptured aneurysms (older patients) and vascular malformations (younger patients). *For further reading on non-traumatic subarachnoid haemorrhage, see non-traumatic neurological emergencies chapter*.

Key imaging appearances

– Curvilinear hyperdensity within the sulci, sylvian fissures and basal cisterns
– Crosses suture lines
– Acute blood around the circle of Willis forms a five pointed star.

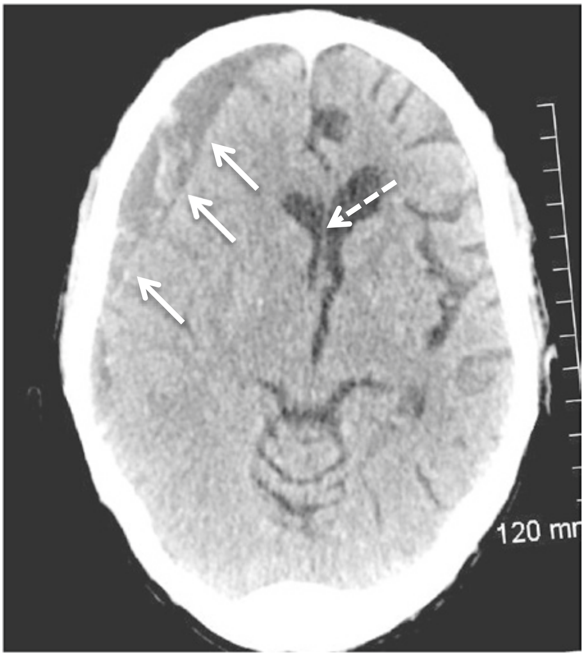

Fig. 5 A 45 year old man with a history of alcohol addiction is brought to the Emergency Department with increasing confusion. He reports a history of multiple recent falls. A non-contrast CT brain is performed. This axial image demonstrates a crescentic extra-axial collection (solid arrow) overlying the right cerebral hemisphere consistent with a subdural haematoma. This collection is predominantly of low density but contains areas of high density, this is an acute-on-chronic subdural haematoma. Note also the midline shift due to associated mass effect- the midline structures are displaced to the left (labeled with dashed arrow)

Intraventricular haemorrhage

- Acute haemorrhage within the ventricular system can be primary—as a resulting from tearing of vessels lining the ventricular wall
- Secondary intraventricular haemorrhage is more commonly encountered, resulting from extension from large intraparenchymal or subarachnoid haemorrhages
- Intraventricular hemorrhage can obstruct the flow of CSF causing hydrocephalus (Fig. 6).

> **Radiologist's tips: mimics of intracranial haemorrhage**
>
> - Beware of several structures within the brain which can normally calcify and be mistaken for acute haemorrhage:
>   - Pineal gland
>   - Choroid plexus with in the lateral ventricles

Intra-axial Lesions

Cortical contusion

- Bruising of the brain surface as a result of blunt injury. When contusions contain foci of haemorrhage, the term haemorrhagic contusion is used.

Fig. 6 An axial image of a non-contrast CT brain demonstrating normal calcification of the choroid plexuses (dashed arrows) and pineal gland (solid arrow). This normal finding can be mistaken for acute haemorrhage

- It occurs most frequently in the frontal and temporal lobes.
- Contusion can occur as a coup injury (at the site of cranial impact) and as a contrecoup injury (occurring opposite the site of cranial impact).

Intraparenchymal haemorrhage

- Traumatic intraparenchymal haemorrhage is on the same spectrum of injury as haemorrhagic contusion.
- Intraparenchymal haemorrhages are often multiple and usually located in the frontal and temporal lobes.
- Large intraparenchymal haematomas cause surrounding cerebral oedema, exacerbating the associated mass effect (Fig. 7).

Diffuse Axonal Injury (DAI)

- This is due to a high velocity deceleration or rotational forces resulting in shearing of axons.

Fig. 7 A 72 year old man on warfarin presented after a fall at home. On presentation to the Emergency Department, he had left sided weakness and a reduced level of consciousness (GCS of 12). A non-contrast CT brain was performed. This axial image demonstrates a large acute intra-parenchymal haemorrhage (white areas on the right side of the brain). The mass effect of the haemorrhage is causing subfalcine herniation—this is a form of herniation where part of the right side of the brain is pushed medially and below the falx cerebri (dashed arrow). There is resultant hydrocephalus of the left lateral ventricle (dashed arrow) due to compression of the third ventricle

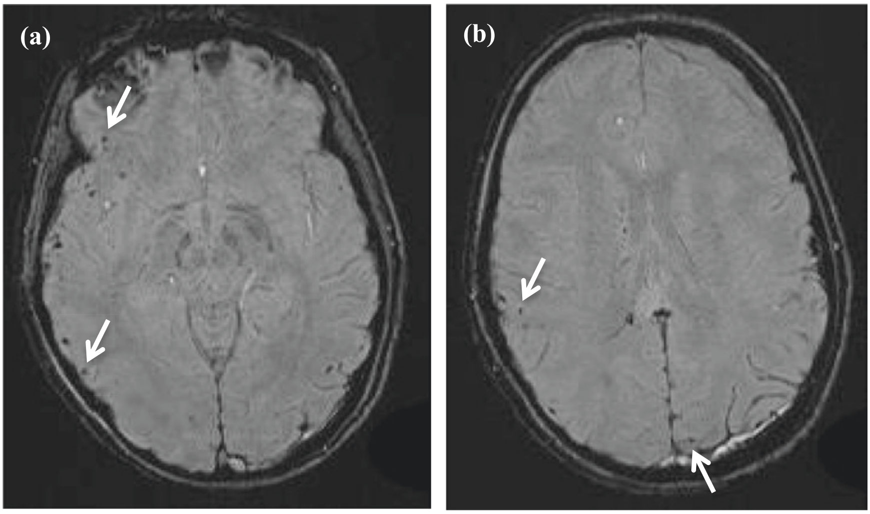

Fig. 8 A 46 year old woman sustained head trauma in a road traffic accident. On presentation she was comatose (GCS 7). A CT scan showed a shallow subdural haematoma. Her GCS remained low and an MRI was performed for further evaluation. These MRI susceptibility weighted images (a sequence which is sensitive to haemorrhage) show numerous small foci of low signal (black dots, several of which are labeled with arrows) at the grey-white matter junction, characteristic of diffuse axonal injury

- This should be clinically suspected in patients with a persistent vegetative state following trauma (GCS <8). DAI is associated with high levels of morbidity and mortality in patients sustaining head trauma.
- It is characterised by multiple small lesions at the grey–white matter junction, corpus callosum and brainstem. These lesions are often haemorrhagic.
- MRI is the key imaging modality to demonstrate these microbleeds.
- CT has poor sensitivity for DAI. Consider DAI in patients post head trauma with a low level of consciousness despite a reassuring CT brain (Fig. 8).

Mass Effect and Herniation

- The mass effect resulting from haematoma cause elevation in intracranial pressure and can lead to herniation.
- The Monro–Kellie doctrine, proposed two centuries ago remains a useful hypothesis. This states that the cranial cavity is a structure with a fixed volume containing brain, CSF and blood. If the volume of blood increases, displacement of CSF and brain will result to maintain the fixed volume.
- Herniation is the displacement of brain parenchyma from one compartment to another. It is one of the leading causes of mortality in patients who sustain head trauma.

- The early recognition of mass effect and herniation is essential as these patients will benefit from emergency decompressive surgery.

Herniation syndromes

– Subfalcine herniation:

  - This is the most common type of herniation and involves displacement of the cingulate gyrus under the falx cerebri
  - Clinically patients usually develop headache and contralateral limb weakness (motor cortex compression).
  - Often associated with contralateral hydrocephalus due to obstruction of the foramen of Monro.

– Uncal herniation:

  - This involves herniation of the medial aspect of the temporal lobe (the uncus) across the tentorium cerebelli.
  - Uncal herniation can cause compression of the adjacent third cranial nerve, resulting in palsy (fixed, dilated pupil)
  - With uncal herniation, the contralateral cerebral peduncle can also be compressed leading to ipsilateral hemiparesis. This false localising sign is known as Kernohan's notch.

– Tonsillar herniation:

  - The most serious herniation syndrome where the cerebellar tonsils herniate through the foramen magnum. When this occurs there is compression of the medulla, resulting in respiratory arrest.

Radiologist's tips: recognising mass effect

- Compare the side without haemorrhage to the side with hemorrhage. On the side of the haemorrhage, look for displacement of CSF from the cortical sulci—this is called **sulcal effacement** ie pressure forces the fluid out of the sulci.
- On the side of the haemorrhage, look at the lateral ventricle, when this appears compressed or smaller when compared to the opposite lateral ventricle **ventricular effacement** is present indicating mass effect.
- Observe the midline structures, such as the falx cerebri. These should be centrally located. With increasing intracranial pressure, there is displacement of the midline structures away from the side of the haemorrhage. This is called **midline shift**.

Skull Fractures

- Skull fractures are classified anatomically:
  - Skull vault fractures
  - Skull base fractures

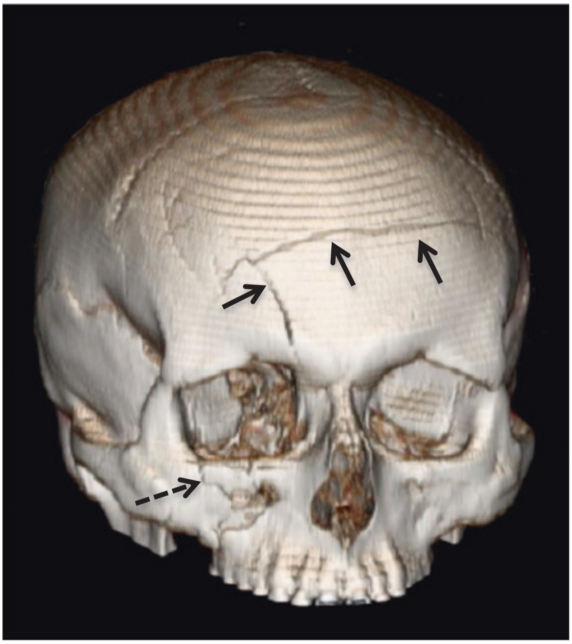

Fig. 9 A 3D reconstruction of a CT performed for a patient with a comminuted frontal bone fracture (solid arrows). There is also a fracture of the right maxilla (dashed arrow)

- 3D reconstruction of CT images is helpful in the evaluation of skull fractures.
- Skull fractures can be linear or compound, depressed or elevated and open or closed.
- Depressed fractures are often treated surgically.
- While patients who sustain trauma and have skull fractures are more likely to have intracranial haemorrhage than patients without skull fractures, the presence of a skull fracture in itself does not correlate with severity of brain injury.
- There are several important clinical signs that suggest a skull base fracture:
  - "Panda eyes"—periorbital bruising
  - Battle sign—bruising over the mastoid process
  - CSF rhinorrhoea—leakage of CSF into the paranasal sinuses.
- Base of skull fractures that involve the temporal bone are of particular concern as the inner ear structures can be disrupted resulting in hearing loss and leakage of CSF from the ears (Fig. 9).

Suggested Reading

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