17 Radiological Evaluation of Head Trauma

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Recommendations

Level I

Data are insufficient to support Level I recommendations for this subject.

Level II

Data are insufficient to support Level II recommendations for this subject.

(Please note that there are no cohort or randomized studies in part due to the fact that head CT is the gold standard for evaluation of head trauma, and therefore it would be unethical to make randomized studies.)

Level III

A CT scan of the head is recommended as first-line examinations for a patient with head injury.

Evaluation of vascular injuries requires specific angiography series with contrast (CT, MRI, DSA) (Shetty et al. 2016).

MRI within the first days after trauma should be reserved for patients where the CT does not sufficiently explain the clinical state of the patient (Shetty et al. 2016).

17.1 Overview

CT imaging is the examination of choice in the acute setting because it is readily available and fast, offers full-body investigation with detailed imaging including imaging of bones with reconstruction in all planes and allows close observation of the patient.

In unstable patients, the teamwork between the radiologist, anaesthesiologist and trauma surgeon becomes vital to select the correct examination, to monitor the patient and to avoid motion artefacts. In these cases, immediate radiological assessment should be carried out to ensure the quality of images and the need for supplementary examination (i.e. angio).

The time of examination has significantly decreased with recent advances in technology, allowing for full-body imaging in a few minutes.

CT of the head is in most places performed with helical technique, as multidetector CT scanners are readily available in most trauma centres. This will allow reconstruction in all planes and

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evaluation of both soft tissues and bones from one scan series. It is recommended to include the facial skeleton from the hard palate in cranial direction including the mandible if there is clinical evidence of that region being involved. Some centres perform one scan series that cover the cervical spine, facial skeleton, brain and skull in one. Some neurosurgical centres use neuronavigation for emergency procedures such a placement of an external ventricular drain, and in such setting it is beneficial to ensure that the primary trauma protocol is compatible with their navigation software.

Haematomas will appear white (hyperdense) in the right window setting, whereas ongoing bleeding will appear darker (hypodense), and older haematomas will be similar to grey matter (isodense).

Contusions of the brain parenchyma appear as focally darker areas around punctate haemorrhages, often more apparent on later scans.

Diffuse cerebral oedema is seen as a diminished differentiation of grey-white matter boundaries, sulcal obliteration and narrowing of the basal cisterns and often also the ventricular system.

Also the falx and tentorium will appear whiter than normal against the brain parenchyma. Focal oedema is seen darker against the surrounding more normal parenchyma, but also with the above-mentioned signs.

Diffuse axonal injury (DAI) is often underestimated or not seen on CT. MRI is the examination of choice for DAI, where lesions will appear as small black spots on T2-weighted gradient echo series, but MRI is not as readily available as CT and is far more complex to perform with traumatized patients. MRI should therefore be reserved for those patients where CT within the first days after trauma does not sufficiently explain the clinical state of the patient.

One should always evaluate:

- Scalp lesions—lacerations, foreign bodies, oedema and/or subgaleal haematomas.
- Skull fractures—including the facial bones.
- Extra-axial lesions—epidural haemorrhage, subdural haemorrhage, subarachnoid haemorrhage and/or intraventricular haemorrhage.
- Intra-axial lesions—intraparenchymal haematomas, contusions, oedema with or without herniation and/or DAI.

The possibility of vascular injuries should also be considered. Cranial CT is usually performed as a non-contrast study, and more specific angiography series (CT, MRI or angiography) with contrast may be necessary.

Tips, Tricks and Pitfalls: CT Imaging of the Head

To avoid overlooking critical injuries in the immediate setting, perform a systematic evaluation using three different window settings:

- Brain parenchyma window (Level 30–40 Hounsfield Units (HU); window: 65–120 HU).
  - Is the ventricular system of normal size, and symmetrical around the midline?
  - Is there any extra- or intra-axial blood?
  - Is the grey-white matter differentiation normal? Are there any focal lesions?
  - Are the cortical sulci discernible and symmetrical, or are they narrowed or even obliterated?
  - Are the basal cisterns of normal size and symmetrical?
  - Are there any scalp lesions?
- Subdural window (L: 70–100 HU; W: 150–300 HU):
  - To avoid overlooking smaller subdural haematomas due to the density of bone and artefacts at the interface between the bone and soft intracranial tissue, use a subdural window. This will allow you to detect a thin layer of sub- or epidural blood.
- Bone window (L: 500 HU; W: 2000–4000 HU):
  - Are there any fractures involving the skull base or the calvarium? If so, are there dislocations and/or fragments?

– Is the optical canal intact?
– Is the carotid canal intact?
– Are there any indirect signs of fracture, i.e. opacification of the nasal sinuses and/or mastoid cells or intracranial air bubbles?
– Are there fractures of the facial bones?
– Are there any foreign bodies extra- or intracranially?

Especially regarding fractures, make good use of the possibility of three-dimensional reconstructing.

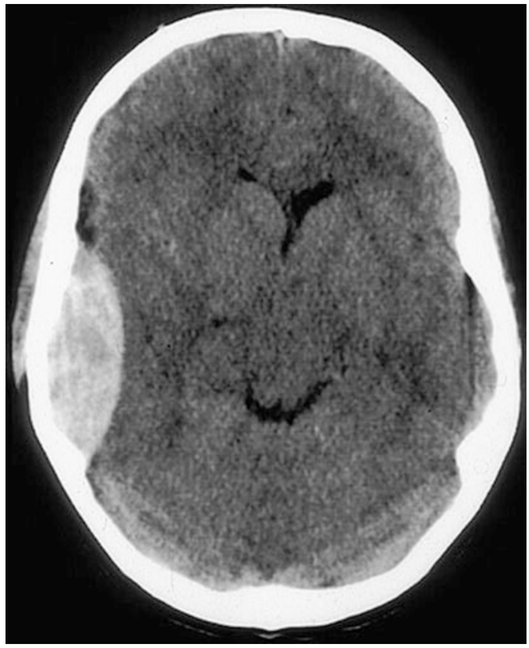

Fig. 17.1 Epidural haematoma

17.2 Background

Intracranial lesions can be subdivided into extra- and intra-axial lesions.

17.2.1 Extra-axial Lesions

Epidural haematomas (Fig. 17.1)

- Located between tabula interna and dura.
- Ninety per cent of cases occur in association with skull fractures involving the middle meningeal artery or less common one of the venous sinuses.
- Rarely crosses sutures but can cross the midline.
- Usually a biconvex appearance.

Subdural haematomas (Fig. 17.2)

- Located between the dura and arachnoid.
- Venous bleeding from superficial bridging cortical veins.
- Cross sutures but not midline.
- Often located along the falx cerebri or tentorium cerebelli.

Fig. 17.2 Acute subdural haematoma

- Concave appearance towards brain surface.
- Chronic subdural haematomas appear dark; fresh bleeding in a chronic subdural haematoma will appear as white areas, often in compartments.
- After 2 days to 2 weeks, subdural haematomas can become isodense and very difficult to discern from the brain. Look for shift of midline or difference of right and left hemisphere sulci.

Traumatic subarachnoid haemorrhage (Fig. 17.3)

- Fresh blood found focally in most cases in a few sulci over the convexities or in the basal cisterns often the interpeduncular.
- It may look as though the sulci are effaced, when in fact it is blood replacing the CSF.
- If there is abundant and diffuse spread of SAH, one should always consider rupture of an aneurysm. Perhaps that was the cause for the traumatic incident to happen.

Intraventricular haemorrhage

- Seen as fresh blood (white on CT) in the ventricular system.
- Can be caused from direct trauma with tearing of subependymal veins, breakthrough from parenchymal hematoma or reflux from SAH.

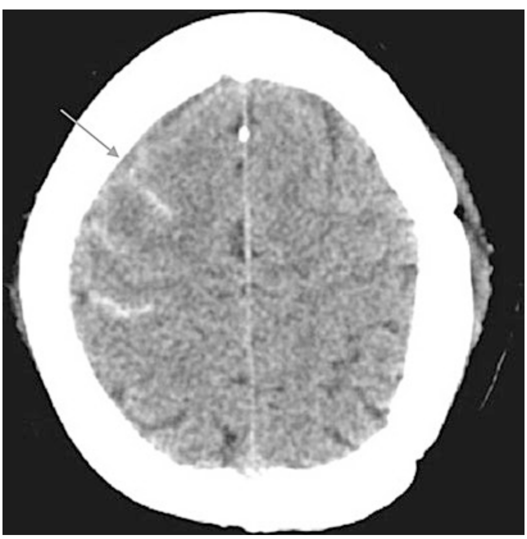

Fig. 17.3 Acute traumatic subarachnoid haemorrhage

- Often, the intraventricular bleeding is seen as blood in the posterior part of the occipital horns with a blood-CSF level. Even very small amounts of blood can be detected here (Parizel et al. 2005).

17.2.2 Intra-axial Lesions

Cerebral contusions (Fig. 17.4)

- The most common injury of the parenchyma.
- Are seen as punctate haemorrhages that after a few days are surrounded by oedema, often multiple, located near the brain surface supratentorially.
- Are caused as the brain hits the skull base or the falx/tentorium and are therefore often located inferiorly and anteriorly in the frontal and temporal lobes.

Intracerebral haematomas

- Larger than contusions.
- Located deeper within the brain parenchyma.

Fig. 17.4 Multiple brain contusions

- Frequently progress during the first few post-traumatic days, especially if a surgical decompression of epi- or subdural haematomas has been performed.
- A few days after the trauma, an oedema around the haematoma will occur.

Diffuse axonal injury (Fig. 17.5)

- Caused by shearing of the axons in rotational acceleration/deceleration closed head injuries.
- Most often not seen on the initial CT or only as very small haemorrhages at the grey-white matter boundaries.
- Can appear during the next few days, but as over 50% are non-haemorrhagic, they will not appear on CT with certainty.

MRI is much more reliable for showing DAI. The patient's clinical condition will often be worse than expected from the first CT. The use of advanced MRI techniques such as diffusion tensor images/tractographies, MR spectroscopies and functional MRI have shown promise in experimental settings, but is not yet standard in the clinical setting.

Cerebral oedema (Fig. 17.6)

- Can be diffuse.
- Associated with DAI or hypoxia, but can also develop without concomitant traumatic lesions.
- Develops during the first 24–48 h.
- Focal oedema can be associated with intra- or extra-axial haemorrhage.
- Can cause compression of blood vessels and eventually evolve into ischaemic areas of the brain.

Cerebral herniations

- Occur secondary to intra- or extra-axial expansive lesions and/or oedema.
- Subfalcine herniation is radiologically the most common type. It involves displacement of the cingulate gyrus under the inferior margin of the falx, compression of the ipsilateral

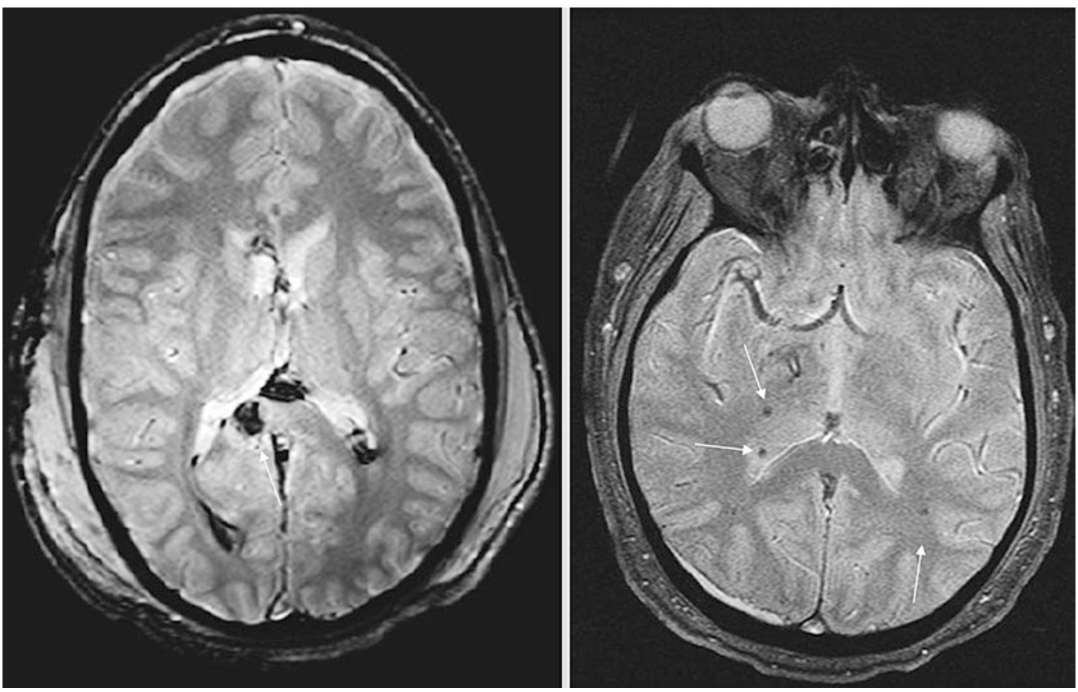

Fig. 17.5 Diffuse axonal injury, DAI and intraventricular haemorrhage

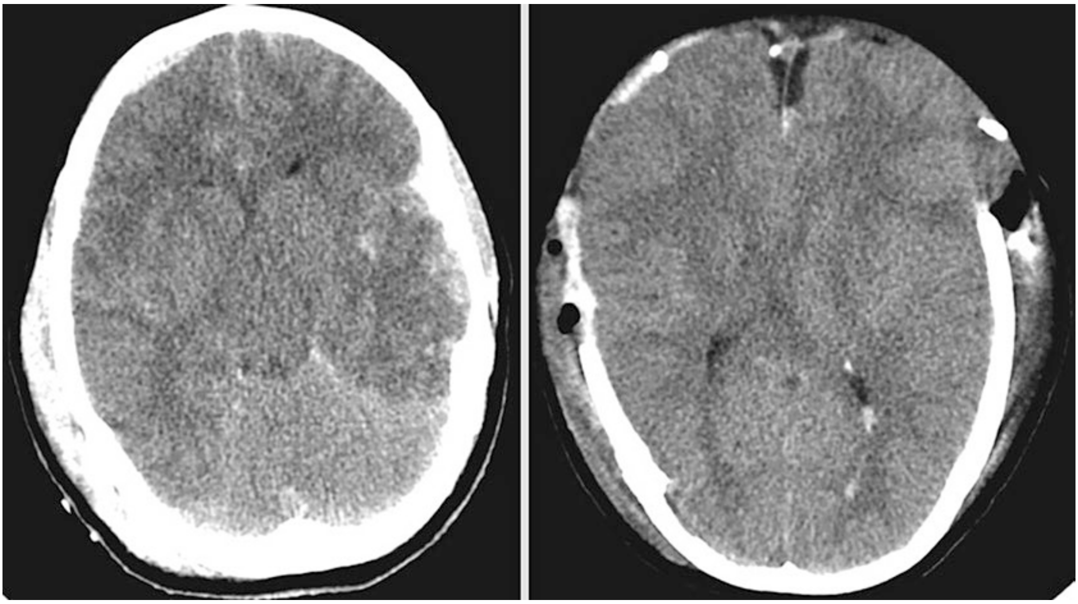

Fig. 17.6 Cerebral oedema. Day 1 and day 2 with bilateral craniectomy

lateral ventricle, blocking of the foramen of Monro and dilatation of the opposite lateral ventricle and midline shift.

- The anterior cerebral artery can be compressed until occlusion with infarction following.
- Transtentorial herniation is most often descending, where the medial part of the temporal lobe is pressed downwards, narrowing the ipsilateral basal cisterns and compressing the oculomotor nerve and eventually the posterior cerebral artery with infarction following.
- Can also be ascending with the vermis dislocated upwards, obliteration of the fourth ventricle and subsequent hydrocephalus.
- If the intracranial pressure increases, eventually herniation and incarceration at the foramen magnum will occur (Parizel et al. 2005).

17.2.3 Vascular Injuries

- Compression of vessels due to raised ICP can cause hypoperfusion and eventually infarction.
- Trauma can cause dissection or laceration of vessels either intra- or extra-cranially and hypoperfusion or thrombus (Fig. 17.7).

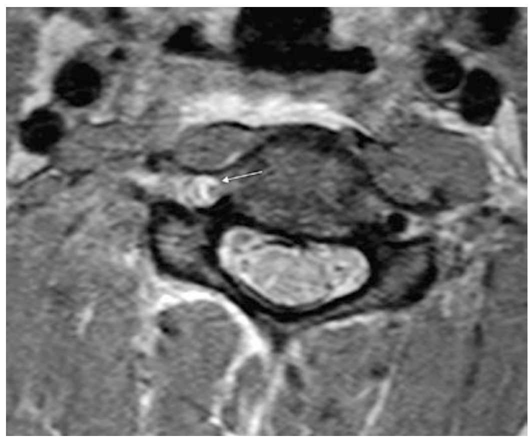

Fig. 17.7 Dissection of the right vertebral artery

- Subarachnoid haemorrhage can cause vasospasm and subsequent infarction, although the clinical course is often milder than in aneurysmal haemorrhage (Kramer 2013).

17.2.4 Skull Fractures

Skull fractures will not be presented in detail. Facial fractures, however, represent the risk of respiratory problems and should be assessed on the first CT scan. One should pay particular attention to the orbits, especially the optic canal, the central skull base, especially the carotid canal, and the temporal bone as fractures here may require immediate surgical intervention. Intracranial air bubbles imply fractures involving the nasal sinuses or temporal bone.

17.2.5 Specific Intracranial and Cervical Vascular Concerns

Suspected vascular injury and in particular vascular dissection require MRI or CT angiography. A conventional angiography may be necessary.

Lack of cerebral circulation confirms brain death. In these cases, filling of the intracerebral vessels during conventional angiography is absent due to extremely increased intracranial pressure. Angiography is considered to be a confirmatory test in doubtful situations, where brain death has to be stated before possible organ donation (Yousem and Nadgir 2017).

17.3 Specific Paediatric Concerns

In children with trauma, unilateral infarction is seen in association with acute subdural haematoma. Also, cerebral oedema is more common in children than in adults.

17.3.1 Non-accidental Injury (NAI) or 'Battered Child Syndrome'

Always consider NAI in young children with head trauma, particularly in those without appropriate trauma history. Most NAI head injuries occur under the age of 2 years. The neurological presentation is often non-specific. CT is the most appropriate acute imaging procedure (Lonergan et al. 2003). For additional information on possible "Child abuse", see also Chap. 4.3.

Typical imaging findings in NAI are:

- Skull fractures (Fig. 17.8)
- Subdural haematomas, often of different age (Fig. 17.9)

Fig. 17.8 Complex skull fracture in a child

Fig. 17.9 Subdural haematoma, hypoxic ischaemic encephalopathy and subfalcine herniation

- Cerebral oedema
- Hypoxic ischaemic encephalopathy (Figs. 17.9 and 17.10)
- Rarely intraventricular, intracerebral or epidural haematomas

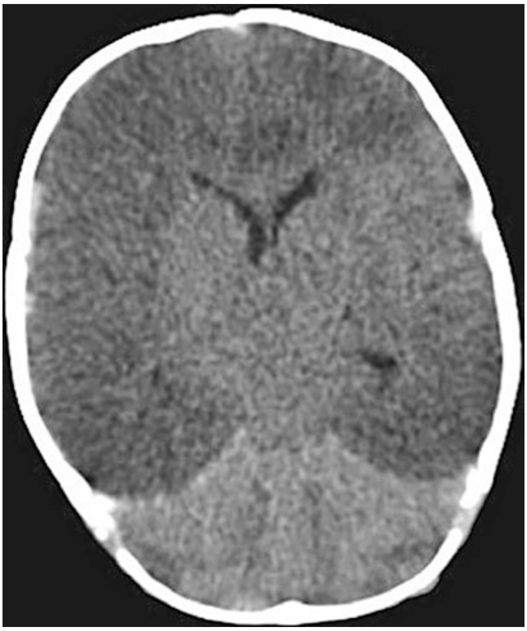

Fig. 17.10 Acute reversal sign ('white cerebellum') due to diffuse hypoxic brain injury

Tips, Tricks and Pitfalls: Paediatric Head Traumas

- Accidental skull fractures are usually linear and unilateral, affect the parietal bones and do not cross sutures.
- Non-accidental fractures are often more complex.
- Linear skull fractures can be missed on axial CT scans!
- Accidental subdural haematomas are more often unilateral, non-accidental more often bilateral.
- Non-accidental subdural haematomas extend more often into the interhemispheric fissure.
- Acute reversal sign ('white cerebellum') + loss of grey-white matter differentiation + interhemispheric subdural haematoma is suggestive of NAI.
- Subdural haematomas become isodense after about a week (depends on size), but dating of subdural collections is very imprecise.
- MRI gives greater detail of subdural haematomas, may help to date the injury and is helpful to assess the extent of the parenchymal injury.
- Remember: None of the aforementioned features are pathognomonic!
- Remember also that children with temporal arachnoid cysts may get subdural and/or intra-cystic haematomas even after mild head traumas!

A child suspected for NAI should not be sent home! Contact the paediatrician on call! Refer to a complete skeletal survey if NAI is suspected in infants and young children. Occult injury is rare in children over 3 years of age.

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