ABSTRACT

Objective: To present a simplified approach to computed tomography (CT) of the head to facilitate the understanding and diagnosis of common acute cerebral abnormalities in the critically ill patient.

Data sources: Published articles and texts on cerebral disorders and CT diagnosis.

Summary of review: In the unconscious and acutely ill patient a head CT is often performed to assess the possibility of an organic or 'space occupying' cerebral lesion. While specialist radiological interpretation is often available during the day, when an 'out of hours' emergency occurs the diagnosis of an intracerebral abnormality often relies upon the intensivist's interpretation of the head CT scan.

With an understanding of the position and appearance of normal intracerebral structures (and artifacts) common acute cerebral disorders can be easily assessed by the non-radiologist, facilitating the correct diagnosis and the appropriate management.

Conclusions: Head CT is the commonest CT performed in the intensive care unit. In many patients who are sedated or ventilated, neurological examination is sometimes difficult and CT becomes important in clarifying patient's neurological status. A simple approach to the interpretation of brain CT images assists in the management of these cases. (Critical Care and Resuscitation 2001; 3: 35-44)

Key words: Computed tomography, intracranial lesion, acute cerebral trauma, acute intracerebral haemorrhage

This is the first of a series of articles designed to provide intensivists and other specialists in acute care medicine with a basic understanding of common intensive care unit (ICU) related problems frequently evaluated by CT. These articles will have a similar format, discussing a few pertinent technical aspects of CT and its indications, followed by case examples of common ICU-related clinical problems.

The normal head CT scan

The normal head CT scan is performed with the gantry angled to avoid as much bone as possible within the image and to reduce the radiation dose to the eye. Thus, structures near the ‘vertex’ on the head CT are relatively posterior, with the top slice normally covering the posterior frontal lobe (Figure 1). This also explains the differences in appearance of lesions using magnetic resonance (MR) imaging compared with CT imaging, as all MR images are non-angled axial representations (Figure 2).

At the level of the foramen magnum the cerebrospinal fluid (CSF) space is normally present (Figure 3) which is reduced when tonsillar herniation is present. At the base of the skull the anterior, middle and posterior cranial fossae and the roof of the orbits are seen (Figure 4).

At the level of the suprasellar cistern the midbrain, fourth ventricle and cerebellar vermis can be found (Figure 5).

Above the level of the suprasellar cistern, the thalamus and lentiform nuclei may be observed (Figure 6) and above this level the lateral ventricles become obvious (Figure 7). The frontal and parietal lobes are divided by the central sulcus (Figure 8) and at the ‘vertex’ this image is posterior to the true vertex due to gantry angulation (Figure 9).
Technical aspects and artifacts

Motion is by far the most common artifact limiting the technical quality of a head CT scan (Figure 10 & 11). This is because many patients with cerebral irritation are agitated and are unable to cooperate. In most instances, this can be overcome by patient restraint and repeat scans as necessary.

Each scan acquisition takes approximately one second and thus for each slice the patient only requires to be still for one second at a time. Sometimes however, in severely agitated patients, sedation or anaesthesia may be necessary.

Figure 1. Head computed tomography gantry angulation results in less bone artifact and reduces radiation delivery to the orbits, resulting in the topmost scan being posterior to the vertex.

Figure 2. A magnetic resonance image of the head demonstrating the differences in scan planes compared with the head CT in figure 1.

Figure 3. A normal head CT at the level of the foramen magnum where the cerebrospinal fluid surrounds the medulla (M).

Figure 4. A head CT at the level of base of skull demonstrating the anterior, middle and posterior cranial fossae and roof of the orbits (a streak artifact is present through the posterior fossa).
Hardware artefact is the other consideration in post craniotomy patients and patients with external fixation for unstable cervical spine injuries. Metal (and bone) is relatively impenetrable by X-rays and thus a ‘shadow’ is cast resulting in streak artifact. The posterior fossa may also difficult to visualise with current CT imaging because the surrounding bone attenuates the x-ray beam resulting in “streak” artifact. However, this problem will soon be resolved by future improvement in CT technology with multislice CT enabling higher doses of radiation to be delivered to improve resolution of posterior fossa images.

Figure 5. A head CT at the level of the suprasellar cistern demonstrating the midbrain (M), fourth ventricle (*) and cerebellar vermis (V). Streak artifact is also present in the posterior fossa.

Figure 6. A head CT at the level of the thalami demonstrating the lentiform nuclei (LN) and caudate head (C).

Figure 7. A normal head CT scan at the level of the atria of the lateral ventricles

Figure 8. A normal head CT scan at the level of the centrum semiovale (CS). The location of the central sulcus is highlighted by the white dotted line (dividing the frontal and parietal lobes).
Contraindications for head CT are rare. Clinically unstable patients should be transferred to the CT suite with caution as there is often reduced monitoring of patients in transit and in the CT department.

Trauma patients with suspected cervical spine injury should also be moved to the CT suite with caution. Some advocate a lateral cervical spine x-ray before head CT in cases of head trauma to ensure that there is no cervical instability present.

The concept of “mass effect”

“Mass effect” is an important concept when considering the effects of intracranial space occupying disorders. Because of the fixed volume within the cranium, a small increase in volume of the intracranial contents will result in a rapid increase in intracranial pressure. This may be due to either a direct mass effect (e.g. epidural haematoma) or an obstruction to the CSF flow (e.g. hydrocephalus). The effects of an increase in intracranial pressure is often more hazardous than the primary lesion alone. Therefore, when evaluating brain CT, one must always assess the possibility of raised intracranial pressure.

The CSF space acts as a buffer for brain volume changes, thus when there is a raised intracranial pressure, the subarachnoid space is the first to be compressed. This generalization is true even in cases of obstructive hydrocephalus, where the unobstructed CSF spaces (e.g. the sulci) are diminished. Compare the sulci in cases of cerebral oedema (e.g. Figures 12 & 13) with the sulci in normal cases (e.g. Figures 6 & 7).

Cerebral oedema

There are two types of cerebral oedema: vasogenic oedema and cytotoxic oedema. Vasogenic oedema is commonly found in cases of intracranial malignancy and is due to an abnormal permeability of the blood brain barrier (Figure 12). This type of oedema affects...
predominantly the white matter. Cytotoxic oedema, on the other hand, is due to cell death and tends to affect both grey and white matter (Figure 13).

The key features of cerebral oedema are: loss of the grey-white differentiation and sulcal and ventricular effacement due to increased brain volume, and later development of hypodensity.
Subarachnoid haemorrhage
The commonest cause of subarachnoid haemorrhage is trauma. The commonest cause of non-traumatic haemorrhage is aneurysm rupture. Blood in the CSF will result in hyperdensity, for example, in the suprasellar cistern (Figures 14 & 15).

Hypertensive intracranial haemorrhage
Hypertensive intracranial haemorrhage has a predilection for the brain parenchyma supplied by the penetrating branches of the middle cerebral artery and basilar artery. Approximately 60% of hypertensive haemorrhages occur in the basal ganglia (Figure 16). Hypertensive encephalopathy without haemorrhage manifests on CT as areas of vasogenic oedema in the basal ganglia and in the posterior circulation cortex and subcortical areas.

Acute cerebral thrombosis
The commonest finding of an acute non-haemorrhagic stroke less than 4 hours old is a normal head CT. Even at 12 hours, only 50-60% of head CT scans are normal. Thus, CT should be used not to diagnose stroke but rather to exclude a haemorrhagic event which may contraindicate anticoagulation.

In the few cases where stroke is visible on the head CT the distribution of infarction may give clues as to the cause (Figures 17, 18 & 19). For example, if multiple vascular distributions are involved, embolic stroke should be considered (Figure 18). If the stroke is in a distribution that crosses vascular territories, then ischaemia can result from hypoperfusion (i.e. watershed infarct) due to hypotension (e.g. Figure 19), although other causes such as vasculitis, venous infarction or metabolic causes should be considered.
Chronic subdural haematoma

A subdural haematoma usually begins as a space occupying lesion that is hyperdense to brain tissue and gradually organises to become hypodense.

In the interim period it may assume a density that is close to brain parenchyma and may be missed, if the secondary signs of sulcal effacement and mass effect are not recognised (Figure 20).

Cerebellar haemorrhage/infarct

Cerebellar infarction can cause sudden and devastating symptoms due to parenchymal ischaemia as well as due to oedema of the midbrain, pons and fourth ventricle (which can lead to hydrocephalus, e.g. Figure 21). Haemorrhagic transformation may also lead to “mass effects”.

Cerebellar haemorrhage may be due to various causes, including stroke, arteriovenous malformations or tumour. Clinically, cerebellar haemorrhage behaves more aggressively than cerebellar infarction and often requires acute decompression due to the rapid pressure increase caused by the increase in haematoma size.

Hydrocephalus

Hydrocephalus occurs if there is an obstruction to cerebrospinal fluid flow (Figure 23). It may be internal (i.e. noncommunicating, if there is a blockage in the foramina of Luschka or Magendie) or external (i.e. communicating, if the reabsorptive capacity of the arachnoid villi are reduced).
Cerebral abscess
This condition is now relatively rare and may be found in immunocompromised individuals or in cases of endocarditis or pulmonary arterio-venous shunting (Figure 24). It may also complicate bacterial meningoencephalitis and sinusitis. Multiple lesions can suggest embolic disorders but cerebral metastases may also have an identical appearance.

Trauma
Severe head trauma results in a spectrum of CT findings including small haemorrhagic contusions, cerebral oedema, haemorrhage, (e.g. subarachnoid subdural, extradural, intracerebral), and skull fractures (Figures 25, 26 & 27)

Figure 22. A CT image demonstrating a cerebellar haemorrhage.

Figure 23. Hydrocephalus. Note the disproportionate enlargement of the lateral ventricles relative to the cerebral sulci. In severe cases the sulci may be effaced completely.

Figure 24. An abscess in the right cerebral hemisphere. Note the peripherally enhancing mass in the centrum semiovale and the vasogenic oedema in the adjacent white matter.

Figure 25. A right extradural haematoma and small haemorrhagic contusion in the parenchyma of the left posterior parietal lobe - a contra-coup lesion.
Small haemorrhagic contusions manifest as small areas of hyperdensity in the cortical or subcortical brain substance. They may also mark the site of a contra-coup injury.

Often, skull fractures present with ancillary signs of adjacent haematoma, contusion or air cell opacification if the fracture crosses a facial sinus. However, to thoroughly evaluate a skull fracture, it is imperative that bone windows are used to view images, otherwise skull fractures are easily missed. In figure 26 the image is windowed for soft tissues; in figure 27 the image is windowed for bone, demonstrating how easy it is to see the craniotomy defect on the bone windows which is barely discernable on the soft tissue windows.

Other important information obtained in a head CT in a trauma patient include skull base fractures (which may lead to CSF rhinorrhoea), fractures through the carotid canal (which may result in carotid artery dissection) and fractures through the petrous temporal bones (which may cause deafness or VII nerve palsies).

Herpes simplex encephalitis

Herpes simplex encephalitis has a predilection for the limbic system and commonly presents with bizarre symptoms and the head CT that is predominantly normal.

However, when it does manifest on head CT, it commonly presents as asymmetric areas of oedema in the temporal lobes extending into the basal ganglia (Figure 28). MRI is a more sensitive test for herpes encephalitis.9

Head CT is a useful tool in evaluating neurological problems in the ITU patient. However, care should be exercised to systematically evaluate the scans to avoid the pitfalls.
REFERENCES