Computed tomography of the brain: a pictorial review

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This pictorial review briefly describes the basic principles of computed tomography scanning of the brain. A series of commonly encountered intracranial pathologies is then reviewed.

Computed tomography (CT) scanning of the brain has revolutionized the diagnosis and assessment of both neurological and neurosurgical cases over the last 20–30 years. More recently, imaging of the brain has been further aided by magnetic resonance imaging (MRI).

However, CT remains the radiological examination of choice in the evaluation of severe head injuries. CT clearly depicts acute intracranial haemorrhage, as well as demonstrating bone for associated fractures. In addition, CT scanning is widely available as an on-call service, and through the use of modern scanners, the scan times are short. Furthermore, in contrast to MRI, there is no need for specialized anaesthetic equipment if the patient requires ventilation before scanning.

PRINCIPLE OF CT

CT scanning involves a rotating beam of several hundred radiation pulses with a corresponding array of detectors on the far side of the patient. The computerized analysis of the information derived from each of the detectors in turn results in the formation of axial images (cross-sectional slices) of the anatomical site of interest. This can be likened to a light giving a series of shadows of any three-dimensional structure. The analysis of these shadows will ultimately allow an image of that structure to be made. The larger the number of shadows available for analysis, the more detailed final image that can be constructed.

The original, simple axial scanners performed a series of scans at one level which would allow the formation of a single axial image. The scanner would then move the patient further into the scanner and repeat the scan at the next level. More recent scanners perform a spiral of scans as the patient moves through them in a continuous nature. This development in scan technique has occurred because of the arrival of slip-ring technology. The most recent generation of scanners work in a similar way, but a series of detectors (usually 4, but occasionally 16) is used to give greater detail and speed. These are the multi-slice scanners.

Imaging of the brain does not require high speed scanning since, unlike the thorax, it is not susceptible to movement artefact and the scans do not need to be performed on a breath hold. Although more and more scanners are now of the spiral or multi-slice type, they are often programmed to perform simple axial type images of the brain as described below.

For scanning of the brain, the scanner is usually set to provide 5 mm slices through the posterior fossa as far as the petrous temporal bones in order to avoid bone artefact. Above this level, 10 mm axial slices are performed. In view of the radiation dosage, the scanner gantry is usually angled in order to avoid repeated radiation exposure to the eyes.

Images can be manipulated after the scan has been performed in order to demonstrate either brain and/or soft tissue, or bone.

NORMAL BRAIN AND FUNDAMENTALS OF CT INTERPRETATION

On an unenhanced CT scan of the brain (the so-called ‘plain’ scan), the normal grey/white matter differentiation can be appreciated because the myelin-containing white matter appears as lower density (i.e. darker) beneath the peripheral grey matter. Scan assessment relies upon the review of the CSF spaces for symmetry, and that the midline remains central. The normal gyral-sulcal pattern should appear undistorted and symmetrical. There is often calcification in the choroid plexus and occasionally within the basal ganglia (Grainger et al, 2001).

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Acute haemorrhage appears as high density in the acute phase. After this, the appearances depend on the time interval after the haemorrhagic event, and to some extent on the anatomical site of the bleed.

In cases of cerebral ischaemia and/or infarct an CT scan may be normal in the initial 6–12 hours. However, as cerebral infarction becomes established, the infarct is seen as low density within the vascular territory involved. There may be associated oedema causing mass effect in the acute phase (*Table 1*).

An abnormal mass will usually distort the normal gyral pattern and may be associated with surrounding oedema. There will often be abnormal enhancement following the injection of intravenous contrast, which may also clarify subtle appearances on a pre-contrast scan.

CASE DISCUSSION

In the acute clinical setting, CT is usually performed after acute severe head injury, in the evaluation of 'stroke', and in the acutely ill patient with focal neurological signs and impaired conscious level. CT may also be used to examine for focal intracranial abnormality resulting from malignancy or infection (abscess) (*Table 2*).

CT is often performed in the initial work-up of a patient with likely meningitis, and particularly if there are focal neurological signs. However, in cases of non-complicated meningitis or encephalitis, the CT is usually normal and the diagnosis will depend upon lumbar puncture. It is imperative that the CT must not delay treatment or lumbar puncture.

CT is not the preferred initial investigation for suspected multiple sclerosis or acoustic neuroma. These pathologies are better diagnosed by MRI.

This article will now discuss some of the more common pathologies in turn.

HAEMORRHAGE

Acute haemorrhage appears as high density (white) in the acute phase, but this slowly darkens to become iso-dense to brain tissue at 7–10 days after the initial bleed. Darkening continues so that 2–3 weeks after the time of bleed, the area is of lower density than brain tissue, and any associated mass effect is beginning to resolve. More specifically, the patterns described below may be seen (Lindsay et al, 1986; Grainger et al, 2001).

Subarachnoid haemorrhage

In the acute phase, subarachnoid blood appears as high density within the CSF spaces. This is often seen around the circle of Willis but can also extend over the cerebral hemispheres or into the Sylvian fissures. There may be evidence of secondary hydrocephalus. If there is a history of trauma, fractures may also be present (*Figure 1*).

TABLE 1. Appearances of 'stroke' on computed tomography (non-contrast enhanced)

Cause of 'stroke'	Appearance	Nomenclature
Haemorrhage	White	High density
Infarct	Black	Low density

TABLE 2. Discriminating focal lesions on contrast-enhanced computed tomography

Intracranial lesion	Typically single (S) or multiple (M)	Typical enhancement pattern
Metastasis	M	Rim or solid
Astrocytoma	S	Uneven
Menigioma	S	Uniform
Abscess	S	Rim

The cause of a subarachnoid haemorrhage may be indicated by the presence of an underlying aneurysm or arteriovenous malformation. These may demonstrate curvilinear calcification within their walls, but are best seen after the injection of intravenous contrast (*Figure 2*). If the underlying causative lesion is not seen, the distribution of subarachnoid blood may suggest the likely site of the underlying pathology. Ultimately, carotid angiography or, more latterly, magnetic resonance angiography may be needed to reveal the underlying cause.

Intracerebral haematoma

An intracerebral haematoma appears as an area of increased density within the cerebral tissue. This is usually surrounded by low density (dark/black)

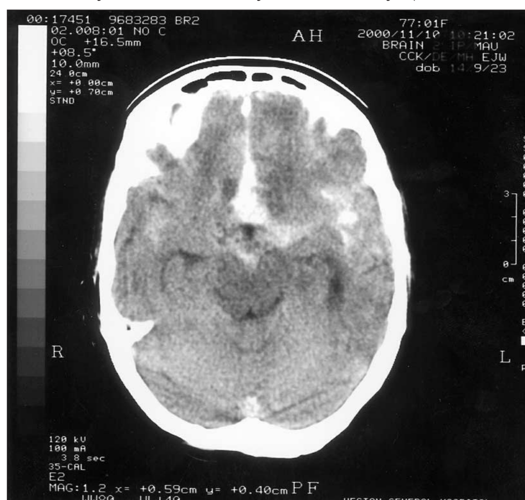


Figure 1. Acute subarachnoid haemorrhage; areas of high density around circle of Willis and the Sylvian fissure.

as a result of peripheral oedema. There is often a large amount of mass effect and compression of the adjacent CSF spaces (*Figure 3*). If there is a history of trauma, then a review on bone window settings may show an underlying fracture.

Acute extradural haematoma

A bleed in the extradural space presents as a lentiform (lens-shaped) peripheral area of high density. This forms as the collecting haematoma peels the dura from the inner table of the skull vault. Owing to the anatomical position of an extradural haematoma, it is limited by dural attachments and consequently does not extend across suture lines. An underlying fracture of the skull vault may be seen and occasionally intracranial gas may be seen if the dura has been breached (*Figure 4*).

Acute or chronic subdural haematoma

A bleed in the subdural space results in a peripherally located crescent of acute high density blood. Bleeding into the subdural space is not limited by dural attachments at the sutures and the bleeding can therefore extend across the cerebral hemispheres (*Figure 5a*). A chronic subdural haematoma demonstrates the same configuration, but is of low density. There may be significant mass effect. Bilateral chronic subdural haematoma are occasionally seen and although these result in a large amount of mass effect, symmetry may be preserved as a result of the pressures on each side counteracting one another (*Figure 5b*).

Figure 2. Arteriovenous malformation, with large curvilinear calcified rims to the feeding vessels.

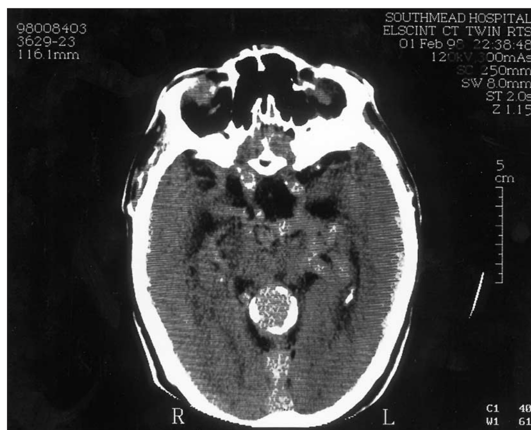
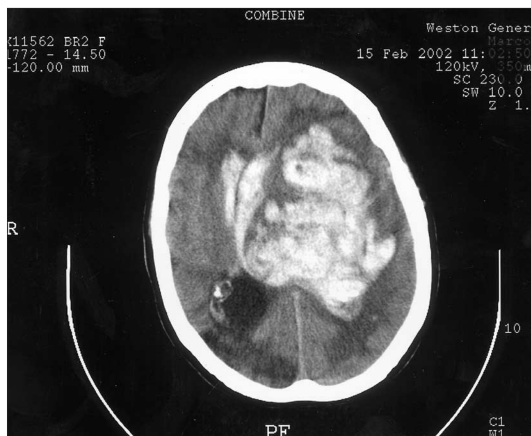


Figure 3. Acute intracerebral haemorrhage, appearing as large area of increased density throughout much of the left cerebral hemisphere. There is extension into the lateral ventricles, and marked mid line shift.



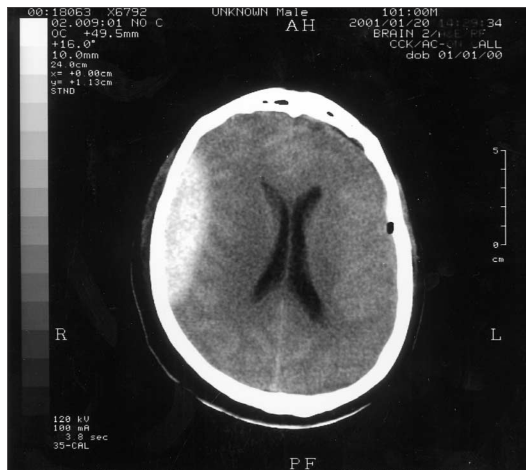
ISCHAEMIA/INFARCT

A decrease in cerebral blood flow may ultimately result in cerebral ischaemia, and ultimately infarction. This usually occurs as a result of local thrombus or embolus. A CT scan performed within the initial 6–12 hours may be normal, but as cerebral infarction becomes established, low density develops in the vascular territory involved (*Figure 6*). Initially, there may be associated oedema and mass effect. There may be increased (luxury) perfusion in the periphery of the infarct, and small areas of haemorrhage may also be seen. With the passage of time, the oedema resolves causing overall volume loss, and there may be resultant compensatory dilatation of the adjacent CSF spaces (Grainger et al, 2001).

INTRACRANIAL MASS LESIONS

A CT scan of the brain is often performed if there is a clinical suspicion of an intracranial mass lesion. The most common cause of a focal mass is metastases while the most common primary intracranial tumours in adults are astrocy-

Figure 4. Acute extradural haemorrhage appearing as lentiform increased density over the right temporoparietal area. Note a bubble of gas on the left side suggesting a breach to the dura and underlying skull fracture (not seen).



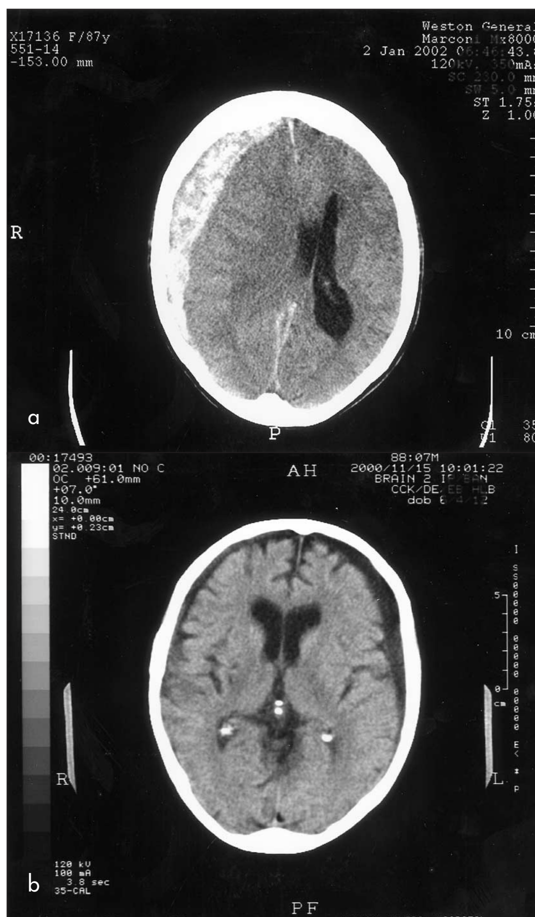
toma and meningioma. Abscess must also be considered in the septic patient with focal neurological signs (Lindsay et al, 1986; Grainger et al, 2001).

Metastases

Metastases usually occur at the grey-white matter border and may be of increased or decreased density with respect to brain tissue. They are often multiple, and indeed their multiplicity is important in their radiographic diagnosis. Metastases usually induce marked surrounding oedema and usually enhance after contrast injection; either uniformly or as a thick and irregular ring (*Figure 7*). A history of previous malignancy is important in making the diagnosis.

The most common tumours to metastasize to brain are primary tumours of the bronchus, breast, kidney and stomach. Malignant melanoma shows the highest frequency of such secondary spread. Review of a recent chest X-ray is often helpful to either demonstrate the primary lesion or to reveal further secondaries.

Figure 5. a. Acute subdural haemorrhage appearing as peripheral crescent-shaped area of high density. b. Bilateral chronic subdural haemorrhages (left greater than right), with relative preservation of midline structures.



Astrocytoma

This is the most common primary brain tumour in adults. They are graded from I to IV depending on their degree of malignancy (Lindsay et al, 1986).

Radiologically, astrocytoma appears as an intracranial mass lesion, often of low density or sometimes of mixed density, particularly if there has been recent bleed into the tumour. There may be a severe oedema reaction adjacent to the mass, and this in conjunction with the mass itself can cause significant mass effect. Similarly, surrounding low density can occur as a result of local tumour invasion (*Figure 8a*). There is usually a heterogenous enhancement pattern (*Figure 8b*), the degree of which corresponds to the grade of the tumour. Calcification or cystic change can rarely occur at the more benign end of the pathological spectrum.

Meningioma

Meningiomas arise from the arachnoid granulations closely related to the venous sinuses, but they are also found over the convexity of the cerebral hemispheres. These tumours are 'extra-axial' in their position and thus com-

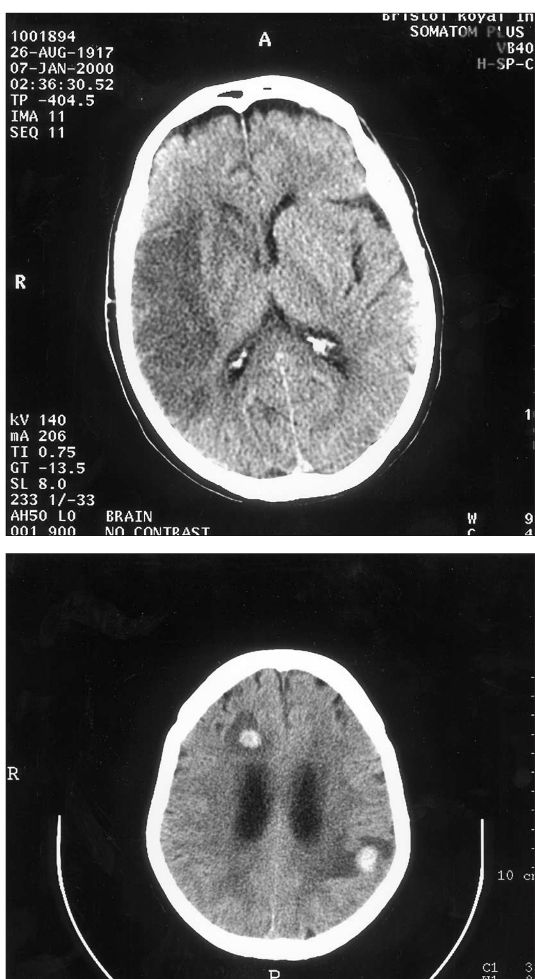


Figure 6. Right middle cerebral artery infarct causing a wedge of low density within the vascular territory of this vessel.

Figure 7. Post intravenous contrast scan, showing dense enhancement of metastases from carcinoma of the oesophagus. Note the surrounding low density oedema.

press rather than invade adjacent brain. Meningiomas are usually benign although they can invade adjacent bone or cause an adjacent osteosclerotic response.

They are found anatomically in sites corresponding to their pathological origin; and thus they are commonly seen adjacent to the falx or sagittal sinus, over the convexity of the cerebral hemispheres or at the skull base (Lindsay et al, 1986).

Radiologically, meningiomas are usually uniformly hyper-dense with respect to normal brain tissue and show dramatic, homogenous enhancement after the injection of radiographic contrast medium (*Figures 9a* and *b*) – the 'light–bulb' sign.

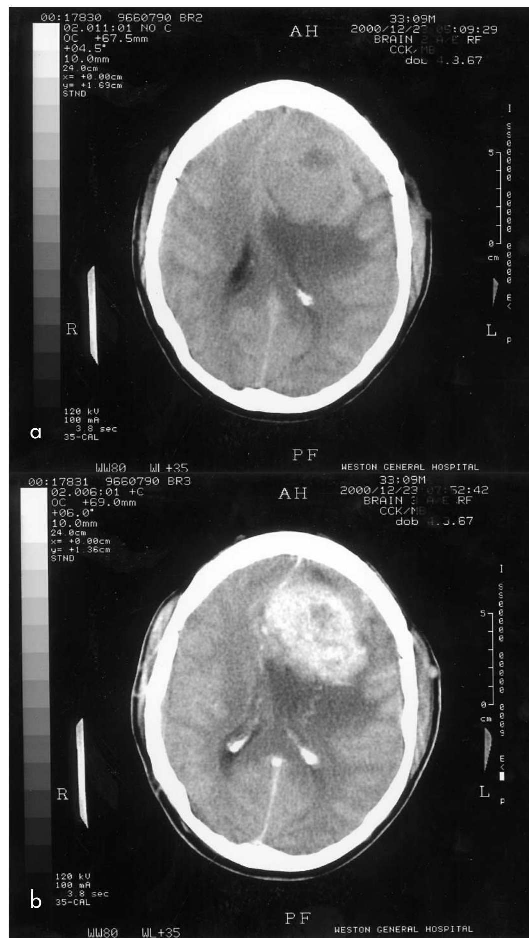


Figure 8. a. Poorly defined density in the left frontal lobe, just discernible from normal cerebral tissue. b. Post intravenous contrast, there is dense irregular enhancement. These are the appearances of malignant astrocytoma.

KEY POINTS

- Computed tomography (CT) can differentiate between acute intracranial haemorrhage and infarct.
- The pattern and distribution of acute haemorrhage or infarct confirms the anatomical site, and suggests the exact pathological diagnosis.
- CT will further evaluate and confirm the nature of intracranial mass lesions.

There may be surrounding area of low density oedema in up to 20% of meningiomas, and uniform areas of calcification may also be present.

Abscess

Intracerebral abscess must be suspected in a septic patient with neurological signs. Suspicion should be raised if there is a history of sinus disease, immunocompromise, intracardiac shunts, pulmonary abscess or subacute bacterial endocarditis (Lindsay et al, 1986).

The radiological appearances may mimic that of an isolated metastasis, although the rim of enhancement is usually finer in outline and although oedema is usually present, this is usually less marked. The adjacent sinuses should be evaluated for underlying infection. Although intracranial abscess is usually solitary, occasionally a daughter loculus is also present (Lindsay et al, 1986). **HM**

Conflict of interest: none.

Grainger RG, Allison DJ, Adam A, Dixon AK (2001) *Diagnostic Radiology A Textbook of Medical Imaging.* 4th edn. Churchill Livingstone, London: 2351–92

Lindsay KW, Bone I, Callender R (1986) *Neurology and Neurosurgery Illustrated.* Churchill Livingstone, Edinburgh: 224–96

Figure 9. a. Pre and (b) post intravenous contrast computed tomography scans showing uniform enhancement within a para-sagittal meningioma.