Cranial computed tomography 2: use in clinical practice

The importance of cranial computed tomography in the diagnosis and follow up of intracranial pathology cannot be underestimated. Clinicians at every level should have a basic understanding of this technique. This second part discusses the practical use of computed tomography in the clinical setting.

Cranial computed tomography is widely available and used in cases of suspected brain pathology. It should complement a thorough history and examination and can localize pathology within the brain to guide patient management. Cranial computed tomography is indicated in the assessment of:

- Stroke
- Brain haemorrhage
- Brain tumour
- Cerebral infection
- Cerebral trauma.

This article comprises two parts – the first covered the technical aspects of cranial computed tomography and this one will look at the place of cranial computed tomography in clinical practice.

Pathology

Stroke and transient ischaemic attacks

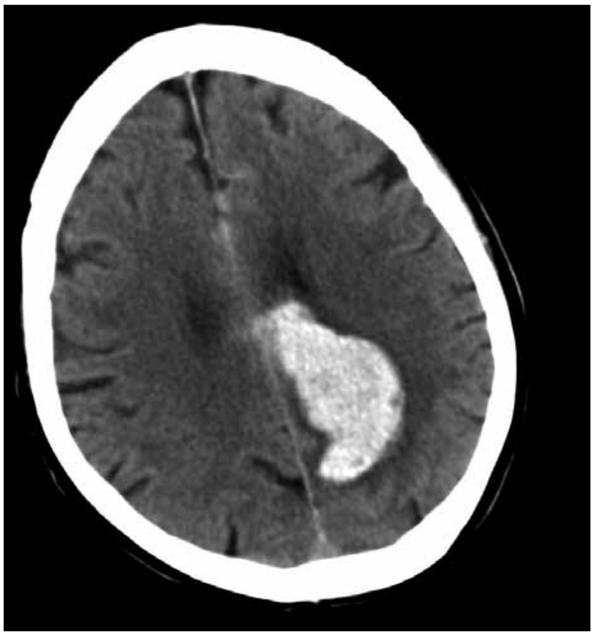
Any vascular interruption within the brain starves distal tissues of blood causing cell death and neurological deficit. This is termed a 'stroke' and is usually thromboembolic (90%) in aetiology (Dahnert, 2007), and less commonly haemorrhagic. In the acute setting, unenhanced cranial computed tomography is used to differentiate between the two. Treatment pathways for infarction require antiplatelet therapy, but haemorrhage needs to be excluded to avoid the catastrophic effects of anticoagulation.

Cranial computed tomography has a high sensitivity (89%) for haemorrhagic stroke (Chaldla et al, 2007). Acute blood within the brain parenchyma appears white on computed tomography and stands out against the adjacent darker brain tissue. Blood has a high attenuation with a Hounsfield unit of 60–70 (*Figure 1*).

In acute infarctive stroke, cranial computed tomography is relatively insensitive (45% at ictus rising to 74% by day 11) (Dahnert, 2007) and radiological features can vary. A normal cranial computed tomography scan does not exclude thromboembolic stroke, and should neurological deficit fully resolve within 24 hours, this is termed a transient ischaemic attack. The significance of patients presenting with a transient ischaemic attack should not be underestimated, and these patients should be considered as an acute medical emergency (Johnston et al, 2000) requiring risk stratification to prevent further non-fatal disabling stroke. In an acute infarctive stroke or transient ischaemic attack, the cranial computed tomography scan may be normal. Large thromboembolic strokes classically show a low density wedge-shaped area with blurring of the grey/white matter junction. Associated vasogenic oedema can press upon adjacent brain tissue and cause mass effect. The computed tomography findings can usually localize the cerebral artery involved, most commonly the middle cerebral artery as demonstrated in *Figures 2* and *3*.

Many hospitals now offer thrombolysis for acute thromboembolic stroke. Any history of intracranial haemorrhage is an absolute contraindication, and performing and interpreting a cranial computed tomography scan is therefore essential before treatment. Some

Figure 1. An unenhanced computed tomography scan showing an acute intracerebral haemorrhage (white) within the left cerebral hemisphere.



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other contraindications are listed below. Thrombolysis therapy has to be administered within 3 hours of symptom onset so speed of brain imaging is very important. The following criteria are taken from National Institute for Health and Clinical Excellence (2007a) guidance.

Inclusion criteria

- Clinical signs and symptoms of a definite acute stroke
- Clear time of onset
- Presentation with 3 hours of onset
- Haemorrhage excluded by computed tomography scan
- Aged between 18 and 80 years.

Figure 2. An unenhanced axial computed tomography slice demonstrating a well-demarcated area of low attenuation, with loss of the grey/white matter interface and mass effect in keeping with an acute left middle cerebral artery infarct.

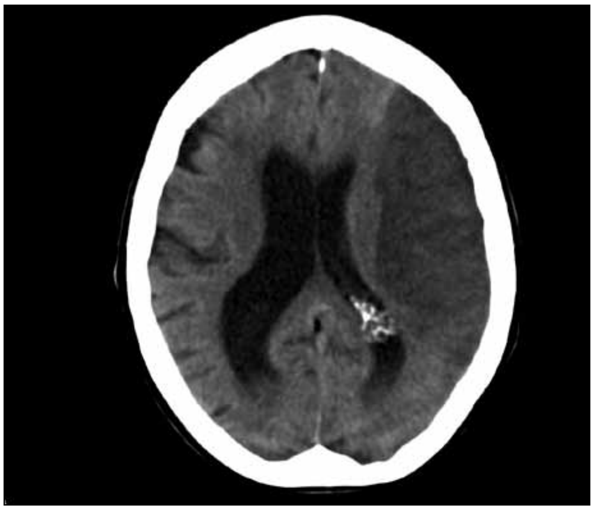
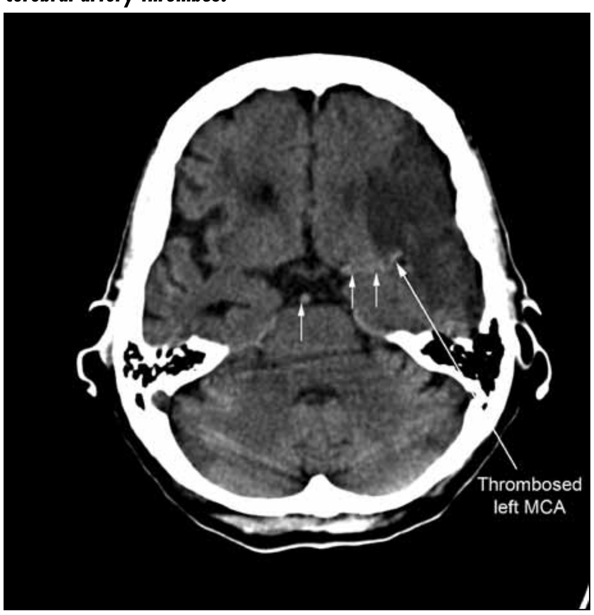


Figure 3. An unenhanced computed tomography scan with arrows demonstrating the 'dense artery sign' of an acute left middle cerebral artery thrombus.



Contraindications

- Any significant bleeding disorder within the last 6 months
- Any significant head injury within the last 3 months
- Current warfarin treatment and an international normalized ratio >1.4
- Suspected subarachnoid haemorrhage with a normal computed tomography
- Acute pancreatitis
- Bacterial pericarditis or endocarditis
- Active hepatitis or portal hypertension
- Documented bleed from an abdominal aortic aneurysm in the last 3 months.

Without revascularization, neuronal demyelination causes atrophy of brain tissue with time, leaving the patient with a permanent neurological deficit (*Figures 4* and *5*).

With respect to the diagnosis of stroke, computed tomography scanning remains the 'workhorse' of the radiology department. Continued advances in technology improve image quality while reducing radiation exposure and scanning time. Although currently a

Figure 4. Bilateral periventricular low attenuation from generalized ischaemia and small vessel disease.

Figure 5. An unenhanced computed tomography scan with a well-established area of encephalomalacia with atrophy in keeping an old right middle cerebral artery infarct.

research tool, functional scanning in the form of perfusion computed tomography is being suggested as a primary imaging modality of the future. As an adjunct to conventional computed tomography, a cranial computed tomography scan is performed at the same level over a fixed period of time while a predetermined contrast load is injected intravenously. As the brain parenchyma is perfused with contrast, changes in the attenuation pattern are mapped. Areas of perfusion deficit that would have ordinarily appeared normal on a conventional computed tomography are unmasked as the blood flow, volume and enhancement pattern are measured. As a functional study, perfusion computed tomography can determine the extent of reversibility following acute disabling stoke and help guide clinicians in their rehabilitation treatment options.

Intracranial haemorrhage

Head injury is a common presentation in emergency departments, associated with road traffic accidents, assaults or simple falls. Full clinical assessment and risk stratification can be made more difficult by alcohol intoxication or changes in conscious level related to concussion. Often these patients present over night, and out-of-hours computed tomography scanning is essential as a missed intracranial haemorrhage can have fatal consequences. To improve best practice, National Institute for Health and Clinical Excellence (2007b) offers guidance for patients presenting with suspected or confirmed head injury.

Computed tomography imaging of the brain should be requested immediately for patients with any of the following:

- Glasgow Coma Scale <13 on initial assessment in the emergency department
- Glasgow Coma Scale <15 2 hours after the injury
- Suspected open or depressed skull fracture
- Any clinical signs of base of skull fracture
- More than one episode of vomiting
- Post-traumatic seizure
- Focal neurological deficit
- Amnesia of events >30 minutes before impact.

Any patient with altered consciousness or amnesia should also have immediate imaging in the following cases:

- Patients over 65 years
- Coagulopathy
- Dangerous mechanism of injury.

Blood can collect in different compartments within the skull vault, and it is clinically important to correctly localize the blood with a view to clinical assessment for morbidity and treatment. Within a district general hospital setting, there is often no neurosurgical consultation onsite and clinicians have to refer a patient for intervention. It is therefore important that a radiologist can accurately localize and describe intracranial pathology for the neurosurgeon to make an informed decision.

Subarachnoid haemorrhage

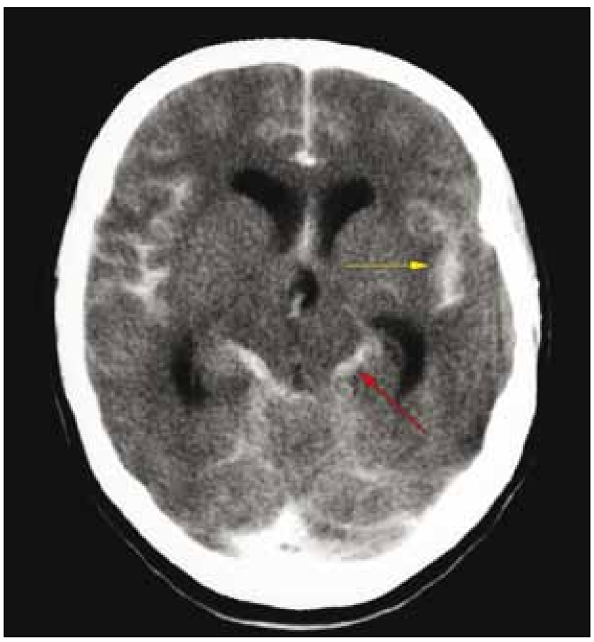
A subarachnoid haemorrhage is blood collected between the pia and arachnoid mater. Causes include ruptured aneurysm, arteriovenous malformation, hypertensive haemorrhage, blood dyscrasias, anticoagulation, eclampsia or trauma. Clinically patients with a subarachnoid haemorrhage commonly present with an acute severe occipital headache ('thunderclap') with associated vomiting, altered conscious state and agitation.

Unenhanced cranial computed tomography demonstrates acute blood (white, Hounsfield unit 60–70) within the CSF spaces (*Figure 6*). Large haemorrhages can be easily seen, but smaller bleeds can be more difficult. A normal cranial computed tomography does not exclude small subarachnoid haemorrhage (sensitivity 90%) (Dahnert, 2007), and lumbar puncture is essential to confirm the presence of normal or altered blood (xanthochromia). Any blood in the CSF space can cause obstruction and put the patient at risk of hydrocephalus and death. Clinicians often feel reassured by requesting a cranial computed tomography scan to exclude the contraindication of raised intracranial pressure before lumbar puncture to reduce the risk of 'coning'. However, cranial computed tomography is not a sensitive exclusion modality (Winkler et al, 2002), and full clinical assessment looking for signs of raised intracranial pressure is advised.

Extradural haematoma

An extradural haematoma is a collection of blood within the space between the inner table of the skull and the dura mater of the meninges. Blood collects in the extra-

Figure 6. An unenhanced computed tomography scan showing an acute subarachnoid haemorrhage. Arrows highlight acute blood within the Sylvian fissure (yellow arrow) and quadrigeminal basal cisterns (red arrow).



dural space running along the inside of the skull. It is strongly associated with direct head trauma and skull fracture, with bony fragments lacerating the meningeal vessels (commonly middle meningeal). Depending on the rate of haematoma expansion, the patient can classically present hours or days after the incident with gradually increasing drowsiness as the haematoma has focal mass effect compressing the brain within the skull.

An unenhanced cranial computed tomography scan usually demonstrates an acute hyperdense collection of blood, but if a few days old, can have varied attenuation appearances. It is differentiated from other extra-axial collections by its shape. The expanding haematoma will have a bi-convex elliptical shape as tracking blood is limited by cranial suture lines (*Figures 7a* and *b*). There may be a degree of mass effect, and image review with bone windows has a high sensitivity for resolving the underlying skull fracture. Compromised patients all require urgent neurosurgical assessment for potential intervention (Marx et al, 2006).

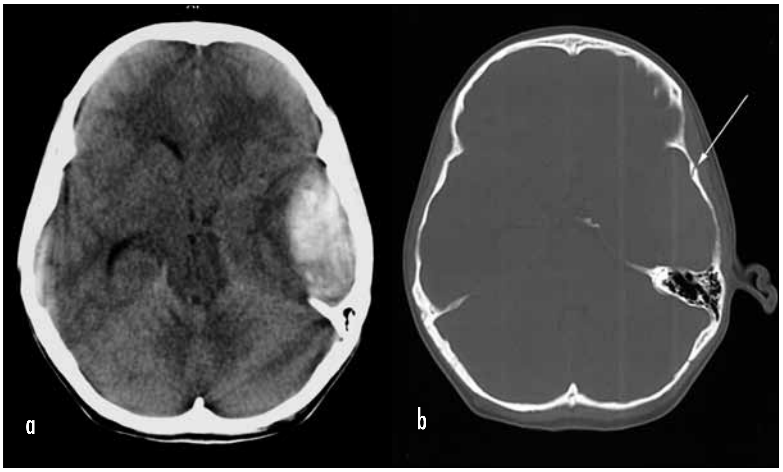


Figure 7. a. The convex elliptical shape characteristic of an acute left-sided extradural haemorrhage as seen on this unenhanced computed tomography scan. b. Bone windows demonstrate an underlying skull fracture (arrow) associated with the left extradural haemorrhage.

Subdural haematoma

A subdural haematoma is a collection of blood in the space between the pia mater and dura mater of the leptomeninges. Laceration of the veins between the two inner layers of the meninges causes blood to accumulate in the subdural space. Although there is an association with direct head trauma and penetrating injury, subdural haematomas are most commonly seen in the elderly. The brain atrophies with age and becomes more mobile within the skull. The bridging cortical veins are stretched, increasing the risk of both spontaneous rupture and disruption after trivial head injury. Blood is free to track along the surface of the brain within the subdural space and is limited only by the falx and tentorium cerebellum.

Cranial computed tomography demonstrates a concave haematoma that, unlike an extradural haemorrhage, crosses suture lines within the skull. The haematoma can have a varied attenuation pattern depending whether it is an acute (*Figure 8*), sub-acute or chronic subdural haematoma (*Figure 9*). Layering of old and fresh blood can be seen in a re-bleed demonstrating an acute-on-chronic picture.

Infection

Cranial computed tomography for the assessment of intracerebral infection is of limited use. Infection and tumour disrupt the blood–brain barrier and allow parenchymal enhancement following the infusion of intravenous contrast.

Figure 8. An unenhanced computed tomography scan with acute blood (arrows) seen in the characteristic concave shape of a subdural haemorrhage.

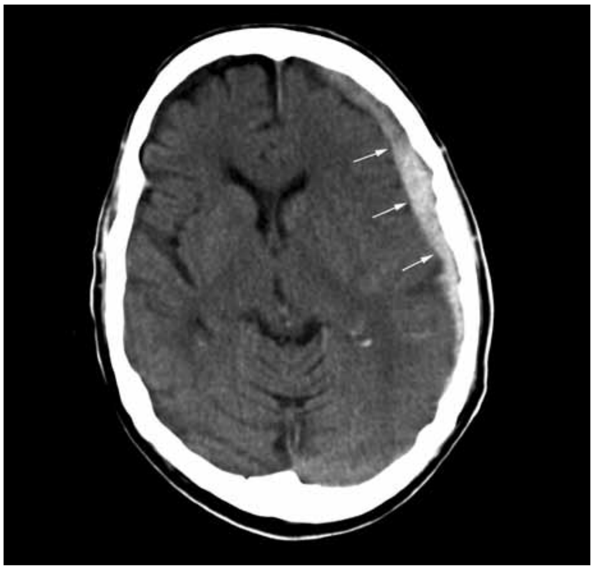
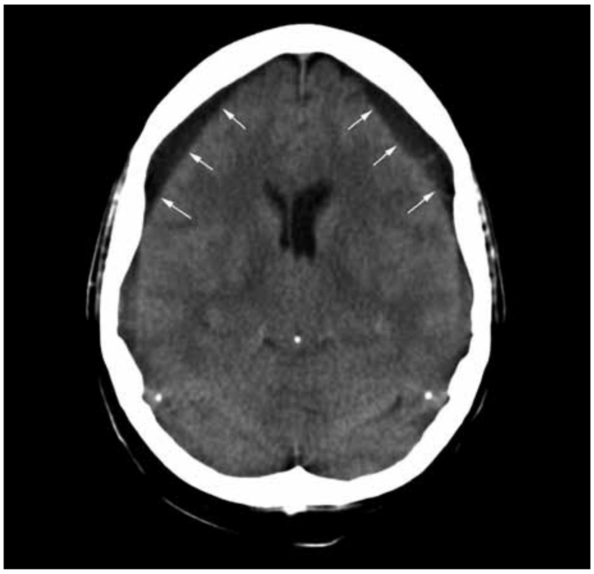


Figure 9. An unenhanced computed tomography scan showing bilateral old subdural haemorrhage (arrows). Note the attenuation difference between acute (*Figure 8*) and chronic blood.



Meningitis

In meningitis an unenhanced computed tomography scan is often normal and lumbar puncture would be required to look for signs of infection within the CSF. As mentioned previously, a cranial computed tomography scan cannot exclude the presence of raised intracranial pressure, and is not an indication for cranial computed tomography before lumbar puncture (van Crevel et al, 2002; Joffe, 2007).

Encephalitis

Patients with encephalitis may also have a normal cranial computed tomography scan, but sometimes brain swelling can cause mass effect with focal areas of high attenuation demonstrating micro-haemorrhage. The patient is often septic with altered conscious level, focal neurology and usually requires intubation. In encephalitis, a magnetic resonance imaging scan would be the preferred imaging modality (Heiner and Demaerer, 2003) having a higher sensitivity and specificity for early parenchymal oedema.

Abscess

Cranial computed tomography is useful in the detection of intracerebral abscess. An unenhanced cranial computed tomography scan shows a well-defined area of low attenuation (fluid density), pressing on the neighbouring parenchyma causing mass effect, with possible locules of gas seen depending on the aetiology. Intravenous contrast should be administered, and a disrupted blood–brain barrier allows contrast to accentuate the circular abscess wall. This is termed 'ring enhancement' (*Figure 10*). Adjacent daughter abscesses may be present. Although characteristic, ring enhancement is not specific for abscess and can also be seen in other conditions including tumour. Ring-enhancing brain lesions include abscess, metastases, glioma, acquired immunodeficiency syndrome toxoplasmosis, lymphoma, infarct or resolving haematoma.

Figure 10. A contrast-enhanced computed tomography scan showing a ring-enhancing lesion (red arrow) and the surrounding oedema (white arrow) of an intracerebral abscess.

Tumour

Primary

Uncontrolled expansion of brain cells results in the growth of an intra-axial primary brain tumour. The wide variety of tumour types is beyond the scope of this article, but the general features are as follows. On unenhanced cranial computed tomography, the majority of brain tumours appear as inhomogeneous low density masses (Dahnert, 2007), with ill-defined margins making it difficult to separate tumour from normal adjacent brain tissue. There may be some vasogenic oedema causing mass effect, and some tumour types may demonstrate focal area haemorrhage or calcification. Disruption to the blood–brain barrier allows brain tumours to demonstrate enhancement. Pre- and post-enhancement cranial computed tomography is helpful, but a magnetic resonance imaging scan is often performed to further characterize the tumour (*Figures 11a* and *b*).

Meningiomas are an extra-axial brain tumour and are the most common of all intracranial tumours in adults. They appear hyperdense on unenhanced computed tomography scan as a result of calcification, and homogenously enhance as they are removed from the blood–brain barrier (Buetow et al, 1991).

Secondary

Although it is important to recognize a primary brain lesion, secondary metastases are more common. In adults, six tumour types account for over 95% of all brain metastases (Wen and Loeffler, 1999):

1. Bronchogenic carcinoma
2. Breast carcinoma
3. Colorectal carcinoma
4. Renal cell carcinoma
5. Melanoma
6. Choriocarcinoma.

Commonly multiple and located at the grey/white matter junction, brain metastases are usually well-defined low density lesions on unenhanced cranial computed tomography unless there is associated haemorrhage (e.g. melanoma). They can be of variable size and seen anywhere in the brain parenchyma. Gross surrounding oedema (more than primary lesions) causes significant mass effect (*Figure 12a*). Following intravenous contrast (*Figure 12b*), small metastases can enhance uniformly but larger lesions demonstrate a ring enhancement pattern. A contrast-enhanced cranial computed tomography often reveals additional lesions. A magnetic resonance imaging scan in conjunction with computed tomography scan is helpful at characterizing metastases further.

Conclusions

This second of two articles on cranial computed tomography has discussed its use in clinical practise. Indicated for the assessment of common intracranial pathologies, cranial computed tomography is the workhorse in the diagnosis and follow up of ischaemic and haemorrhagic stroke, brain tumours, trauma and cerebral infections. As an imaging modality, it has a high sensitivity for acute blood with good resolution in the assessment of bony pathology. This makes its use in trauma and in the assessment of acute stroke essential. Discriminating ischaemic stroke from a 'stroke mimic' (e.g. haemorrhage) is important in the acute setting to help define a treatment pathway. Computed tomography is also often used to exclude other reversible disease in the acute setting because of its ease of accessibility 24 hours a day and relative low cost. A magnetic resonance imaging scan can be a useful adjunct or alternative to cranial computed tomography, but is not always the preferred imaging modality.

Understanding cranial anatomy is very important, and clinical symptoms can be localized to particular territories on computed tomography and should always support a thorough clinical history and examination. Brain haemorrhage and mass lesion are well demonstrated, and intravenous contrast is used to demonstrate characteristic enhancement patterns and improve tissue contrast. The images generated are reproducible and can be electronically transferred between institutions to optimize referral times and patient care. Well established as an imaging modality in teaching and district general hospitals, it is important that clinicians at every level have a basic understanding of cranial computed tomography. BJHM

Conflict of interest: none.

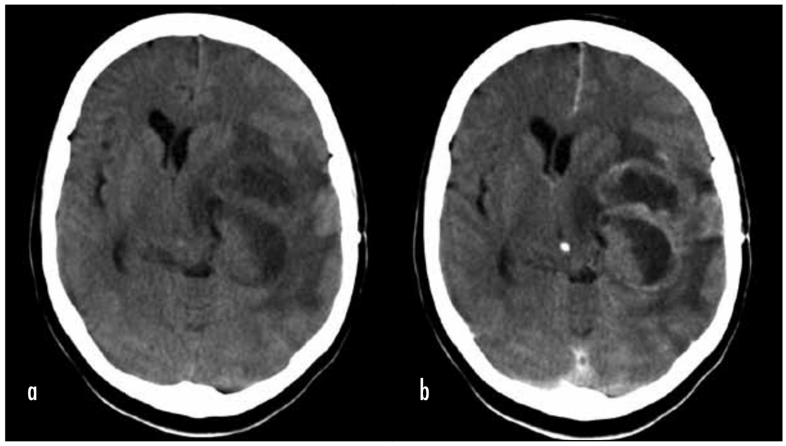


Figure 11. a. A pre-contrast computed tomography scan showing left-sided mixed attenuation lesions causing mass effect and ventricular effacement. b. The same patient following intravenous contrast, demonstrating the ring enhancement pattern of a primary brain tumour.

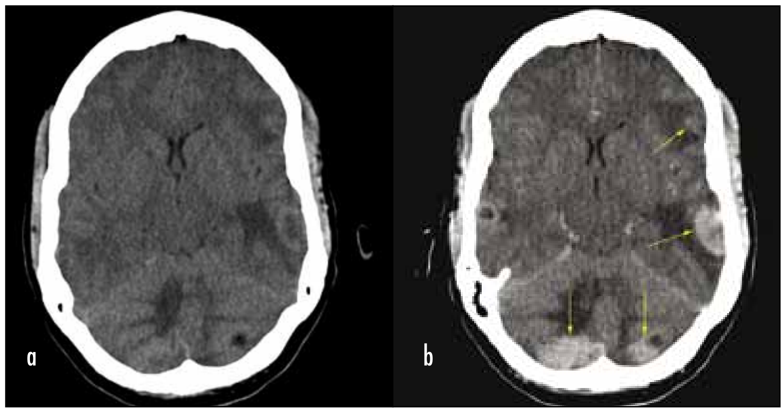


Figure 12. a. A pre-contrast computed tomography scan with multiple mixed attenuation lesions in both cerebral hemispheres with associated mass effect. b. The same patient following contrast infusion, with multiple enhancing metastases seen throughout the brain parenchyma (yellow arrows). Note many of these lesions were invisible on the pre-contrast scan.

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KEY POINTS

- Cranial computed tomography has a high sensitivity for haemorrhagic stroke.
- The importance of a transient ischaemic attack should not be underestimated and patients should be considered as an acute medical emergency.
- Stroke thrombolysis is now established practice with strict inclusion criteria.
- A normal cranial computed tomography scan does not exclude small subarachnoid haemorrhages.
- Secondary tumour metastases are more common than primary brain tumours and often demonstrate ring enhancement on intravenous contrast administration.