The radiological investigation of subarachnoid haemorrhage

Subarachnoid haemorrhage is an important condition with a high mortality, so prompt diagnosis is essential. This article will review the investigation of subarachnoid haemorrhage with a radiological bias. Appropriate clinical correlation will be included and it will look at some of the more interesting areas in the investigation of this condition.

The presenting features of subarachnoid haemorrhage, i.e. sudden onset of severe headache ('worst in my life'), vomiting and altered consciousness, are well recognized. There are various conditions that predispose to subarachnoid haemorrhage, which include autosomal dominant polycystic kidney disease, aortic dissection, Marfan's syndrome, Ehlers–Danlos syndrome and fibromuscular dysplasia.

Subarachnoid haemorrhage accounts for a small proportion of patients with headache presenting to the accident and emergency department and the incidence is calculated to be approximately 6 per 100 000 (Linn et al, 1998). However, the prognosis is poor with approximately 50% mortality and up to one third of survivors have major neurological defects (Hop et al, 1998). Therefore, a prompt diagnosis and initiation of treatment is essential. This article will concentrate on the radiological investigation of subarachnoid haemorrhage. In order to consider the various imaging modalities and interpret their findings, it is necessary to briefly discuss the pathophysiology of subarachnoid haemorrhage.

The causes of subarachnoid haemorrhage

Saccular aneurysms

Approximately 85% of spontaneous subarachnoid haemorrhage arises from saccular aneurysms, which are acquired during life (van Gijn and van Dongen, 1980). Such aneurysms tend to occur at arterial branch points in the circle of Willis and are most common in the region of the anterior communicating artery (*Figure 1*). Aneurysms may be multiple in up to 20% of cases. The incidence of such aneurysms varies according to the population studied but may be up to 6% (Rinkel et al, 1998).

Other causes

Approximately 15% of subarachnoid haemorrhage is not the result of an aneurysm and the other causes will briefly be discussed.

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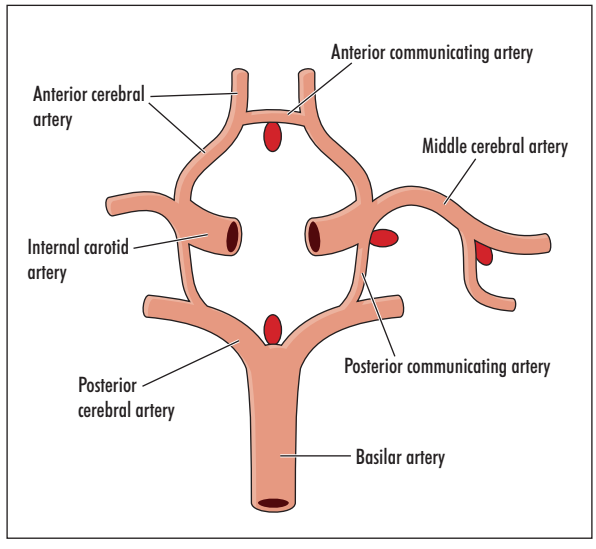
Perimesencephalic haemorrhage is an interesting entity and accounts for approximately 10% of subarachnoid haemorrhage. In this condition, blood is entirely confined to the basal cisterns around the mid-brain. In the majority of patients with this condition, cerebral angiography will be negative, since 96% of bleeds will be non-aneurysmal (Velthuis et al, 1999). In such patients, no angiographic follow up is required since re-bleeds and delayed ischaemia do not occur and the prognosis and recovery is excellent (Rinkel et al, 1991; Brilstra et al, 1997). In fact, whether angiography is required at all in patients with a perimesencephalic pattern of haemorrhage is a matter for debate. This will be discussed later.

Rarer causes of subarachnoid haemorrhage, which will not be discussed here in any detail, include vertebral artery dissection, cerebral and spinal arteriovenous malformations, dural arteriovenous fistulae and septic aneurysms (for example secondary to infective endocarditis), and pituitary apoplexy (among others).

Pituitary apoplexy, i.e. the sudden onset of haemorrhage into a pituitary tumour, is an interesting condition that may present with identical clinical features to sub-

Figure 1. Locations of aneurysms in the circle of Willis. Anterior communicating artery 30–35%, bifurcation of the internal carotid and posterior communicating arteries 30–35%, bifurcation of the middle cerebral artery 20%, basilar artery bifurcation 5%, remaining posterior circulation arteries 5% (not shown).



arachnoid haemorrhage. However, the hallmark of this condition is that patients have a sudden decrease in visual acuity, and in many, eye movements are also affected, as a result of compression of the third, fourth and sixth cranial nerves within the cavernous sinus. A computed tomography (CT) scan in this condition should reveal the source (in the majority a pituitary adenoma) or at least the site of the haemorrhage (the pituitary fossa).

Complications of subarachnoid haemorrhage

Re-bleeding

As indicated, in patients with a non-aneurysmal pattern of haemorrhage (perimesencephalic haemorrhage), the prognosis is excellent, re-bleeding does not occur and no further imaging is required. However, in patients with an aneursymal pattern of bleeding, approximately 10–20% of conventional angiograms fail to demonstrate an aneurysm, which is thought to be the result of vasospasm, thrombosis or obliteration of the aneurysm by rupture. In aneurysmal subarachnoid haemorrhage, there is an approximately 10% risk of rebleeding (Fuji et al, 1996) as well as the potential to develop delayed neurological deficits, after which the prognosis is poor. Therefore, repeated angiography in order to identify an aneurysm is indicated, with a second angiogram after approximately 2 weeks and a further study, if necessary, after a few months. In addition in such patients, a magnetic resonance imaging (MRI) scan of the entire brain and spinal cord is sometimes undertaken to exclude tumours and vascular malformations of the brain or spine.

Acute hydrocephalus

When blood products block CSF outflow, obstructive hydrocephalus results which if untreated, has a very poor outcome.

The investigation of the patient with suspected subarachnoid haemorrhage

Computed tomography scanning

CT scanning is the first-line investigation for acute subarachnoid haemorrhage because acute blood is hyperdense (appears white on CT) and therefore easily identified. MRI could be undertaken as an alternative but this is rarely feasible and in addition there are often safety issues in the acute setting (see below). CT is 95% sensitive to the presence of subarachnoid blood when performed within the first 24 hours of the ictus (Van der Wee et al, 1995) but after this time, the sensitivity decreases. Despite its sensitivity, the detection of subtle subarachnoid haemorrhage is dependent on the skills of the reporting radiologist and small amounts of blood can be overlooked. When subarachnoid haemorrhage is dramatic, the findings are obvious, as shown in *Figure 2*. Less dramatic and some more subtle examples are demonstrated in *Figures 3–8*.

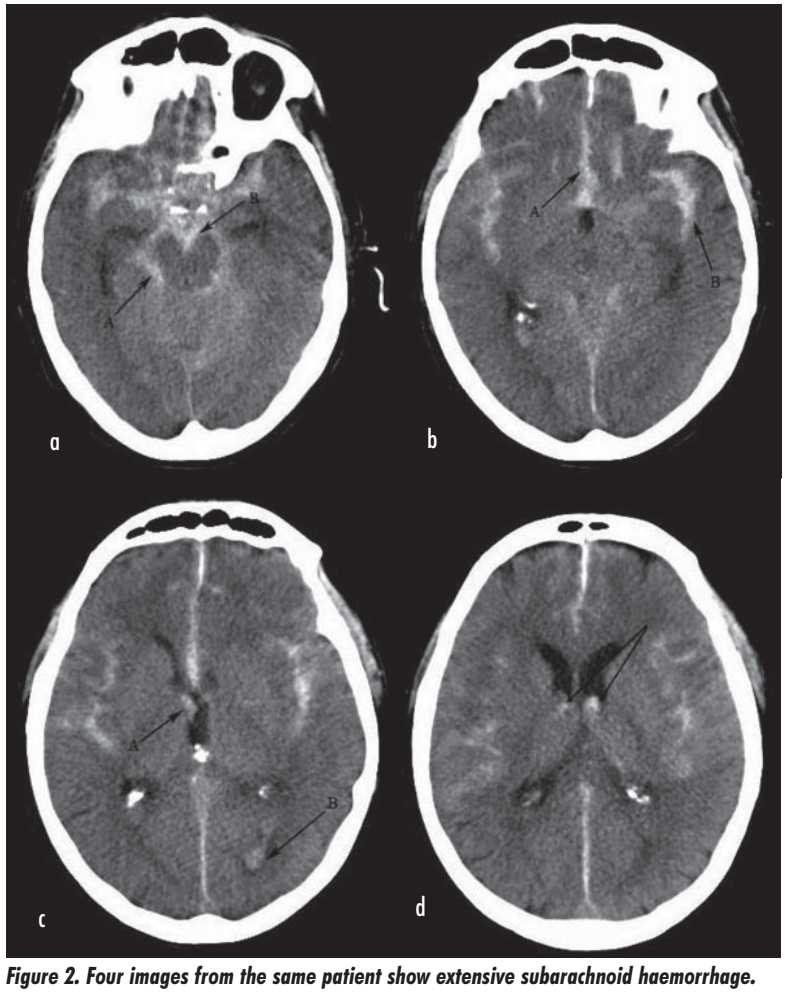


Figure 2. Four images from the same patient show extensive subarachnoid haemorrhage. High density material (blood) is demonstrated (a) within the basal cisterns (A and B represent the pre-pontine and ambient cisterns respectively), (b) in the (A) anterior interhemispheric and (B) sylvian fissures, (c) in the (A) third ventricle and (B) occipital horn of the left lateral ventricle and (d) in the frontal horns of the lateral ventricles (arrowed).

The pattern of blood may indicate the site of the aneurysm (for example blood within the sylvian fissure suggests a middle cerebral artery aneurysm). Of importance, if no blood is identified on CT, aneurysmal subarachnoid haemorrhage is not excluded. Studies can be negative in up to 2% of patients even if performed within 12 hours of the ictus (Sidman et al, 1996). Therefore, in patients with a clinical suspicion of subarachnoid haemorrhage and a normal CT scan, lumbar puncture is mandatory. Numerous studies have addressed this requirement (e.g. Van der Wee et al, 1995; Sidman et al, 1996). Ideally, although this may not be appropriate in all patients, a lumbar puncture should be undertaken at least 6 hours after the onset of the headache in order to enable the formation of bilrubin and oxyhaemoglobin from red cell lysis, which produces the xanthochromia. The 'three tube test' indicates a decrease in the number of red cells in consecutive tubes, but this is very unreliable and can lead to false positive results. The purpose of identifying or excluding the presence of xanthochromia is to ensure that the diagnosis of subarach-

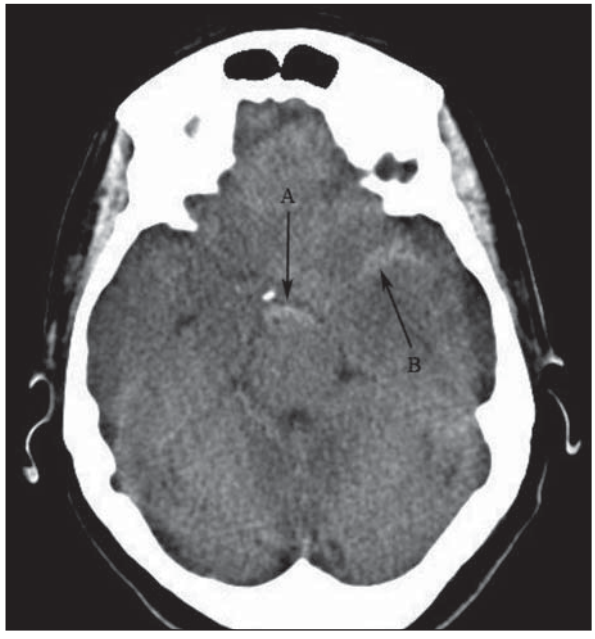


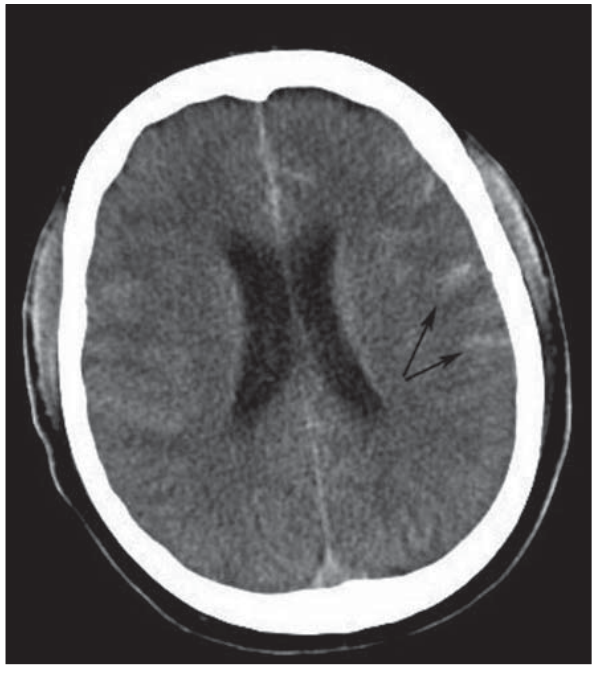
Figure 3. Subtle subarachnoid haemorrhage – high density (blood) in the pre-pontine cistern (A) and left sylvian fissure (B).

noid haemorrhage is made accurately rather than attempting to interpret findings that may relate to a traumatic tap.

Magnetic resonance imaging

MRI is as sensitive as CT when performed in the acute phase (Noguchi et al, 1995) but generally, MRI is more difficult to obtain both as an emergency and out of hours. Further, agitated patients may well require general anaesthesia which has its own safety considerations,

Figure 4. Subtle areas of high density in multiple left sided sulci (arrowed) in keeping with subarachnoid blood.



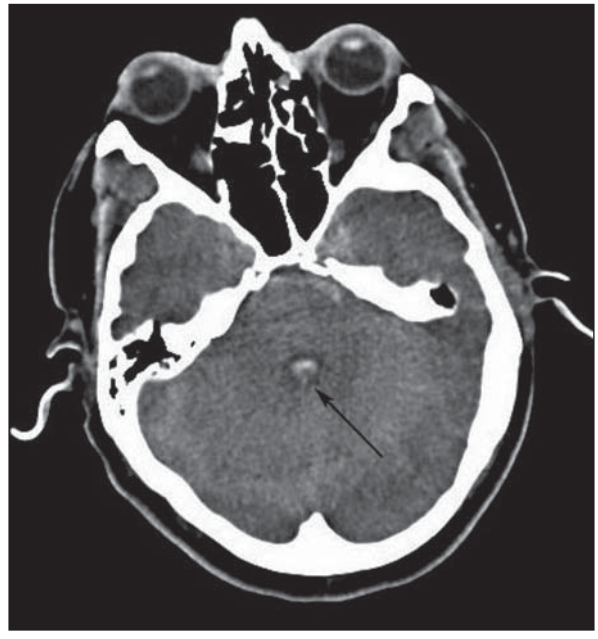
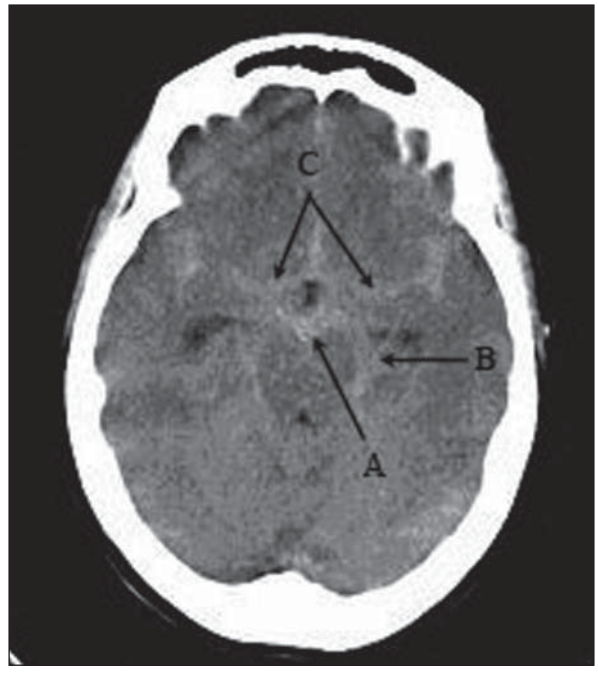


Figure 5. Blood within the fourth ventricle (arrowed).

not withstanding the confined space in the MRI scanner. The sequence of choice is FLAIR (fluid-attenuated inversion recovery) which nulls the signal from fluid (specifically CSF) and therefore makes blood more easily identified. Sub-acute blood is particularly conspicuous on a T2* gradient echo sequence and for such reasons, MRI is a superior modality to CT in the delayed evaluation of subarachnoid haemorrhage, for example when patients present 1–2 weeks following the ictus.

Figure 6. High density material (blood) obliterating the normal appearance of the basal cisterns (pre-pontine (A) and ambient cisterns (B)) and sylvian fissures (C) in keeping with subarachnoid blood.



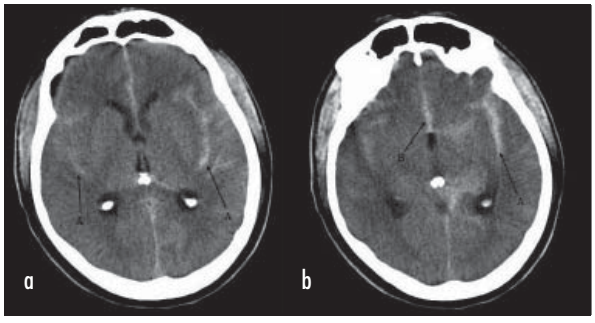


Figure 7. Two images from the same patient showing subarachnoid blood (a) in the sylvian fissures and (b) anterior interhemispheric fissure.

Identifying the cause of subarachnoid haemorrhage

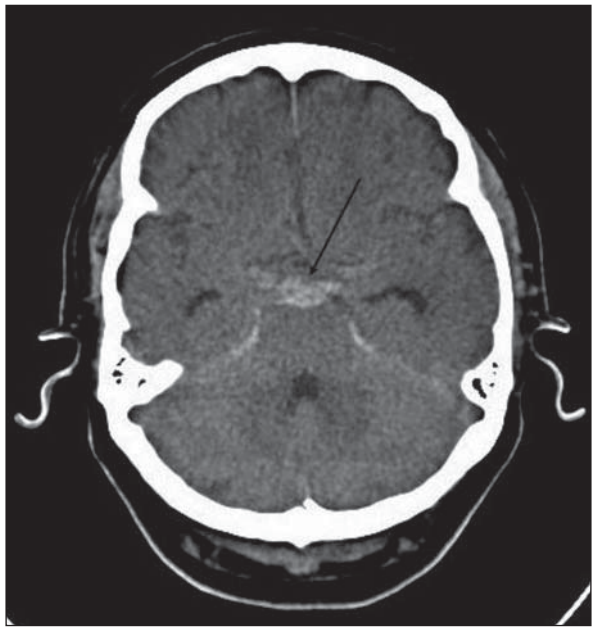
If a subarachnoid haemorrhage is confirmed or xanthochromia found in a patient with negative imaging, what happens next? Subsequent investigations are then undertaken in an attempt to identify the source of the bleeding, which as stated previously is caused by an aneurysm in approximately 85% of patients.

Traditionally, the gold standard for the detection of aneurysms is conventional digital subtraction angiography (*Figure 9*). However, this is a time-consuming procedure and not without significant potential complications, although angiography enables the diagnosis and treatment of an aneurysm at the same sitting, for example by endovascular coiling as demonstrated in *Figure 10*, but not discussed here. The alternatives to angiography and their possible uses will now briefly be discussed.

Magnetic resonance angiography (MRA), as stated, is less suitable in the acute stage when patients may be restless, agitated and need careful monitoring. Nevertheless, the sensitivity and specificity of MRA in the detection of aneurysms is approximately 70–97% and 75–100% respectively, the figures variability depending on aneurysm size, with those less than 5 mm being harder to detect (Wardlaw and White, 2000). The MRA source images are manipulated in order to obtain maximum intensity projections (MIPs) which show the vessels more clearly (*Figure 11*). The main use of MRA is in the screening of the families of patients with SAH.

An alternative technique is CT angiography (CTA). This examination can be undertaken at the same time as

Figure 8. Perimesencephalic haemorrhage – blood is confined to the basal cisterns (in this case the pre-pontine cistern (arrowed)).



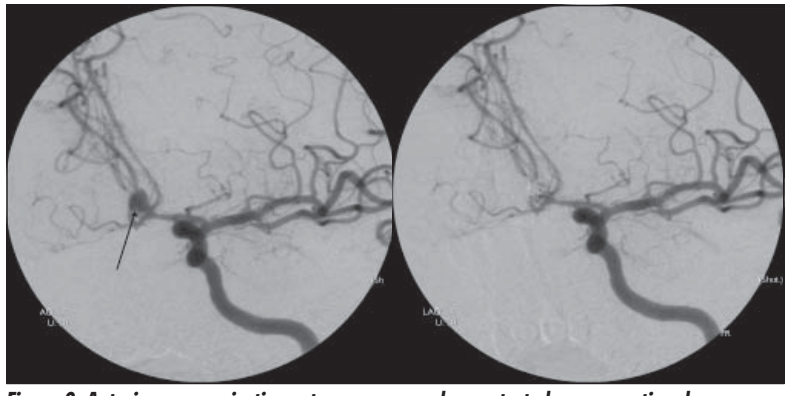


Figure 9. Anterior communicating artery aneurysm demonstrated on conventional angiography (arrowed) with the corresponding post coiling appearances.

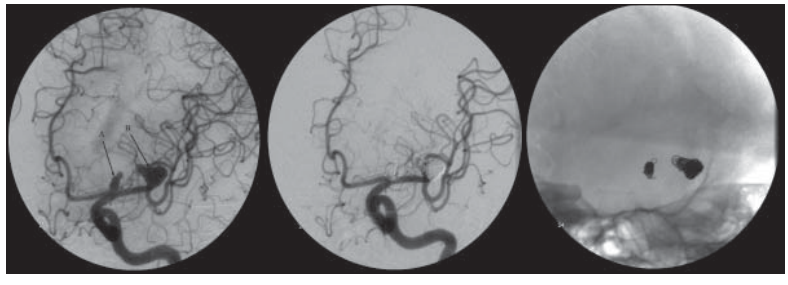
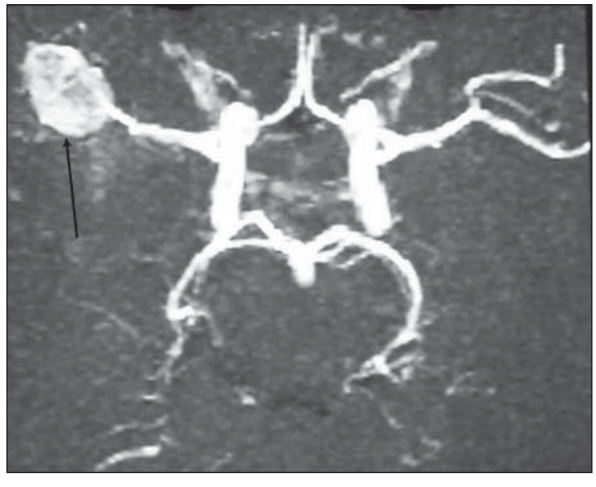


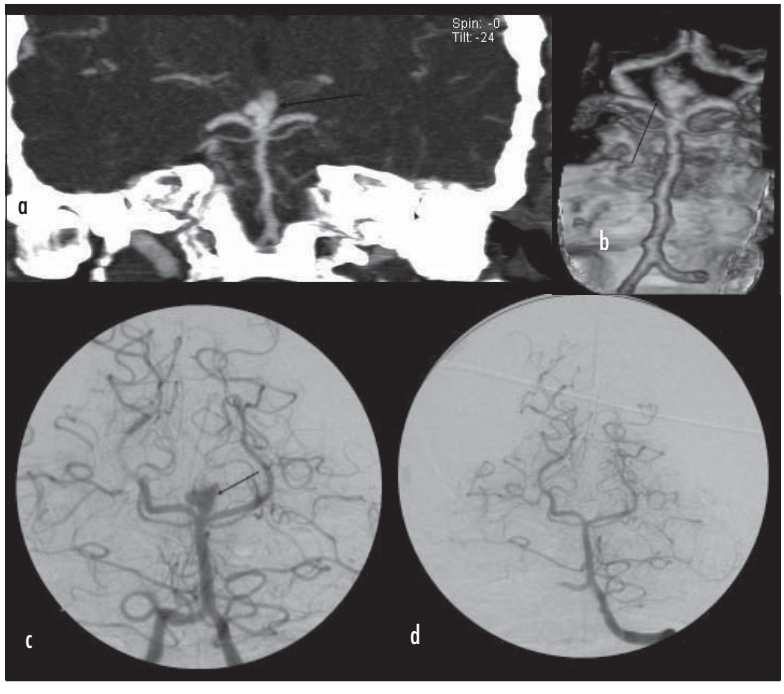
Figure 10. Digital subtraction angiography demonstrating left internal carotid (A) and left middle cerebral artery (B) aneurysms with corresponding post coiling images.

Figure 11. Maximum intensity projection of the circle of Willis demonstrating a right middle cerebral artery aneurysm (arrowed).



the initial CT scan, i.e. when the patient presents. Contrast medium is needed and the axial images obtained are reconstructed and reviewed as MIPs (to maximize intravascular contrast) in the coronal and sagittal planes (*Figures 12* and *13*). CTA has the advantage that it can be performed on ill patients. The sensitivity of CTA in the detection of an aneurysm is similar to that of MRA (Wardlaw and White, 2000). Some studies have suggested that CTA may be superior to conventional angiography (Velthuis et al, 1998) and therefore, in some instances, patients with SAH may be treated on the basis of CTA alone.

Figure 13. A basilar artery tip aneurysm on computed tomography and conventional angiography. a. A coronal maximum intensity projection. b. A reconstructed image (basilar artery tip aneurysm arrowed). c. The corresponding digital subtraction angiography appearance. d. The corresponding post coiling appearance.



KEY POINTS

- Subarachnoid haemorrhage is a common condition with a high mortality; prompt diagnosis is therefore essential.
- The most common cause of subarachnoid haemorrhage is a ruptured aneurysm of the circle of Willis.
- Imaging forms the basis of confirming the diagnosis of subarachnoid haemorrhage.
- A negative computed tomography scan necessitates a subsequent lumbar puncture.
- The cause of subarachnoid haemorrhage may be identified on angiography, traditionally with a digital subtraction technique allowing subsequent endovascular treatment, although computed tomography and magnetic resonance angiography are alternative imaging modalities.
- Perimesencephalic subarachnoid haemorrhage is an entity with a lower morbidity and mortality and invasive imaging may not be needed in patients with this condition since, in the majority, a treatable aneurysm is not identified.

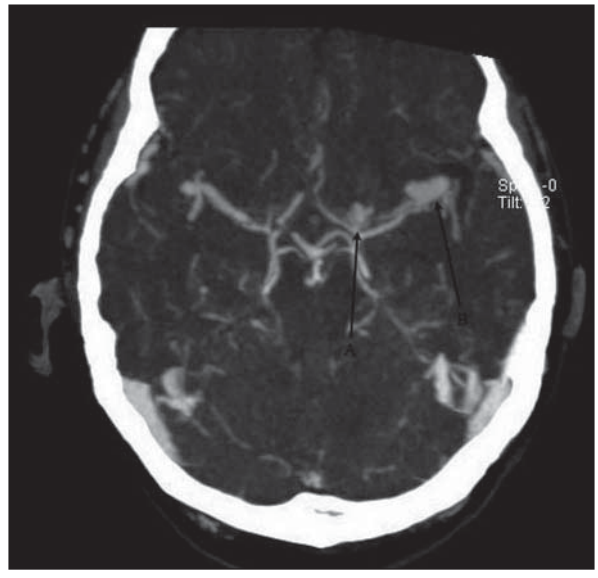


Figure 12. Left middle cerebral and left internal carotid artery aneurysm demonstrated on computed tomography angiography in the axial plane (arrowed).

Since the vast majority of patients with SAH will have an underlying aneurysm that will require treatment (which is likely to be undertaken as an endovascular procedure at the same time as the cerebral angiogram), conventional angiography is still widely undertaken as the subsequent investigation to the initial CT. However, in patients with perimesencephalic haemorrhage, as stated, approximately 96% of cases will have non-aneurysmal causes (Velthuis et al, 1999). In the remaining 4% of patients, the bleeding is the result of a vertebrobasilar aneurysm. The need to identify such an aneurysm in all patients with perimesencephalic haemorrhage has to be weighed against the risk of complications from conventional angiography in the vast majority of patients who have no aneurysm and an already good prognosis. It has been suggested therefore that in such patients, digital subtraction angiography can be omitted in the presence of a normal CT angiogram, which should identify the small proportion of patients who have a perimesencephalic pattern of haemorrhage and an underlying vertebrobasilar aneurysm (Ynte et al, 2000). However, this is a contentious area.

Conclusions

This article has reviewed the radiological investigation of subarachnoid haemorrhage and attempted to deal with some of the discussion surrounding lumbar puncture, perimesencephalic haemorrhage and the uses of CTA and MRA. BJHM

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