

Magnetic resonance angiography of the cerebrovascular system

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SYNOPSIS

Arterial blood flow is not shown clearly by magnetic resonance imaging, but it can be revealed by magnetic resonance angiography. This technique manipulates the signal from blood so that the vessels are distinguished from the surrounding tissues. Magnetic resonance angiography can be used to detect intracranial aneurysms, intracranial vascular disease and thrombosis of the major cerebral veins. It is the investigation of choice if dissection of the carotid or vertebral artery is suspected. Although new techniques can produce images quickly, magnetic resonance angiography is unsuitable for patients who cannot lie motionless inside the scanner until the image is acquired, or who have contraindications to having magnetic resonance imaging.

Index words: aneurysm, atherosclerosis, arterial dissection, stroke.

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Introduction

Magnetic resonance angiography (MRA) is a magnetic resonance imaging (MRI) technique which can distinguish vascular flow from the surrounding tissues. It is now in routine use as a non-invasive tool for imaging the cerebral vasculature. In cerebrovascular disease it is the investigation of choice for patients who are suspected of having:

- unruptured intracranial aneurysms
- intracranial vascular disease associated with acute infarction
- transient ischaemic attacks (TIA) (not all patients require imaging)
- intracranial and/or extracranial dissection of the carotid and/or vertebral arteries
- thrombosis of major cerebral veins and dural venous sinuses.

MRA may also be helpful as part of the initial investigation of patients with suspected intracranial vasculopathies related to a variety of other disorders such as pre-eclampsia/eclampsia, vasculitis, neurofibromatosis, radiation therapy, intracranial infection, and cerebral vascular malformations.

Advances in MR surface coil technology as well as the use of intravenous contrast media have now made it possible to obtain an angiographic study of the cervical and intracranial vessels in a single breath-hold.

Magnetic resonance angiography techniques

All the images are produced using either a time-of-flight (TOF) or phase-contrast technique. The TOF technique takes less time and is more commonly used. It is based on the principle that flowing protons entering a slice of tissue possess full longitudinal magnetisation and therefore high signal intensity. By suppressing the signal from the surrounding tissue, the technique highlights vessels with flowing blood. Phase-contrast techniques utilise velocity differences and phase shifts in moving blood to provide image contrast. This can be used to assess the speed and direction of the blood flow. Both techniques are capable of two- or three-dimensional imaging depending upon whether individual slices or volumes of tissue are excited by the radiofrequency pulse. Reconstruction of the images results in most of the signal from the surrounding soft tissues being removed, allowing the vessels to be visualised in greater detail. Three-dimensional TOF MRA is the technique which is most often used for evaluating the intracranial arteries and veins. Some centres use phase-contrast MRA when imaging the cerebral venous system.

Three-dimensional TOF MRA can be subject to artifacts which may cause misrepresentation of vessel pathology. MRA images are extremely sensitive to degradation by movement, mainly because it takes a relatively long time to acquire the image. If the patient moves or swallows at any time it can render an entire study non-diagnostic. Conventional angiography or ultrasound are preferred for patients who are unable to remain still for approximately 10 minutes.

Routine cerebral MRA does not require the use of intravenous or intra-arterial contrast agents. Intravenous contrast is being used in a new technique; three-dimensional contrast-enhanced breath-hold MRA is being increasingly used to evaluate the cervical and cranial arteries. It has a lower resolution, for the intracranial circulation, than TOF MRA, because it has a larger field of view, but it has the advantage of allowing the cervical and intracranial vessels to be imaged in the time taken for a single breath-hold. The technique is most useful for the evaluation of atherosclerotic disease involving the aortic arch and proximal cervical vessels and for other conditions affecting these vessels such as congenital anomalies and arteritides.

Cerebrovascular applications

Suspected TIA or stroke

Three-dimensional TOF MRA can be used in acute stroke. Images of the internal carotid, vertebral and basilar arteries and their major branches can be obtained in 6–8 minutes (Fig. 1). The small peripheral branches of the anterior, middle and posterior cerebral arteries are too small to be demonstrated by routine MRA.

Intracranial vessels

Irregularities in the calibre and contour of a vessel can suggest the presence of atheroma, thrombus/embolus, or vascular diseases such as fibromuscular dysplasia or vasculitis. A reduced signal within an intracranial internal carotid artery may be a sign of a critical stenosis of the cervical portion of the vessel.

Dural venous sinus thrombosis accounts for approximately 1–2% of acute strokes in young adults. Intracranial venous MRA (MR venography) provides excellent, non-invasive visualisation of the dural venous sinuses and the larger deep cerebral and cortical veins.

Extracranial vessels

Non-invasive techniques such as carotid duplex ultrasound, CT angiography and MRA are now used in preference to angiography in the investigation of suspected extracranial carotid arterial disease. Three-dimensional TOF MRA tends to overestimate the degree of stenosis compared with conventional angiography, but correlates well with the estimates obtained by duplex ultrasound. Ultrasound and MRA have a high sensitivity and specificity in estimating stenoses greater than 70%.¹

MRA is less sensitive than ultrasound for distinguishing between severe stenosis and occlusion. Significant signal loss can occur as a result of turbulent flow near a stenosis and this can in turn lead to difficulty in differentiating between severe stenosis and complete occlusion, but this can usually be resolved with angiography.

At present, the cost and availability of ultrasound make it the investigation of choice in the patient with a suspected critical extracranial carotid stenosis, but MRA can be useful in confirming an equivocal ultrasound abnormality. MRA is the preferred test if arterial dissection is suspected.

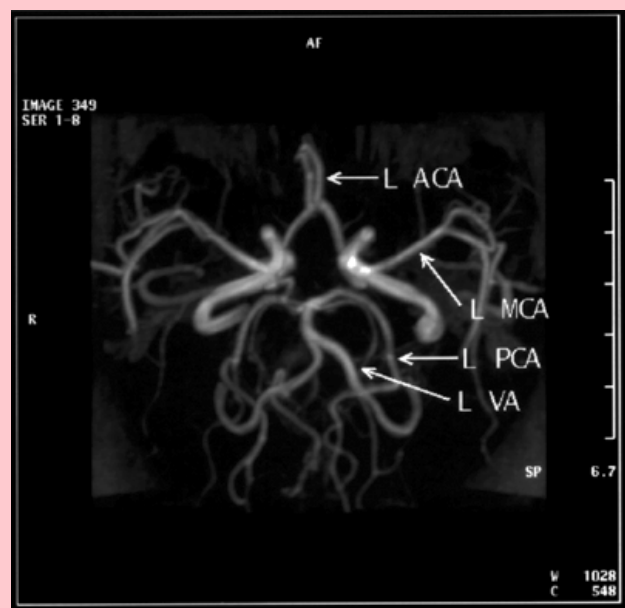
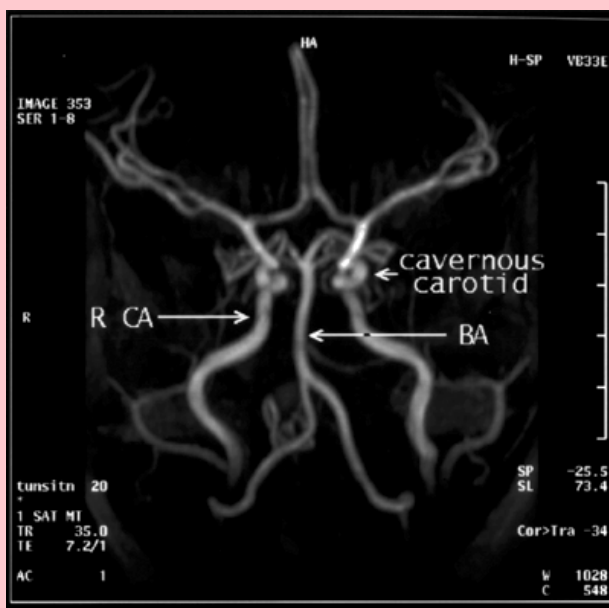
Improvements in MRI hardware, software and coil development, as well as the use of intravenous contrast now allow the cervical vessels to be imaged in a single breath-hold.² Using this technique a complete study of the aortic arch and supra-aortic arteries can be performed in only a few minutes.

Dissection

Dissection of the carotid and vertebral arteries is another cause of arterial occlusion and embolism. It accounts for up to 20% of strokes in younger patients. The goal of MRA is to identify the presence and level of the dissection and to determine the impact on cerebral blood flow. MRA is nearly 100% accurate in revealing a dissection, and has a good correlation with angiography in determining the exact site of the dissection and the degree of stenosis.³ MRI with MRA is currently the investigation of choice for suspected dissection.^{4,5} Difficult cases may require further anatomical clarification with angiography.

Fig. 1

Three-dimensional time-of-flight magnetic resonance angiography of the intracranial vessels supplying and comprising the Circle of Willis



L = left R = right BA = Basilar artery MCA = Middle cerebral artery PCA = Posterior cerebral artery
 ACA = Anterior cerebral artery VA = Vertebral artery CA = Internal carotid artery

Intracranial aneurysms

Rupture of an intracranial aneurysm is the commonest cause of non-traumatic subarachnoid haemorrhage. Conventional angiography is the investigation of choice for an acute subarachnoid haemorrhage confirmed by lumbar puncture or cerebral CT. This is because angiography is more sensitive than MRA in assessing the anatomy and morphology of the aneurysm, to assist the neurosurgeon or interventional neuroradiologist. Angiography is also more sensitive than MRA for aneurysms of less than 3 mm. It is better for patients who are medically unstable or unco-operative as they cannot easily be monitored, sedated and anaesthetised inside the MR scanner.

The role of MRA in screening for asymptomatic aneurysms in people at increased risk is unclear. While the prevalence of asymptomatic aneurysms in the general population is unknown, up to 15% of people with two first degree relatives who have had a subarachnoid haemorrhage will also have an aneurysm. The sensitivity of three-dimensional TOF MRA for aneurysms greater than 3 mm in size has been reported as 95% (Fig. 2). Recent studies have assessed the resource implications of screening people at risk and the theoretical reduction in morbidity and mortality. They concluded that screening would pose a logistical burden, and have major financial implications.⁶ Screening currently is on a case by case basis and is not accurate enough to exclude small (less than 3 mm) aneurysms.

Vascular malformations

Although angiography is the definitive technique for evaluating arteriovenous malformations before treatment, they can be

well characterised by using a combination of TOF and phase-contrast MRA. Currently, MRA is only used in conjunction with angiography.

Conclusion

MRA has become an essential component of MRI in the evaluation of many types of cerebrovascular disease. Further advances in hardware and software in the future will result in improved resolution of smaller vessels. MRA is likely to replace angiography for a large number of clinical applications. Angiography will be reserved mainly for unstable patients and interventional angiographic procedures.

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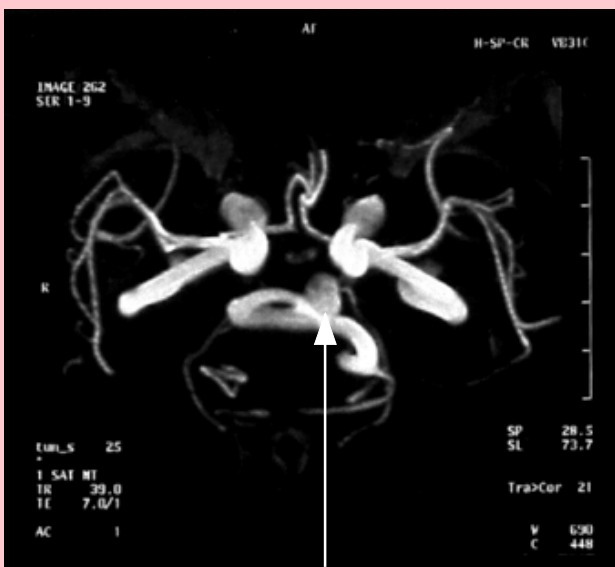
FURTHER READING

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Conflict of interest: none declared

Fig. 2

Three-dimensional time-of-flight intracranial magnetic resonance angiography which demonstrates a 6 mm aneurysm arising from the basilar artery tip and projecting anteriorly



aneurysm

Self-test questions

The following statements are either true or false (answers on page 158)

3. Magnetic resonance angiography is an accurate method of imaging a dissection of the vertebral artery.
4. Magnetic resonance angiography has superseded angiography in the investigation of subarachnoid haemorrhage.