DIAGNOSTIC TESTS

Transcranial ultrasound – clinical applications in cerebral ischaemia

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SYNOPSIS

Transcranial ultrasound can rapidly and non-invasively image blood flow in the major basal intracranial arteries. Its accuracy makes it acceptable for use in screening for haemodynamically significant intracranial stenoses or vessel occlusions. Although it has a relatively limited field of view and is not technically feasible in approximately 10% of cases, the information obtained is becoming increasingly relevant to therapeutic decision-making in the prevention and management of stroke. Transcranial Doppler ultrasound or transcranial colour-coded duplex have the advantages of relatively low cost, ease of repeatability, and excellent safety and tolerability, but they provide inferior spatial and anatomical detail in comparison to angiographic techniques.

Index words: stroke, magnetic resonance angiography, angiography.

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Introduction

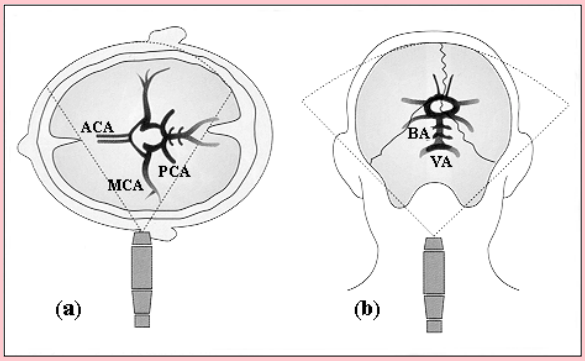
Every year approximately 40 000 Australians have a stroke and by 2020 the number of cases is expected to rise by 60%.[1] Stroke is a heterogeneous disorder with many clinical manifestations and aetiologies. The most common cause is occlusion of a large artery, resulting from or associated with thrombosis and/or artery-to-artery embolism.[2] Angiographic and sonographic imaging of intracranial vessels within six hours of the onset of an ischaemic stroke shows large artery occlusion in up to 70% of patients.[3,4] These occlusions are most commonly caused by emboli and suggest one or more sources in a proximal large artery, the aorta or the heart. In up to 66% of these patients the likely embolic source is atheromatous disease of the extracranial or intracranial carotid arteries, vertebral arteries, basilar artery or middle cerebral arteries. Approximately 5-8% of clinically relevant large artery disease in the anterior circulation (carotid, middle cerebral and anterior cerebral arteries) is located intracranially.[2] This increases to approximately 30% in the posterior circulation (vertebro-basilar/posterior cerebral arteries).[2,5] Although intracranial large artery occlusive disease is a considerably less common cause of artery-to-artery embolism than extracranial disease in the Caucasian population, the absence of a defined embolic source in the extracranial vessels or the heart should prompt evaluation of the intracranial vessels.

Transcranial ultrasound (Fig. 1)

The use of Doppler ultrasound to view intracranial basal artery blood flow was first described in 1982.[6] Subsequent advances in ultrasound technology have seen the use of combination Doppler blood flow imaging and B mode tissue imaging, so-called transcranial colour-coded duplex.[7] This more precisely identifies vessels and, if required, the direction of flow. Doppler beam angle correction gives a more accurate estimate of blood flow velocity in areas of arterial tortuosity.

Fig. 1

Schematic image of the sectional planes for the temporal and foramen magnum acoustic windows



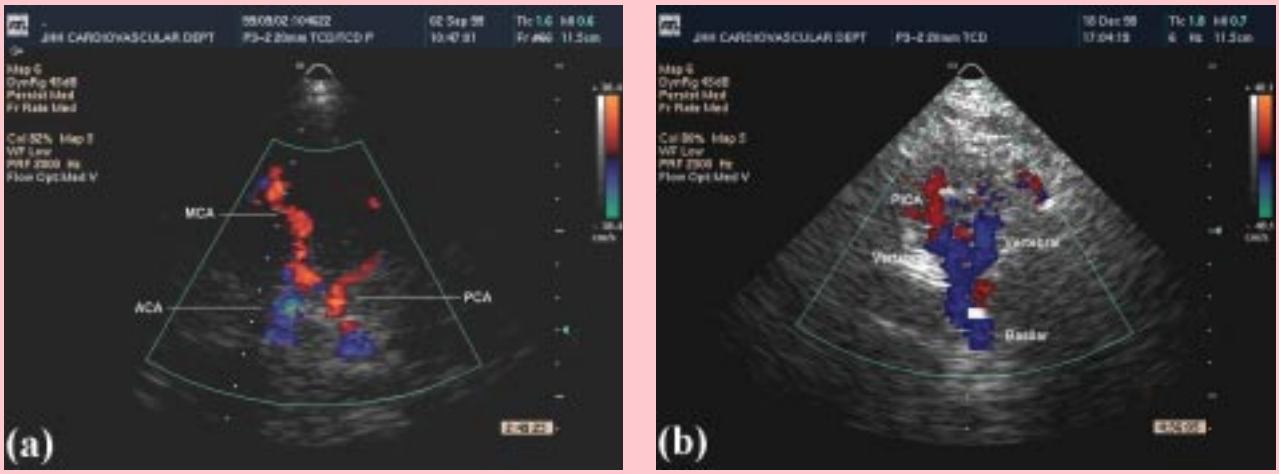
The middle cerebral artery (MCA), anterior cerebral artery (ACA) and posterior cerebral artery (PCA) are imaged via the temporal window (a). The intracranial vertebral arteries (VA) and the basilar artery (BA) are imaged via the foramen magnum window (b).

From Bartels E. Makropathologie. Color-Coded Duplex Ultrasonography of the Cerebral Vessels. Stuttgart, New York: Schattauer 1999.

Fig. 2

Colour-coded duplex scanning of normal intracranial vessels

Images are best seen in the web (HTML) version of this article



Flow direction is colour coded with flow directed towards the transducer coded red, and flow away coded blue. Velocity is colour coded within the red/blue spectrum. Regions of focal velocity increase show as brighter zones.

(a) Segments of Circle of Willis in one cerebral hemisphere as imaged via the temporal acoustic window. This window shows the M1 and M2 segments of the middle cerebral artery (MCA), the P1 and P2 segments of the posterior cerebral artery (PCA) and the A1 segment of the anterior cerebral artery (ACA).

(b) Intracranial vertebral arteries and basilar artery to the mid portion as imaged via the foramen magnum acoustic window. The distal one-third of basilar insonation is often limited and identification of anterior and posterior inferior cerebellar arteries (PICA) is variable.

Transcranial Doppler ultrasound, and more recently transcranial colour-coded duplex, have been used for a variety of clinical purposes:

- screening for vasospasm following subarachnoid haemorrhage
- screening for intracranial vessel stenoses and occlusions in ischaemic stroke or transient cerebral ischaemia
- monitoring changes in intracranial haemodynamics and monitoring for emboli during carotid endarterectomy
- monitoring cerebral perfusion in the neurological intensive care setting.

Examples of transcranial colour-coded duplex studies of a normal circle of Willis and a normal intracranial vertebrobasilar system are shown in Figure 2. Figure 3 shows an example of a flow map and Doppler spectrum imaged in a patient with stenosis of the anterior cerebral artery.

When considering the use of transcranial Doppler ultrasound or transcranial colour-coded duplex as a screening test for occlusive disease in large intracranial arteries, the following issues need to be considered:

- accuracy – sensitivity and specificity
- feasibility – safety and tolerability, availability, cost-effectiveness
- reliability – intra- and interobserver variability in scanning and reporting.

Accuracy

Both transcranial Doppler ultrasound and transcranial colour-coded duplex provide a relatively limited view of the basal cerebral arteries (Fig. 1). The vessels that are visible on transcranial Doppler ultrasound do, however, comprise the more common sites for the development of intracranial large artery occlusive disease. It is also important to appreciate that finding a stenosis using Doppler depends on the detection of a haemodynamic disturbance of sufficient significance to produce an unequivocal elevation in blood flow velocity. In general, this requires the presence of a diameter narrowing of approximately 50% or more (equivalent to a cross-sectional area narrowing of approximately ≥75%). Although somewhat arbitrary, these cut-offs are of clinical relevance as it is not until diameter narrowing exceeds 50% that reduction in blood flow occurs. Studies of the accuracy of transcranial Doppler ultrasound or transcranial colour-coded duplex have tended, therefore, to use 50% or greater diameter narrowing as the threshold of abnormality.

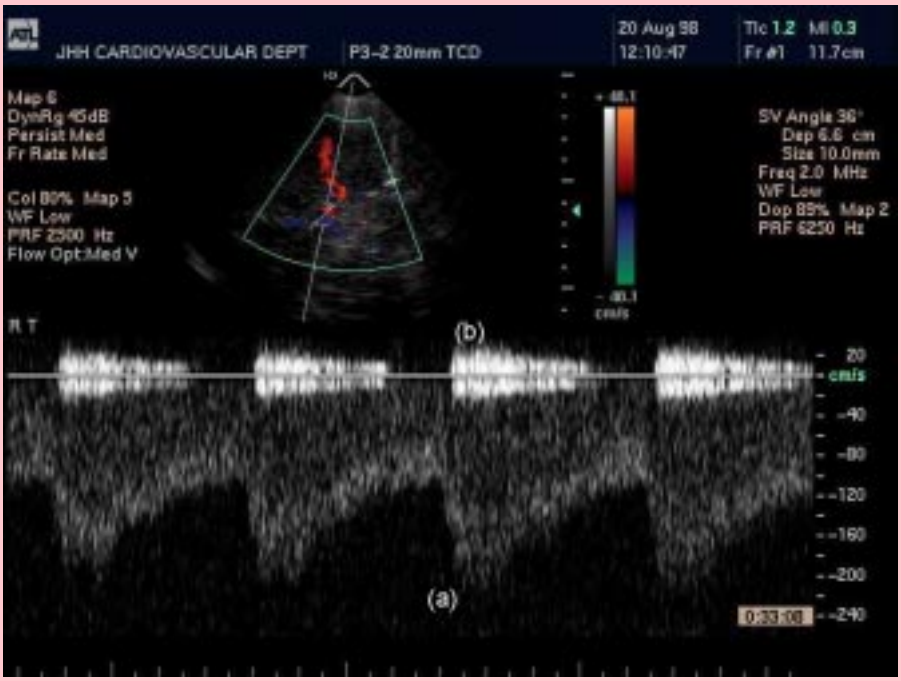
The accuracy of both transcranial Doppler ultrasound and transcranial colour-coded duplex in the detection of intracranial stenoses or occlusions has been investigated in a number of comparative studies. However, there are relatively few studies assessing the accuracy of transcranial colour-coded duplex. More recently, a number of smaller studies have found that advances in instrumentation and the use of echo-enhancing agents can improve image quality and the imaging of vessel segments that are poorly seen with standard techniques.[8,9] These advances are likely to result in improvements in both the feasibility and accuracy of transcranial colour-coded duplex.

In general, the accuracy of transcranial Doppler ultrasound and transcranial colour-coded duplex in the detection of intracranial occlusive disease can be considered acceptable

Fig. 3

Colour flow map and pulse wave Doppler spectrum of a stenosis

Images are best seen in the web (HTML) version of this article



Colour-coded duplex scanning via the right temporal acoustic window shows a focal region of increase in colour intensity in the A1 section of the anterior cerebral artery. This is accompanied by an increase in (a) flow velocity (peak systolic velocity 224 cm/sec), and (b) turbulence (high intensity, low velocity signals). Other general criteria for haemodynamically significant stenoses include circumscribed local increase in flow velocity, and left/right difference in flow velocity (in the above example, left ACA peak systolic velocity was 86 cm/sec).

when performed as 'opportunistic' screening by sonographers and clinicians experienced in its use.

Comparison with angiography

When compared to contrast angiography, transcranial Doppler ultrasound accuracy varies with the technical difficulty typically encountered in imaging any particular segment. The middle cerebral artery stem (M1 segment) is relatively easy to study, so ultrasound has a sensitivity and specificity of 90–99% for finding a stenosis or an occlusion.[10] For the more difficult to image intracranial (V4) segment of the vertebral arteries and the basilar artery, ultrasound has a sensitivity of 70–80% and a specificity of 90–99%.[10,11]

The accuracy of transcranial colour-coded duplex ultrasound is similar to that of contrast angiography. In a study of 310 patients, transcranial colour-coded duplex correctly identified 31 who had a stenosis of 50% or greater (confirmed by digital subtraction X-ray angiography).[12] As all the stenoses were correctly diagnosed as true positives the sensitivity is 100%, but the specificity is 99% because one artery with a stenosis of less than 50% was incorrectly classified as having a stenosis of more than 50% (false positive).

Comparison with magnetic resonance angiography (MRA)

Intracranial MRA has a reasonable accuracy in comparison to contrast angiography for intracranial stenoses.[13] The studies to date also suggest a good correlation between MRA and transcranial colour-coded duplex for imaging a stenosis or occlusion. In the anterior circulation arterial segments, transcranial colour-coded duplex has an estimated sensitivity of 75% and specificity of 99%, while in the posterior circulation, the sensitivity is 88% and the specificity 99%.[14]

Feasibility

The main limitation of transcranial ultrasound is the inadequacy of the acoustic window through either the temporal bone or the foramen magnum. The temporal window is more likely to be inadequate for ultrasound in women and the elderly. Up to 10% of patients undergoing transcranial Doppler ultrasound and up to 20% undergoing transcranial colour-coded duplex have inadequate acoustic windows for an optimal study. These proportions can be reduced to less than 5% with the use of intravenous transpulmonary echo-contrast drugs, however, these drugs increase the complexity and cost of the investigation.

Transcranial Doppler ultrasound and transcranial colour-coded duplex have no recognised adverse effects, a potential advantage over X-ray angiography which carries a risk of contrast allergy and stroke[15], or computerised tomographic angiography that uses ionizing radiation and also requires intravenous contrast media. The ultrasound studies are well tolerated, a potential advantage over MRA which sometimes triggers claustrophobia, necessitating the use of intravenous sedation.

Transcranial Doppler ultrasound and transcranial colour-coded duplex cost less than angiography, and the portability of the equipment allows the examination to be performed at the patients' bedside and at repeated intervals if necessary.

Studies assessing the cost-effectiveness of transcranial Doppler ultrasound or transcranial colour-coded duplex in cerebrovascular disease have not been reported.

Reliability

One of the potential limitations in all diagnostic vascular ultrasound is that a high level of technical and procedural skill is required to obtain the best quality images. In addition, a clear understanding of the clinical question being asked often enhances the detail obtained by the sonographer. Both these issues are particularly pertinent to transcranial ultrasound. While there are established criteria[16] for the diagnosis of intracranial stenoses and occlusion using either transcranial Doppler ultrasound or transcranial colour-coded duplex, there are few studies evaluating intra- or interobserver variations in reporting.

Imaging influences management

Advances in brain imaging techniques now allow therapeutic decisions about the acute management and prevention of stroke to be made with a detailed understanding of the nature and severity of the underlying arterial pathology.[17] For example, in intracranial occlusive disease, the finding of a middle cerebral artery or basilar artery occlusion in a patient with an acute stroke, is an indication for the use of thrombolytic therapy (in appropriately resourced centres).[18,19] Conversely, the finding of a high grade intracranial stenosis in the artery supplying a recently ischaemic region of the brain, should prompt the clinician to consider prescribing anticoagulation rather than antiplatelet therapy for secondary prevention, as present evidence suggests anticoagulation has a therapeutic advantage. Without imaging to assess the arterial pathology, the most appropriate evidence-based intervention cannot be identified.

Conclusion

The major clinical application of transcranial ultrasound is as a specific investigation for intracranial occlusive disease when used in conjunction with ultrasonic studies of the extracranial cerebral vasculature and computerised tomographic scanning of the brain. This information can be used to guide the choice of treatment for preventing and managing strokes. Advances in instrumentation and the application of echo-contrast drugs are likely to improve the accuracy and reliability of transcranial ultrasound techniques.

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NOTE

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Conflict of interest: none declared

Self-test questions

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

1. Patients with an allergy to contrast media should not have colour-coded duplex scanning.
2. Occlusions of large cerebral arteries are usually caused by emboli from elsewhere in the vascular system.