Imaging in vascular disease

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Abstract

Accurate imaging and interpretation of the vascular system is fundamental to the management of patients with vascular disease. This is especially important when considering evidence-based intervention for carotid and aneurysmal disease. This article introduces basic principles, advantages and limitations of imaging modalities frequently used to assess patients with vascular disease. The roles of duplex ultrasonography (DUS), computed tomography (CT), magnetic resonance imaging (MRI), and digital subtraction angiography (DSA) in the vascular patient are reviewed.

Keywords Computed tomography; digital subtraction angiography; duplex ultrasonography; magnetic resonance angiography; vascular

Introduction

Accurate imaging and interpretation of the vascular system is fundamental to the management of patients with vascular disease. This is especially important when considering evidence-based intervention for carotid[1] and aneurysmal[2,3] disease. Knowledge of the basic principles, advantages and limitations of various imaging modalities is crucial. This not only allows the clinician to use the most appropriate imaging for the clinical situation, but also to understand the degree of certainty that the imaging modality reflects the real anatomy in the patient. The aim of this article is to review the roles of duplex ultrasonography (DUS), computed tomography (CT), magnetic resonance imaging (MRI), and digital subtraction angiography (DSA) in the vascular patient.

Duplex ultrasonography (DUS)

Basic principles

Ultrasonography involves the transmission, absorption and partial reflection of high frequency sound waves in tissue. Anatomical detail (B-mode scan) can be obtained because sound waves are reflected at the interface between adjacent tissues in the body, when the tissues have different physical characteristics (density and compressibility). Information about blood flow is reliant on the Doppler effect: there is a change in the frequency of the sound wave if there is a change in the relative position of the observer (the ultrasound transducer) and the source/reflector (the moving blood reflecting the sound wave). The Doppler shift equation is used to calculate the velocity of the blood.

DUS combines B-mode ultrasound with pulsed-wave Doppler. Using the image to define the anatomy of the blood vessel, the specific area/depth of tissue is then assessed using regular short bursts of ultrasound (pulsed wave Doppler). Thousands of pulses are sent along the ultrasound beam and as the velocity of the blood changes with systole and diastole, the frequency of the reflected pulse changes (like the sound of an ambulance siren changes when passing by in the street). These numerous frequency shifts are mathematically aggregated or gated and displayed as a spectral pattern or in colour.

Beyond a stenosis the waveform will change from triphasic (Figure 1**a** and **b**) to biphasic (Figure 1**c**) or monophasic. Flow of a liquid is equal to the product of mean velocity and cross-sectional area. As such, in an attempt to maintain flow, velocity will increase as cross-sectional area reduces. Only when the stenosis becomes critical (>70% diameter reduction) will the flow itself be reduced. DUS involves the measurement of peak systolic and end diastolic velocities up-stream and within the stenosis. These velocities can be used independently to estimate degrees of stenosis using validated tables,[4] or most commonly as a ratio (peak systolic velocity ratio (PSVR); before lesion: at lesion). A PSVR 2:1 is associated with >50% stenosis and PSVR 4:1 with a >75% stenosis.

Indications and advantages of DUS

DUS is safe, non-invasive, does not involve ionizing radiation and is well tolerated. It is widely applicable to all peripheral arterial disease and provides dynamic information. It is the first line investigation for most arterial and all venous disease (superficial venous reflux and DVT).

Limitations of DUS

Like all ultrasonography, DUS is operator dependent. Clinicians are not provided with a full anatomical image, but with a written report and a pictorial representation of the technologist's interpretation of the spectral analysis only.

DUS has median sensitivities of 88%–90% and median specificities of 96%–99% in detection of a >50% stenosis/occlusion when digital subtraction angiography is used as the gold standard, though diagnostic accuracy falls below the knee.[5,6] Calcium does not transmit sound waves, thus it is difficult to gain accurate information about blood flow in heavily calcified (tibial) arteries. Body habitus and overlying gas, often make assessment of the iliac vessels difficult. Additionally, its use at wound sites is uncomfortable and impractical, and the operator-dependent acquisition times can be lengthy, e.g. if both legs are examined.

Computerized tomography angiography (CTA)

Basic principles

Computerized tomography involves a fan-shaped beam of ionizing radiation delivered from a tube source rotating helically round a patient. The amount of radiation which passes through the patient to the detectors is dependent on the attenuation coefficient of the tissue, which in turn is mainly dependent on the electron density of the tissue. This one-dimensional data is

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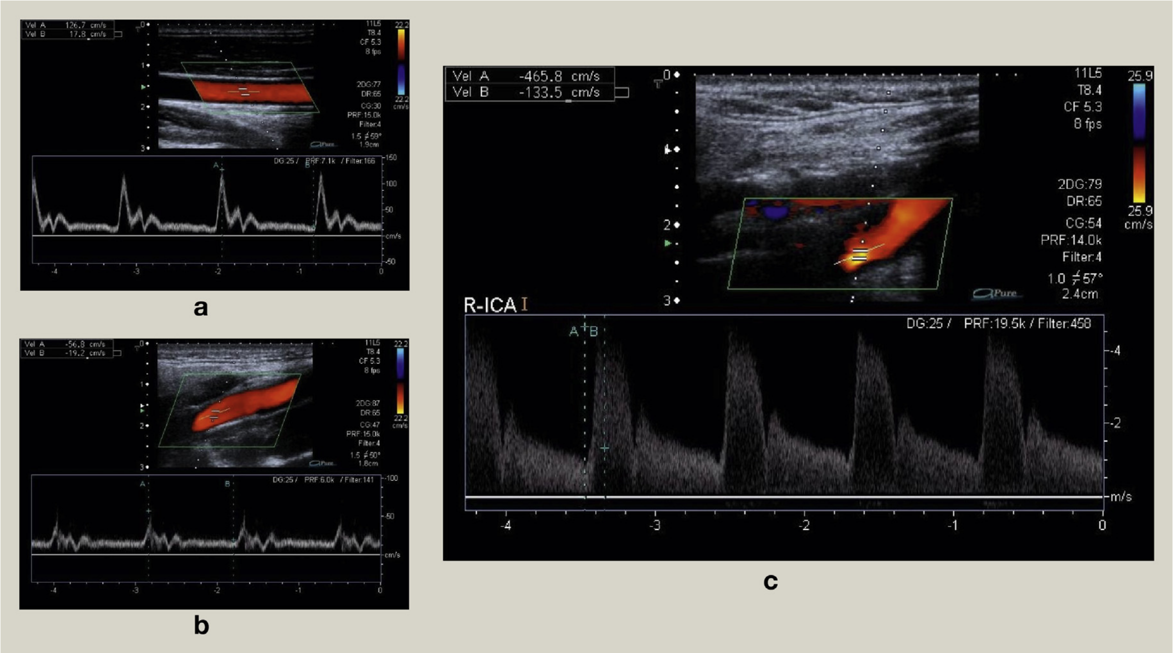

Figure 1 (**a**) and (**b**) show a normal common and internal carotid artery waveform. Figure 1**c** shows a significant stenosis (>70%) within the internal carotid artery — note the aliasing (yellow colour in the colour flow image) and the high peak systolic velocity of >400 cm/sec.

then mathematically reconstructed into a two dimensional image. Multi-detector spiral data acquisition CT scanners allow multiple axial slices to be taken in a single tube rotation and large areas of the body to be scanned in a matter of seconds.

Indications and advantages of CTA

CTA may be used to non-invasively image any part of, or the complete, vascular tree. It is the standard imaging modality of choice for assessment of most arterial disease, including

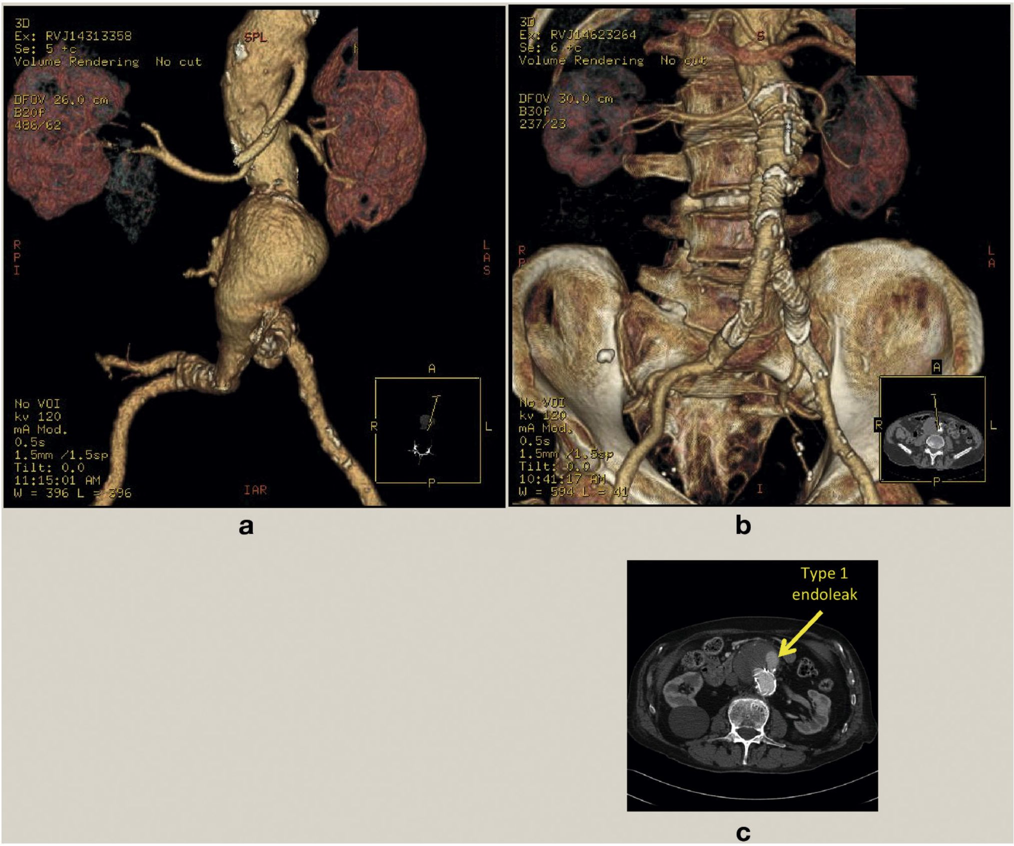

Figure 2 (**a**) CT angiogram of a patient with a complex abdominal aortic aneurysm. (**b**) shows the result following endovascular repair. (**c**) shows contrast within the sac arising from a type I endoleak.

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