The future of vascular ultrasound

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The advent of Duplex scanners in the late 1970s and early 1980s enabled, for the first time, the measurement of blood flow velocity from specific areas within blood vessels. This in turn allowed more accurate assessment of the degree of stenosis/occlusion. The further development of colour flow scanners in the late 1980s and early 1990s moved vascular ultrasound on to become the front-line investigative technique for vascular assessment.

Since that time there have been significant advances in medical ultrasound hardware and software that have improved quality and resolution of B-mode and colour flow to greatly enhance their clinical usefulness. As computer speed and power increase rapidly, it is probable that some of the current emerging technologies will develop to have as big a clinical impact as colour flow and Duplex. This article gives a brief summary of newer imaging techniques, and their potential for development in vascular ultrasound.

Contrast enhanced ultrasound (CEUS) is one of the oldest of the ‘new’ technologies. It has not yet become a widespread or routine technique, but has undergone resurgence in recent years. Microbubble contrast agents are used to depict low volume flow and perfusion, on the principle of increased backscatter and resonance from tiny encapsulated bubbles of gas that are injected into the body. It is a safe and easy technique, providing one has the appropriate equipment, as most common techniques require contrast-specific software. It also has benefits over other perfusion imaging methods, as it does not involve ionising radiation, and has no nephrotoxicity. Several different imaging protocols are available, employing pulse inversion and harmonic techniques. Contrast is currently used in echocardiography (myocardial contrast echocardiography) and in general radiology for imaging the liver, prostate and breast. Limited use of contrast agents in general vascular ultrasound imaging has been reported, with further potential in areas such as EVAR (endovascular aneurysm repair) surveillance (figure 1) and the identification of adventitial and intra-plaque angiogenesis (vasa-vasorum).

Another ultrasound development that has been available for some time, but has not yet found an essential clinical application, is 3D/4D scanning. First described in the mid 1980s, it became commercially available in the mid 1990s, and mostly found use in obstetrics. Three-dimensional data blocks are produced simply by sweeping a 2D beam through a volume of tissue. The most significant recent development has been the replacement of mechanical sweeping with 2D array transducers. These matrix transducers, by imaging the three imaging planes simultaneously, also have the capability of displaying these orthogonal views together in real time. This should speed workflow and reduce transducer manipulation to minimise repetitive strain injuries. The applications to vascular ultrasound are not yet established, but acquisitions of volume data can produce series of cross sectional B-mode images, similar to CT and MR, which has been used in AAA screening (figure 2). Three-dimensional and 4D imaging could have a role in carotid scanning, particularly in measuring lumen diameters, and in allowing complete archiving and remote reporting of scans. A weakness in using 3D in vascular ultrasound to develop ‘ultrasound angiography’ is that colour flow cannot be reproduced usefully within the greyscale data set. At the moment there is a problem in the way the data is collected due to the cardiac cycle. Each part of the 3D volume is acquired during different parts of the cardiac cycle so that there will be incomplete colour filling in arteries. Solutions would involve some form of cardiac gating, or selecting data at peak systole.

A general problem with colour flow is that conventionally it has poorer resolution than B-mode due to longer pulse lengths. Broadband Doppler (such as Advanced Dynamic Flow – Toshiba Medical Systems), and direct visualisation of moving blood cells in B-mode (B-flow – GE Medical Systems) overcome spatial resolution artefacts. These methods have great advantages in the assessment of stenoses (figure 3) as they improve the display of surface character-
istics and flow channels, which allows more reliable measurement of the stenosis extent.

In vascular imaging, the counterpart to improvements in the visualisation of flow are improvements to the imaging of surrounding tissue. The quality and resolution of B-mode has developed with upgrades in transducer and scanner technologies. Nevertheless, it is still generally true in ultrasound that, however good the quality of the image, the ability to distinguish different tissue types will rely on the experience and training of the operator. Several attempts have been made over many years to produce automated systems that can distinguish between cyst, haematoma, calcification, lipid, etc, and code those differences on an image. Ideally, this would allow assessments to be made of the likely presence of disease within tissue during a scan, or to determine the composition of a specific lesion.

Elastography is an established tissue characterisation technique based on the measurement of local tissue deformation in response to some sort of applied mechanical stress. Although requiring some assumptions about the physical properties of the tissue, it gives a more quantitative measure of stiffness than manual palpation, together with a strain map. Current clinical applications are in the assessment of the breast, liver and prostate. From a vascular perspective, intravascular elastography can be used in plaque characterisation, using changes in intra-luminal pressure to produce the stress. The strain image shows areas of high strain in soft areas and low strain in calcified regions. A future development in vascular imaging may be to perform venous elastography to assess the age of venous thrombus.

Acoustic Structure Quantification is a tissue characterisation package developed by Toshiba Medical Systems for use in liver assessment. Changes in the probability density function of the echo signal between normal and fibrotic tissue are used to produce quantitative data and to colour-code B-mode images. This approach may again be applicable in vascular ultrasound to investigate plaque morphology and thrombus age.

Characterisation of tissue would automate the assessment of disease currently confined to the subjective assessments of experienced users. A further approach is to make vascular imaging more accessible to interpretation by non-specialists. Perspective volume rendering (Fly Thru – Toshiba Medical Systems) displays a 3D volume data set in a way that allows interrogation of the interior surface of cavities, ducts and blood vessels. Cross-sectional ultrasound data is added to the plane surface data to enable the user to ‘fly through’ a cavity or vessel, viewing the interior surface of the cavity. This has the potential, with refinement, to aid in the visualisation of the surface characteristics of plaque and the friability of thrombus (Figure 4).

The future of vascular ultrasound indicated by these emerging techniques is both to enhance the quality of information available to the operator, and to provide new diagnostic information for clinicians. None of these will move from limited or experimental use to become normal and routine parts of a scan until they can be shown to improve the quantification of vascular disease, or to reduce current subjective limitations. However, as these methods clearly show potential in this direction, they will only be adopted more widely if we make the effort to put them into practice and report on their usefulness.

References


