Chapter 1: Ultrasound and Contrast Ultrasound

Introduction

Ultrasound is a tomographic imaging technique that can provide anatomical and functional images with high resolution and great flexibility at low cost (Kremkau 1997; McDicken 1991). Structural detail down to around a millimetre is available without the need for contrast agents (Fig. 1.1). The high intrinsic contrast is produced by the tissues’ structure at a submillimetre level and is chiefly attributable to the differences in rigidity and density between fluids, watery tissue, connective tissue and fat. The tomograms are formed very rapidly, allowing real time imaging so that studies are quick and interactive. Immediate viewing of tissue motion is intrinsic to ultrasound imaging; examples include the effects of respiration or palpation and the direct visualisation of the position of a biopsy needle (Pederson et al. 1993). The tomograms can be taken in any plane, allowing optimal display of critical anatomy and pathology. Small, self-contained scanners can be made and these can be taken to the patient’s bedside (Machi and Sigel 1996). No or minimal preparation is required so that the procedure is well tolerated, the only practical problem for the liver being abdominal tenderness that may make probe contact painful. The hazards of ionising radiation do not exist and the acoustic powers used in diagnosis appear to be completely safe, though there are emerging concerns over the possibility that its interaction with the microbubbles used as contrast agents may produce free radicals that could be injurious.

The flexibility of ultrasound technique has led to several specialised applications. Small transducers can be mounted on an endoscope with the advantage that higher quality images are obtained because higher frequency ultrasound can be used (Bezzi et al. 1998). Endoscopic ultrasound is, of course, somewhat invasive and only tissues with a few centimetres of the gut wall are accessible. The same is true of intravascular ultrasound. Small transducers suitable for use in the operating theatre offer the benefit of higher resolution as well as of guiding needle placement for biopsies or cannulation of small portal vein branches while the development of transducers small enough to fit into standard laparoscopic instruments extends these advantages to minimally invasive surgery (Herman 1996; Barbot et al. 1997; Klotter et al. 1986).

Doppler has extended the role of ultrasound in the diagnosis and management of vascular pathology of the liver and is now an indispensable component of hepatic imaging (Grant 1992). It is particularly helpful in liver transplants, both pre-operatively [to establish portal vein (PV) and caval patency] and post-operatively (for the PV and hepatic artery) and in the Budd Chiari syndrome. In cirrhosis Doppler can establish the patency of the PV and of many types of shunts. For spectral (pulsed) Doppler, a sensitive gate is positioned over a vessel and the temporal pattern of flow analysed to display its velocity spectrum; volume flow can also be estimated, though with less precision (Fig. 1.2). In colour Doppler, a vascular map is presented as an overlay on the grey scale scan to provide a form of angiogram that gives a non-invasive picture of vascular anatomy (Fig. 1.3)
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Though the haemodynamic information is limited (only mean velocity or, in power Doppler, the number of moving red cells, is presented) the anatomical information gained is an extremely valuable addition to imaging. Colour and spectral Doppler are complementary, the former providing images, the latter functional information on blood flow.

However, this description omits some important limitations to the uses of ultrasound. Image quality is affected by body habitus, slim patients giving the best images because resolution deteriorates with depth as inevitable result of the greater attenuation of higher frequencies; for this reason ultrasound is particularly valuable in paediatrics. This problem has been reduced by the development of non-linear (tissue harmonic) imaging and by the increasing bandwidth of newer transducers so that the most appropriate frequency can be selected electronically (Kono et al. 1997). Bone and gas are impenetrable; in practical terms this is only an occasional problem for the liver because the intercostal spaces allow adequate access in almost all patients if the subcostal route is difficult to use.

Fig. 1.1. In a sagittal section through the left liver, the caudate lobe (segment 1) can be seen posterior to segments 2 and 3. Note the fine stippled texture of the liver’s parenchyma. IVC, inferior vena cava; RAT, right atrium

Fig. 1.2. In this spectral Doppler tracing the sensitive gate has been placed over the middle hepatic vein (arrowhead) and the trace shows the normal pattern where the predominant flow towards the heart (shown below the line to indicate flow away from the transducer) is interrupted by reverse flow as blood is returned to the liver in cardiac systole.