Diagnostic ultrasound is an invaluable technique in the management of a variety of skeletal disorders. Technical innovations such as colour-flow Doppler, 3-D surface reconstruction and ultrasound contrast agents have introduced new areas of practice and the quality of the images has continued to improve. These developments have led to better understanding of the role of diagnostic ultrasound in clinical orthopaedic practice, with increased awareness of its strengths and weaknesses. There are now well-established societies concerned with musculoskeletal ultrasound and a number of practitioners who specialise exclusively in this area of imaging.

The significant strength of diagnostic ultrasound is its safety and relative availability, but its disadvantages are the dependence on a skilled operator and the long learning curve. It is easy for the inexperienced to produce dangerously inaccurate results. Ultrasound examinations are very patient-interactive and subjective; the images of an examination cannot be adequately reviewed away from the patient. The dynamic aspects of the test are also important. These factors mean that there are no films which can be reviewed for the purposes of audit. Quality must be monitored by measures of outcome, comparison with the results of other methods of imaging and by correlation with the findings at operation. These tasks require a level of organisation and effort which may be overlooked in a busy practice.

In this review we will cover the established areas of ultrasound practice in which its value has been proven in well-controlled trials. We will mention circumstances in which ultrasound is applied but has a less pivotal role in management and we will then discuss potential areas of development, especially as related to more recent technology.

**Established indications**

**Developmental dysplasia of the hip in the infant.** Instability of the hip is a relatively common finding clinically, but the diagnosis of a true dislocation is of vital importance. The relationship of the unossified femoral head to the acetabulum is seen better by ultrasound than by plain films since the cartilage can be appreciated (Fig. 1). The hip can be scanned by ultrasound statically and dynamically in a coronal plane. Several authors have given guidelines and devised methods of measurement including assessment of acatabular depth and shape. Graf assesses the relationship between the bony roofline and that of the cartilage compared with a baseline, while others also use subjective assessment of coverage of the femoral head by the cartilaginous acetabulum using a baseline along the iliac wing. These methods give an objective measure of the development of the hip although there is debate as to how easy it is to reproduce the results.

Ultrasound has become an essential part of the management of hip dysplasia. Its exact role in screening is currently under debate. There is general agreement that ultrasound increases the rate of detection of abnormalities of the hip, but it is not yet clear whether widespread population screening is cost-effective. The current consensus in the UK is that screening of high-risk groups is prudent but there are no firm recommendations regarding population studies.

**Irritable hip.** Ultrasound should be the first line of investigation in the assessment of the irritable hip. It will detect an effusion (Fig. 2), allowing aspiration of the joint for symptomatic relief and the exclusion of septic arthritis. It can be used to visualise fragmentation of the femoral head in Perthes' disease and can sometimes detect a slipped upper femoral epiphysis. Ultrasound-guided joint aspiration will also shorten or avoid the need for inpatient care. The use of local anaesthetic jelly and ultrasound guidance means that the aspiration is a minor outpatient procedure which does not require general anaesthesia.

**Pathology of the rotator cuff.** The supraspinatus tendon can be visualised with the arm in adduction and internal rotation (Fig. 3). Small tears can be seen and measured by dynamic testing. Ultrasound is more sensitive than MRI in diagnosing these and has a high correlation with the findings at operation. More subtle areas of calcification within the tendon are seen better by ultrasound than by MRI and their visualisation is comparable with plain films. It is likely that with the latest technology more subtle calcification will be seen by ultrasound.
Ultrasound has advantages over MRI since the other shoulder can be scanned at the same appointment and the area of maximum tenderness directly ascertained from the patient, allowing the scan to be concentrated on this site. Other muscles of the rotator cuff can also be examined. The presence of fluid about the biceps tendon and subdeltoid bursa may indicate a subtle tear of the supraspinatus tendon or other intra-articular pathology. The head of the humerus can be seen and a fracture, osteophytosis or erosions visualised. Ultrasound cannot, however, reliably detect pathology within the bone and it is a technique which requires considerable experience to master.

**Soft-tissue masses.** An ultrasound scan may readily diagnose a soft-tissue swelling such as a popliteal cyst, with the classic soap-bubble appearance of a cystic lesion arising through the medial head of the gastrocnemius muscle. It is of particular value in the assessment of other cystic lesions and in solid soft-tissue masses (Fig. 4). Neuromas may mimic cysts since they are low in echogenicity and may show acoustic enhancement. Techniques of colour and power Doppler allow the detection of vascular lesions and help in judging the safety of soft-tissue biopsy. Vascular imaging with ultrasound is a much cheaper and faster way of assessing blood flow than the use of gadolinium enhancement in MRI. Ultrasound is often used as an adjunct to MRI in the assessment of soft-tissue lesions, in which a high signal may not always indicate a cystic mass and the vascularity may not be apparent. Ultrasound can also be used to aid biopsy of the mass when there is any doubt in its diagnosis.

**Tendon and ligament abnormality.** Ultrasound now rivals MRI in the assessment of tendon pathology. The ease of scanning the opposite limb and the patient’s participation in the procedure help to detect more subtle problems. Fluid
Figure 3a – A partial tear of the supraspinatus tendon (coronal plane); the tear is outlined on the second image. The tendon substance is bright and the tear is dark. Figure 3b – A full-thickness tear of the supraspinatus tendon with wide retraction. The only muscle which can be seen above the head of the humerus is the deltoid.

Figure 4a – A neurofibroma in the forearm overlying the radius. Figure 4b – A lymph node which typically is lower in echoes than surrounding tissues. It might be mistaken for a cyst by the unwary.

Figure 5

Full-thickness tear of tendo Achillis with an interposed haematoma.
around a tendon and inflammation within it, which present as a reduction of the echogenicity of the tendon, can easily be seen and small tears can be assessed dynamically.

Ultrasound is commonly used in the diagnosis of patellar tendinosis, \textsuperscript{14} rupture of the tendo Achillis (Figs 5 and 6) \textsuperscript{15,16} and tears of the supraspinatus. It can also be used to visualise tendons at the elbow in injuries such as tennis and golfer’s elbow in which the oedema and thickening of the insertion will be apparent. Clinically, this is only of real value if there is doubt about the diagnosis and it would be rare for the management of the patient to be influenced by such a finding.

In the carpal tunnel syndrome the tendons at the wrist may be assessed for thickening, \textsuperscript{17} while occult ganglia and mass lesions may be excluded. Tendons and ligaments of the finger may be examined to show tendinopathy, rupture and neoplasia. Ultrasound is also useful in judging the integrity of ankle ligaments and can be used to guide the injection of steroid into an inflamed tendon sheath in any location.

Sound knowledge of the anatomy and careful dynamic imaging are essential for proper and accurate diagnosis. To accomplish this a cross-sectional anatomy text is an invaluable bench book.

**Monitoring of limb lengthening.** Callus at the site of the osteotomy in limb lengthening is visualised much earlier by ultrasound than by plain films (Fig. 7). If the gap in the bone is measured by both techniques a judgement of the formation of mature callus is possible.\textsuperscript{18} If the distraction at the site of the osteotomy is too slow then the gap will fill rapidly and this can be detected on ultrasound before changes occur on plain films. If the bone is distracted too quickly formation of a cyst can be seen in the gap by ultrasound. Apart from slowing the rate of distraction, ultrasound-guided aspiration of the cysts may be useful.\textsuperscript{19}

**Adjuncts to other imaging**

**Deep-venous thrombosis.** Ultrasound is a quick, easy and non-invasive way to detect deep-venous thrombosis in the leg after hip or knee replacement and has largely replaced venography. If a vein is freely compressible this is a good indication that there is no thrombus present.\textsuperscript{20}

**Detection and drainage of abscesses.** Abscesses are easily and accurately detected by ultrasound (Fig. 8). If there is doubt regarding the nature of a cystic swelling, it can easily be punctured under ultrasound guidance. Drainage is then a useful first-line therapy and an indwelling catheter can be inserted and left in as an option to an open surgical procedure.\textsuperscript{21}
Bone pathology. Ultrasound may be used to detect subperiosteal collections of fluid in osteomyelitis in early childhood (Fig. 9). This may be seen very early on an ultrasound examination and may precede changes on the plain films.\textsuperscript{22,23} Subperiosteal fluid can also be observed adjacent to fractures or deposits of bone tumour. It is important to know the clinical circumstances and to compare the ultrasound findings with plain films.

While fractures or osteophytes may be detected by ultrasound it cannot rival the precision of plain films in their demonstration and of MRI in subtle fractures. Ultrasound may be useful in the diagnosis of some bone tumours where there is a large soft-tissue element, for example in Ewing’s sarcoma. An ultrasound-guided biopsy may be the simplest method of confirming the diagnosis. In osteochondromas, ultrasound or MRI may be used to measure the thickness of the cartilage cap to help to judge whether malignant transformation has occurred.\textsuperscript{24}

In trauma, ultrasound has proved to be better at diagnosing rib fractures than plain films and it may also detect a small pneumothorax not visible on the chest radiograph.\textsuperscript{25} Muscle injuries. Muscle injuries may be difficult to see on MRI. The ability to assess both limbs and the participation of the patient can be invaluable in the diagnosis of partial and complete muscle rupture using ultrasound (Figs 10 and 11). Abnormal striation in muscle, local haemorrhage and dynamic separation of muscle fibres are all signs of trauma. It is possible to judge the extent of injury and to help to predict the time of recovery using ultrasound.\textsuperscript{26} The presence of a palpable lump due to muscle herniation can also be confidently diagnosed ultrasonographically\textsuperscript{27} whereas it may be missed with MRI.

Foreign-body localisation. Only radiopaque foreign bodies can be seen on plain films. Metal fragments as small as 0.5 mm and wood >0.7 mm, glass >2 mm and plastic >4 mm in size can be detected by ultrasound, thus aiding the clinician in their diagnosis.\textsuperscript{28} Preoperative localisation by ultrasound will help to reduce the extent of the surgical incision required to excise the foreign material.\textsuperscript{29}

Additional uses for ultrasound

Joint injection. It is known from studies that the accuracy of placement of an intra-articular injection may be as low as 29%, if performed blindly.\textsuperscript{30} Ultrasound can be employed to guide joint injections more accurately and can also be
used therapeutically in the removal of calcium deposits commonly seen in the rotator cuff of the shoulder.\textsuperscript{31}

**Antenatal diagnosis of orthopaedic problems.** Ultrasound is used widely in the antenatal period for the detection of anomalies, not least those affecting the musculoskeletal system.

It allows the early detection of club foot (Fig. 12). This may occur in isolation, but also has a high association with other fetal anomalies and chromosomal abnormalities; its diagnosis should prompt the clinician to do further antenatal tests.\textsuperscript{32} Femoral anomalies in Down’s syndrome, amniotic band lesions, arthrogryposis and dwarfism are other problems which can be detected antenatally using ultrasound.

**New techniques**

Areas of current interest include 3-D surface reconstruction, the use of power Doppler (Fig. 13)\textsuperscript{33} and contrast agents\textsuperscript{34} to show tumour vascularity or hyperaemia in inflammatory joint disease and the dynamic assessment of joints (Fig. 14). With the exception of the last, the new techniques have an unproven clinical use but serve to illustrate the developments in the rapidly expanding area of ultrasound scanning. It is likely that ultrasound will gain a greater place in the management of rheumatology, sports injuries and trauma subsequent to these developments.
together with the superior quality of superficial, soft-tissue visualisation afforded by modern equipment.

Conclusions

Ultrasound is an invaluable diagnostic technique in orthopaedic practice. It should be performed by an experienced operator since there are many pitfalls which may lead to incorrect diagnoses in the hands of the novice. As its place becomes more accepted, its use will extend to all the areas of practice described above. At present the applications are limited by the lack of experienced sonographers, but as demand increases this will improve.

Regular audit of practice and comparison with other imaging techniques and surgical results are essential to an accurate diagnostic practice. This is particularly true of ultrasound, where it is all too easy to be tempted to over-diagnose and to be blinkered to the weakness of a technique. Even in the established areas of practice, ongoing regular assessment is vital, and therefore liaison between the clinician and sonographer will become even more important in order to allow this exciting diagnostic tool to reach its full potential.

Fig. 13
Power Doppler ultrasound demonstrates a periarticular vessel. This would appear in colour on the monitor.

Fig. 14
A posterior axial view of the glenohumeral joint before and after ‘habitual’ subluxation which shows a change in alignment.
References