

Basic principles of imaging methods

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Conventional radiography Although it is over 120 years since the discovery of x-rays by - Roentgen in 1895, conventional radiography continues to play a central role in the diagnostic pathway of many acute orthopaedics. X-rays emitted from an x-ray source are absorbed to varying degrees by different materials and tissues and therefore cause different degrees of blackening of radiographic film, resulting in a radiographic image. This differential absorption is dependent partly on the density and the atomic number of different substances. In general, higher density tissues result in a greater reduction in the number of x-ray photons and reduce the amount of blackening caused by those photons. In terms of conventional radiographs, a large difference in tissue structure and density is required before an appreciable difference is manifested radiographically. The different densities visible consist of air, fat, soft tissue, bone and mineralisation, and metal. Different soft tissues cannot be reliably distinguished as, in broad terms, they possess similar quantities of water (Figure 8.1 Manipulation of x-ray systems and x-ray energies, as used in circumstances such as mammography, may allow better differentiation between some soft-tissue structures. Despite this inherent lack of soft-tissue contrast, conventional radiography has many advantages. It is cheap, universally available, easily reproducible and comparable with prior examinations and, in many instances, has a relatively low dose of ionising radiation in contrast to more complex examinations. However, injudicious repeat radiography, particularly of the abdomen, pelvis and spine, can easily result in doses similar to CT. The lack of soft-tissue contrast allows little assessment of the internal architecture of many abdominal organs. To obviate this problem, techniques employing the administration of contrast material combined with radiography have long been used. These techniques include intravenous urography (IVU) and barium examinations (Figure 8.2). IVU involves a series of radiographs taken before and after contrast injection, but has been largely superseded by CT urography, which is more accurate in detecting and defining pathology (Figure 8.3 further modification of conventional x-rays uses fluorescent screens to allow real-time monitoring of organs and structures as opposed to the 'snapshot' images obtained with radiographs. This is used to follow the passage of barium through the bowel, obtaining dedicated images at specific points of interest only. Motility of the bowel can also be assessed in this way. Fluoroscopy is used extensively in interventional radiology, allowing the operator to guide catheters and wires into the patient while monitoring their position in real time. Naturally, with the more sustained use of ionising radiation, the cumulative doses tend to be greater than when obtaining a conventional radiograph. Ultrasound Ultrasound is the second most commonly used method of imaging. It relies on high-frequency sound waves generated by a transducer containing piezoelectric material. The generated sound waves are reflected by tissue interfaces and, by ascertaining the time taken for a pulse to return and the magnitude and direction of a pulse, it is possible to form an image. Medical ultrasound uses frequencies in the

range 3–20 MHz. The higher the frequency of the ultrasound wave, the greater the resolution of the image, but the less depth of view from the skin. Consequently, abdominal imaging uses transducers with a range of frequencies.

Figure 8.1 Supine abdominal radiograph of a patient with small bowel obstruction demonstrates multiple dilated small bowel loops. The different densities visible are air (within the bowel), bones, soft tissues and fat. The different soft tissues, subcutaneous and intra-abdominal, cannot be differentiated. Figure 8.2 Barium swallow examination showing a malignant stricture (arrow) due to an oesophageal carcinoma.

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Figure 8.3 Coronal maximum intensity projection image from a computed tomography intravenous urogram shows a transitional cell carcinoma in the left renal pelvis (arrow) with normal excretion of contrast on the right. Figure 8.4 Longitudinal transvaginal ultrasound scan of the uterus demonstrates thickening of the endometrium in a patient during the secretory phase of the menstrual cycle. Figure 8.5 Transverse ultrasound image of the liver in a patient with colorectal cancer shows a solitary liver metastasis. (a) (b) Figure 8.6 Sagittal ultrasound image of the liver (a) in a patient with cirrhosis demonstrates nodularity of the liver surface and extensive ascites. Doppler ultrasound (b) illustrates portal vein flow with a normal direction.

and venous disease, in which stenotic lesions cause an alteration in the normal velocity. Furthermore, diffuse parenchymal diseases, such as cirrhosis, may cause an alteration in the normal Doppler signal of the blood vessels of the affected organ. The advantages of ultrasound are that it is cheap and easily available. It is the first-line investigation of choice for assessment of the liver, the biliary tree and the renal tract (Figures 8.5 and 8.6). Ultrasound is also the imaging method of choice in obstetric assessment and gynaecological disease. High-frequency transducers have made ultrasound the best imaging technique for the evaluation of thyroid and testicular disorders, in terms of both diffuse disease and focal mass lesions. It is also an invaluable tool for guiding needle placement in interventional procedures such as biopsies and drainages, allowing direct real-time visualisation of the needle during the procedure. Ligament, tendon and muscle injuries are also probably best imaged in the first instance by ultrasound (Figure 8.7). The ability to stress ligaments and to allow tendons to move during the investigation gives an extra dimension, which greatly improves its diagnostic value. The use of 'panoramic' or 'extended field of view' ultrasound (Figure 8.8) provides images that are more easily interpreted by an observer not performing the examination, and are of particular assistance to surgeons planning a procedure.

Ultrasound will demonstrate most foreign bodies in soft tissues, including those that are not radio-opaque. It is dependent, and most of the information is obtained during - the actual process of scanning as opposed to reviewing the static images. Another drawback is that the ultrasound wave - is highly attenuated by air and bone and, thus, little information is gained with regard to tissues beyond bony or air-filled structures; alternative techniques may be required to image these areas.

Summary box 8.4 Ultrasound

Figure 8.7 Ultrasound of the dorsal surface of the wrist shows the normal fibrillar pattern of the extensor tendons. There is increased fluid (arrow) within the tendon sheath in this patient with extensor tenosynovitis. Figure 8.8 Panoramic ultrasound of the calf. The normal muscle fibres and the fascia can be identified over an area measuring approximately 12 cm.

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 Superb soft-tissue resolution in the near field
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 Endocavity ultrasound for gynaecological and prostate disorders
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