REVIEWS

The value of current developments in radiology to the accident and emergency department—a pictorial review

David C F Lloyd

The vast majority of patients presenting into an accident and emergency (A&E) department can be managed either with no imaging or with standard radiography. For selected patients, advances in technology have led to a wealth of useful imaging techniques. In this article I shall be reviewing some of the modern advances in radiology which are most applicable to the A&E department.

Ultrasound

Ultrasound is a well established imaging technique though its role in the assessment of minor and major trauma continues to evolve and to be a subject of debate. Ultrasound can be performed rapidly in the resuscitation room. Unlike computerised tomography (CT), therefore, it can be performed while the patient is being resuscitated and can be repeated if necessary without moving the patient. For this reason it has been suggested that it should be used as a screening and sorting investigation and not directly compared with CT.¹ Free fluid and organ lacerations may be visualised (fig 1). Sensitivities for the presence of free intraperitoneal fluid have ranged from 82% to 93% and specificities from 94% to 100%.¹⁻⁶ Detection of

the exact site of injury is less reliable, and depends on the organ involved. Goletti *et al*⁶ found a 98% sensitivity and a 99% specificity for free fluid, but a 93.5% sensitivity for splenic lesions and an 80% sensitivity for liver lesions, with only 20% sensitivity for diaphragmatic injuries, and 0% for detecting injuries of hollow visci, biliary tree, and vessels. The overall sensitivity to the site of injury in this paper was 72.9%. Ultrasound is very useful but is operator dependent, and visualisation of structures can be difficult in the severely injured patient who is unable to cooperate or be easily moved, and in whom access may be difficult.

Musculoskeletal ultrasound is an area which has grown rapidly over the last few years. This is because of higher resolution probes, improved image processing, and increasing awareness of the applicability of this imaging technique to injuries of the musculoskeletal system. Haematomas, muscle tears, and tendon injuries can be accurately detected and quantified⁷⁻¹¹ (fig 2). Joint effusions and periosteal elevation can be detected with high sensitivity in children with suspected osteomyelitis or infected joints (7).

Non radio-opaque foreign bodies are well detected with high resolution ultrasound (fig 3). Investigation is indicated in patients with persistent inflammation following a penetrating injury which may have resulted in deposition of a foreign body.

Colour Doppler ultrasound has facilitated visualisation of the veins in the lower limbs so that this has now become an accepted non-invasive alternative to venography. This technique demands an experienced operator but now enables visualisation of the calf veins as well as the popliteal and femoral veins.¹²⁻¹⁴ Colour Doppler ultrasound may also occasionally be of value in patients with vascular injuries such as post traumatic pseudoaneurysms.

Spiral computerised tomography

As computer power has increased and x ray technology has improved, so CT scanners have become faster at performing their jobs. A modern scanner at the top of the range now requires no cooling time and can scan the whole body, taking 0.75-1 s to perform each section. With more complicated algorithms for

Department of
Radiology, Cardiff
Royal Infirmary,
Newport Road, Cardiff
CF2 1SZ, UK
D C F Lloyd

Correspondence to:
Dr David C F Lloyd,
consultant radiologist.

Figure 1 Ultrasound scan of the left upper quadrant showing spleen (s) and left kidney (k). Free fluid is seen at the inferior edge of the spleen (broad white arrow). A splenic haematoma is also demonstrated (curved white arrow).

Figure 2 Partial tear of the Achilles tendon. In the transverse section (TS) the achilles tendon is seen as an oval structure (open arrows) with a hypoechoic (dark) focus (solid arrow) representing the tear involving approximately 25% of the cross sectional area. In the longitudinal section (LS) the fibres of the achilles are seen running across the image between the open arrows, with a partial tear again seen as a hypoechoic (solid arrow) focus.

Figure 3 (A) Wood foreign bodies as shown on ultrasound (arrows) as hyperechoic structures. The left image shows a longitudinal section of a fragment of wood. The right image is a transverse image showing the short axis of this and a second piece of wood. (B) Photograph of the foreign bodies after removal.

interpreting the data, modern CT scanners can also produce images with a continuous spinning tube and continuous table movement rather than stepwise progression, thus acquiring a helix of data. This advancement is known as spiral or helical CT, and allows 60–75 cm (for example, a thorax and abdomen) to be scanned in one minute.

Figure 4 Contrast enhanced computerised tomograph showing extensive peritoneal clot, with a site of extravasation of contrast due to active bleeding from a liver laceration (arrow). L, liver; a, aorta; s, spleen; c, peritoneal blood and clot.

Speed of acquisition for the A&E patient allows rapid diagnosis in severely injured patients and avoids delay in the x ray department. Better images can be obtained during contrast enhanced examinations before contrast is diluted within body spaces. Contrast enhanced CT is extremely accurate in the detection of injury and in the evaluation of the individual organs.^{15–20} It is possible to detect contrast medium extravasations from the injured bowel, urinary tract, or from the vascular spaces during active bleeding (fig 4).^{21–22} It is, however, important to remain vigilant to avoid overuse which can delay a patient's access to theatre and waste resources.¹⁷ The patient should always be resuscitated and have a secure airway before transfer to the CT scanner. The haemodynamically unstable patient should be stabilised. If this is not possible, direct transfer to theatre for surgery should be considered without CT. The role of CT in suspected traumatic injury to the aorta is limited. Fisher *et al* showed that it was only of value if normal, and this was the case in only 25% of their patients. The procedure delays aortography or transoesophageal echo and adds to contrast and radiation dose.²³

In patients with fractures, the extent of the fracture and position of fragments of bone are well demonstrated (fig 5). The immense processing power enables reconstructions to be performed in any plane following acquisition of multiple fine axial sections. Using a different method of processing, three dimensional images can be produced (fig 6). All these techniques allow a better understanding and assessment of fractures.²⁴

Magnetic resonance imaging

Magnetic resonance imaging (MRI) has a vast application to traumatised patients. It is exquisitely sensitive to the presence of oedema and haemorrhage, as well as being able to delineate the soft tissue and bony anatomy clearly. It has been well shown to be a reliable method for detecting fractures which are occult on plain radiographs (fig 7).^{25–29} Fracture extent, displacement, and associated injuries^{29–31} can be accurately assessed. Soft tissue injuries

Figure 5 (A) Plain film demonstrating subtle deformity in the superior pubic ramus towards the right acetabulum. (B) Computerised tomography clearly shows the acetabular fracture with the degree of displacement.

Figure 6 Three dimensional reconstruction in a patient with a complex facial fracture following axial scanning.

including injuries to the menisci of the knees, ligaments, tendons, and muscles are detected and assessed with great accuracy (fig 8).³²⁻⁴⁰

MRI is extremely useful in evaluating patients with spinal injuries. It allows visualisation of the entire cervical, thoracic, and lumbar

spine in optimal planes. One can look for spinal cord damage⁴¹ and assess for unstable fractures of the spine by looking at associated ligamentous disruption (fig 9).

Up to now MRI scanners have been extremely expensive and the more powerful scanners remain costly and continue to become more sophisticated. However, there is a new breed of dedicated small part MRI scanners now commercially available (Arto-scan, Esaote Biomedica, West Newlands Industrial Estate, Somersham, Huntingdon, Cambridgeshire, UK). These produce good quality images and can be used for knees, ankles, elbows, and wrists. They can be purchased for under £200 000 and may in the future find a valuable role in the A&E and fracture clinic areas. Exclusion of scaphoid fractures and rapid assessment of knee injuries on the first visit, for instance, may prove cost-effective, avoiding follow up and unnecessary immobilisation.

Computed radiography

With standard radiography, the image is formed either by direct effect of x rays on a film, or more commonly by the effect of x rays on a screen which is in close contact with the film and emits light that in turn exposes the film. These screens are more sensitive to x rays than the film itself and allow a lower dose of x rays to the patient to achieve exposure of the image.

In most established digital techniques, the film screen combination is replaced by a plate. The exposed plate is read by laser, and the information stored as a digital image. Spatial resolution of the image is high although not quite as high as plain film. This image can then either be printed onto film or viewed on high resolution monitors. The raw data contain a very wide range of information, and thus a soft tissue view and a bony view can both be obtained from a single exposure by manipulating the way the data are displayed (fig 10). A lower dose of x rays can be used to produce similar quality images, and there is more tolerance within the system for inaccurate exposure. Therefore there are less repeat radiographs, further lowering radiation dose to the patient. Similarly it allows imaging of the cervicothoracic junction in cases which would be more difficult with plain radiography.

Evidence on successful use of digital radiography is mixed. The maximum throughput, the resolution, and the ease of image manipulation depend to an extent on the money spent and how up to date the equipment is. Several studies have shown digital radiography to be as good as standard radiography⁴² or better,^{43,44} and Phillips *et al*⁴⁴ were able to halve the dose of x rays in a paediatric population without significant degradation of the image. The use of a hospital-wide image transfer system along optical fibres has also been shown to be of value for diagnosis and management.⁴⁵ Kondoh *et al*⁴⁶ have, however, pointed out the decreased resolution for fine detail when compared to plain radiography. The decreased spatial resolution may not be important clinically

Figure 7 (A) Plain radiograph shows no evidence of a hip fracture. (B) Magnetic resonance imaging clearly shows the fracture line (arrow) in this patient with a radiologically occult femoral neck fracture.

Figure 8 (A) Magnetic resonance imaging of a normal patellar tendon (arrows). (B) Similar section in a patient with a complete tear of the patellar tendon. The low signal (black) of the normal tendon has been replaced with a high signal (white) of oedema and haemorrhage.

and in at least some instances, such as the detection of foreign bodies, computed radiography may be superior to plain films.⁴⁷ This is because the ability to manipulate image contrast can compensate for the decreased spatial resolution.

Teleradiology

Teleradiology involves the transmission of images from one site to another, usually along telephone lines. This allows images to be viewed in a remote location at the same time as a central location and allows prompt reporting of images from the central location. This is already widely used in many departments, including our own, for digitally acquired low resolution data such as CT.

To extend this facility to transmission of x rays, the radiograph must be in digital format.

This can either be acquired digitally as above or films may be read by digitisers. Digitising film results in some loss of information and the digitised film does not contain the same information as an image that has been acquired from a plate digitally. However, teleradiology has already started to become established. This may become of increasing value in those hospitals which do not provide, or have difficulty in providing, on-site radiological diagnosis. Links may be set up within a hospital, between hospitals, or between hospitals and home.

The quality of a teleradiology system depends to a large extent on how up to date it is and how much money is spent on it. There are thus some conflicting results and opinions in published reports, though the practice of teleradiology continues to grow.⁴⁸⁻⁵⁵ The fact

Figure 9 Magnetic resonance imaging in a patient with an unstable injury to the cervical spine at C5-6. High signal due to oedema and haemorrhage is seen disrupting the annulus and posterior longitudinal ligament (curved arrow) and the interspinous and supraspinous ligament (straight arrow).

that the raw data show different information depending on the way they are displayed is one of the potential medicolegal drawbacks of the digital system.⁵⁶

Computer aided diagnosis

Computer aided diagnosis is still in its infancy, but several different approaches have been adopted.⁵⁷ The most basic is essentially a computerised textbook which will display examples of the diagnosis suggested by the operator, list the differential diagnoses, and state the diag-

nostic features. At the next level is an interactive database where the doctor (or other) enters the information available on the patient, the symptoms, and the radiographic findings, and the computer gives a differential diagnosis ranked according to probability.

With the ability to acquire digital images and to digitise film, the images can now be presented directly to the computer for image analysis and diagnosis. The computer can then highlight possible abnormalities that should be looked at carefully by the radiologist or clinician. Eventually this process of spotting potential abnormalities should progress to detection of abnormalities and suggesting diagnoses. All these processes are, however, still in their infancy and fraught with problems. In one study attempting to detect edges as a way of detecting pneumothorax, the ribs had to be detected manually to avoid confusing the software.⁵⁸ This prototype still detected 0.44 false positives per image and had a sensitivity of only 77%. It is thus as yet of no current value. Such a system may, after further development, have potential in fracture detection, but it will be difficult to avoid false positives due to normal joint spaces, trabeculae, and normal vascular channels.

Conclusion

Radiology has advanced rapidly over recent years and offers potential to revolutionise the management of some patients in the A&E department. Much work will be required to demonstrate cost-effectiveness and clinical effectiveness of these developments.

Figure 10 Digital radiograph. The left image shows processing like a standard radiograph. On the right, processing with a different algorithm with edge enhancement demonstrates not only bony, but also soft tissue structures to better effect (note the skin anteriorly).

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