The scaphoid is the second largest of the carpal bones and is named due to its boat-like shape (derived from the Greek word *scaphon*). It is situated laterally in the proximal carpal row, articulating with the distal radius proximally and forms joints with the lunate, capitate, trapezoid and trapezium. The scaphoid can be divided into proximal, mid and distal thirds for ease of description. The middle third is often referred to as the 'waist'. On the palmar surface of the distal pole is the small scaphoid tuberosity where the flexor retinaculum and flexor carpi radialis tendon attaches.

The scaphoid is the most frequently injured carpal bone, usually resulting from a fall onto an outstretched hand in active young patients (peak incidence in the second and third decades). The bone itself can fracture or the scapholunate ligament can rupture, leading to a rotatory subluxation of the scaphoid.

Up to 80% of scaphoid fractures occur through the waist of the bone, with proximal pole fractures more common than distal pole. The single-vessel retrograde arterial blood supply to the scaphoid bone (from distal pole to proximal pole) ensures that the distal pole has excellent blood supply, whereas the supply to the proximal pole is more tenuous and is prone to avascular necrosis. In addition, as 80% of the bone surface is covered in articular cartilage, there is limited capacity for periosteal healing, thus delayed union and non-union is often seen.

Early confirmation of the presence of a fracture is important in order to ensure adequate immobilisation and referral to orthopaedic/hand surgery teams and to avoid unnecessary prolonged immobilisation in patients without fractures. Many hospitals have protocols for the investigation of suspected scaphoid fractures, beginning with radiographs and utilising cross-sectional imaging if a diagnosis is not made initially. There have been some recent studies showing that early use of MRI scanning significantly alters patient management in the majority of cases.

In our hospital the imaging of scaphoid injuries is carried out according to the following algorithm that was developed between the emergency department and the imaging department (see diagram 1).

We use CT as the modality of choice for investigation of occult fractures at the second Emergency Department review. All imaging modalities are further discussed below.

**Radiological evaluation of scaphoid fractures**

Plain radiographs
A routine scaphoid series consists of four views of the wrist joint and scaphoid, the PA, lateral, semi-pronated oblique and semi-supinated oblique (figure 1).

However, even with a dedicated scaphoid series of radiographs, up to a third of scaphoid fractures remain occult. Traditionally, patients with clinical suspicion of a scaphoid fracture but negative radiographs are immobilised in plaster pending a repeat series of radiographs in 7-14 days, at which time the fracture is often visualised due to disuse osteoporosis and surrounding hyperaemia.

To avoid prolonged immobilisation following equivocal imaging, scaphoid fractures can also be further investigated using a wide variety of imaging modalities. These are usually performed where clinical suspicion remains despite negative radiographs, but may also be utilised when assessment of complications and/or assessment of healing is required.

**Secondary investigations**

Radionuclide scintigraphy has been used historically to detect injuries as it has high sensitivity for the identification of acute fractures. However, the specificity and spatial resolution of scintigraphy is limited, plus the comparatively long acquisition times have meant it is becoming less frequently used in practice.
High resolution ultrasound scanning of the scaphoid using a high frequency linear probe, in longitudinal and axial planes from palmar, lateral and dorsal directions has been published as an alternative to MRI or CT scanning. The visualisation of cortical discontinuity or periosteal elevation and surrounding haematoma were used as criteria for diagnosing an acute fracture. The advantages of using ultrasound include speed, availability, not using ionising radiation plus its lack of contraindications (compared with those of MRI). However, the limitations are that it is a highly user-dependant technique and not all surfaces of the scaphoid can be imaged using ultrasound due to its orientation.

CT scanning has excellent spatial resolution, making it ideal for the evaluation of occult fractures. It has a reported sensitivity and specificity of up to 97% and 100% respectively, is widely available and quick. Thin sections are obtained parallel to the long axis of the bone. The patient lies prone with arm extended above their head and the wrist held in radial deviation. These sections are then reformatted in three dimensions and volume rendered to demonstrate the presence of fractures and also enable detailed assessment of fracture healing (see figure 2). CT scanning is the modality of choice for assessing the displacement, angulation and deformity of scaphoid fractures. The volume rendered images are also useful for appreciation of the bony morphology and subsequent surgical planning.

MRI scanning has the advantage of allowing the assessment of soft tissue and ligamentous injuries, together with being exquisitely sensitive for the presence of bone marrow oedema. By demonstrating bone marrow oedema, trabecular fractures can be diagnosed even without cortical involvement. MRI, however, is less readily available, scan times are longer and may be contra-indicated in patients with indwelling metalwork or electronic devices.

Digital tomosynthesis has been developed from the principles of conventional linear tomosynthesis which has been used since the 1930s, most commonly in intravenous pyelogram examinations. With recent advances in digital imaging, a series of low-dose images are acquired during a single sweep of an x-ray tube through a limited angle. Many projections are acquired in a short time (10 seconds) and the data are then manipulated using filtered back-projection to provide high-resolution images of a three-dimensional structure. This digital tomosynthesis technology has been used successfully to image the wrist, generating approximately 30 projections through a 40 degree angle and reconstructing images at 1 or 2mm slice thickness. There have been several case studies where digital tomosynthesis of the scaphoid has demonstrated fractures that were not visible on plain radiographs.

Complications of scaphoid fractures

Avascular necrosis (AVN)
The blood supply of the scaphoid makes it vulnerable to AVN. The gold standard test for diagnosing AVN is surgical inspection for surface bleeding, but this is obviously not ideal. Both CT and MRI scanning have been used to investigate AVN, with varying levels of sensitivity and specificity. In particular, demonstration of sclerosis on CT can be misleading as this can be secondary to new bone formation following a transient period of ischaemia and subsequent revascularisation (see figure 3).

Non-union
Non-union is diagnosed when no radiographic signs of healing are seen six months following fracture. The fracture site commonly appears sclerotic with surrounding bone resorption and a persistent radiolucency fracture line (see figure 3). An initial delay in fracture diagnosis can lead to higher rates of non-union, with frequencies up to 88% following a four-week delay. However, healing can still be achieved in the vast majority of these cases if surgical intervention is subsequently performed. CT scanning is useful both for the diagnosis of non-union and the pre-operative surgical planning.

Carpal instability
Injuries to the carpal bones or their linking ligaments can lead to carpal mal-alignments, which are termed instabilities. These are classified according to the resultant angulation of the proximal carpal row with the long axis of the radius, into either dorsal intercalated segment instability (DISI) or volar intercalated segment instability (VISI). These can be diagnosed using plain radiographs, using the following diagnostic patterns.

DISI pattern of instability shows an increased scapholunate angle (greater than 60 degrees) on the lateral radiograph, with dorsal angulation of the lunate and triquetrum (see figure 4). The PA radiograph demonstrates a scapholunate distance greater than 4mm.

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FIGURE 2
A reformatted coronal CT image of the left wrist of a 57-year-old female, demonstrating an oblique fracture through the waist of the scaphoid (arrow) occult on plain film images.

FIGURE 3
A coronal reformatted image of a 31-year-old male showing non-union of a scaphoid waist fracture with proximal pole sclerosis characteristic of avascular necrosis.

FIGURE 4
STIR coronal and T1 sagittal MRI arthrogram images in a 35-year-old male seven weeks following an injury to the right wrist, demonstrating an increased scapholunate distance (arrowed). There is dorsal tilt of the lunate (white dotted line) respective to the normal alignment (black dotted line) indicating a secondary DISI pattern of carpal instability.
VISI pattern of instability is characterised by a decreased scapholunate angle (less than 30 degrees) with volar angulation of the lunate and scaphoid.

Diagnosis of a carpal instability should highlight disruption of inter-carpal ligamentous structures and lead to further investigations of these structures.

**Imaging for soft tissue structures around the wrist**

CT and MR arthrograms are performed when damage to the intrinsic structures of the wrist joint is suspected. They are often utilised to investigate ligamentous injuries, especially the scapholunate ligament (see figure 5). The injection site of choice should be on the side of the wrist opposite the symptoms to help distinguish iatrogenic spill from a true capsular disruption. Intra-articular injection of a contrast agent is generally performed under fluoroscopic guidance, but ultrasound, CT or MR guidance may be also used.

MR and CT arthrograms can accurately display both full and partial ligament tears and allow precise localisation of the injury. Fluid in the mid-carpal joint is a sensitive, but nonspecific, finding of SL or luno-triquetral ligament tears. Indirect signs of instability can also be present, suggesting the presence of complete interosseous or capsular ligament tears. These signs include SL separation, abnormal SL angle, instability patterns of the dorsal or volar segments, and rotatory subluxation of the scaphoid bone itself.

Indirect MR arthrography uses the administration of intravenous MR contrast followed by five to 10 minutes of light exercise. This has been shown to produce enhancement in joints, allowing the evaluation of intrinsic structures; however, it lacks capsular distension, which is achieved by direct injection techniques.

**Conclusion**

Overall, injuries to the scaphoid and its intrinsic ligaments are common, frequently under-diagnosed due to occult features on imaging and missed injuries have serious long-term sequelae such as AVN, non-union or instability. By utilising advanced imaging methods in cases with high clinical suspicion of injury, the missed-diagnosis rate can be reduced, leading to timely surgical intervention or immobilisation and a subsequent reduction in complication rates.

**Further reading**


**FIGURE 5**

Coronal STIR and T1 MRI arthrogram images in a 66-year-old male, demonstrating an increased scapholunate distance secondary to scapholunate ligament injury (blue arrow). In addition, there is low T1 signal in the proximal pole of the scaphoid (white arrow) consistent with early avascular necrosis.