Introduction
The 'scaphoid' (Greek word ‘skaphe’ for boat) is an obliquely oriented bone on the radial side of the wrist, which bridges the distal and proximal carpal rows. The body of scaphoid is bean-shaped with a dorsal sulcus and a ridge. (Fig. 1) The tubercle is offset from the distal end by about 45°.

It has six surfaces, four of which are articular facets; the dorsal and palmar surfaces are non-articular with multiple arterial foramina. The blood supply is mainly (75%) from branches of the radial artery that pass through the attachment of capsule to the dorsal ridge and these also supply the proximal pole. In 20% of scaphoids, most of the arterial foramina are in the waist area of the bone with no more than a single foramen in the proximal third. Fractures occurring in these scaphoids may therefore be left without adequate blood supply to the proximal pole.

Although the scaphoid is mainly intra-articular and covered with cartilage, there are important sites for attachment of ligaments. Along the ulnar aspect of the proximal pole, the scapholunate interosseous ligament joins the scaphoid to the lunate. More radial is the radioscapophacapitate ligament, which has a substantial insertion on the waist of the scaphoid. At the distal articulation of the scaphoid is the v-shaped scaphophalangeal ligament.

Mechanism of injury
Extreme dorsiflexion of the wrist with compression of the radial side of the palm commonly causes middle-third scaphoid fractures. Falls backward, with a hand directed anteriorly, are most likely to force extreme dorsiflexion. Less commonly, forced dorsiflexion against a steering wheel in a motor vehicle accident or a ball forcing the palm dorsally can cause a scaphoid fracture. Rare mechanisms may involve forced palmar flexion of the wrist or axial loading with the hand clenched in a fist.

Assessment and classification

Table I. Accuracy of clinical tests in diagnosis of scaphoid fractures

<table>
<thead>
<tr>
<th>Clinical tests</th>
<th>Specificity (%)*</th>
<th>Sensitivity (%)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Snuff box tenderness²</td>
<td>40</td>
<td>90</td>
</tr>
<tr>
<td>Effusion (On ultrasound)⁶</td>
<td>91</td>
<td>50</td>
</tr>
<tr>
<td>Tenderness over scaphoid tubercle⁷</td>
<td>57</td>
<td>87</td>
</tr>
<tr>
<td>Scaphoid compression test⁹</td>
<td>92</td>
<td>94</td>
</tr>
<tr>
<td>Combined¹⁰</td>
<td>74</td>
<td>100</td>
</tr>
</tbody>
</table>

Specificity= Number of true negatives/(Number of true negatives+ Number of false positives)
Sensitivity= Number of true positives/(Number of true positives+ Number of false negatives)

Table II

Investigations
The standard radiographs for a scaphoid fracture include four views of the wrist: the postero-anterior (PA) with ulnar deviation; lateral; semi-pronated oblique; and semi-supinated oblique. Other authors have suggested even more views. Scaphoid waist fractures are best seen on an ulnar deviated angled PA view and true lateral film. Dorsal sulcal fractures are best seen on a 45° semi-pronated oblique view on which
the fracture line runs from the dorsal apex of the ridge adjacent to the lunate. (Fig.1). Proximal pole fractures are best seen on a 45° semi-supinated oblique view.15

‘Clinical’ scaphoid fracture (diagnosis not certain) (Fig. 2). A patient who has sustained a dorsiflexion injury, has pain and tenderness on the radial side of the wrist but whose adequate radiographs don’t show a fracture is considered to have a ‘clinical’ scaphoid fracture. Initial radiographs detect a fracture in 85–90%16 but it can be occult in up to 10-15% of cases.17

Adequate management includes:

a. Advise the patient of the possibility of a fracture and 10% or so rate of non-union.

b. Advise the patient to restrict activity or to use a removable splint to limit wrist, and therefore scaphoid, movement.

c. Give the patient the option of being treated in a cast with a 3% chance of subsequently identifying a fracture, and

d. Review the patient after two or three weeks; if at this interval, clinical signs still suggest a fracture (swelling, tenderness in the anatomical snuff box and more than 20% restriction of grip strength) further radiographs or other imaging is obtained:

- If it is readily available, Computed Tomography (CT) scan of scaphoid in the sagittal plane can be used to rule out a scaphoid fracture. This is obtained by placing the patient prone in the scanner with the hand above the head, in full pronation and neutral flexion.19 This identifies the true longitudinal axis of the scaphoid20 and can define the location, pattern, and displacement of the scaphoid fracture.

- A magnetic resonance imaging (MRI) can be used to identify a scaphoid fracture but is more useful for non-specific wrist pain and can detect other associated injuries to the wrist. It is superior to a repeat radiograph21 and bone scintigraphy22 for occult fractures of scaphoid.

- Another alternative is high-resolution ultrasonography23 to identify cortical disruption. Radiocarpal effusion, and scapho-trapezium-trapezoid effusion may also indicate a fracture.24 Ultrasonography is user dependent.

- In acute fractures, Dynamic MRI scans after bolus administration of gadolinium estimates blood flow through bone although it doesn't measure perfusion. This technique assesses bone marrow vascularity and by implication, scaphoid vascularity.25 There is a no clear correlation between sclerosis seen on plain radiographs and blood flow assessed by dynamic MRI.26

**Treatment**

The options for treatment of the broken scaphoid include cast immobilisation and surgical fixation.

**Cast immobilization.** Short arm casts with the thumb left free provide adequate immobilisation for scaphoid fractures27 as restriction of wrist motion will prevent movements at the scaphoid fracture site. Such a cast allows the use of the hand and the elbow is not immobilized. Long-arm casts have offered no advantage over short-arm casts in preventing interfragmentary motion with forearm rotation.28 The position of the wrist in the cast does not affect healing.29 Casting for 6–8 weeks will predictably heal 90% to 95% of scaphoid waist fractures.30,31 but possible patient inconvenience and work restrictions when in the cast have prompted some to advocate internal fixation with a screw.32,33

**Undisplaced fractures (Fig. 3).** The best approach for a patient with an undisplaced acute scaphoid fracture is to consider

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**Table II. Classifications of scaphoid fractures**

<table>
<thead>
<tr>
<th>Site of fracture</th>
<th>Russe11</th>
<th>Herbert12</th>
<th>Mayo clinic13 (Distal pole)</th>
<th>Prosser14 (Radiographic)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuberosity fracture</td>
<td>Type A (Stable)</td>
<td>A1 Tubercle</td>
<td>Distal (5%) (Union rate 100%)</td>
<td>Type I Fractures of tuberosity</td>
</tr>
<tr>
<td></td>
<td>A2 Incomplete</td>
<td></td>
<td></td>
<td>Type 2 The dorsal sulcus</td>
</tr>
<tr>
<td>Waist fracture</td>
<td>Horizontal oblique</td>
<td>Type B (Unstable)</td>
<td>Middle (65%) (Union rate 80%)</td>
<td>Type II Distal intra-articular</td>
</tr>
<tr>
<td></td>
<td>Transverse</td>
<td>B1 Oblique distal third</td>
<td></td>
<td>Type III Osteochondral fracture</td>
</tr>
<tr>
<td></td>
<td>Vertical oblique (5%)</td>
<td>B2 Displaced</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>B4 Fracture dislocations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type C</td>
<td>Delayed union 6 weeks after plaster</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Type D</td>
<td>D1 Fibrous nonunion</td>
<td>Type 1 The ‘surgical waist’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D2 Sclerotic Nonunion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>D3 Nonunion with fixed DISI</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proximal pole fracture</td>
<td>Type B3</td>
<td>Proximal third</td>
<td>Proximal (30%). (Union rate 64%)</td>
<td>Type 3 The proximal pole</td>
</tr>
<tr>
<td></td>
<td>Type D4</td>
<td>Nonunion with AVN</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
patient’s unique circumstances and discuss risks and benefits of both non-operative management and surgery. There are at present six clinical trials comparing casting with surgery in acute scaphoid fractures. The rate of bony union for both methods is greater than 90%. Systematic reviews have found no difference in union rate or time to return to work, and any surgical benefits are transient. A cost-utility analysis of open reduction and internal fixation (ORIF) versus cast immobilization for acute non-displaced scaphoid fractures showed that casting was less costly than ORIF but surgery reduced immobilization time and patient had a “shorter time off work”. However, patients are exposed to complications with surgery.

Displaced fractures (Fig. 4). Displaced fractures risk nonunion. They can heal with conservative treatment but malunite. Displaced fractures could benefit from realignment of the fracture fragments followed by stable internal fixation. In most cases, palmar exposure of the scaphoid limits injury to the blood supply of the scaphoid. It is easier to address very proximal fractures through a dorsal exposure. The headless screw has become a popular device but the use of alignment jig has been abandoned as it can damage the scaphotrapezial joint.

Cannulated screw fixation has become popular for open as well as percutaneous fixation. Kirschner wires inserted into each scaphoid fragment as joysticks allow manipulation of the fragments to achieve reduction. In patients with fracture comminution, particularly with compromise of the palmar cortex, primary bone grafting may be needed. The screw must be positioned within the centre of the scaphoid, as the time to healing is shorter. Central screw placement is achieved more consistently with cannulated screws than with Herbert screws.

Identify union. Assessment of union is by repeat clinical observation and serial radiographs. We believe union is a process rather than a single event at a specific time in the natural history of healing. Time to union is a flawed observation as it depends on when the observer conducts the radiographs or scans. Radiograph can be unreliable at identifying union and even experienced observers (both surgeons and radiologists) may not consistently agree on scaphoid union on radiographs taken 12 weeks after injury. If doubt persists about union, a CT scan of scaphoid will resolve it. Bridging trabeculae across the whole cross-section of the scaphoid on CT scan confirms union and the wrist can be mobilized. Partial union of the scaphoid is common (up to 40%) and with bridging trabeculae across more than 25% of the cross-section of the scaphoid, it progresses to full union without the need for further plaster immobilization. Nonunion is the absence of radiographic signs of healing at 12 weeks and a clear gap on a CT scan.
Return to activity. This has to be individualised to the patient and the personality of the fracture. The patient is advised against contact sport for two to three months and counselled about the risk of refracture. Grip strength and range of movement is initially better in those who undergo surgical fixation compared with those treated in different casts for 8 to 12 weeks but no difference is found after that time. Prolonged above-elbow cast immobilisation beyond 8 weeks is not well tolerated, especially by younger patients who want to return to work and sports as soon as possible and should be avoided.

For athletes, treatment programs have been modified such that standard fiberglass casts are exchanged for soft or padded casts on game days. The soft casts are required to minimise the potential for injury to other athletes. This has not caused healing problems provided treatment is not delayed. An alternative approach is internal fixation of minimally or undisplaced fractures, which avoids cast immobilisation. The fixation is not strong enough to allow impact on the hand in contact sports. Fractures of the proximal pole of the scaphoid. 5% of all scaphoid fractures involve the proximal pole (proximal fifth of the scaphoid). The primary concerns are the small size and avascularity of the proximal fragment. Prolonged immobilization and a high rate (30%) of nonunion have been reported so fixation may be favored for these fractures.
If the fragment is large, a headless compression screw can be used. It is critical to obtain good, preferably central, purchase on the proximal fragment, and ideally the screw should be placed orthogonal to the plane of the fracture. If the fragment is too small to accept such a screw, then Kirschner wires can be used to hold the fracture reduced, and sometimes trans-articular fixation is required. Union rate after open reduction and internal fixation is around 66%.43

Outcome. After a healed fracture, 20% patients have some pain and tenderness at 1.7 to 2.6 years but grip strength and wrist movement were nearly normal.44 Marked radiocarpal osteoarthritis developed in only 2% of cases 36 years after a healed fracture and can be associated with pain or weakness; work has shown that osteoarthritis can develop in only 6% of patients who do not have any symptoms on re-examination, compared with three of the seven who had symptoms.45

Complications
Nonunion46,47 (Fig. 5) (Table III).
- Untreated nonunion: Asymptomatic patients with an undisplaced, stable non-union should be advised of the possibility of late degenerative changes.48 Osteoarthritis is found in 100% of patients with symptomatic nonunion after 10 year but symptoms do not correlate with the severity of arthritis or the duration of nonunion. Long-term follow-up after untreated scaphoid nonunion has shown radiological osteoarthritis but many patients retain satisfactory function.
- Treated nonunion: The overall union rate of scaphoid nonunions treated by Herbert screw and bone grafting was 84% but delayed union and stable nonunions had significantly better union rate (87%) compared with those with unstable nonunions (60%) (Table III).49

Malunion. Malunion is usually a flexion deformity of scaphoid but can be an ulnar translation or pronation of the distal fragment. The effect of malunion of the scaphoid on wrist function remains unclear. In a study on cadavers, the simulated scaphoid malunion reduced wrist extension and this was proportional to the angular deformity.50 Clinical studies have, however, shown that mild malunion is well-tolerated.51,52 Treated nonunion53 can lead to malunion with a humpback scaphoid and this has previously been reported to have a significant impairment of function and restriction of movements but it is not clear whether it leads to early osteoarthritis.

Avascularity. Increased radio-opacity of the proximal fragment is thought to represent avascular necrosis of the scaphoid. There is poor agreement between observers on whether the proximal part of the scaphoid was avascular in radiographs taken 12 weeks after a scaphoid fracture.30 This appearance is a poor predictor of vascularity of scaphoid seen at operation. Vascularity can also be assessed at the time of surgery and by taking a biopsy. Biopsy can, however, be misleading because of the patchy pattern of avascular necrosis and the sample can contain both viable and dead osteocytes.54 Radionuclide bone scanning is sensitive and can reveal early avascular necrosis but is inaccurate in acute fractures and is not quantifiable.55 Gadolinium contrast-enhanced MR imaging quantifies the extent of necrosis of the proximal fragment and has a good correlation with surgical and histologic findings and the subsequent healing of the nonunion.25
Summary
We treat almost all our patients with a scaphoid fracture in a below elbow plaster with the thumb free for 6–8 weeks. At that stage, if there is any doubt about union, we get a CT scan and operate if needed. We consider surgery for displaced scaphoid fractures causing dorsal intercalated segment instability (DISI) deformity, proximal pole fractures, associated perilunate injuries, open fractures, and fractures in multiply injured patients. Other decision-making factors are whether there is a great potential for morbidity from prolonged immobilization, the occupation of the patient, and a clear failure of healing after non-operative treatment of the fracture.

Table III. Classification systems for scaphoid nonunion

| Number | Type of Nonunion (Dias) | Issues | Treatment options | Slade and Geissler (Treatment) | Mack and Lichtman (Treatment) | Gupta
|--------|------------------------|--------|-------------------|--------------------------------|-------------------------------|-----
| 1      | No Deformity Early Cystic | Stability | Percutaneous Percutaneous | Cancellous Cancellous | Grade I Acute fractures with late presentation (rigid fixation) | Type I Non-displaced stable nonunion without degenerative changes (bone grafting with or without hardware) | Group 1 Fractures with delayed Union
|        |                        |        |                   |                               | Grade II Fibrous union (rigid fixation) | Group 2 Stable Nonunion | Nonunion without DISI
|        |                        |        |                   |                               | Grade III Correctly aligned nonunions with <1mm gap (rigid fixation) | Group 3A Nonunion with DISI deformity | Group 3B Nonunion with DISI deformity
| 2      | Mobile Stability/ reconstruction | Open reduction | Usually corticocancellous | Rarely Cancellous alone | Grade IV Non-unions with cystic changes between 1 and 5mm. (debridement, bone grafting) | Grade V Non-unions with deformity requiring structural bone grafting | Type II Unstable owing to fragment displacement, require (reconstruction normal carpal stability with graft)
|        |                        |        |                   |                               | Grade VI Non-unions with necrosis (vascularisation bone graft and non-unions with SNAC deformity (scaphoid excision and carpal reconstruction) | Grade III Accompanying mild arthritis (Initial radiocarpal then narrowing between the radius and scaphoid) (ORIF with bone graft with or without radial styloectomy) | Group 3A Nonunion with DISI deformity |
| 3      | Deformed               | Reconstruction | Open reduction | Tricortical Russe | Grade V Non-unions with deformity requiring structural bone grafting | Grade VI Non-unions with necrosis (vascularised bone graft) and non-unions with SNAC deformity (scaphoid excision and carpal reconstruction) | Type III Accompanying mild arthritis (Initial radiocarpal then narrowing between the radius and scaphoid) (ORIF with bone graft with or without radial styloectomy) |
| 4      | Osteonecrotic          | Prevent Collapse | Vascularised bone graft | | | Grade VI Non-unions with necrosis (vascularised bone graft and non-unions with SNAC deformity (scaphoid excision and carpal reconstruction) | Type IV Midcarpal arthritis without radiolunate arthritis (partial/ complete wrist arthrodesis) |
| 5      | Arthritic              | Pain Management | Denervation, Exostectomy, Partial scaphoid excision, Partial/Full fusion | | | Type V Midcarpal arthritis with radiolunate arthritis (partial/ complete wrist arthrodesis) |
SCAPHOID FRACTURES

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References

8. Munk PL, Lee MJ. A com-

21. Ya A. The natural history of scaphoid non-

26. Downing ND, Oni JA, Davis TR, Yu TD, Dawson JS, Martel AL. The relationship between proximal pole blood flow and the subjective assessment of increased den-

28. McAdams TR, Spisas S, Beaulieu CF, Ladd AL. The effect of pronation and supi-

30. Dias JJ, Taylor M, Thompson J, Brenchel LJ, Gregg PJ. Radiographic signs of union of scaphoid fractures. An analysis of inter-observer agreement and reproduc-

38. Thummel TE, Clarke T, Kredor HJ. Non-union of the scaphoid. Treatment with can-