The scaphoid is the most commonly fractured carpal bone. Initially, diagnosis may be difficult.\textsuperscript{1,2} Scaphoid fractures are subject to many complications such as non-union, malunion, and radiocarpal arthrosis. Even with appropriate treatment, it may be difficult to confirm union of a particular fracture.\textsuperscript{3} As with any fracture, prompt diagnosis and appropriate treatment is critical to achieving good results.

Anatomy

The term scaphoid comes from the Greek word for boat “skaphe.” It is also called the os naviculare, from the Latin “navicularis,” meaning “of or related to shipping.” The complex structure of the scaphoid has been likened to the shape of a small boat or skiff. The scaphoid is present in most mammals but is most often fused to the lunate. It can be divided into the proximal pole, waist, and distal pole.

Eighty percent of the surface of the scaphoid is covered with articular cartilage. The proximal pole articulates with the radius and lunate and the distal pole articulates with the capitate, trapezium, and trapezoid as far proximally as the palmar scaphoid tubercle.

The predominantly articular nature of the scaphoid leaves little area for the entrance of blood supply. The pattern of blood supply to the scaphoid has been clearly documented by Taleisnik and Kelly\textsuperscript{4} and by Gelberman.\textsuperscript{5} At the dorsal ridge of the scaphoid, dorsoradial vessels from arches in the dorsal wrist capsule enter and provide 70% to 80% of the vascularity. The distal pole has additional blood supply from nutrient arteries from the radial artery. These perforate in the area of the scaphotrapezium ligament attachment. This pattern of vascularity leaves proximal fractures at great risk for osteonecrosis.

Biomechanics

Scaphoid fractures are commonly the result of a fall on an outstretched hand. Weber and Chao\textsuperscript{6} produced scaphoid waist fractures in cadaver wrists by applying a dorsiflexion load to the radial half of the wrist with the wrist in 95° to 100° of extension. The palmar aspect of the bone would fail in tension and the dorsal aspect in compression.

The scaphoid functions as the mechanical link between the proximal and distal rows. Fracture of the scaphoid results in abnormal kinetics and load distribution about the wrist. Smith\textsuperscript{7} demonstrated in simulated scaphoid fractures that opposing rotational moments on the proximal and distal poles caused dorsal angulation of scaphoid fractures, the so-called “humpback” deformity. The proximal row may assume an extended position and lead to the development of a DISI deformity as demonstrated by Mack\textsuperscript{8} and Ruby.\textsuperscript{9} Abnormal loading of the distal fragment on the radial styloid leads to arthrosis. Vender\textsuperscript{10} identified the predictable and time-dependent development of arthritis in scaphoid non-unions and coined the term SNAC (scaphoid non-union advanced collapse). Cadaveric studies have demonstrated a loss of wrist motion with scaphoid deformity.\textsuperscript{11}

History and Physical Examination

Scaphoid fractures typically occur in a young, active population and may present acutely or chronically. Initial radiographs may be negative. The examination of a patient with an acute fracture will reveal tenderness on palpation in the anatomic snuffbox, pain on palpation of the distal tuberosity volarly, pain on axial compression of the thumb metacarpal (scaphoid compression test), decreased range of motion, and swelling.
A chronic scaphoid fracture presents with decreased motion, particularly in dorsiflexion, a loss of grip strength, and radial wrist pain.

**Radiographic Evaluation**

Due to its complex geometry, the scaphoid is difficult to adequately visualize using plain radiographs. In addition to posteroanterior and lateral views, several other views are used to aid the clinician in diagnosing and classifying scaphoid fractures. The semipronated oblique view allows the best visualization of the waist. Unlar deviated and clenched-fist views may also provide additional information.

A technetium-99 bone scan can be used to confirm a suspected scaphoid fracture. Ganel and colleagues had no false negatives if the scan was obtained more than 48 hours after injury.

Computer tomography (CT) scans can be used to establish diagnosis, assess fracture displacement and geometry, and assess healing. Scans should be obtained in two planes based on the long axis of the scaphoid, an oblique sagittal and direct coronal. Sagittal-plane images are best obtained by placing the patient prone on the scanner with the hand held overhead, in full pronation and neutral flexion. The arm is held in 45° across the gantry. For the coronal-plane images, the forearm is placed in neutral. One millimeter sections should be obtained. Sanders reported the CT scan to be the “gold standard” for assessing the humpback deformity in scaphoid fractures.

Magnetic resonance (MR) imaging has become increasingly popular in the evaluation of scaphoid injuries, healing, and vascularity. MR scans provide increased soft tissue detail without the use of ionizing radiation. Various imaging techniques may aid in differentiating proximal pole sclerosis from hyperemia. Dorsay and associates showed that MR imaging might be cost effective in the diagnosis of occult fractures as well.

**Classification**

Various investigators have classified scaphoid fractures based on location, obliquity, and time from injury. Additionally, methods to determine instability have been discussed based on fracture line visibility and displacement. Herbert’s classification system is most commonly used. Fractures are divided into four types: Type A, stable acute fractures; Type B, unstable acute fractures; Type C, delayed unions; and Type D, established non-unions. Herbert stated that a fracture seen through both cortices has potential instability. Cooney and coworkers stated that any fracture with more than 1 mm of displacement is unstable.

**Treatment**

The treatment of acute scaphoid fractures depends primarily on location and displacement. Distal pole fractures are typically avulsion fractures of the tuberosity or impaction fractures of the distal articular surface. These fractures are well vascularized and Prosser and colleagues have demonstrated rapid healing in 4 to 6 weeks in a short arm thumb spica cast. There is a significant incidence of malunion of the distal articular surface, but the long-term implications of these malunions are unclear.

Non-displaced, stable waist fractures have traditionally been treated in short- or long-arm casts for variable lengths of time. Many investigators have shown that union rates of greater than 90% can be achieved with prompt recognition and continuous immobilization. Hambridge and associates evaluated wrist position in short arm casting and found no difference in union rates. Clay and coworkers found no difference in union rates with or without the inclusion of the thumb in the cast.

Long-arm versus short-arm casting remains controversial. Biomechanical studies in cadavers have shown fracture site motion during forearm rotation. The clinical data is less clear. Alho and colleagues showed no difference in union rates in their prospective study. Gellman and associates, in a randomized, prospective study of long-arm versus short-arm casting, had no non-unions in the long-arm group and two non-unions in the short-arm group. The time to union was shorter in the long-arm group as well.

Open reduction and internal fixation is the treatment of choice for displaced scaphoid fractures. Some investigators recommend operative stabilization of acute, non-displaced scaphoid fractures as well. Surgical stabilization also is complicated by the difficulty in determining fracture union. Dias and coworkers showed poor interobserver reliability for radiographic signs of union as well as a 12.3% non-union rate at one year for stable, cast-treated fractures. The young, active population that typically sustains scaphoid fractures is often unable or unwilling to tolerate several months of immobilization for reasons related to either work or athletic activities.

Excellent results have been demonstrated with operative treatment of acute scaphoid waist fractures. Saeden and associates prospectively compared Herbert screw fixation versus long-arm casting for stable waist fractures. With an average of 12-year follow-up, there was no statistical difference in the outcome of the two groups. The operative group returned to work in a shorter amount of time.

Fractures of the distal two-thirds can be approached with a Russe volar approach. This approach avoids the predominantly dorsal blood supply. Many internal fixation devices are available and should be selected based on surgeon comfort and experience. Postoperatively, gentle range of motion can be started after wound healing. Heavy labor and sporting activities should be avoided until fracture healing. Rettig and Kollias published the results of 12 athletes treated operatively through a volar approach. The patients were able to return to sporting activities after, on average, six weeks.
Percutaneous fixation of acute scaphoid fractures has been advocated by several investigators. The risk of devascularizing fracture fragments is lessened and the ligaments and volar capsule are protected. The fracture must be nondisplaced or reducible through closed means. Haddad and Goddard had a 100% healing rate of minimally or nondisplaced fractures at 8 weeks. Bond compared volar percutaneous screw fixation to cast treatment in military personnel and showed a significantly shorter time to union and return to work.

Fractures diagnosed more than four weeks after injury may be at greater risk for non-union if treated with cast immobilization. Mack and Wilkens studied fractures treated by closed means after a delay in diagnosis. Though the union rate was 90%, the time to union was 20 to 24 weeks. These fractures may be best treated with operative fixation.

Proximal pole fractures are particularly challenging due to the small size and poor vascularity of the fracture fragments. Non-union rates of proximal pole fractures, even nondisplaced ones, tend to be high. Time to union in a cast can be as long as 9 months. Most investigators recommend acute open reduction and internal fixation. A dorsal approach as described by DeMaagd and Engber can be used. A short arm thumb spica cast is used postoperatively for four weeks. Rettig and Raskin reported a 100% union rate in 17 acute proximal pole fractures treated with Herbert screws. The average time to union was 11 weeks for the displaced fractures and 9.5 weeks for the nondisplaced group.

Dorsal percutaneous fixation was popularized by Slade. It is useful for nondisplaced proximal pole fractures or displaced fractures that are reducible by closed means. Slade and colleagues and Yip and associates both showed 100% union rates at an average of 12 weeks.

Whether open or percutaneous fixation is used, proper screw placement is key. Trumble showed a significantly longer time to union in fractures where the screw was not placed in the central third. Cannulated screws were more consistently placed in the central third than Herbert screws.

Summary
Scaphoid fractures are a common injury in young, active populations. Non-displaced fractures have a high union rate if promptly treated with cast immobilization. Displaced fractures and proximal pole fractures are best treated with operative fixation. There are a variety of techniques and implants available to the surgeon. The surgical approach and fixation device should be based on fracture characteristics and surgeon experience. Operative fixation of non-displaced fractures is an option in patients who would prefer to avoid prolonged cast immobilization.

References