ABSTRACT

IMAGING OF SCAPHOID FRACTURES

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Learning Objectives:

1. To review briefly normal anatomy including vascular supply of the scaphoid bone, mechanism of injury in scaphoid fractures, and classification of the scaphoid fractures.
2. To review complications of scaphoid fractures (delayed union, nonunion, malunion, osteonecrosis, scaphoid nonunion advanced collapse/SNAC wrist).
3. To review concepts, advantages and disadvantages, of all imaging techniques [Radiography, Magnetic resonance Imaging (MRI) and Computed Tomography (CT)] that are currently utilized in diagnosis of the scaphoid fractures and their complications.
4. To briefly review treatment options of acute scaphoid fractures and their complications and potential complications of surgical treatment.

Purpose:

To be comfortable with the imaging work-up and diagnosis of acute scaphoid fractures and their complications in everyday radiology practice.

General Content:

Scaphoid Bone/Normal Anatomy

The proximal pole of the scaphoid is fixed in place by the distal radius at its proximal aspect, radially and dorsally; by the radioscapophocapitate and long radiolunate ligaments volarly; and by the lunate and capitate bones at the ulnar aspect. The distal pole of the scaphoid bone is relatively mobile. Anatomic location of scaphoid bone makes it prone to trauma.

Scaphoid Fractures/Imaging

Scaphoid fractures are the second most common fractures of the upper extremity after the distal radius fractures. Approximately 65% of carpal bone fractures involve the scaphoid bone. These fractures are frequently seen in young adults as a result of fall on outstretched palm of the hand. Mechanism of injury may also be dorsiflexion secondary to fall, and hyperextension with radial deviation. Transverse tensile fractures begin in the palmar cortex.

By location, scaphoid fractures may involve the proximal pole (15-20%), waist (70-80%), and tubercle or distal pole (5-10%). Scaphoid fractures can also be classified according to
direction of the fracture line (horizontal oblique, transverse, vertical oblique) and the degree of stability of the fracture fragments. Fractures of the distal radius and ulna and of the other carpal bones may be present as well.

After the clinical exam, standard radiographs should be the initial imaging modality for suspected scaphoid fractures. Dorsal tilting of the proximal pole and palmar tilting of the distal pole with scaphoid waist fractures resulting in dorsal angulation of the fractured scaphoid is described as a humpback deformity which is best seen on sagittal CT and MR images.

If the radiographs are negative and the fracture is clinically suspected, MRI is the imaging modality of choice for detection of occult fractures.
Acute non-displaced proximal pole scaphoid fracture was difficult to visualize on initial radiographs. MRI study performed the same day clearly visualized the fracture line and associated bone marrow edema of both proximal and distal poles. Radiograph obtained 8 weeks post ORIF showed healed fracture line with intact surgical hardware.

Transscaphoid perilunate fracture dislocation is a serious injury involving the greater and lesser carpal arcs which requires prompt reduction and surgical fixation.
Trans-radial trans-scaphoid perilunate fracture dislocation

Complications of Scaphoid Fractures/Imaging

a) Scaphoid Fracture Healing and Nonunion

The reported incidence of scaphoid fracture nonunion is 5-15%. The time required for healing of scaphoid fractures depends on the location. Fractures of the scaphoid waist may require 6 to 8 weeks or longer to heal, and the nonunion is diagnosed if the fracture does not unite in 6 months. Delayed unions and fracture nonunions are most common with proximal pole fractures, vertical oblique fractures of the middle third, and with displacement of the fracture fragments. Unstable nonunions are associated with displacement of the fracture fragments, DISI deformity, osteoarthritis and SNAC wrist.

Radiographic and CT abnormalities include sclerosis of the fracture margins, cyst formation, widening of the scapholunate interval, bone resorption and, subsequently, osteoarthritis. Multislice CT with axial oblique reformatted images parallel to the long axis of the scaphoid bone and coronal and sagittal reformats is frequently valuable for the evaluation of delayed union and nonunion sites; metal reduction artifact allows good evaluation of the fracture sites transfixed by orthopaedic hardware (screws). MRI shows a persistent intermediate signal intensity fracture line without continuity of the bony trabeculae. Increased signal at the fracture site on the fluid sensitive sequences is consistent with instability. MRI may also show injury of the adjacent tendons or ligaments (radioscaphocapitate, long radiolunate).

b) Scaphoid Fracture Malunion

The scaphoid bone may heal in an abnormal position and this malunion is usually in flexion resulting in foreshortening; fractures of the distal part are of main concern. Scaphoid malunion may result in alteration of carpal mechanics with resultant osteoarthritis causing pain and decreased motion or strength. If symptomatic, the malunion may be surgically corrected.
c) Scaphoid Osteonecrosis

The reported incidence of scaphoid osteonecrosis is 10-15% which rises to 30-40% with scaphoid nonunions. The proximal pole is most frequently involved secondary to absence of a separate vascular supply. On radiographs, osteonecrosis most frequently becomes apparent 3 to 6 months after the injury when the involved fragment shows increased density. CT is more sensitive in depiction of subtle findings of increased density/sclerosis in the affected fragment.

At the present time, MRI without and with contrast is the imaging modality of choice to evaluate for occult osteonecrosis. Low signal intensity on all sequences is consistent with osteonecrosis/nonviable marrow in the chronic phase. Lack of increased signal on the fluid sensitive sequences and lack of enhancement on the T1W fat suppressed sequences post intravenous administration of Gadolinium-based contrast agents is indicative of ischemia/osteonecrosis. “Normal” signal intensity on the T1W images without fat suppression with lack of increased signal on fluid sensitive sequences and lack of enhancement on the post-contrast sequences indicates the presence of mummified fat/early osteonecrosis. Contrast-enhanced sequences show better correlation with surgical findings and postoperative results. Diffuse marrow hyperintensity may represent proximal pole ischemia with reactive edema in the distal pole. Additionally, osteonecrosis may demonstrate normal or increased signal intensity on the T2W sequences and usually has a patchy pattern. Low signal intensity on the T1W sequences does not necessarily mean osteonecrosis; this appearance may reflect ischemia and potentially viable tissue.

MRI was reported to be useful to determine whether vascularized bone graft incorporation and revascularization of the proximal scaphoid pole has occurred in the setting of avascular scaphoid nonunion.

A. Nonunited proximal pole scaphoid fracture with osteonecrosis of the proximal pole B. Nonunited scaphoid waist fracture status post screw fixation and bone grafting with osteonecrosis of the proximal pole
Nonunited proximal pole scaphoid fracture post screw fixation and bone grafting without Osteonecrosis

MR images show scaphoid fracture with osteonecrosis of the proximal pole (note decreased signal on STIR, “normal” on T1W and lack of enhancement on post contrast images in the proximal pole of the scaphoid consistent with early osteonecrosis/mummified fat)

Scaphoid Nonunion Advanced Collapse (SNAC Wrist)

SNAC wrist comprises osteoarthritis of the radiocarpal joint between the distal pole of the fractured scaphoid and distal radius which may be accompanied by osteoarthritis of the midcarpal joint. SNAC wrist occurs with the greater arc injury. Fragmentation and collapse of the proximal pole occur in the late stages.
Treatment Options for Scaphoid Fractures and their Complications

Nondisplaced, uncomplicated fractures may be treated conservatively with immobilization and casting with the union rate up to 95%. Displaced fractures are treated surgically with an interfragmentary screw fixation with a success rate of approximately 92%. Symptomatic scaphoid nonunions are treated surgically with vascularized bone graft and interfragmentary screw fixation. Reasons cited for poor results include the size of the proximal fragment, degree of displacement, bone grafting method, surgical techniques, and the presence of osteonecrosis of the proximal fragment, which is the most important factor in predicting the likelihood of success or failure.

A. Intraoperative image shows guide wires in scaphoid nonunion site and bone graft donor site in the distal radius between the retractors. B. Postoperative radiograph in the same patient shows screw fixation of scaphoid waist fracture nonunion with bone grafting.
Scaphoid Fracture and Fracture Complications: Treatment Algorithm