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Review Article

Managing scaphoid fractures. How we do it?

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ABSTRACT

The scaphoid is the common carpal bone to be fractured. Proper clinical and radiological evaluation is required to establish its diagnosis. The management of acute fractures includes conservative treatment with cast in minimally displaced to open reduction and internal fixation in case of displaced ones. The established nonunion requires open reduction, bone grafting and internal fixation.

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1. Introduction

Scaphoid is a key carpal bone contributing significantly in the biomechanics of the wrist. It is the most common carpal bone to be fractured, second only to distal radius fractures in wrist injuries and hence diagnosis and treatment of scaphoid fractures holds a great relevance.

2. Blood supply of scaphoid

The scaphoid fracture first described in 1905 by Destot, a French surgeon, anatomist and radiologist,¹ derives its name from the Greek word skaphos meaning boat. Scaphoid has unique anatomy to its credit when surrounding bones and its arterial supply is considered. It articulates with all five surrounding bones (distal radius, os capitatum, os lunatum, os trapezium and os trapezoidum). Eighty percent of the scaphoid bone consists of cartilage forming articular surface, leaving limited space for entrance of the supplying arteries.

The main blood supply to the scaphoid enters through the non-articular dorsal ridge at the waist of the bone and the volar tubercle at the distal aspect of the bone. A dorsal branch of the radial artery accounts for 80% of the blood supply of the scaphoid. A separate volar arterial branch to the scaphoid enters the tubercle and accounts for 20–30% of the scaphoid's blood supply, mainly to the distal portion. The proximal pole of the scaphoid relies entirely on intramedullary blood flow. This unusual retrograde nature of blood supply renders proximal pole susceptible to avascular necrosis after a fracture through waist.²

3. Anatomy and biomechanics

Location of scaphoid is such that it crosses both proximal and distal rows. Scaphoid flexes and extends with wrist flexion and extension respectively. Scaphoid controls flexion and extension of lunate and distal carpal row and, as wrist moves from neutral to ulnar deviation, proximal row flexes dorsally

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and scaphoid appears longer and clearer, hence necessitating an ulnar deviation view radiograph. With scaphoid fractures, proximal scaphoid extends and distal scaphoid flexes causing gap dorsally which gradually assumes a humpback deformity. There are 7 ligaments that crossover or attach to the scaphoid or lunate. These are the scapho-lunate interosseous ligament (SLIL), the radioscapocapitate ligament (RSC), the long radiolunate ligament, the short radiolunate ligament, the scaphotrapezial ligament (ST), the dorsal radiocarpal ligament (DRC), and the dorsal intercarpal ligament (DIC). Of these, SLIL is the primary stabilizer of the SL joint. Dividing the DIC alone or the ST alone had no effect on scaphoid and lunate kinematics during either wrist flexion/extension or wrist radial/ulnar deviation.³

4. Mechanism of injury

The typical trauma mechanism is a fall on the outstretched hand with the wrist in radial deviation, causing the scaphoid bone to impact against the distal radius concavity, most likely resulting in a fracture in the middle of the scaphoid. There is an increased chance of a proximal pole fracture when falls occur on the wrist in abduction.⁴ Scaphoid fracture is expected when wrist is dorsiflexed beyond 97° and radial deviation past 10°.

5. Diagnosing scaphoid fractures

Early diagnosis and treatment of scaphoid fractures is prime to avoid complications like nonunion, avascular necrosis and osteoarthritis. Diagnosis of scaphoid fractures is done with the help of clinical examination and radiographs which typically include posteroanterior, lateral, semipronated oblique view and posteroanterior with ulnar deviation. Scaphoid fractures is known for its occult nature being frequently missed on initial radiographs done immediately. For this radiographs are repeated at a later date to diagnose these occult fractures (Fig. 1a, b, c). Other investigations used for diagnosing are bone scintigraphy, MRI, CT and high frequency sonography. Systemic review and meta analysis of all these modalities have suggested marked inconsistency in imaging protocols for suspected scaphoid fractures amongst various investigators and different hospitals.^{5–11}

6. Classification

Fractures of the scaphoid can be classified in various ways. The Mayo classification⁶ divides scaphoid fractures into proximal (10%), middle (70%) and distal (20%) fractures. Within the distal third, distinction is made between the distal articular surface and the distal tubercle. The Herbert classification¹² is based on the stability of the fracture. Unstable fractures are fractures with a displacement of more than 1 mm or an angulation of more than 15° between the fragments. Additional fractures, trans-scaphoid-perilunate dislocations, multifragment fractures and proximal pole fractures are also classified as unstable. The anatomic classification

according to Russe¹³ predicts the tendency of the fracture to heal. The classification distinguishes among horizontal oblique, transverse or vertical oblique fracture lines. The vertical oblique fracture is unstable, whereas the horizontal oblique and the transverse fractures are more stable fractures.

The potential healing mechanisms of scaphoid fractures are identical to those of fractures in general and can involve either primary or secondary healing, depending on the degree of displacement. Though any treatment that promotes scaphoid fracture healing can be considered successful, one that promotes primary healing is clearly favourable as scaphoid fractures do not make callus and are unable to heal by secondary bone healing. Nevertheless, radiographs remain the modality of choice to assess union, defined as “the restoration of bony architecture across the fracture site”.¹⁴ In this respect radiographs are most commonly used to identify trabeculae crossing the fracture line or sclerosis at the fracture line. Typically the appearance of healing on MRI is seen as a “double line” representing the fracture line coupled with the revascularization front. A failure of this front to proceed is almost always associated with eventual nonunion.¹⁵ As healing progresses to union, the only definitive sign of union is the return of normal marrow continuity across the fracture line.¹⁶ CT scans are also helpful especially reformatting in multiple planes which allows three dimensional assessment of the trabecular architecture of the scaphoid. If there is evidence of bridging bone across the fracture site on a CT scan, it is considered evidence of radiographic healing.

Scaphoid fractures fail to unite in 5%–25% of cases.¹⁷ Further nonunion rate is increased by factors like displacement greater than 1 mm, delay in diagnosis/immobilization more than 4 weeks, location at the waist or proximal pole, and a history of smoking.¹⁸

7. Treatment

Treatment of scaphoid fractures has evolved from rigid long immobilization as told by Watson – Jones to early surgical treatment pioneered by Russe, McLaughlin and Pashis. Currently, treatment is done based on location of fracture and degree of displacement identified through the diagnostic tools. Tuberosity fractures and undisplaced fractures can mainly be treated by direct functional bracing and cast immobilization. Also, operative percutaneous treatment can also be done to avoid long immobilization and to achieve early range of motion in undisplaced fractures. There are no functional differences between these two groups at 2 years¹⁷ and 10 years.¹⁹ Displaced fractures are dealt with operative intervention. Proximal pole fractures which are susceptible for nonunions and waist fractures with more than 1 mm displacement and scapho-lunate angle of either more than 60° or less than 30° are considered as unstable²⁰ and requires operative intervention.

8. Non-operative

Early functional treatment using a bandage or orthosis has its role in clinically suspicious scaphoid fractures without

Fig. 1 – a: Immediate after trauma (AP and lateral view of wrist). b: MRI detects the occult fractures. The white arrow suggestive of fracture. MRI revealed fracture the same day. c: Same patient after 2 weeks showing fracture line.

radiological signs. Such patients are advised radiographs after 14 days to confirm and managed accordingly. Inadequate immobilization of a scaphoid fracture increases the chances for pseudo-arthritis by 30%.^{21–23} In case of an occult or stable scaphoid fracture according to the current Herbert classification, cast immobilization is still treatment of choice. Scaphoid fractures are hard to immobilize, as explained before by complex biomechanics of scaphoid since it moves nearly with every motion of the hand, wrist and forearm causing movement of the bone and pressure on the fracture line. Therefore, even an “above the elbow” cast may be applied.²⁴ There are different types of cast immobilization for a scaphoid fracture either with or without inclusion of the thumb. There is no study proving a better consolidation with regard to the type of cast that is used; however immobilization in slight dorsal extension seems to have a positive effect on the grip strength and range of motion of the wrist joint.^{25–27}

Immobilization is usually of 6 weeks in most undisplaced and stable fractures, though requiring frequent radiographs for signs of healing.

9. Surgical treatment

Strelt²⁸ in 1970 first advised percutaneous fixation of scaphoid fractures, but it required both improved fluoroscopic imaging for better screw placement and the development of a more easily placed screw. Headless compression screw developed by Herbert,¹² and later its modification into a headless cannulated screw by Whipple²⁹ and others^{30,31} made this possible. With the use of a headless compression screw, Whipple²⁹ added the use of arthroscopy to assist in reduction and developed a cannulated headless screw to allow for percutaneous insertion. Later, Slade et al.³¹ expanded on Whipple's

concept of arthroscopic assistance with a dorsal, arthroscopy-assisted, percutaneous approach, using the ring sign of the flexed scaphoid to aid in guide wire placement within the centre of the scaphoid, and popularized the dorsal approach. Percutaneous fixation can be done via palmar or dorsal approach (Fig. 2a, b, c). The palmar approach has achieved much popularity because of the excellent clinical outcomes as reported by various authors.^{32,33} However, some authors^{31,34} recently has shown that the dorsal approach provides better targeting and more precise placement of the screw. The overall results of recent studies of percutaneous fixation of scaphoid fractures have shown a 100% union rate for surgically fixed fractures from both the palmar and dorsal approach.^{30,31,35} The importance of screw position in the scaphoid has been emphasized by various authors.^{34,36} The central placement of the screw in the proximal fragment of the scaphoid is of utmost importance and is associated with excellent clinical outcome. Complications were also reported related to both methods of fixation.³⁶ Injury to the superficial branch of the radial artery, delayed union, complex regional pain syndrome, and infection using the palmar approach have

been reported in literature^{17,36} However, there has been controversy about the complication rate in the dorsal approach, with some authors³⁷ reporting it to be higher than others.³⁸ The palmar approach may be advantageous in certain cases as it is easy to find the entry because the guide wire does not cross the radiocarpal joint, it is technically less demanding and it is easy to maintain fracture reduction with wrist extension. Further, there is no risk of injuring the extensor tendons. Though Bushnell et al³⁷ have suggested that complications in dorsal percutaneous cannulated screw fixation of scaphoid fractures may be more common than previously reported, recently it has been demonstrated by experimental studies that the dorsal approach is more appropriate in terms of screw placement and is associated with no complications.³⁶ The structures at risk with the dorsal approach include the extensor pollicis longus tendon, the extensor indicis proprius tendon, the extensor digitorum communis to the index, and the posterior interosseous nerve.³⁹ Many authors⁴⁰ have described placement of the guide wire for the scaphoid screw in a true percutaneous (no incision) manner using fluoroscopy, while others⁴¹ have advocated making a 3-mm incision

Fig. 2 – a: Proximal pole fracture. b: Healed fracture lateral view and AP view in ulnar deviation (Percutaneous fixation dorsal approach).

around the guide wire to accommodate the placement of the screw. 45° pronated view can be done for better assessment of the screw position as recommended by Jeon et al.³⁶ Percutaneous K-wire fixation is also an option, though rigid fixation does not occur unless supplemented by casing. Also, another operation is required for its removal. Indeed, internal fixation through percutaneous fixation allows increased and early union with early restoration of hand function with preservation of ligaments with less disruption of blood supply (Fig. 3a, b, c, d, e, f).

Open fixation can also be done through dorsal or palmar approach (Fig. 4a, b). Distal pole and waist fractures can be treated by volar approach, while dorsal approach is required for easy screw placement in case of proximal pole fractures. Different screw systems used for fixation of scaphoid fractures are Acutrak standard screw, Acutrak mini screw, Bold screw and Synthes 3.0 mm headless screw. In an in-vitro study, the Acutrak Standard screw (Acumed, Hillsbro, OR, USA) provided more compression than the Bold screw (Wright Medical Technology, Memphis TN) and Acutrak Mini screw

Fig. 3 — a: Fracture waist of scaphoid. b: Marking in AP view. c: Percutaneous guide wire insertion. d: cannulated drill and guide wire. e: Lateral view after fixation. f: Stab wound after suturing.

Fig. 4 – a: Trans-scaphoid – perilunate dislocation. b: Radiograph showing union of scaphoid and preservation of carpal architecture.

(Acumed, Hillsbro, OR, USA).²³ As well, the Synthes 3.0 mm headless screw (Synthes Inc, Westchester, PA, USA) provided reliable compression in a cadaveric model.⁴² In another cadaveric study, the Acutrak 2 Standard screw provided more reliable compression when compared to the Synthes headless compression screw. They relate this to the thread pattern. The Acutrak 2 is a fully threaded design that generates a large amount of thread-to-bone contact area. In comparison, the Synthes screw has fewer threads, which results in less thread-to-bone contact area, and thus greater stresses on the cancellous bone. The comparatively greater loss of compression experienced by the Synthes screw, may be evidence of the gradual failing of trabeculae due the higher stresses.⁴³

10. Nonunion scaphoid

Scaphoid fractures treated non-operatively face nonunion in 5–10% cases.^{44,45} Further nonunion rate is increased by factors like displacement greater than 1 mm, delay in diagnosis/immobilization greater than 4 weeks, location at the waist or proximal pole, and a history of smoking.¹⁸ The Russe inlay bone grafting procedure is a reliable treatment for symptomatic nonunion of the scaphoid.¹³ The volar approach minimizes damage to the blood supply and facilitates correction of any flexion deformity (Fig. 5). Russe inlay bone

grafting or iliac crest bone grafting with screw fixation results in a success rate of 90%.¹³ But conventional bone grafting usually fail when it is completely avascular, not bleeding and

Fig. 5 – United fracture after tricortical iliac crest graft and screw fixation from volar approach.

there is evidence of necrotic bone. Vascularized bone grafting may introduce a source of angiogenic and osteogenic factors to the nonunion site.^{46,47}

10.1. Approach to treatment

Determining the location of the nonunion, the degree of collapse, and viability of the proximal fragment are important steps in approaching the treatment of scaphoid nonunions. Without AVN, waist fractures are best treated via a volar approach, and proximal pole fractures via a dorsal approach. Fractures with AVN of the proximal pole are best served by a dorsal approach with a vascularized bone graft. Plain radiographs are helpful, but not foolproof, in determining whether or not the scaphoid fracture involves the proximal pole. The fracture often angles from distal volar to proximal dorsal, which can make the plain radiographs deceiving. CT can help differentiate nonunions in the waist from those in the proximal pole, especially when there is substantial bone resorption.

CT scans provide the most precise definition of the osseous anatomy. The sagittal images, parallel to the long axis of the scaphoid, obtained from CT scans provide the best view to determine the extent of collapse (the so-called “humpback deformity”), and assist in planning for bone grafting procedures. The lateral intrascaphoid angle described by Amadio and colleagues, and the height-to-length ratio of the scaphoid described by Bain and colleagues can be accurately measured with a CT scan. These measurements, obtained from sagittal images parallel to the long axis of the scaphoid, can help to accurately identify the magnitude of collapse and angulation of the scaphoid. The classic radiographic signs of sclerosis, cystic changes, and areas of significant bone resorption are not always reliable indicators of the presence of avascular necrosis in scaphoid nonunion. Recent studies have established the value of MRI in assessing vascularity of the proximal pole. Low signal on both T1- and T2-weighted images appears to be associated with the greatest compromise of vascular supply and poor healing rates when traditional non-vascularized grafts are used. Proximal fragments with an absence of T1-weighted marrow signal have demonstrated osteonecrosis, empty bone lacunae, and poor uptake of fluorescent bone labels on biopsy. In contrast, retention of some proximal pole signal has been associated with viable bone when examined histologically, and normal uptake of fluorescent labels. When the MRI demonstrates avascular necrosis of the proximal pole, the authors recommend a vascularized bone graft.

Early vascularized grafts were often based on a pedicle from the pronator quadratus insertion on the distal radius. Recently, a number of vascularized bone graft sources have been described, including the ulnar artery, volar carpal artery, vascularized periosteal flaps of distal radius, capsular-based flap vascularized graft, implanting the second dorsal intermetacarpal artery into nonunion sites with inlay corticocancellous bone graft, and even a free vascularized graft from the iliac crest. At present, the most frequently used donor sites include the dorsoradial aspect of the distal radius, first described by Zaidenberg and colleagues, and the second metacarpal graft.

The vascularized bone graft described by Zaidenberg relies on the superior irrigating arterial branch of the radial artery that has been defined as the 1, 2 intercompartmental supra-retinacular artery (1,2 ICSRA). This artery travels in a distal-to-proximal direction along the retinaculum, between the tendons of the first and second dorsal compartment. The 2, 3 ICSRA can also be used. These vascularized grafts can be harvested through the same dorsal approach used for internal fixation of the scaphoid nonunion.

10.2. Salvage procedures

Other salvage procedures include radial styloidectomy with partial scaphoid excision and/or posterior and anterior interosseous neurectomy. More complex procedures include limited intercarpal fusion, proximal row carpectomy, scaphoid excision and 4-corner fusion, and total wrist fusion.^{48,49}

Conflicts of interest

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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