Carpal Fractures and Dislocations

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*All figures belong to Brian J Page, MD and/or Douglas S Fornfeist, MD unless otherwise indicated.
Objectives

• Anatomy
• Mechanism of Injury
• Imaging
• Scaphoid Fractures
• Perilunate Injuries
• Other Carpal Fractures
Anatomy

- 8 bones in 2 rows
- Bridge the forearm and hand
- Proximal carpal row provides wrist movement and congruency
  - Scaphoid, lunate, triquetrum
- Distal carpal row is relatively more fixed to the metacarpals
  - Trapezium, trapezoid, capitate, hamate
- Pisiform – sesamoid, not part of either row

Anatomy

- Ligaments of wrist are predominantly contained within the joint capsule (extrinsic ligaments)
- Carpal bones tightly linked by capsular (extrinsic) and interosseous (intrinsic) ligaments
  - Capsular (extrinsic) ligaments connect carpal bones to forearm bones (proximally) and metacarpal bones (distally)
  - Interosseous (intrinsic) ligaments traverse the carpal bones

Mechanism of Injury

- Most common is fall on outstretched hand (axial compression)
- Hyperextension causes both tensile and shear stresses
- Tensile forces cause most linear fractures
- Compressive and shear forces cause comminution
- Direct vs. indirect
Imaging

- Plain radiographs (multiple views necessary):
  - Most carpal fractures:
    - Posteroanterior (PA)
    - Lateral
    - Obliques (45-degree radial oblique, 45-degree ulnar oblique)
    - Scaphoid view (ulnar deviation)
  - Intercarpal ligament injury:
    - Clenched-fist AP
    - Clenched pencil view (modified clench-fist view)

Advanced Imaging

• CT scan
  • Useful for suspected (occult) carpal fractures, fracture displacement, malunion, nonunion, and bone loss
  • Assessment of union

• MRI
  • Useful for suspected (occult) carpal fractures
  • Assessment of AVN
  • Ligament injuries

• Ultrasound
  • Suspected carpal fractures, ligament injuries

• Bone scintigraphy
  • Suspected carpal fractures, avulsion fractures

Scaphoid nonunion on T1 MRI

Scaphoid Fractures

- 2-7% of all orthopedic fractures
- Most common carpal bone fractured (~15% of all wrist fractures)
- Frequently missed
  - X-rays may miss nondisplaced fractures
- Tenuous blood supply leads to potential complications
- Complications
  - Nonunion
  - Malunion
  - Avascular necrosis
  - Carpal collapse

Scaphoid Anatomy

- Retrograde blood supply
- Two vascular pedicles originating from the scaphoid branches of the radial artery
  - Dorsal branch
    - Enters via the small foramina along the spiral groove and dorsal ridge of the scaphoid
    - Supplies 70-80% of the scaphoid proximally (including the proximal pole)
  - Volar branch
    - Enters via the scaphoid tubercle
    - Supplies 20-30% of distal scaphoid

Scaphoid Anatomy

• “skaphos”-Greek word for boat
• Bridges proximal and distal rows
• Twisted peanut or “S” shaped
• 45-degrees from longitudinal and horizontal axes of the wrist
• >80% of surface area is covered with articular cartilage
  • Increased risk for delayed union and nonunion

Scaphoid Anatomy

- >80% covered with articular cartilage (implications)

- Heals with little/no callus (intramembranous ossification)

- **Proximal pole** is cover almost completely with cartilage
  - Little, if any, perforating vessels → high incidence of osteonecrosis

- Scaphoid flexes with wrist flexion and extends with wrist extension

Scaphoid Anatomy

- Divided into 3 regions:
  - Proximal pole (10-25% of fractures)
  - Waist (65-80% of fractures)
  - Distal pole and tubercle (5-10% of fractures)
Scaphoid Fracture - Exam

• Surface anatomy of the wrist
  • Anatomic snuffbox bordered by the EPL tendon ulnarly and the EPB radially

• Physical Exam Findings
  • Anatomic “Snuffbox” tenderness
    • Ulnar deviation exposes scaphoid waist for easier palpation
  • Pain with palpation of the scaphoid tuberosity
  • Pain over SL ligament with the wrist flexed to palpate the proximal pole
  • Limited painful wrist ROM, especially forced dorsiflexion
  • Beware of the “wrist sprain” that may actually be an occult scaphoid fracture
Mechanism of Injury

- Axial load across hyperextended and radially deviated wrist
- Hyperextension of wrist past 95 degrees
- Wrist in extreme flexion and ulnar deviation

Differential Diagnosis

- Scapholunate instability
  - Pain and clicking in wrist
  - Tender just distal to Lister’s tubercle
  - Positive “Watson” test
- FCR tendon rupture or tendinitis
- Radial styloid fracture
- De Quervain’s tenosynovitis (radial styloid tenosynovitis)
- CMC (basal) joint arthrosis
- Radio-scaphoid arthrosis
Watson Test (Scaphoid Shift Test)
Diagnosis of Scaphoid Fractures

• X-rays – false negative up to 25% of the time
• CT scan
• MRI – most accurate
• Bone scan – rarely used these days
Diagnosis of Scaphoid Fractures

• Plain radiographs
  • PA, Lateral, Pronated Oblique, and Ulnar deviation (scaphoid view) views

• “Occult” fracture
  • Repeat x-ray in 2 weeks if suspicion remains high after initial negative x-ray

• “Stripe” sign
  • Obliteration or radial displacement of the fat pad normally seen between the radial collateral ligaments and the EPB/APL tendon complex
Classification of Scaphoid Fractures

• Usually by location:
  • Proximal third (10-25%)
  • Middle third (waist) (65-80%)
  • Distal third and Tuberosity (5-10%)

• Why is this so important?
  • Primary vascular supply enters dorsal ridge and runs retrograde to the proximal scaphoid
  • The more proximal the fracture, the more likely are healing complications
Treatment of Acute Scaphoid Fractures

• Non-Operative Management
  • Short vs Long-arm cast (still controversial)
  • Apparently equivalent SAC vs. LAC & spica vs. standard cast
  • Duration
    • Distal pole and tubercle fractures: 6-8 weeks
    • Waist fractures: 8-10 weeks
    • Proximal pole fractures: 10-12 weeks or longer

• Operative Management
  • Percutaneous pin or screw fixation
  • ORIF

Indications for Surgical Intervention

- Displacement ≥1 mm
- Lateral intrascaphoid angle > 35°
- Height-to-length ratio >0.65
- Bone loss or comminution
- Perilunate fracture-dislocation
- Dorsal intercalated segmental instability
- Any proximal pole
- Poor patient compliance
Operative Management

• Open reduction, internal fixation (ORIF)
  • Headless screws
  • K-wires (probably mainly for salvage procedure)

• Percutaneous fixation with cannulated screw
  • Volar approach for distal fractures
  • Dorsal approach proximal fractures
  • Either can be used for scaphoid waist fractures
Distal Tubercle Fractures

- More common in children
- Should be treated with cast immobilization for 6-8 weeks
- Could be old
- Don’t miss more proximal extension
Waist Fractures

• Non-displaced fractures
  • Cast immobilization for 8-10 weeks
  • Percutaneous cannulated screw fixation

• Displaced fractures (>1mm) or vertical/oblique fractures
  • Open reduction and internal fixation
  • Volar approach
Volar Approach-Exposure

- Gentle zig-zag incision directly over the course of the flexor carpi radialis tendon
OTA ONLINE VIDEO – Scaphoid ORIF

Percutaneous Fixation

Cannulated headless compression screw
Retrograde (volar) or anterograde (dorsal)

Proximal Pole Fractures

• High rate of nonunion-50%
• Best treated with early internal fixation
• Exposure typically from dorsal approach
• If nonunion, may benefit from vascularized bone graft?
  • MRI can help determine if there is AVN
Author Proposed Algorithm for Suspected Scaphoid Fractures

Wrist Injury

(+) Physical Exam
- X-rays: Normal
  - Immobilize 7-10 days (thumb spica)
  - Symptomatic: Repeat X-ray
- X-rays: Scaphoid fracture
  - Treat according to fracture type

(-) Physical Exam
- Treat other injuries accordingly

Asymptomatic:
- No X-rays
- Treatment complete

MRI or CT (if early diagnosis is necessary)
- Treat according to advanced imaging findings

X-rays: Normal
- Recast & follow up at 3 weeks
- X-rays: Scaphoid fracture
  - Treat according to fracture type

Complications

• Avascular necrosis (proximal pole)
• Malunion
• Nonunion
  • Approximately 10%
  • Location of nonunion will determine approach to scaphoid
  • Waist:
    • Volar approach
    • Deformity correction
    • Bone graft
  • Proximal pole:
    • Dorsal approach
    • Consider vascularized bone graft
• Scaphoid Nonunion Associated Collapse (SNAC)
Scaphoid nonunion surgery with placement of bone graft
Carpal Instability

• Lunate is the key to carpal stability
  • Linked to scaphoid and triquetrum by strong interosseous ligaments
  • Injury to scapholunate or lunotriquetral ligaments lead to **dissociative carpal instability patterns**
    • \( SL \rightarrow DISI > LT \rightarrow VISI \)

• Proximal and distal carpal rows are attached by capsular ligaments (extrinsic ligaments) on each side of the lunocapitate joint
  • Injury to these ligaments leads to abnormal motion between the two rows, and **non-dissociative wrist instability patterns**
  • Much rarer than DISI or VISI

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4514919/
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4117698/

Perilunate Injuries - General Information

• Young individuals with high demands
• Frequently missed
• High risk of post-traumatic degenerative change
  • https://pubmed.ncbi.nlm.nih.gov/19931988/
• Surgical reduction/repair outperforms closed reduction with casting
  • https://pubmed.ncbi.nlm.nih.gov/26205701/
• Often associated with ligamentous injury
• High incidence of associated nerve injury
  • https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4642473/
• Vascular and/or tendon injury possible (less common)
• Uncommon, but most common form of wrist dislocation
• Perilunate dislocation (PLD) vs Perilunate fracture-dislocation (PLFD)
General Information

• Spectrum of injuries involving the carpus
• Variable disruption of carpal anatomy
  • Ligamentous vs. bony
• Some consistent patterns
• Constant feature
  • Lunate-Capitate relationship is disrupted
Injury Progression (Mayfield 1980)

I. Scapholunate (SL) Dissociation or Scaphoid Fracture
II. Lunocapitate Dislocation through the space of Poirier
III. Lunate Triquetrum Disruption or Triquetrum Fracture
   I. Dorsal Perilunate Dislocation
IV. Complete Palmar Lunate Dislocation
Perilunate Variations

• Purely ligamentous (PLD)
• Fracture through greater arc combined with ligamentous injury (PLFD)
  • Trans-scaphoid perilunate fx-dislocation most common
    • 97% of PLFD
    • 95% scaphoid fractures at waist

3 Most Common Patterns

• Perilunate dislocation
• Transscaphoid perilunate fracture-dislocation
• Lunate dislocation
Perilunate Dislocation
Transscaphoid Perilunate Fracture-Dislocation

Lunate dislocation
Mechanism of Injury

• Most common is fall on outstretched hand (axial compression)
• Hyperextension causes both tensile and shear stresses
• Ulnar deviation
• Tensile forces cause most linear fractures
• Compressive and shear forces cause comminution
• Direct vs. indirect
Gilula’s Lines

Physical Exam

• Moderate/Severe Swelling
  • Must be evaluated for acute carpal tunnel syndrome >>compartment syndrome of forearm/hand
    • Acute carpal tunnel syndrome warrants urgent surgical release
    • Neuropraxia may be only exam finding (finger flexors innervated proximally)

• Short and thick wrist

• Limited motion / crepitus

• Palmar or Dorsal prominence

• Median nerve symptoms may be present if lunate dislocated
Imaging

• Good quality PA/ lateral/ oblique
  • 20% misinterpreted on initial radiographs
• PA in traction sometimes helpful
Radiographic Studies

• PA
  • Disruption of arcs - Gilula
  • Cortical ring sign
  • Abnormal interosseus spacing
  • Overlap of proximal / distal rows
  • Associated greater arc fractures
  • Radial styloid fracture
Imaging

• Lateral (True lateral with wrist in neutral)
  • Lunate and/or Distal Row not aligned with radius
  • Abnormal Scapholunate/Radiolunate angles
  • Spilled Teacup
Initial Treatment

• Closed reduction with adequate sedation
  • In finger traps with 10-15 lbs. traction for 5-10 minutes
  • Maneuver
    • Wrist extension
    • Counterpressure - palmar over lunate
    • Gradual wrist flexion with direct pressure over capitate
Closed Reduction Percutaneous Pinning

• Closed Reduction Percutaneous Pinning
  • Most injuries require fixation to maintain reduction
  • Requires anatomic reduction
    • Reduce and pin lunate to radius
    • Reduce and pin capitate to lunate
    • Reduce and pin scaphoid to lunate
    • Reduce and pin lunate to triquetrum
    • Reduce and pin scaphoid to capitate
  • Difficult to assess alignment, osteochondral injury
  • Median nerve compression
Open Reduction Internal Fixation

• ORIF Preferred (Green ; Herzberg)
  • Direct visualization
  • Ligamentous repair
  • Decompression of median nerve

• Several Approaches – no hard evidence supporting one vs. another
  • Dorsal
  • Volar
  • Combined dorsal /volar Repair of fractures (dorsal/volar)
    • Repair SL and LT ligaments (dorsal)
    • Repair of palmar radiocarpal ligaments (volar)
    • Decompression of median nerve palmar (volar)
Dorsal Approach – Repair SL ligament
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<tr>
<th>Volar Approach</th>
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<tr>
<td></td>
<td>Lunate may be dislocated volarly</td>
<td>Volar mid-carpal ligament tear</td>
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Salvage Procedure

• Salvage Procedures
  • Proximal Row Carpectomy (PRC)
    • Severe open injury
    • Chronic injury
      • consider repair 3-12 weeks
      • reduction may be difficult after 2-3 weeks
      • > 12 weeks - PRC vs. arthrodesis
Complications

• Arthrosis
• Avascular necrosis of scaphoid /lunate
• Transient ischemia more common
• Median neuropathy
• Residual carpal instability
Outcomes

• Poor prognosis for full return to full previous function
• Poor prognostic factors:
  • Open injuries
  • Delayed treatment
  • Osteochondral fractures of the head of the capitate
  • Carpal malalignment
• Nearly all patients experience decreased grip strength and range of motion
• Arthritis on imaging does not correlate with functional outcome scores
• Usually stiff, low pain, functional wrist despite arthrosis

Other Carpal Fractures

• Young active individuals with high demands
• Not a common injury
• Frequently missed (radiographs can be misleading)
• High risk of post-traumatic degenerative change with non-anatomic reductions
• Often associated with ligamentous injury
• High incidence of associated nerve, vascular, and tendon injury
Trapezium Fractures

• Third most common carpal bone fractured
• 6% of all carpal fractures
• Associated with fractures of the thumb metacarpal (e.g. Bennet fracture) and/or the radius
• 5 patterns:
  • Vertical transarticular (most common)
  • Horizontal
  • Fractures of the dorsoradial tuberosity
  • Fractures of the anteromedial ridge
  • Comminuted fractures
Trapezoid Fractures

• Corner-stone of the carpal arch
• Wedge-shaped: wider dorsally
• Isolated fractures are very seldom
• Fewer than 20 cases in the literature
Capitate Fractures

• 1-2% of all carpal fractures
• Isolated injury or in association or trans-scaphoid perilunate fracture-dislocation (aka scaphocapitate syndrome)
• Mx: High-energy fall with hyper-extended and radially deviated wrist
• 4 patterns:
  • Transverse fracture of the proximal pole
  • Transverse fracture of the body (most common)
  • Verticofrontal fracture
  • Parasagittal fracture
Hamate Fractures

• 2% of all carpal fractures
• 2 major patterns of fractures
  • Hook of the hamate
    • Common in stick-handling sports (e.g. golf, baseball, tennis)
    • 3 types
      • Avulsion of tip (FCU)
      • Fracture through the base
      • Fracture through the waist
  • Body of the hamate
Hook of Hamate Fractures

- 2-4% of all carpal fractures
- Mx: Direct blow to hamate bone
  - (e.g. sports with gripping baseball, golf, etc.)
- Commonly missed on standard X-ray
  - Carpal tunnel view (image) can be helpful
- CT and MRI may help
- Deep branch of ulnar nerve lies under hook
- Tx: Patient dependent, time to presentation dependent
  - Conservative: Immobilization (<3m)
  - Surgery: Excision vs ORIF (>3m)
Lunate Fractures

- 1% of all carpal bone fractures (most occur as part of perilunate injury)
- 5 groups
  - Frontal fractures of the palmar pole
  - Osteochondral fractures of the proximal joint
  - Frontal fractures of the dorsal pole
  - Horizontal fractures of the body
  - Transarticular frontal fractures of the body
Triquetrum Fractures

• 2nd most common carpal fracture

• 2 major groups
  • Chip fractures of the dorsal rim (dorsal rim/cortical avulsion fractures)
    • Most can be treated with immobilization if there is not wrist instability
    • “Pooping duck” sign (see image)
    • https://pubmed.ncbi.nlm.nih.gov/33483875/
  • Fractures through the body
Pisiform Fractures

- Functions as a sesamoid within FCU tendon sheath
- 2% of all fractures of the carpal bones
- 4 types
  - Transverse: most common
  - Parasagittal
  - Comminuted: neurovascular injury
  - Pisotriquetral impaction
Treatment of Carpal Fracture (other than scaphoid)

- Unified concept of treatment
- 4-6 weeks of cast immobilization for stable, non-displaced fractures
- Exceptions are the head of the capitate and the “waist” of the hook of the hamate due to poor vascularity—relative indication for ORIF
- For unstable and/or displaced fractures: open anatomic restoration and ligament repair
References


15. Wickremasinghe NB, Buckworth AD, Clement ND, Hagieson MG, McQueen MM, Rim D. Acute median neuropathy and carpal tunnel release in perilunate injuries can we predict who gets a median neuropathy? J Hand Microsurg. 2015;7(1):217-240.
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