

Carpal Fractures and Dislocations

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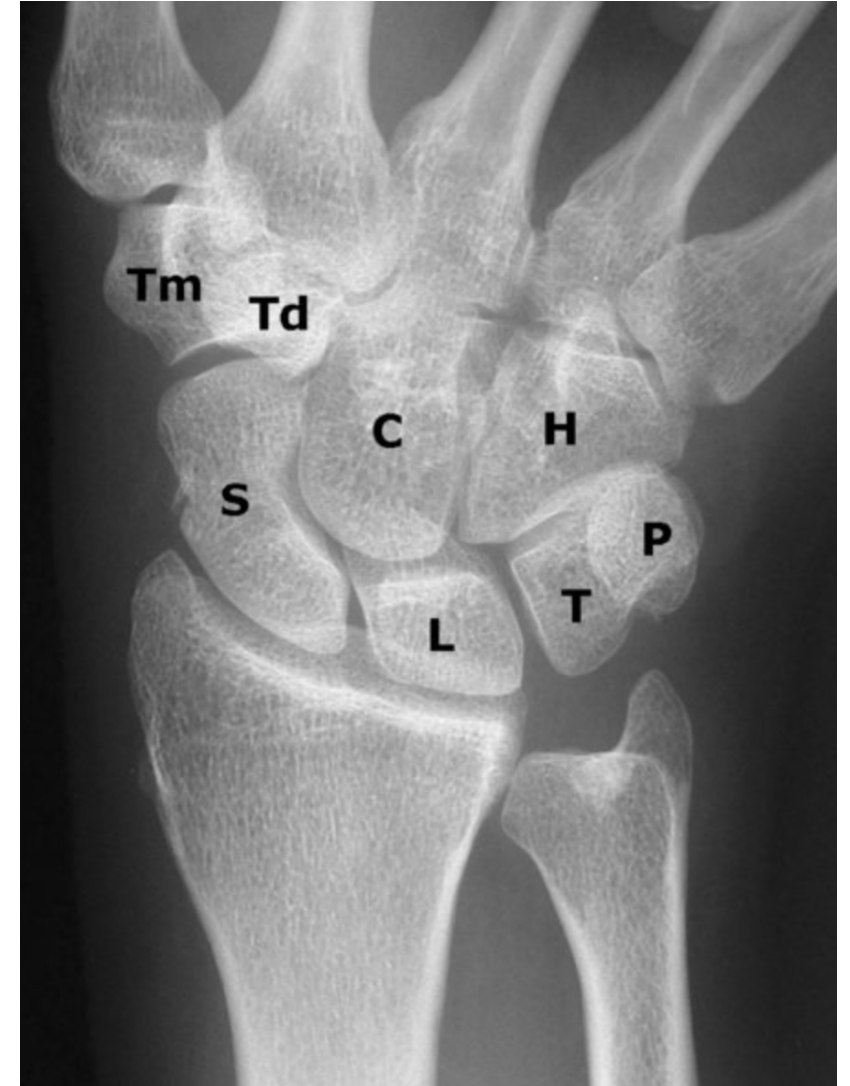
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Objectives

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

Anatomy

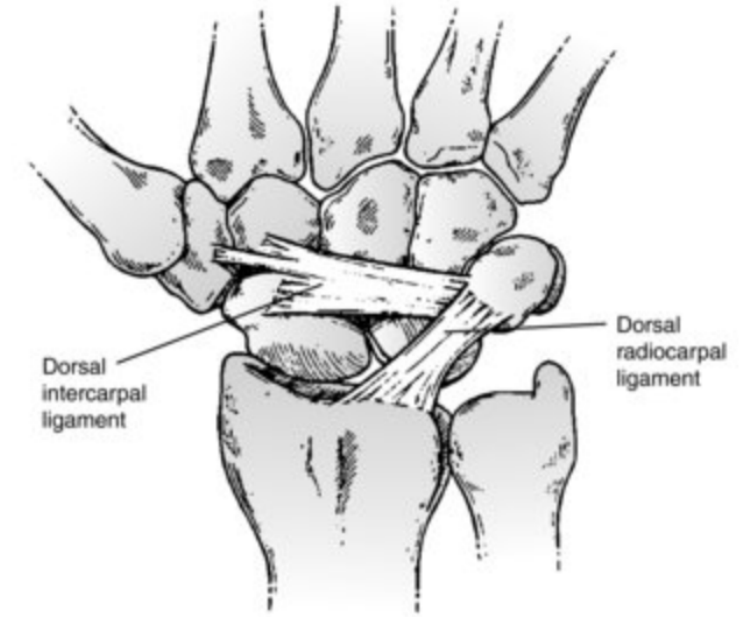
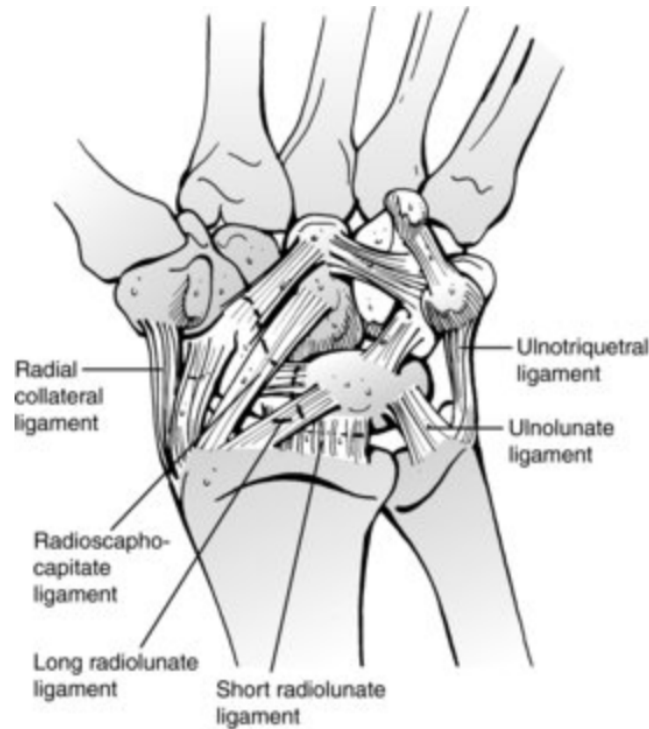
- 8 bones in 2 rows
- Bridge the forearm and hand
- Proximal carpal row provides wrist movement and congruency
 - Scaphoid, lunate, triquetrum
- Distal carpal row is relatively more fixed to the metacarpals
 - Trapezium, trapezoid, capitate, hamate
- Pisiform – sesamoid, not part of either row



Duckworth AD, Strelzow J. Chapter 43. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019.

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



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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)
 - <https://pubmed.ncbi.nlm.nih.gov/12772096/>



Duckworth AD, Strelzow J. Chapter 43. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019.

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

Duckworth AD, Strelzow J. Chapter 43. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019.a

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

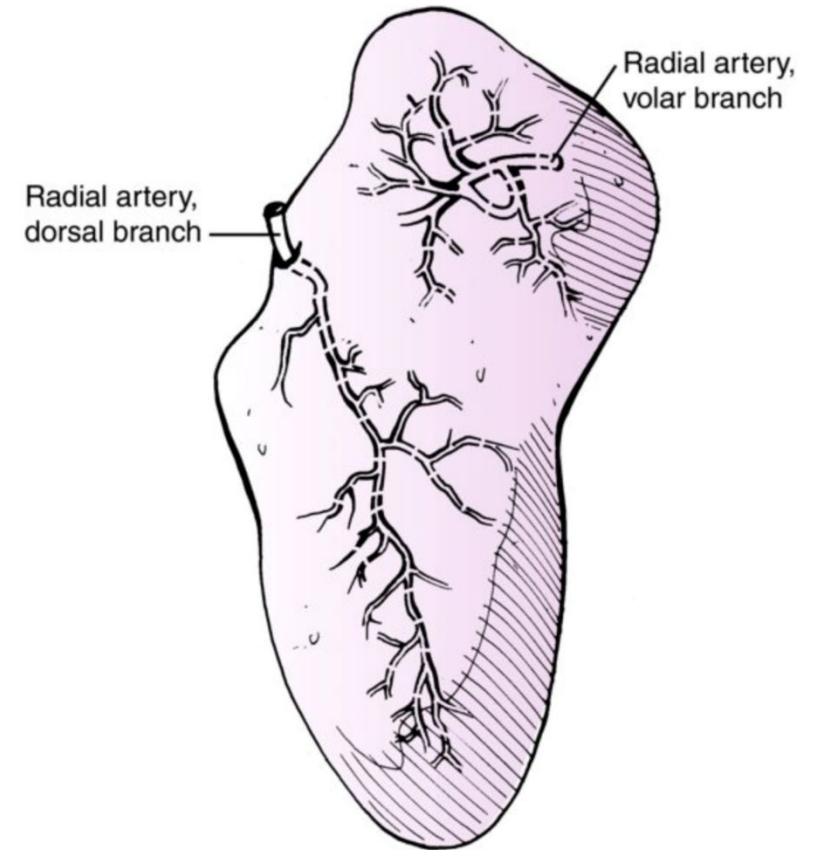


Scaphoid Fracture

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Scaphoid Anatomy

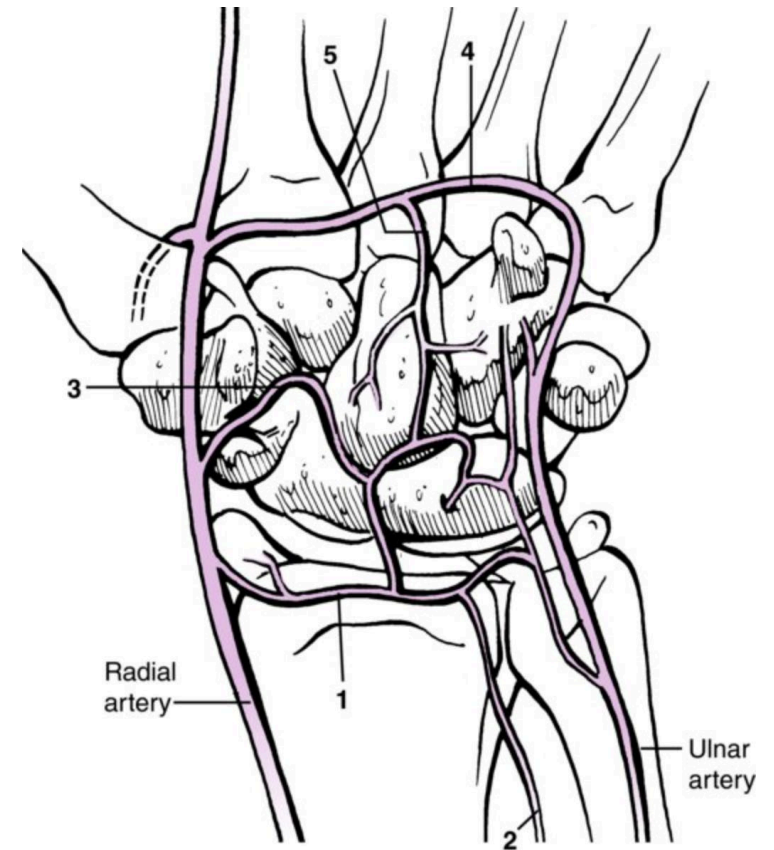
- Retrograde blood supply
- Two vascular pedicles originating from the scaphoid branches of the radial artery
 - Dorsal branch
 - Enters via the small foramina along the spiral groove and dorsal ridge of the scaphoid
 - Supplies 70-80% of the scaphoid proximally (including the proximal pole)
 - Volar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



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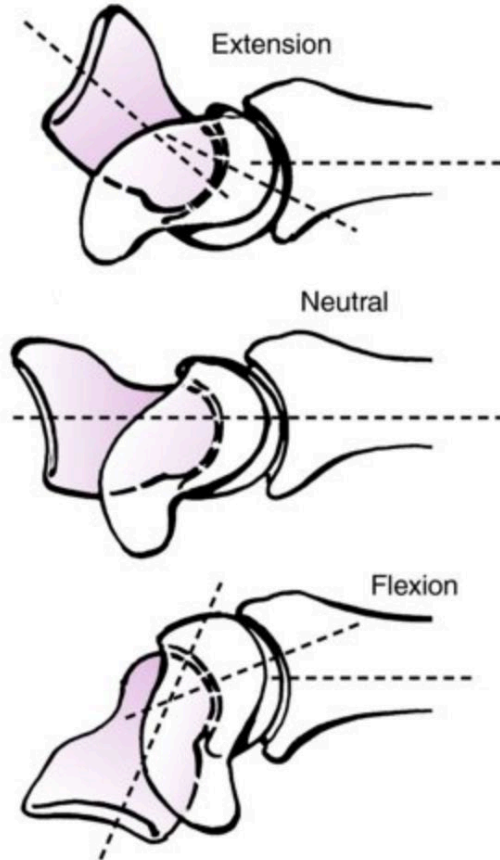
Scaphoid Anatomy

- “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



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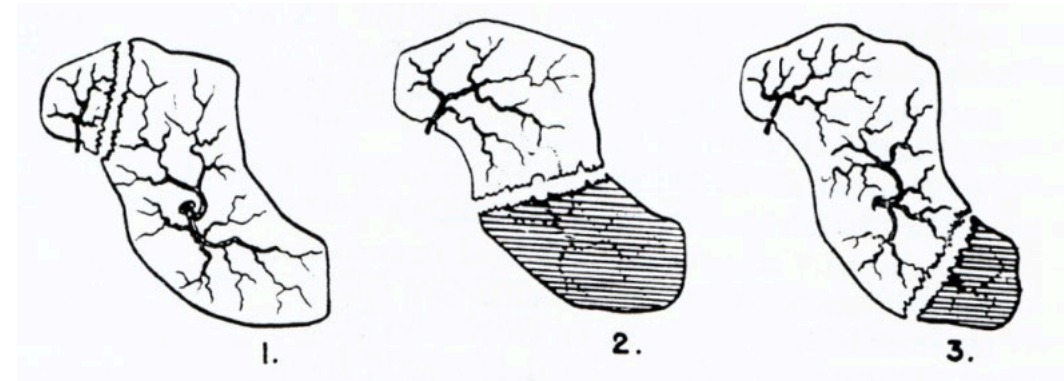
Scaphoid Anatomy



- >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

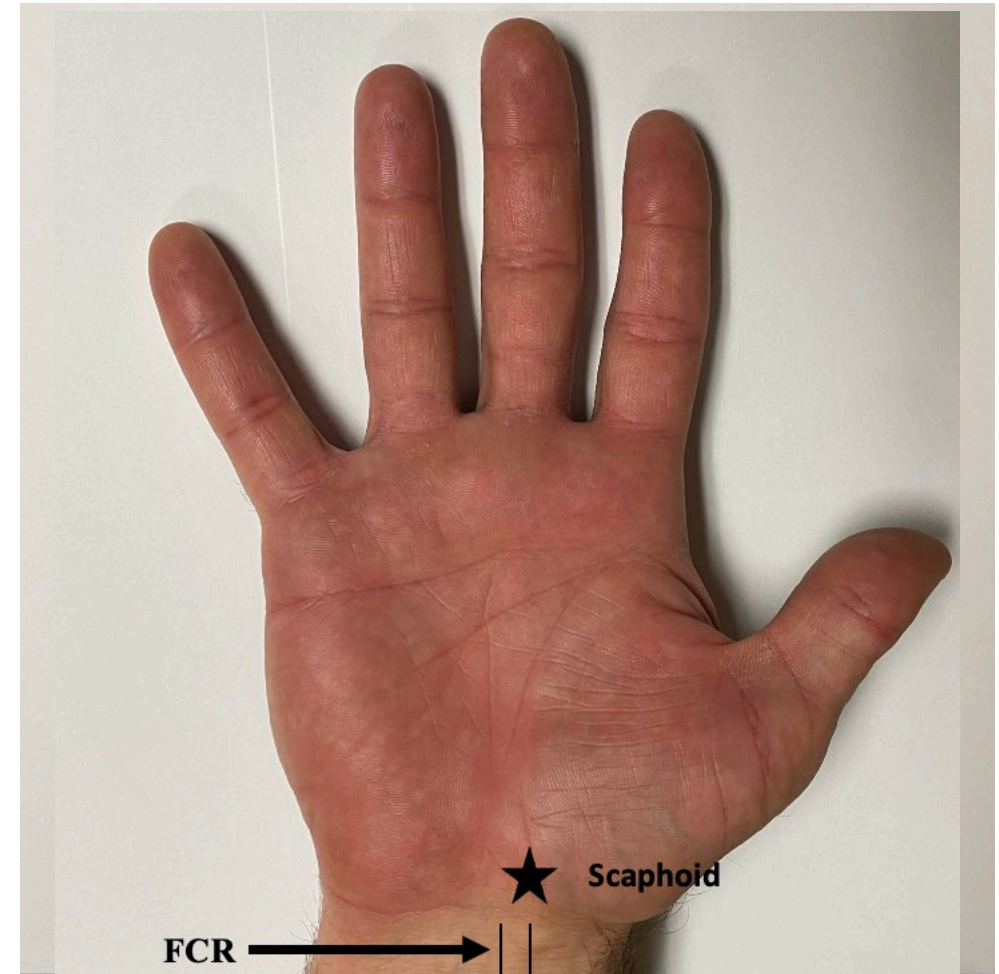
Scaphoid Anatomy

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



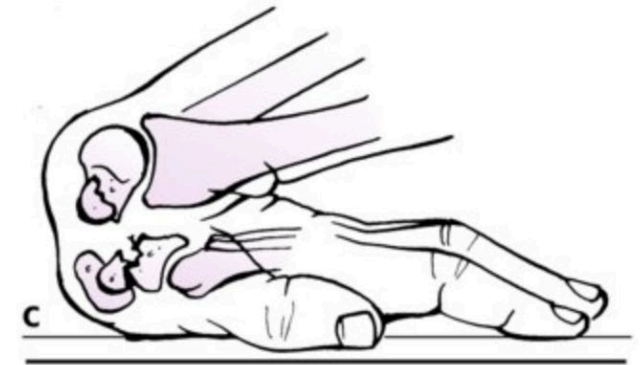
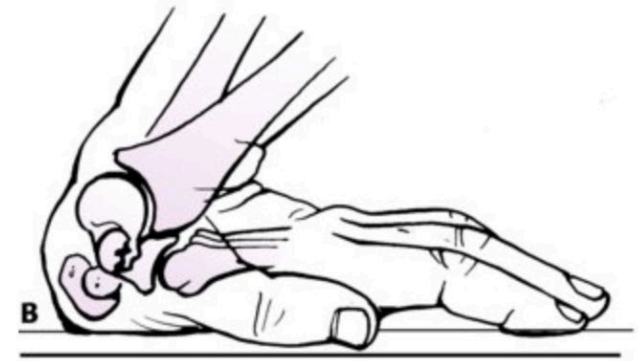
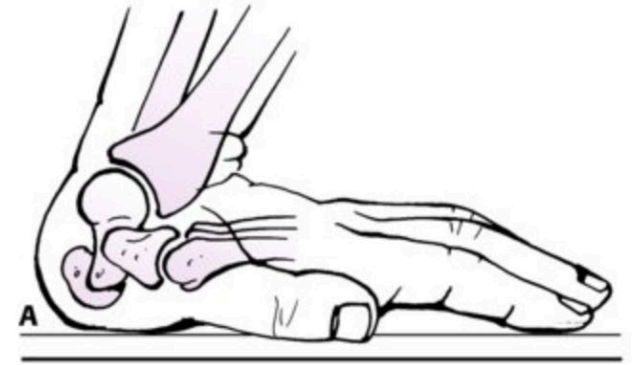
Scaphoid Fracture - Exam

- 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

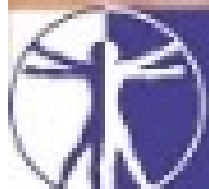


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Differential Diagnosis

- 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)



Assessment

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
 - Karl JW, Swart E, Strauch RJ. Diagnosis of occult scaphoid fractures: a cost-effectiveness analysis. *J Bone Joint Surg Am.* 2015;97(22):1860-1868.
<https://pubmed.ncbi.nlm.nih.gov/26582616/>
 - “Stripe” sign
 - Obliteration or radial displacement of the fat pad normally seen between the radial collateral ligaments and the EPB/APL tendon complex
<https://pubmed.ncbi.nlm.nih.gov/14521890/>
<https://pubmed.ncbi.nlm.nih.gov/2794717/>



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



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- 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 $> 35^\circ$
- 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

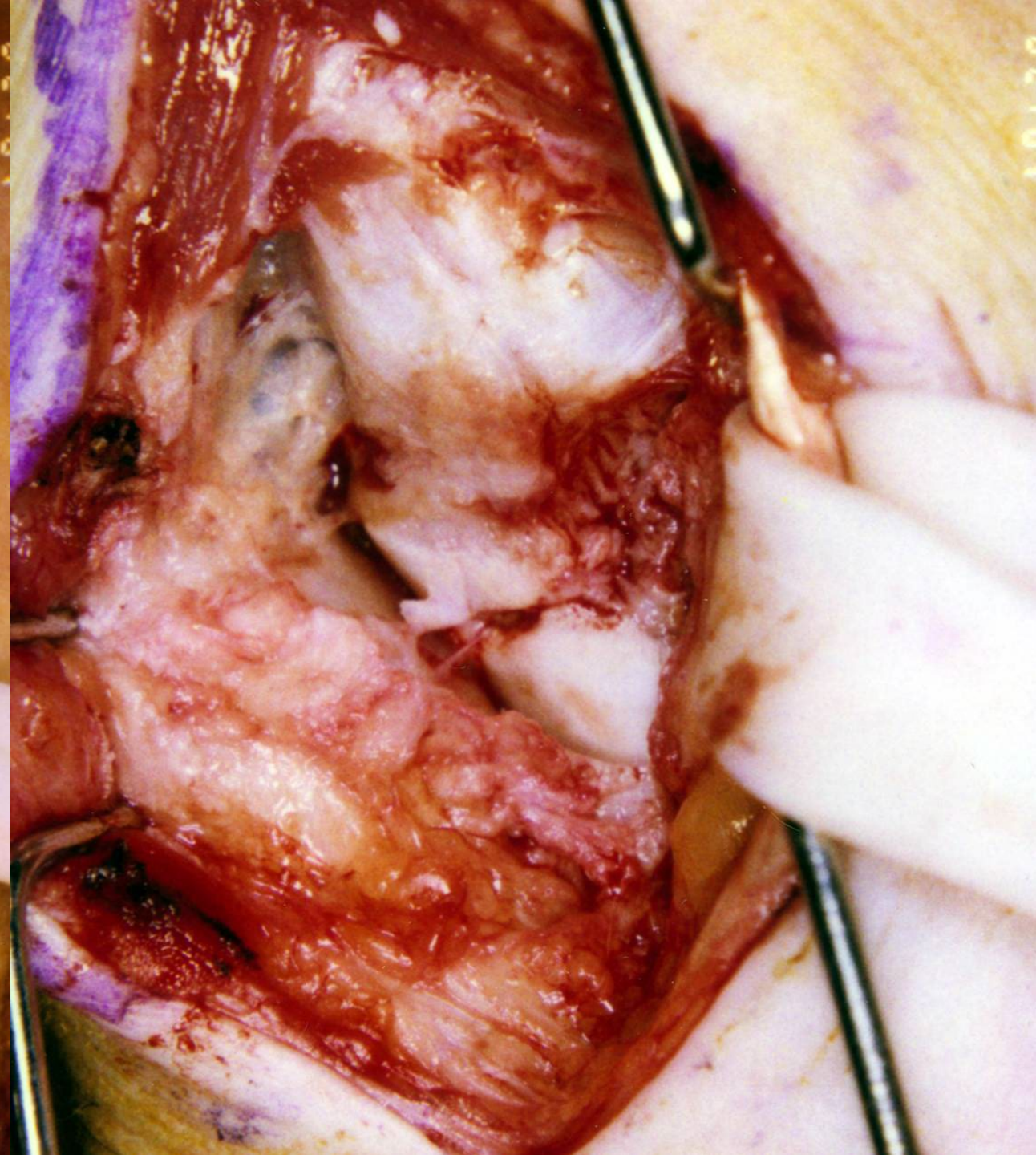
- Non-displaced fractures
 - Cast immobilization for 8-10 weeks
 - Percutaneous cannulated screw fixation
<https://pubmed.ncbi.nlm.nih.gov/31895249/>
- Displaced fractures (>1mm) or vertical/oblique fractures
 - Open reduction and internal fixation
<https://pubmed.ncbi.nlm.nih.gov/32175096/>
 - Volar approach





Volar Approach-Exposure

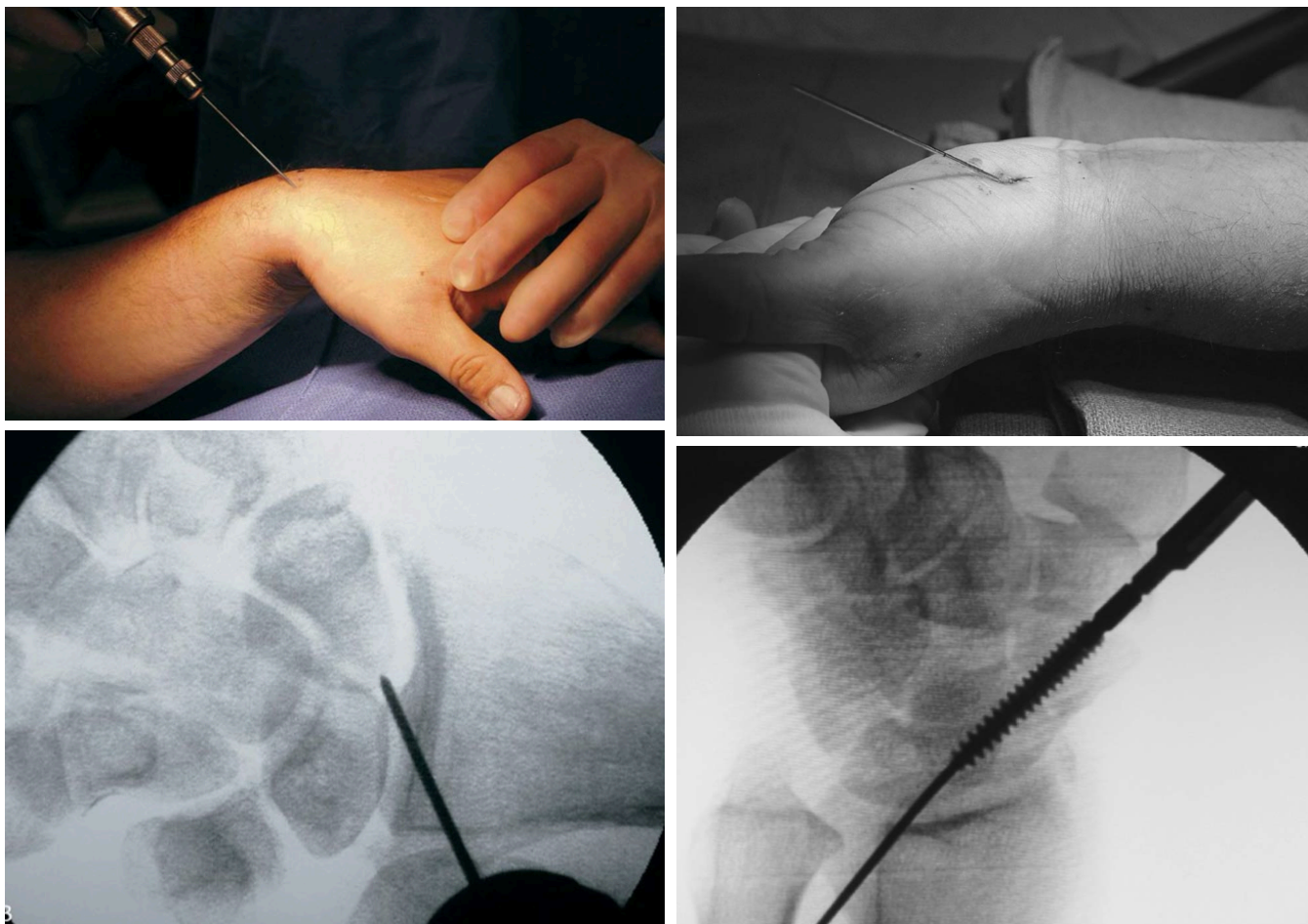
- Gentle zig-zag incision directly over the course of the flexor carpi radialis tendon



OTA ONLINE VIDEO – Scaphoid ORIF

<https://otaonline.org/video-library/45036/procedures-and-techniques/multimedia/16776659/scaphoid-orif>

Percutaneous Fixation



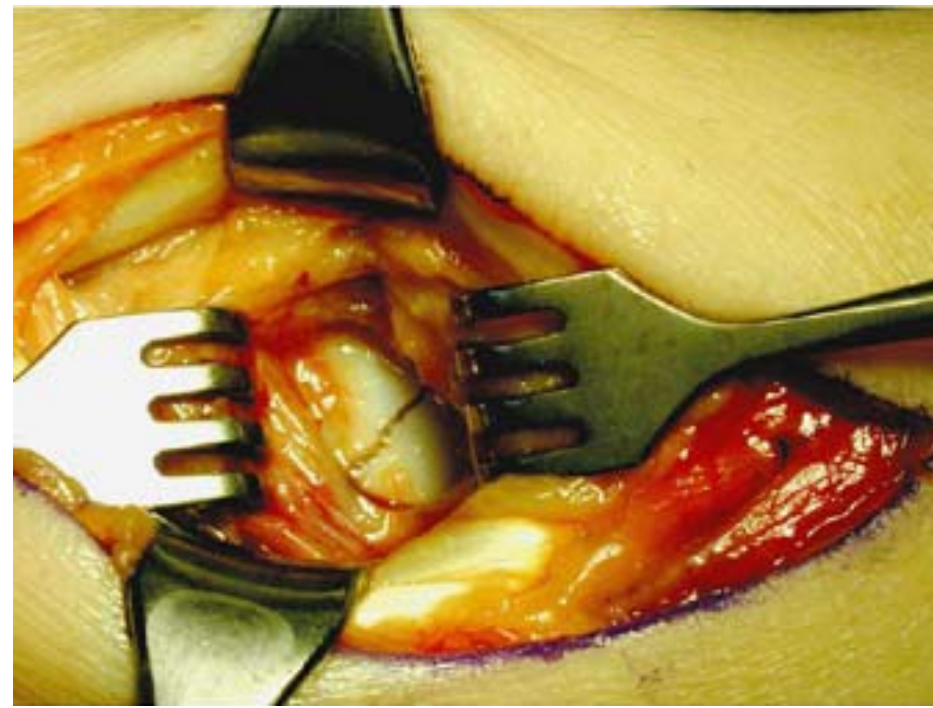
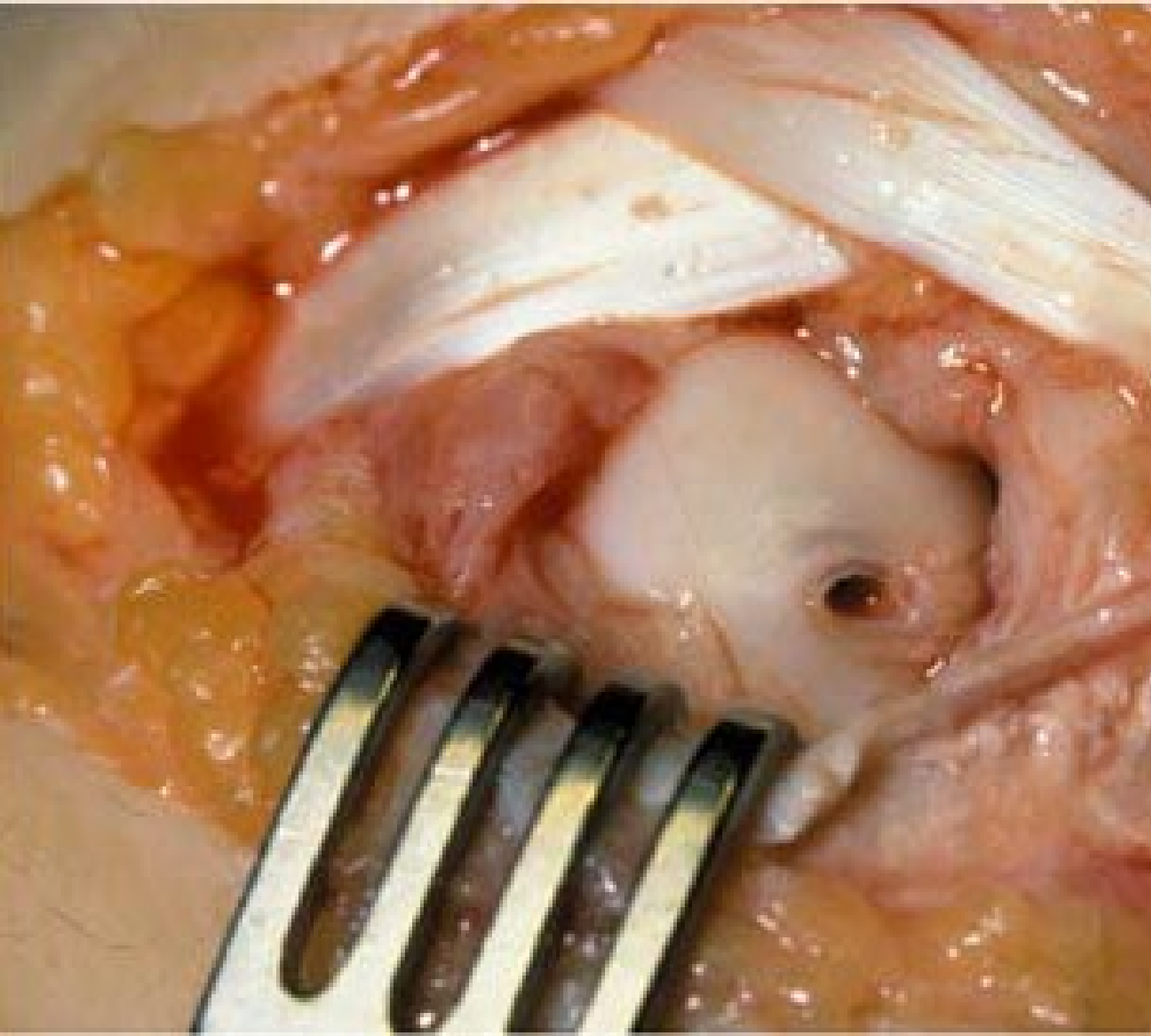
Cannulated headless
compression screw

Retrograde (volar) or
anterograde (dorsal)

Proximal Pole Fractures

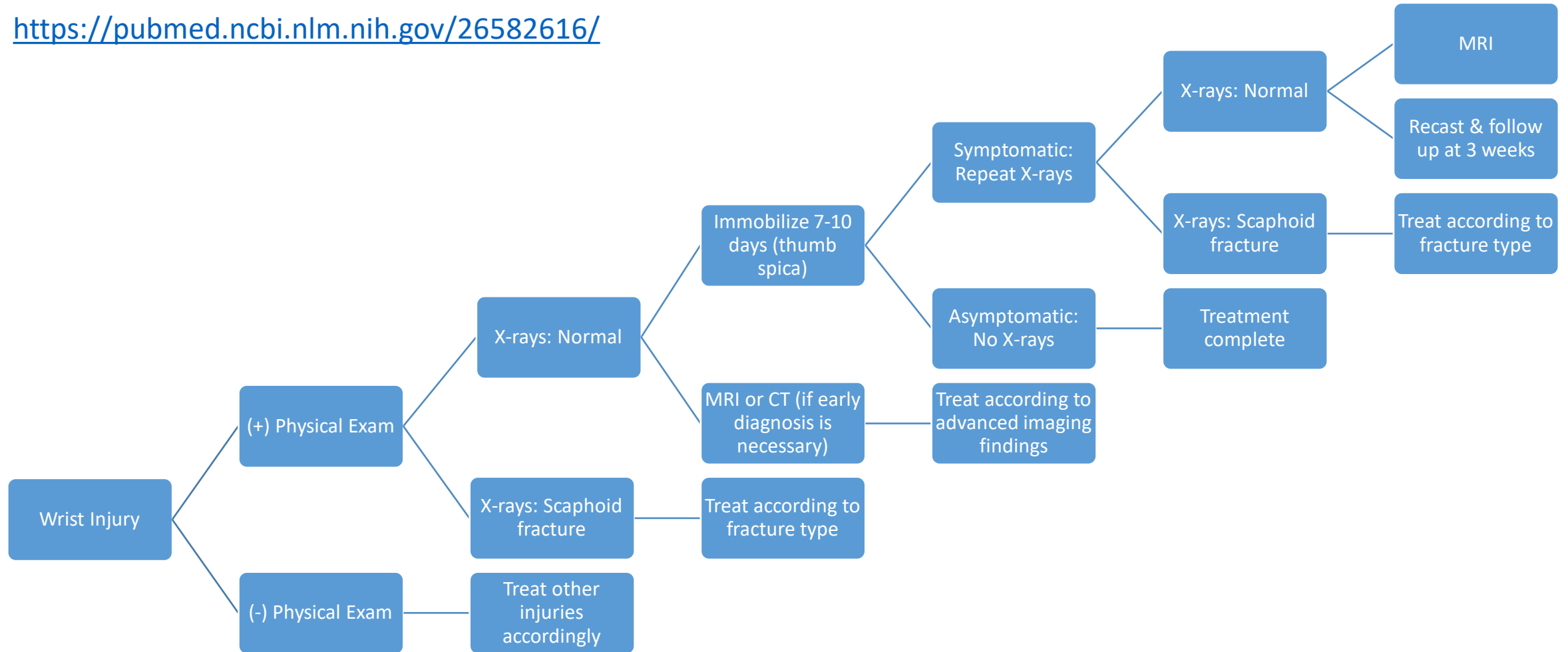
- High rate of nonunion-50%
- Best treated with early internal fixation
- Exposure typically from dorsal approach
- If nonunion, may benefit from vascularized bone graft?
 - MRI can help determine if there is AVN





Author Proposed Algorithm for Suspected Scaphoid Fractures

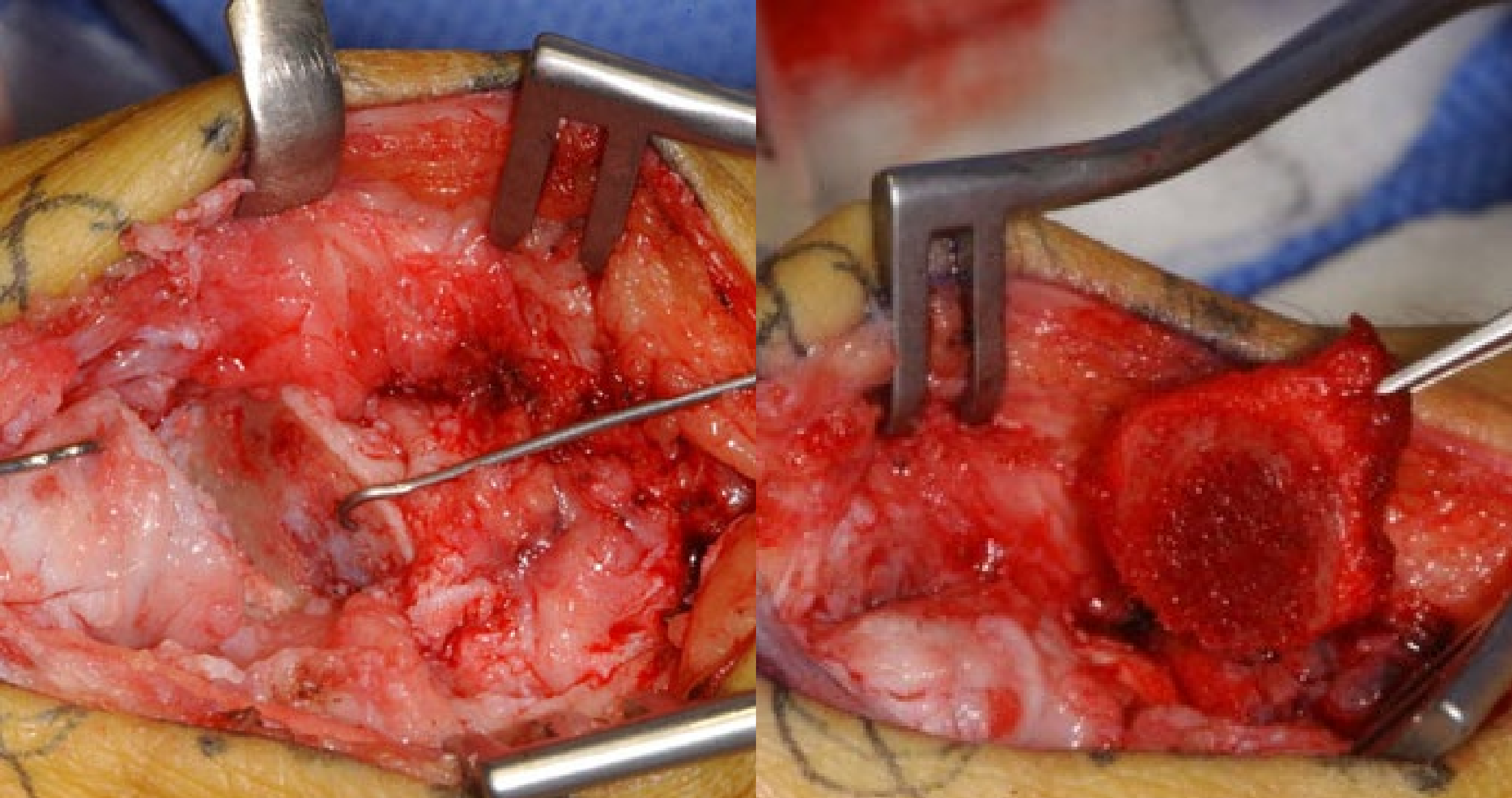
<https://pubmed.ncbi.nlm.nih.gov/26582616/>



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)



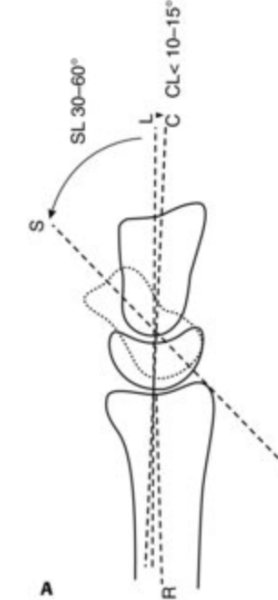
Scaphoid nonunion surgery with placement of bone graft

Carpal Instability

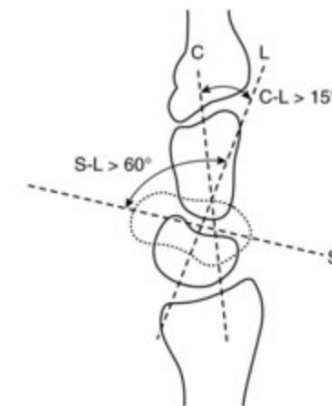
- Lunate is the key to carpal stability
 - Linked to scaphoid and triquetrum by strong interosseous ligaments
 - Injury to scapholunate or lunotriquetral ligaments lead to **dissociative carpal instability patterns**
 - (SL \rightarrow DISI $>$ LT \rightarrow VISI)
- Proximal and distal carpal rows are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

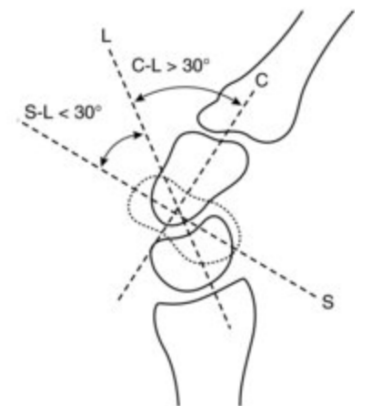


Dorsal intercalated segment instability (Dorsiflexion carpal instability)



B
1. Dorsal tilt of lunate
2. Volar tilt of scaphoid

Volar intercalated segment instability (Volarflexion carpal instability)



C
1. Volar tilt of lunate
2. Dorsal tilt of capitate

Duckworth AD, Strelzow J. Chapter 43. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019.a

Perilunate Injuries - General Information

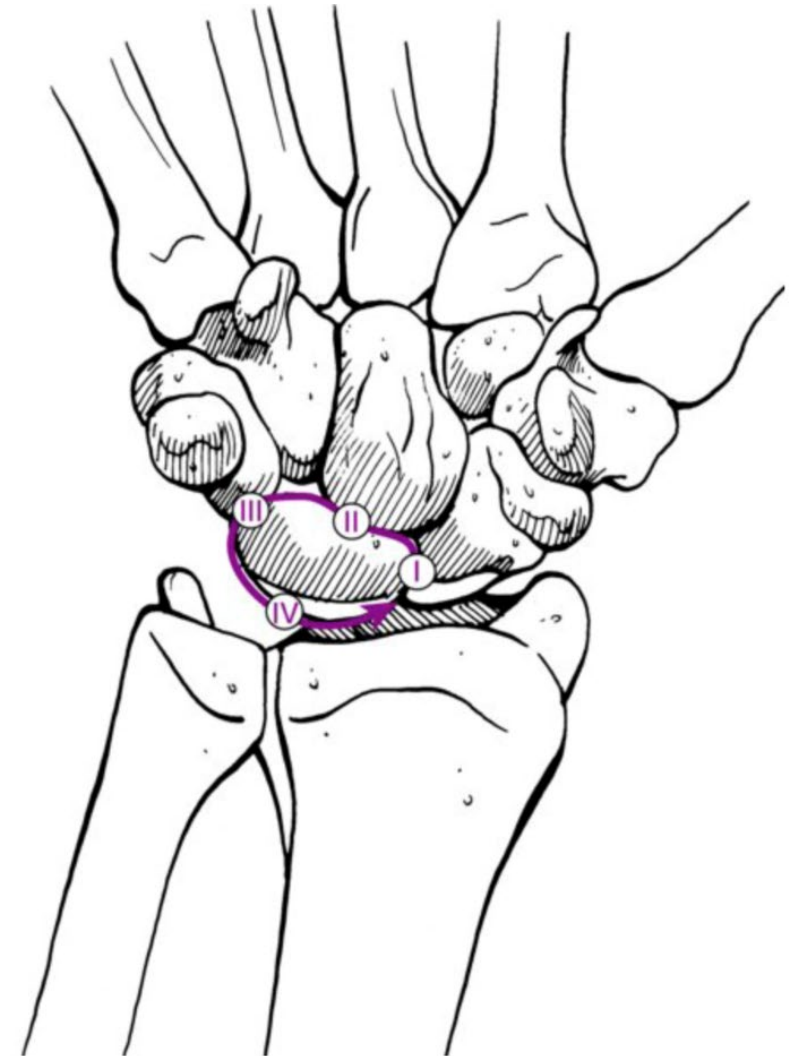
- Young individuals with high demands
- Frequently missed
- High risk of post-traumatic degenerative change
 - <https://pubmed.ncbi.nlm.nih.gov/19931988/>
- Surgical reduction/repair outperforms closed reduction with casting
 - <https://pubmed.ncbi.nlm.nih.gov/26205701/>
 - <https://pubmed.ncbi.nlm.nih.gov/25207292/>
- 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)

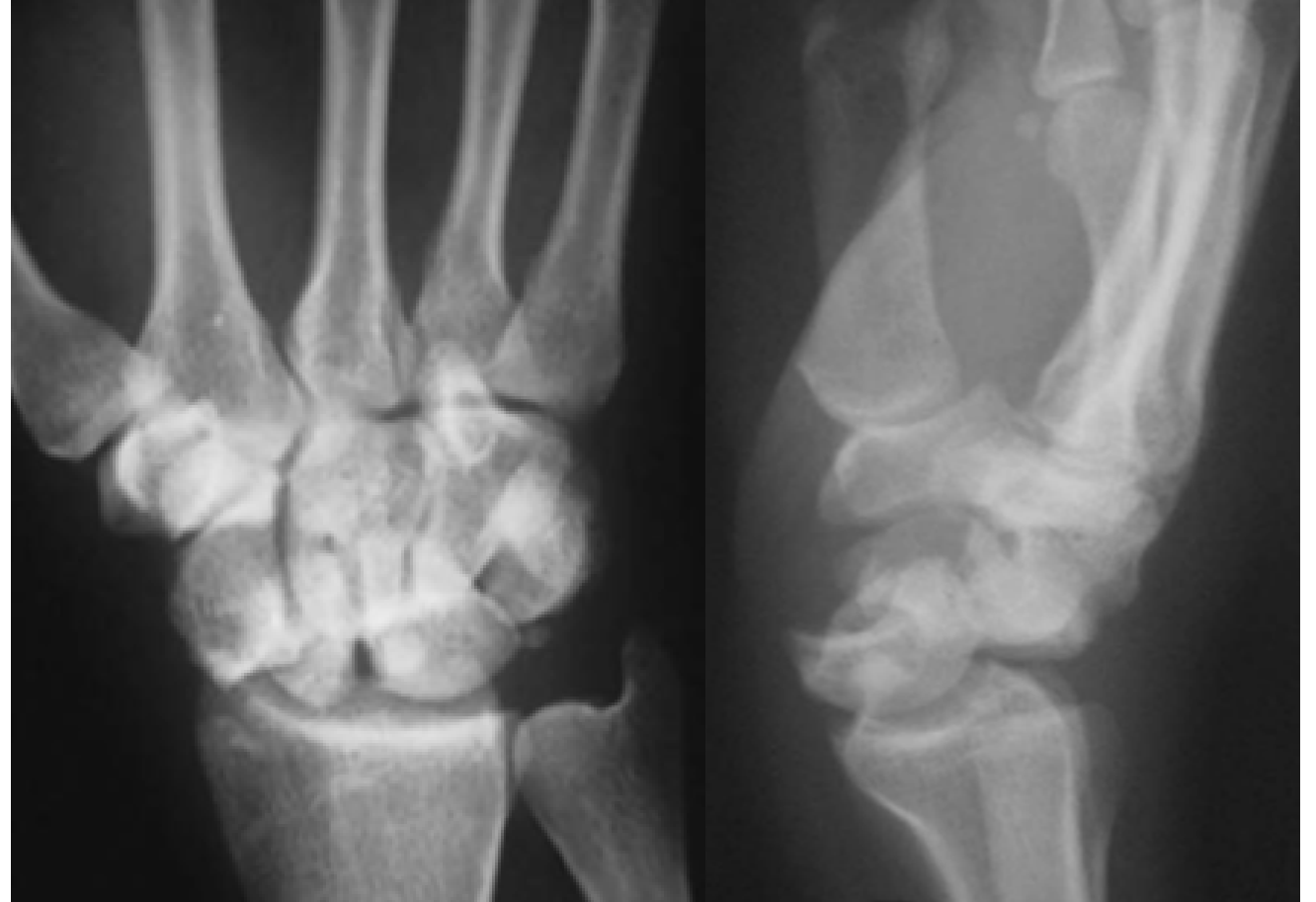
- I. Scapholunate (SL) Dissociation or Scaphoid Fracture
- II. Lunocapitate Dislocation through the space of Poirier
- III. Lunate Triquetrum Disruption or Triquetrum Fracture
 - I. Dorsal Perilunate Dislocation
- IV. Complete Palmar Lunate Dislocation



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Perilunate Variations

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



Komurcu M, Kürklü M, Ozturan KE, Mahirogullari M, Basbozkurt M. Early and delayed treatment of dorsal transscaphoid perilunate fracture-dislocations. J Orthop Trauma. 2008;22(8):535-540.

3 Most Common Patterns

- Perilunate dislocation
- Transscaphoid perilunate fracture-dislocation
- Lunate dislocation

Perilunate Dislocation



Transscaphoid Perilunate Fracture-Dislocation



Images from: Komurcu M, Kürklü M, Ozturan KE, Mahirogullari M, Basbozkurt M. Early and delayed treatment of dorsal transscaphoid perilunate fracture-dislocations. *J Orthop Trauma*. 2008;22(8):535-540.

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

Duckworth AD, Strelzow J. Chapter 43. In: Tornetta P, Ricci WM, eds. Rockwood and Green's Fractures in Adults, 9e. Philadelphia, PA. Wolters Kluwer Health, Inc; 2019.







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

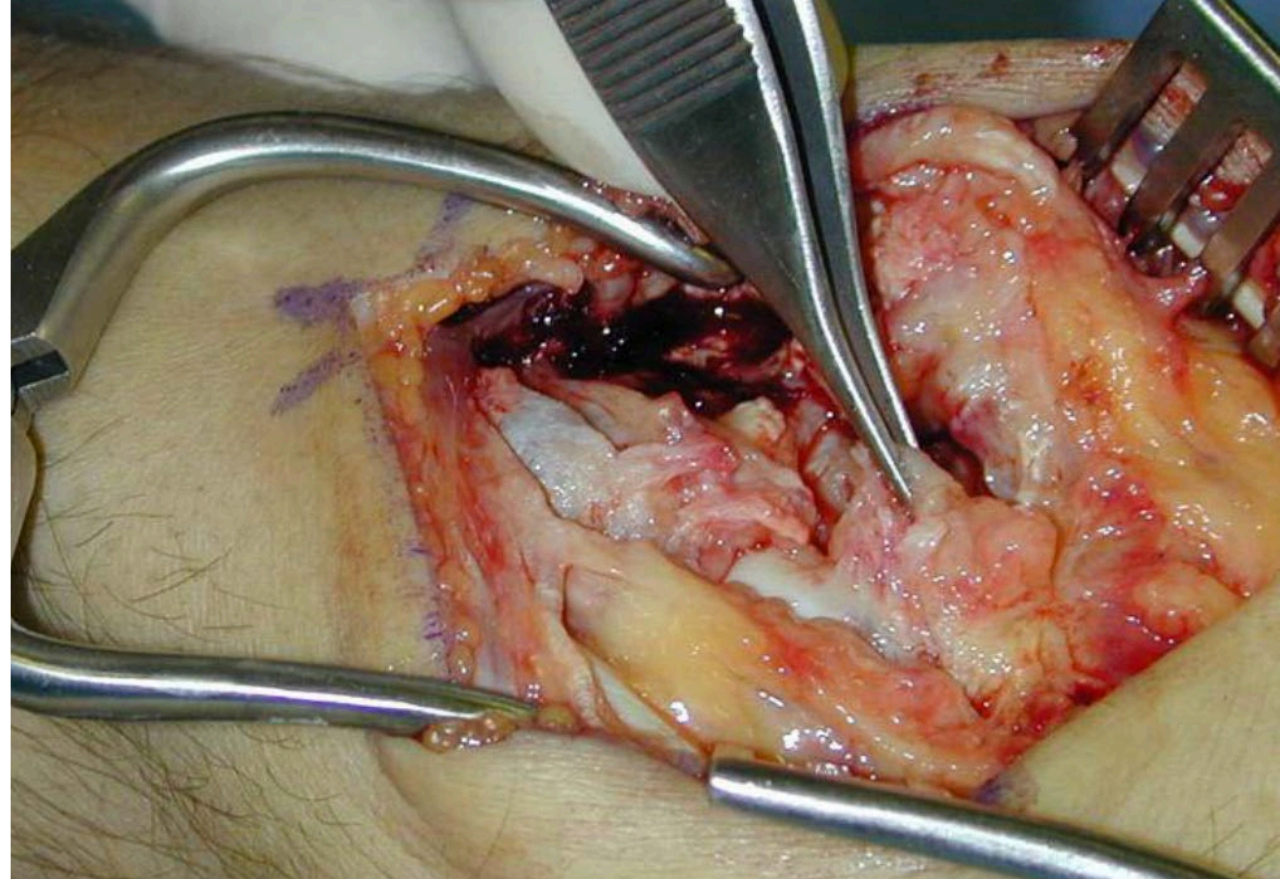
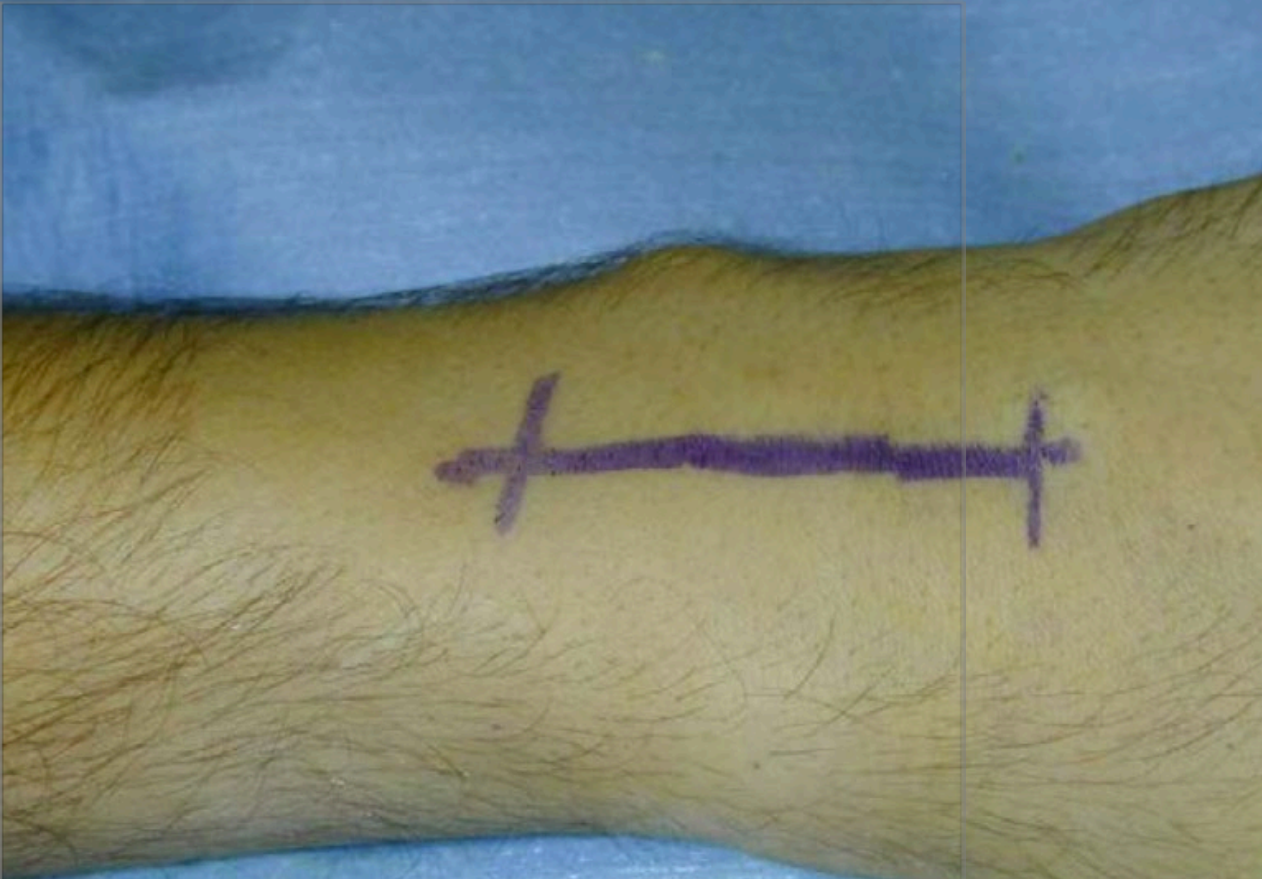
- Closed reduction with adequate sedation
 - In finger traps with 10-15 lbs. traction for 5-10 minutes
 - Maneuver
 - Wrist extension
 - Counterpressure - palmar over lunate
 - Gradual wrist flexion with direct pressure over capitate

Closed Reduction Percutaneous Pinning

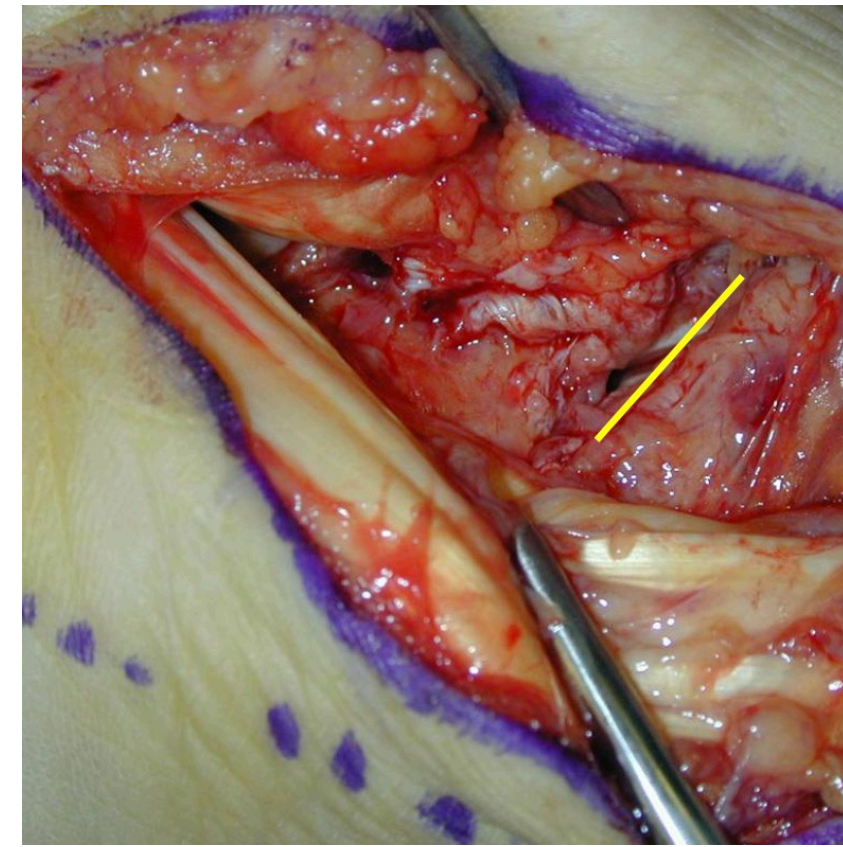
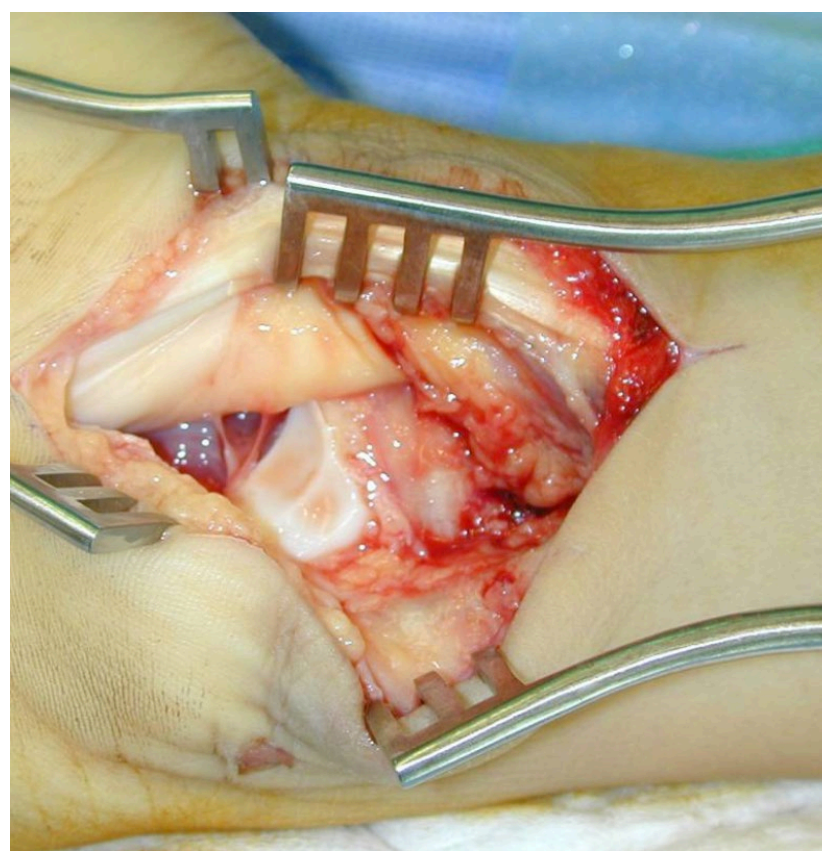
- Closed Reduction Percutaneous Pinning
 - Most injuries require fixation to maintain reduction
 - Requires anatomic reduction
 - Reduce and pin lunate to radius
 - Reduce and pin capitate to lunate
 - Reduce and pin scaphoid to lunate
 - Reduce and pin lunate to triquetrum
 - Reduce and pin scaphoid 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



Volar Approach

Lunate may be dislocated volarly

Volar mid-carpal ligament tear

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
 - <https://pubmed.ncbi.nlm.nih.gov/6715820/>
- 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

<https://pubmed.ncbi.nlm.nih.gov/21885701/>

<https://pubmed.ncbi.nlm.nih.gov/30403823/>

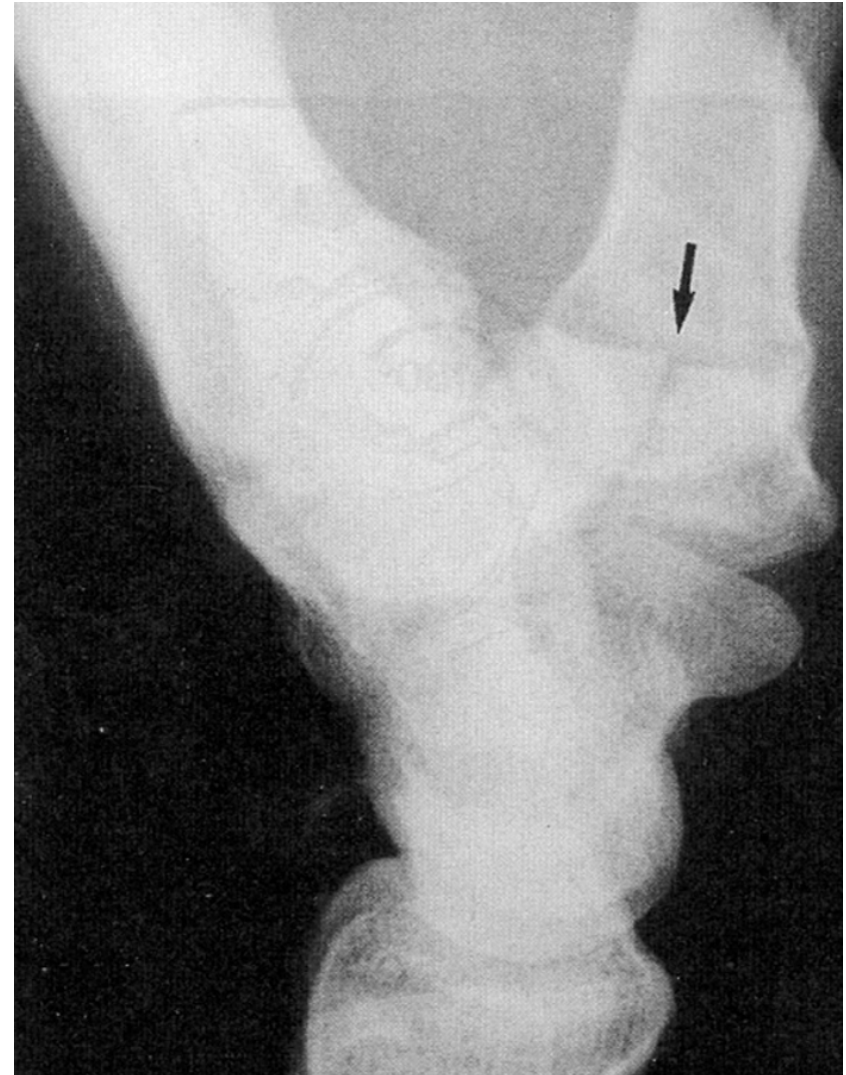
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Other Carpal Fractures

- 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 transscaphoid 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



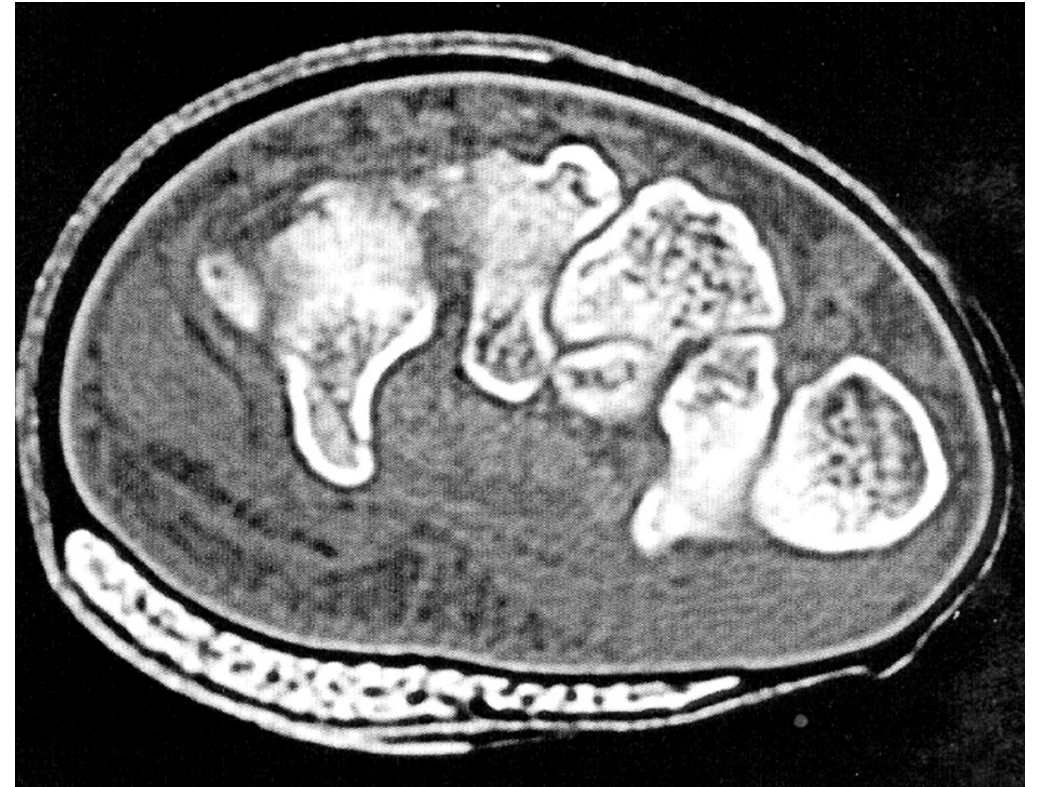
Hamate Fractures

- 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

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