MRI Anatomy and Injuries of the Hand

SPR MSK Course January 16, 1:15-2:00
Andrew Zbojniewicz, MD
Cincinnati Children’s Hospital
University of Cincinnati
Introduction

• Protocol guidance for injuries to the hand
• Review anatomy pertinent to an accurate diagnosis of trauma to the hand
• Illustration of pathology through case examples
Protocol
Technique

• Dedicated surface coils
  – 3 or 5 inch surface coil
  – Wrist coil
  – Microscopy coil

• Hand = “palm”, fingers, thumb

• Trauma/mass versus rheumatology/infection
Protocol

• Trauma/mass
  – Focus on region of interest and one adjacent finger (sagittal plane) for comparison

• Rheumatology/infection
  – Wider coverage
Finger or Thumb Protocol

- Coronal T1
- Coronal T2 FS
- Sagittal T2 fs
- Axial T2 fs
- Axial PD or IW
- Sagittal T1 (optional)
- Coronal STIR (optional)
- Coronal GE (optional)
Thumb protocol
Thumb protocol
Thumb protocol
Thumb protocol
Thumb protocol
Thumb protocol
Thumb protocol
Thumb protocol
Anatomy
Anatomy

- Ligaments and tendons at the carpus/metacarpus level
- Metacarpophalangeal (MCP) joint
- Proximal interphalangeal joint (PIP)
- Distal interphalangeal joint (DIP)
Intrinsic versus extrinsic ligaments

• Intrinsic ligaments
  – Between carpal bones
  – Eg. Scapholunate (SL) ligament, lunotriquetral (LT) ligament, scaphotrapeziotrapezoid ligament

• Extrinsic ligaments
  – From carpal bone to bones of the forearm, retinacula, or tendon sheaths
  – Eg. Volar extrinsic ligaments, dorsal extrinsic ligaments
Extrinsic ligaments

• Volar extrinsic ligaments
  – Radioscaphocapitate, radiolunotriquetral (long radiolunate), ulnolunate (TFCC), ulnotriquetral (TFCC), radioulnar (TFCC)

• Dorsal extrinsic ligaments
  – Dorsal radiotriquetral ligament, dorsal intercarpal ligament, radioulnar ligament (TFCC)
Dorsal extrinsic ligaments

• Function
  – Provide stability for wrist motion

• Pathology
  – Frequently injured during fall on an outstretched hand
    • Dorsal wrist sprain
    • May contribute to scapholunate dissociation
  – Impingement

AJR 193;161:119-125
Anatomy

• Dorsal radiotriquetral ligament
  – Lister tubercle +/- radial styloid to dorsal tubercle of triquetrum

• Dorsal intercarpal ligament
  – Triquetroscolapheoid and triquetrotrapezial fascicles
    • Also from dorsal tubercle of triquetrum (V shape)
    • May be single ligament or branched
    • Contains connections to SL and LT ligaments

AJR 193;161:119-125
Dorsal extrinsic ligaments

- Intercarpal
- Radiotriquetral
- Dorsal tubercle of triquetrum
Dorsal extrinsic ligaments

- intercarpal
- band to radial styloid
- band from Lister tubercle
Muscles and tendons

- **Extrinsic muscles**
  - Extensor digitorum (communis)
  - Extensor indicis (proprius)
  - Extensor digiti (quinti) minimi
    - Primary muscles involved in extension of MCP joints

- **Intrinsic muscles**
  - Interosseous and lumbrical muscles
    - Extension and flexion of PIP/DIP joints (through contribution to extensor mechanism)
    - Flexion MCP joints
Extensor tendons

- Large anatomic variation
- Tendon multiplicity > ulnar side
- Typical arrangement
  - Single extensor indicis and extensor digitorum for index finger
  - Single thick extensor digitorum for middle finger
  - Double extensor digitorum tendon for ring finger
  - No extensor digitorum to small finger, instead double extensor digiti minimi tendon
Extensor tendons

• Typical variations
  – Double extensor indicis tendon
  – Double or triple extensor digitorum tendon for middle finger
  – Single or triple extensor digitorum tendon for ring finger
  – Single or double extensor digitorum tendon for small finger
Intertendinous connections

• AKA connexus intertendineus, juncturae tendinum
• Function
  – Create space between extensor tendons
  – Redistribute force between tendons
  – Coordinate extension of fingers
  – Stabilize MCP joints
• Three patterns: filamentous, fibrous, or tendinous
• Intertendinous fascia
• May mask tendon lacerations
Extensor tendons
Intertendinous connections
Intrinsic muscles

• Lumbricals (4)
  – Tendinous origin and insertion
    • Radial to flexor digitorum profundus
  – Palmar to transverse metacarpal ligament
  – Flex MCP joint, extend interphalangeal joints

• Interosseous (7)
  – Three palmar: adduct fingers, flex MCP joint, extend interphalangeal joints
  – Four dorsal: abduct fingers, flex MCP joint, extend interphalangeal joints
Intrinsic muscles

* interosseous
* Adductor pollicis
* lumbricals
Metacarpophalangeal (MCP) joint

• Primary static stabilizers
  – Volar plate
  – Collateral ligaments
• Primary dynamic stabilizers
  – Extrinsic muscle/tendons
  – Intrinsic muscles/tendons
• Sagittal band
• A1 pulley
• Deep transverse metacarpal ligament
Metacarpophalangeal (MCP) joint

- **Sagittal band**
  - Fibrous sheet surrounding MCP joint
  - Forms extensor hood with extensor tendon
  - Inserts from extensor tendon to volar plate and adjacent capsular structures
- **Function:**
  - Extend proximal phalanx in conjunction with tendon
  - Stabilize the tendon
  - Limit proximal excursion of tendon
Metacarpophalangeal (MCP) joint

- Collateral ligaments
  - Proper collateral ligament
    - Dorsolateral metacarpal head to volar base of proximal phalanx
    - Antagonistic with accessory collateral ligament
      - Taut in flexion
  - Accessory collateral ligament
    - Dorsolateral metacarpal head to volar plate
    - Taut in extension
MCP joint anatomy

- Sagittal bands
- Collateral ligaments
- Volar plate
- A1 pulley
- Transverse metacarpal ligament
Proximal interphalangeal (PIP) joint

- **Primary static stabilizers**
  - Collateral ligaments
  - Volar plate
- **Primary dynamic stabilizers**
  - Extensor mechanism (apparatus)
  - Flexor tendons
- A3 pulley
- Retinacular ligaments
  - Connects conjoined tendons to volar plate and pulley mechanism at PIP joint
Extensor mechanism (apparatus)

- Extensor tendon continues at level of proximal phalanx as central and lateral bands (slips)
  - Central band (slip) receives fibers from intrinsic tendons
    - Insert onto the dorsal tubercle of middle phalanx
  - Lateral bands (slip) merge with fibers from intrinsic tendons to form conjoint tendons
    - Conjoint tendons connect centrally by triangular ligament and terminate at distal phalanx as terminal tendon
Extensor mechanism (apparatus)
Extensor mechanism (apparatus)

Intrinsic muscle contributions
Extensor mechanism (apparatus)
Extensor mechanism (apparatus)
Extensor mechanism (apparatus)
Extensor mechanism (apparatus)

Central slip

Lateral bands
Extensor mechanism (apparatus)
Central band (slip) extensor mechanism
Collateral ligaments

Proper collateral ligaments
Flexor digitorum superficialis

FDS

FDP
Flexor digitorum superficialis
Volar plate

• **Function**
  – Forms the palmar side of the joint capsule
  – Prevents hyperextension

• **Distal attachment**
  – Volar lip of base of middle phalanx

• **Proximal attachment**
  – Check-rein ligaments
    • Two U-shaped elastic lateral bands attach to the proximal phalanx
Volar plate

Check-rein ligament
Pulley anatomy A4
Distal interphalangeal joint

- Terminal tendon
  - Formed by conjoint tendons
    - Secured centrally by triangular ligament proximal to insertion
    - Inserts at dorsal base of distal phalanx
- Flexor digitorum profundus insertion
- Collateral ligaments
- Volar plate
Distal interphalangeal joint

Conjoint tendons

Triangular ligament
Distal interphalangeal joint

- Terminal tendon
- Collateral ligaments
- Volar plate/FDP tendon
Distal interphalangeal joint

Volar plate/FDP tendon

Terminal tendon
Pathology
Dorsal hand pain

• Dorsal wrist sprain
• Ganglion
• Dorsal carpal impingement
• Carpal boss
• Stress fracture
• Other
18 year old dorsal wrist pain

Dorsal wrist synovitis
18 year old dorsal wrist pain

Dorsal wrist synovitis
18 year old dorsal wrist pain

Subacute dorsal wrist wrist sprain

Ganglion from scapholunate joint
14 year old gymnast with chronic wrist pain

Dorsal synovitis (dashed arrow); arthroscopically debrided

intercarpal ligament

radiotriquetral ligament
Dorsal carpal impingement

- Dorsal radiocarpal/synovial impingement produced with weight-bearing on a hyperextended wrist
- Offending activities
  - Push-ups, bench press, gymnastics
- Treatment
  - Activity modification
  - Arthroscopic debridement of dorsal synovitis +/- excision of articular branch of posterior interosseous nerve

12 year old level 9 gymnast with pain at dorsal wrist
12 year old level 9 gymnast with pain at dorsal wrist

Carpal boss; partial coalition
Carpal boss

- Osseous protuberance at base of 2\textsuperscript{nd} or 3\textsuperscript{rd} metacarpal, between the trapezoid and capitate
  - Degenerative osteophyte, os stylodeum, partial coalition
  - Multiple other proposed etiologies
    - Sequelae of prior trauma, chronic remodeling of bone related to extensor carpi radialis brevis attachment, exostosis, accessory capitate bone
Carpal boss

- Dorsal hand pain +/- swelling with activity and relieved by rest
- Etiology of pain
  - Altered biomechanics in adjacent joints
  - Irritation of overlying extensor tendons
  - Irritation from trauma or repetitive use
  - Secondary arthritis
  - Presence of ganglion or inflamed adventitial bursa
Carpal boss

- Typically affects dominant hand
- Associated with sporting activities such as tennis, gymnastics, and boxing
- Treatment
  - Behavioral modification, NSAIDs, corticosteroid injection, immobilization
  - Surgery for refractory cases
    - Concerns about third CMC joint instability with resection; arthrodesis
17 year old girl softball player with dorsal hand pain

Fused os styloideum
11 year old boy lacrosse and baseball with 2-3 months aching dorsal and radial wrist/hand pain

Partial coalition between capitate and 3rd metacarpal
14 year old girl tennis player with 2 weeks of pain at the dorsal hand. No known injury. Hurts only when playing and hitting a ball, specifically forehand.
Metacarpal stress fracture

• Described in tennis, rowing, softball, and badminton
  – Ulnar aspect base of the second metacarpal
    • Occasionally third metacarpal or fourth proximal phalanx
  – Often adolescent female between 13 and 18 years old
  – Increase in intensity of training and semi-Western or Western grip
  – Mechanical force is increased with forehand stroke

• May mimic carpal boss clinically

AJSM 2010;38(6): 1215-1220
Metacarpal stress fracture

• Treatment
  – Rest
  – Switch grip?
  – Absence of pain typically between 6-12 weeks
  – Gradual return to sport

AJSM 2010;38(6): 1215-1220
17 year old girl with 5th MCP pain; chronic blunt trauma with bruising on exam, no specific injury.
17 year old girl with 5\textsuperscript{th} MCP pain; chronic blunt trauma with bruising on exam, no specific injury.

Chronic contusion from repeated blunt trauma during volleyball.
17 year old girl with 5th MCP pain; chronic blunt trauma with bruising on exam, no specific injury

Intertendinous connections
Traumatic Finger Injuries
Traumatic Finger Injuries
Usefulness of MRI

- Confirm tendon tear
  - Which tendons
  - Retraction?
- Capsuloligamentous structures
  - Stener lesion
  - Pulley injury
  - Collateral ligament integrity
- Clinically ambiguous cases with no radiographic abnormality
Thumb injuries

- Gamekeeper (skier) thumb
  - Valgus force injures ulnar collateral ligament (UCL)
- Radial collateral ligament (RCL) also can be injured
- UCL and RCL important for grasping strength
- Incompetence can lead to pain, weak grasp strength, instability, and ultimately degenerative joint disease
Thumb injuries

• Collateral ligament injuries most common indication for MRI
  – Usually performed when no bone fragment present
• Clinical question?
  – Integrity of ligament
    • Complete versus partial tear (may determine need for surgery)
  – Stener lesion
    • Ulnar collateral ligament retracts superficial to the adductor pollicis aponeurosis
    • Indication for surgical treatment
Thumb collateral ligament injury treatment

- **Acute**
  - Thumb spica cast
  - Surgery
    - Fail casting
    - Stener lesion

- **Chronic**
  - Surgery when instability develops

- **Surgery**
  - Suture repair
  - Ligament reconstruction
  - Arthrodesis
Is there a UCL tear?
Is there a UCL tear? NO

Chronic radial collateral ligament tear; repaired with suture anchors
Acute UCL distal tear

Adductor aponeurosis

UCL tear

UCL tear confirmed on palmar slice
Acute vs subacute vs chronic tears

- **Acute tear**
  - Ligament discontinuity, high signal on fluid sensitive sequences within or at attachment sites
  - Reactive bone and soft tissue changes
  - Joint effusion
- **Subacute tear**
  - Healing response/granulation tissue and synovitis can make things difficult
  - +/- Bone and soft tissue changes
- **Chronic tear**
  - No bone marrow or soft tissue changes (unless instability/DJD)
  - Ligament quality
    - Intermediate intrasubstance signal on fluid sensitive sequences
    - Size
      - Thick, thin, wavy
13 year old with thumb injury in football one week ago

- Proximal UCL avulsion
- Adductor aponeurosis
- Distal UCL intact
15 year old catching baseball and someone slid into his hand beginning of June.

Imaging performed 2 months after injury; MRI from dorsal to palmar.

UCL detached from proximal phalanx, but secure at metacarpal; substantially scarred and thickened superficially.

Imaging performed 2 months after injury; MRI from dorsal to palmar.
17 year old initial injury 3 years ago; casted; reinjured 2 months prior to MRI

Fracture malunion
Fall one week ago

Stener lesion

Image courtesy of Robert Oostveen, MD
16 year old playing football and dislocated ulnarly

Acute avulsion RCL and check-rein ligament
16 year old right thumb injury after slamming in door 3 months ago
16 year old right thumb injury after slamming in door 3 months ago

- RCL tear
- Cartilage loss/misshapen condyle
- Osteophyte
16 year old right thumb injury after slamming in door 3 months ago

- Osteophyte
- Normal comparison
- Normal cartilage
- Normal comparison
16 year old right thumb injury after slamming in door 3 months ago

Cartilage fragment
15 year old with history of multiple prior injuries to thumb

Subacute RCL tear with poor quality ligament necessitating reconstruction
15 year old girl soccer injury to thumb two years ago. Persistent pain with activity not improved with PT.
15 year old girl soccer injury to thumb two years ago. Persistent pain with activity not improved with PT.

Chronic RCL and UCL tears; At surgery scar tissue with no distinct ligaments and abnormal laxity with stress under anesthesia necessitating autograft reconstruction.
MCP joint
Subacute sagittal band injury

Normal comparison

Normal comparison
PIP joint
PIP joint

- Most common site of injury
- Collateral ligament and volar plate most frequent sites of injury
- Volar plate injuries
  - Normal cleft at articular side between volar plate and osseous insertion
  - Wide, complete gap indicates tear
  - Heterogenous signal
  - Contour abnormality
PIP joint

- Coronal instability
  - Abducting or adducting force
    - Mild sprain – no instability
    - Moderate sprain – partial tear +/- instability
    - Severe sprain – complete tear and major instability and often dislocation
      - Volar plate avulsion (partial or complete)
PIP joint

• Sagittal instability
  – Hyperextension mechanism
    • Type 1 – isolated volar plate injury (avulsion at middle phalangeal base or check-rein ligament)
    • Type 2 – type 1 + additional periarticular soft tissue damage +/- dorsal subluxation middle phalanx
    • Type 3 – fracture-dislocation
      – Stable < 40% articular surface; collateral ligaments attached to middle phalanx
      – Unstable > 40% articular surface; volar plate and collateral ligaments attached to fragment
        » Requires surgery
PIP joint

• Sagittal instability
  – Compression mechanism
    • Force occurs on semi-flexed PIP joint +/- rotational component
  – Unilateral collateral ligament and at least partial avulsion volar plate
    • Volar subluxation or dislocation of middle phalanx
    • Potential injury to central slip
  – “Buttonhole” injury
    • Condyle from proximal phalanx trapped between central slip and lateral band
    • Requires surgical reduction
12 year old girl jammed finger
12 year old girl jammed finger

MRI 5 months later
12 year old girl jammed finger

Volar plate
12 year old girl jammed finger

Volar plate fracture
12 year old girl jammed finger
12 year old girl jammed finger
14 year old dislocated finger at football
14 year old dislocated finger at football; subacute MRI

Volar plate fracture
14 year old dislocated finger at football

RCL complete tear

Volar plate
14 year old dislocated finger at football

Defect in bone/cartilage
14 year old dislocated finger at football
17 year old girl left small finger injury without dislocation; initial radiographs

Initial injury
17 year old girl 4 weeks out from left small finger injury without dislocation, but with fixed flexion at PIP joint

One month from initial injury
17 year old girl 4 weeks out from left small finger injury without dislocation, but with fixed flexion at PIP joint

One month from initial injury
17 year old girl 4 weeks out from left small finger injury without dislocation, but with fixed flexion at PIP joint.

Entrapped lateral band

Complete tear RCL and entrapped lateral band
17 year old girl 4 weeks out from left small finger injury without dislocation, but with fixed flexion at PIP joint

Lateral band repair, RCL repair, triangular ligament repair, volar plate release
Injury to small finger PIP skeletally immature patient

May 2009

August 2009
Injury to small finger PIP skeletally immature patient

- Intact central slip
- Radial UCL tear
- Longitudinal tear
Injury to small finger PIP skeletally immature patient

Pseudo-boutonniere deformity
Pulley injury

• Rock climbers
  – Extensive forces on A2 and A3 pulleys due to powerful flexion of fingers with MCP joint extension, PIP joint flexion, and DIP joint extension

• Begins at A2, progresses to A3, A4
Pulley stress maneuver - normal
Pulley stress maneuver - normal
DIP joint
Mallet finger
Mallet finger
Jersey finger

- Sudden hyperextension of a flexed finger
- Most common at ring finger
- Injury to the flexor digitorum profundus at the distal interphalangeal joint

Classification
- Type 1 – retraction of tendon into palm
- Type 2 – retraction of tendon to PIP joint
- Type 3 – avulsion of bone fragment that gets caught up at A4 pulley
- Type 4 – type 3 with avulsion of FDP tendon from fracture fragment
Jersey finger
Jersey finger
Jersey finger

LONG RT HAND

Retracted FDP

FDS

RING FINGER

MID

PROX
Jersey finger
Jersey Finger
Mineralization in the hand

- Not rare
- Often at phalanges
- Florid reactive periostitis
- Bizarre osteochondromatous proliferation (BPOP), Nora lesion
- Turret exostosis
- Subungual exostosis
Florid reactive periostitis

- AKA Fibro-osseous pseudotumor of the digits
- Variant of myositis ossificans (similar histopathology)
  - Lacks well-defined zoning phenomenon
- Most common in phalanges
  - Proximal phalanx of index finger most common
- Radiographs
  - Soft tissue mass
  - ~ 50% calcification or periosteal thickening
  - Lucent cleft between calcification and underlying cortex
Bizarre Parosteal Osteochondromatous Proliferation (BPOP)

- AKA Nora lesion
- “Well-marginated mass of heterotopic mineralization arising from the periosteal aspect of an intact cortex, without medullary changes”
- Lacks corticomedullary continuity
- Most common in hands
- Trauma frequently associated
- May mimic chondrosarcoma on histology
- No known malignant transformation
Bone formation in the hand

• Spectrum of reactive lesions with a natural progression?
• Argument against
  – Recurrence much more common with BPOP
  – Chromosomal translocations recently shown with BPOP
• Take-home point
  – Mineralization often seen in the hand and frequently after trauma
  – Osteosarcoma extremely rare in digits
Mineralization in hand

Coronal T1

Axial T1 FS post contrast
Mineralization in hand

Axial T1 FS post-contrast

UCL disruption
Mineralization in hand

- Index case
- Clear association with prior trauma
- Evolution from florid reactive periostitis to BPOP?
Conclusion

• Hand is actually three distinct parts for trauma imaging
  – Discrete protocol design for “palm”, fingers, and thumb

• Understanding anatomy is key to accurate diagnosis

• MR imaging appearance of hand injuries often predicated on acuity of injury
  – Chronic injuries more difficult and subtle to diagnose
References