Fracture University: A Review of Adult Fractures
Distal Humerus to Distal Phalanx

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Learner Objectives

Able to:
(1) Teach a colleague the fundamental principles of fracture healing
(2) Teach a colleague 3 mechanisms by which bones heal
(3) Understand why distal humerus fractures are challenging to surgically repair
(4) Understand the mechanics of why pseudo-clawing can occur following a metacarpal fracture
(5) Describe the path of deforming forces seen in an Essex-Lopresti fracture
(6) Explain to a patient why elbow extension against resistance is not permitted following repair of an olecranon fracture
(7) Verbalize why a proximal phalanx fracture assumes an apex volar posture
(8) Teach a peer which fragment of a Bennett's fracture is located and which is displaced and why
(9) Confidently find information regarding orthopedic fractures in relevant, up-to-date literature

Outline

- 3 types of bone healing
  - Cortical
  - Cancellous
  - Compression
- Goals and limitations of classification systems
  - Characterize/describe features
  - Guide treatment decisions
  - Predict outcomes
  - Universal drive to name and categorize things
  - Hierarchy
  - Weak link: inherent variability in human observation
  - ↑ Describing fractures
  - ↑ Educational tools
  - ↓ Guiding treatment
  - ↓Predicting outcomes
- Distal humerus fractures
  - Complex regional anatomy
  - Fracture comminution
  - Limited points for secure fixation
  - Bimodal: young high energy / elderly low energy falls, poor bone quality
  - All nerves at risk
  - Anatomy of the distal humerus
    - Triangular shape
    - Humeral diaphysis diverges into medial and lateral bony columns in the metaphyseal portion of the distal humerus
    - Trochlea is base of triangle
  - Many attempts at classification systems

    - Blood supply to the distal humerus is entirely dependent on a single nutrient vessel that terminates 3-4 cm above the olecranon fossa
    - Challenges to fixation
        - Small, cancellous distal fragments → poor fixation potential
        - Complex osseous anatomy makes plate contouring difficult
        - Hardware cannot violate articular surfaces of olecranon, coronoid, radial fossae
        - Osteoporotic bone
    - Complications
        - Ulnar nerve injury
        - Infection
        - Heterotopic ossification
        - Non-union
        - Stiffness
- Coronoid fractures
    - Rarely occur in isolation
    - Pathognomonic for an episode of elbow instability
    - Coronoid process is one of the primary constraints providing ulnohumeral joint stability
        - Coronoid and radial head provide a buttress against posterior displacement and subluxation of the elbow joint
        - Radial head prevents valgus instability
        - Coronoid prevents varus instability
        - Coronoid process extends medially from the ulna, lengthening the articular surface and cupping the medial trochlea
    - Anterior band of the MCL inserts at the base of the coronoid process
    - Brachialis has a broad insertion distal to the coronoid process
    - Anterior capsule inserts a few millimeters below the tip of the coronoid process
- Anatomy of elbow stability
    - 3 primary static constraints
        - Anterior bundle of the MCL
        - LCL complex
        - Ulnohumeral articulation
    - Secondary contraints
        - Radiocapitellar articulation
        - Common flexor tendon
        - Common extensor tendon
        - Capsule
- Traumatic elbow instability
    - Valgus posterolateral rotatory mechanism
        - As the elbow dislocates posteriorly
        - Radial head and/or coronoid process can fracture as they collide with the distal humerus
    - Varus posteromedial rotatory mechanism
        - Fracture of anteromedial facet of the coronoid process with either a LCL injury, a fracture of the olecranon, or both
- Dislocation terminology
    - Dislocation is a complete disruption of the joint with loss of contact between the articulating surfaces of adjacent bones
    - Fracture dislocation is a joint dislocation with significant fracture. Priority is the dislocation. Protect the health of the articular cartilage

- Dislocation + radial head fracture + coronoid fracture
    - "Terrible triad"
    - Tip of the coronoid fracture
        - Does not extend into the sublime tubercle
        - Anterior capsule is attached to the fracture fragment
    - Radial head fracture
    - MCL and LCL are usually disrupted
    - The addition of a coronoid fracture, no matter how small, to a dislocation of the elbow and fracture of the radial head, dramatically increases instability
- Olecranon fractures
    - Anatomy
        - Junction of the olecranon process with the proximal ulna metaphysis occurs at the transverse groove of the olecranon
        - Triceps has a broad, thick insertion into the posterior/proximal olecranon
    - Key is to restore the contour of the trochlear notch of the ulna
    - Olecranon fractures often occur in patients with poor bone quality
    - All are intra-articular fractures
    - Mayo classification
- Radial head fractures
    - Anatomy
        - Slightly elliptical cross section
        - Articulates with: lesser sigmoid notch of the ulna, lateral lip of the trochlea, capitellar surface
        - Slight angulation of the proximal radius with the shaft
        - PIN runs deep to the supinator along the lateral aspect of the radial neck
        - Small non-articulating surface area
        - Radial head is an important valgus stabilizer of the elbow, especially in the context of an incompetent MCL
        - Radial head tensions the LCL and thus contributes to posterolateral rotatory stability of the elbow
        - Radial head is an axial stabilizer of the forearm
    - Mechanism of injury
        - Fall on an outstretched hand, forearm pronated
        - Load is axial (with elbow at 35-80 degrees of flexion), valgus, posterolateral rotation
    - Mason classification I-IV
    - Non-displaced fractures can occur in isolation
    - Displaced fractures are frequently associated with ligament injuries of the MCL, LCL, or IOM
    - Fractures of the coronoid, olecranon and capitellum are commonly seen with fractures of the radial head
    - The radial head is an important stabilizer of the elbow in the setting of these associated bony and ligamentous injures
    - Must not remove the radial head in the presence of an incompetent MCL or IOM. Replace with prosthetic radial head of native radial head is not repairable
    - Loss of terminal extension is more common than loss of forearm rotation
    - Supination is more difficult to regain than pronation
- Monteggia fractures
    - Fracture of the proximal ulna with an associated dislocation of the radial head
    - Associated radial head fracture implies inherent violation of the annular ligament

  - No involvement of the trochlear notch
  - Dislocation of the radial head
  - Bado classification: Types 1-4
    - For types 1-3, once ulnar fractures are repaired, radial head reduces
    - Annular ligament is disrupted, but TFCC and IOM remain intact
- The forearm axis
  - Critical link between the elbow and wrist
  - A functional joint
  - All parts contribute to propelling the radius around the stable ulna
  - Axis of rotation is an oblique line connecting the radial head and the ulnar styloid
  - Forearm serves as the origin for muscles inserting on the hand
  - Forearm places the hand in space
  - Radius and ulna are connected at the PRUJ and the DRUJ and with the IOM
  - IOM separates the anterior and posterior compartments of the forearm
  - IOM is a secondary restraint to proximal migration of the radius relative to the ulna. Critical for longitudinal stability
  - Radius, ulna, IOM, TFCC, DRUJ, PRUJ form the forearm ring. Disruption of this ring at any site can result in loss of normal forearm motion. Must be restored
  - Compartment syndrome
  - Encourage you to read chapter 23 in Green's Operative Hand Surgery, 6th edition
- Forearm fractures
  - 4 distinct fracture patterns: isolated radius, isolated ulna, both bone, Galeazzi, Monteggia
  - Radius shaft fracture
    - Unique bowed shape. Bucket handle analogy
    - Supported between PRUJ and DRUJ. Vulnerable to direct trauma through its diaphysis
    - Takes load transmission during a fall on an outstretched hand (FOOSH)
    - Significant energy of trauma must be present before the forearm bones are broken.
      - Most are caused by a fall from a standing height, direct blow, or traffic accident
    - Fractures of the shaft of the radius and ulna are often displaced
      - Large force need to break the bone
      - Pull of forearm musculature
    - Isolated radial shaft is controversial. Assumed to be a Galeazzi fracture until proven otherwise.
    - It is possible to have a radius shaft fracture without DRUJ involvement
  - Galeazzi fracture dislocation
    - Diaphyseal fracture of the radius with DRUJ dislocation
      - Fracture at the junction of the middle and distal thirds of the radius
    - Wrist hyperextension with pronation and axial load
    - Angular deformity of the radius
    - Radial shortening
    - Dorsal prominence of the ulnar head
    - Strong deforming forces acting on the distal fragment: pronator quadratus, brachioradialis, thumb extensors/abductors
    - Fracture of necessity. Must repair surgically
  - Ulna shaft fracture
    - Isolated fractures of the ulnar shaft are common forearm injuries
    - Direct blow, raising arm to protect from a blow

    - Unstable if more than 50% displacement and >10° angulation, PRUJ/DRUJ instability
    - When occur in true isolation, closed, non-displaced distal and mid-shaft ulnar fractures can be treated non-operatively
      - Splinting effect of the radius
    - Displaced fractures need surgical repair
    - Mechanical importance of the ulna as a stable unit of the forearm
  - Both bone fracture
    - More common in children
      - Differences in diaphyseal bone mechanics
      - In adults: high energy, open fractures
    - Defined as isolated diaphyseal fracture of both the radius and ulna with no injury to the DRUJ and PRUJ
    - Powerful deforming forces of the forearm muscles
    - Closed treatment=poor outcome with loss of forearm rotation
    - Goal of fixation: anatomic reduction and plate fixation of bones with restoration of the radial bow
      - Average height of bow is 15mm
    - Standard compression plates
    - Separate incisions to prevent synostosis
    - At risk for compartment syndrome
  - Essex-Lopresti Lesion
    - Radial head fracture with DRUJ dislocation and IOM disruption
    - Longitudinal radioulnar dissociation
    - Complete disruption of the forearm axis
    - Rare
    - Often missed because focus is on radial head fracture
    - Wrist and forearm are only minimally tender
    - Mechanism of injury: violent axial compression force that results in longitudinal radioulnar disruption and damage to the DRUJ, PRUJ and IOM and fracture of the radial head
    - Radius is completely freed from all constraints to the ulna!
    - Must not excise the radial head!
- Distal radius fractures
  - Anatomy
    - Articular plateau on which the carpus rests
    - 23 concave articular surfaces
    - Radial inclination 23°
    - Palmar tilt 11°
    - Ulnar variance 1mm
    - Compelling evidence links restoration of anatomy to restoration of function
    - Ulnar variance: line parallel to the medial corner of the articular surface of the radius and a line parallel to the most distal point of the articular surface of the ulnar head. Both lines are perpendicular to the long axis of the radius
    - Teardrop: volar projection of the lunate facet of the distal radius. Mechanical buttress for subluxation of the lunate. 3 mm. Difficult to capture with fixation
    - Articular surface balances over the volar cortex of the diaphysis of the radius
  - Colles
    - Extra-articular

        - Dorsal comminution
        - Dorsal angulation
        - Dorsal displacement
        - Radial shortening
            - Impaction
        - Ulnar styloid fracture
    - Smiths
        - Volar and proximal displacement of distal fragment
    - Bartons
        - Displaced, unstable, articular fracture subluxation of the distal radius
        - Displacement of the carpus along with the articular fracture fragment
        - Shear fracture
    - Chauffeur's or backfire fracture
        - Shear fracture
        - Displacement of the carpus and avulsion of attached radial styloid
        - Notorious for concomitant injuries to the intercarpal and extrinsic radiocarpal ligaments
    - Lunate load, die punch fracture
        - Depression of the dorsal aspect of the lunate fossa
    - Classification systems
        - Frykman's
        - Melone's
        - AO
        - Mayo
        - Fragment Specific
        - Columnar
    - Compression fractures of the articular surface
        - Difficult to reduce in a closed fashion
        - Role of the lunate in the creation of the intra-articular fracture
        - Lunate splits the lunate fossa into 2 characteristic fragments
        - Scaphoid impacts the radial styloid and results in a shearing fracture
    - Associated soft tissue injuries seen with DRFs
        - Scapholunate interosseous ligament injury
        - Lunotriquetral interosseous ligament injury
        - Radioulnar ligament (TFCC)
        - Triangular fibrocartilage disk
        - Median nerve compression
- Carpal bone fractures
    - Carpal bone fractures are probably more common than reported
    - Complex articulations (complex 3D relationships) make plain radiographic interpretation of the wrist confusing to many MDs
    - Scaphoid
        - Links the proximal and distal rows of the carpus
        - Subjected to continuous shearing and bending forces
        - Most commonly fractured carpal bone
        - 80% covered with cartilage which limits ligamentous attachment and vascular supply
        - Proximal, distal, waist fractures
            - Majority occur at the waist
        - Mechanism of injury: hyperextension + load

- Begins at the volar waist with a tensile failure and propagates to the dorsal surface with compression loading
- Scaphoid impinges on dorsal rim of the radius

§ Scaphoid fractures heal by intramembranous ossification
- No fracture callus to provide initial stability

§ Waist fractures that are displaced greater than 1mm or have a SL angle of greater than 60° or less than 30° are considered unstable. Need fixation

§ If the fracture is not visible on the initial radiographs and there is a strong suspicion of a fracture based on clinical presentation, re-xray after 1-2 weeks of immobilization. Resorption at fracture site will become visible

§ Proximal pole fractures are prone to delayed union or non-union secondary to unique blood flow in scaphoid

§ Humpback deformity of a scaphoid mal-union

- Hamate
  - § Fractures that involve the hook
    - Racquet, club, bat
    - Non-dominant hand for golfers and baseball
    - Dominant hand for tennis and racquetball
    - Presents as chronic pain at the base of the hypothenar eminence
    - c/o ulnar nerve paresthesias and weakened grip
    - Pain with resisted IV and V flexion is worse in ulnar deviation than radial deviation
    - Chronic, unrecognized hook fracture can lead to rupture of the FDS or FDP
    - Difficult to see on standard xray views
      - Need specialized views: carpal tunnel view, supinated oblique view, or CT scan
    - Limited blood supply to the hook
      - Prone to non-union
    - Multiple attachments: transverse carpal ligament, pisohamate ligament, flexor digiti minimi, opponens digiti minimi
    - Hamate hook is the ulnar border of the carpal tunnel and the radial border of Guyon's canal
    - Base of the hook of the hamate serves as a pulley for flexor tendons (particularly IV and V)
      - Flexor tendon forces decrease following excision
    - Proximity of ulnar nerve
    - Hook of hamate fracture is in the differential diagnosis for ulnar sided wrist pain

- Metacarpal Fractures
  - Fractures of metacarpals and phalanges are the most common fractures of the upper extremity
  - Most can be managed non-operatively
  - Most are functionally stable before and after reduction
  - Fracture patterns can be broken down to head, neck, shaft and base. Base fractures are really CMC joint fracture/dislocations
  - MC head is unicondylar (phalangeal head is bicondylar)
  - MP joint is a 3-sided box (radial & ulnar proper/accessory collateral ligaments and volar plate)

- At MP joint, the volar plates are connected to each other by the deep transverse intermetacarpal ligament
- For each 2mm of metacarpal shortening, 7° of extensor lag can be expected
- Indications for fixation
  - Irreducible fractures
  - Mal-rotation (spiral or oblique fractures)
  - Intra-articular fractures
  - Open fractures
  - Segmental bone loss
  - Poly-trauma / multiple fractures
- MC head fractures
  - Rare
  - Usually intra-articular
  - Often index (immobile)
  - Comminution is common
  - Often lose >45° of flexion
  - Articular defects remodel over time
    - In contrast to weight bearing joints, articular incongruities are tolerated and painless
  - Treatment is very individualized
- MC neck fractures
  - Boxer's fracture
  - Usually IV and V
  - Clenched MP strikes a solid object
  - Angulates with apex dorsal deformity
  - Impact occurs on the dorsum of the metacarpal head, causing comminution of the volar neck
  - Intrinsic muscles lie volar to the axis of rotation of the MP joint and maintain a flexed MP head
    - MP flexed position in a splint reduces the myotendinous deforming forces. Neutralizes deforming forces
  - Pseudo-clawing: hyperextension at MPJ, flexion deformity at the PIPJ
    - In contrast, oblique and spiral fractures tend to shorten and rotate more than angulate
    - Rotation is not tolerated. 10° of mal-rotation results in 2cm of overlap at digit tip
  - Treatment is controversial
  - Nonunion is uncommon
  - IV and V tolerate angulation
  - Lack of PIPJ active extension (pseudo-clawing)
  - Prominence of MC head in palm
- MC shaft fractures
  - 3 types
    - Transverse
      - Axial load, angulate apex dorsal, intrinsics deform
      - Reduction required for >30° for V, >20° for IV, any angular deformity for III and II
    - Oblique (or spiral)
      - Torsional force that can cause rotational mal-alignment

            - Mal-rotation is poorly tolerated and difficult to assess on plain xray. Assess scissoring with digit flexion
        - Comminuted
            - Direct impact
            - Soft tissue injury
            - Shortening
    - Immobilization works well for most MC shaft fractures
    - Inherently stable secondary to the transverse metacarpal ligament
    - Effective compensatory MPJ hyperextension
    - Border digits are less stable (only tethered on one side)
  - Complications of MC fractures
    - Mal-union
    - Dorsal angulation
    - Shortening
    - Mal-rotation
- Phalangeal fractures
  - Four precision links
  - MC, P1, P2, P3
  - Many similarities in fracture patterns
    - Base, shaft, head
    - Difference in deforming forces
    - Differences in functional consequences
    - Fixation
      - Pins
      - Micro screws
      - Plates
  - Proximal / middle phalanx fractures
    - Articular
      - Condylar fractures: uni- and bi-
      - Comminuted intra-articular fractures
      - Dorsal/volar/lateral base fractures
      - Fracture dislocations
      - Shaft fractures extending into the joint
    - Non-articular
      - Neck
      - Shaft
      - Base
    - Phalangeal fractures that are stable and non-displaced can be managed with buddy taping or splint immobilization
    - Extra-articular fractures do well
    - Articular injury has a major influence on ultimate result and function
    - Many P2 fractures can be managed non-operatively. Comminution does not necessarily mean surgery. In a crush injury, the periosteal sleeve may remain intact and hold the fragments together
    - Transverse fractures are more stable than oblique or spiral
    - Proximal phalanx fractures exhibit apex volar angulation. Proximal fragment is flexed by the interosseous muscle insertion
    - Angulation of middle phalanx fractures depends on where the fracture is located

        - Transverse fractures in the distal ¼ of P2 will exhibit apex volar angulation secondary to the pull of the proximal fragment into flexion by the FDS
        - Transverse fracture in the proximal ¼ of P2 will exhibit apex dorsal angulation secondary to the pull of the distal fragment into flexion by the FDS and pull of the proximal fragment into extension by the central slip insertion at the base of P2
        - Overall, angulation is unpredictable
    - Key points for phalangeal fractures:
        - Intra-articular fractures are very difficult to manage
        - Poor tolerance for plates
        - K-wires and interfragmentary screws are preferable
        - Tendon adherence
        - No tolerance for shortening and rotation
        - Respect the delicateness of the fixation
- Distal phalanx fractures
    - Very common
    - Classified:
        - Tufts
        - Shaft
        - Intra-articular
            - Dorsal base avulsion
            - Dorsal base shear
            - Volar base
            - Complete articular
    - The tuft is an anchoring point for the specialized architecture of the digital pulp, a honeycomb structure of fibrous septae that contain pockets of fat in each compartment
    - The dorsal surface of the distal phalanx is the direct support for the germinal matrix of the nail.
    - FDP (volarly) and terminal tendon (dorsally) insert at the base of the distal phalanx. Fractures distal to those insertions are not subject to myotendinous deforming forces
    - Volar and dorsal base fractures are unstable
    - Mallet finger
        - Forced flexion of the DIP joint of an actively extended finger
        - Disruption of the terminal extensor mechanism
        - Tendinous injury vs bony avulsion fracture
        - Unopposed flexion of the FDP
        - Fractures that involve over 1/3 of the articular surface of the DIP joint will present with significant volar subluxation. Surgery may be indicated
    - FDP avulsion fracture of the distal phalanx
        - Forced hyperextension of an actively flexed finger
        - Ring finger is most common
        - Jersey finger
        - Requires surgery to restore flexion at the DIP joint
        - No role for conservative treatment
        - Leddy classification
- Thumb metacarpal fractures
    - Thumb MC head fractures

- Rare because the longitudinally directed force necessary to fracture the bone is dissipated at the CMC joint

§ Thumb MC shaft fractures
- Uncommon because of the absence of a stable proximal fixation of the base of the MC (CMC joint)
- Force directed to the shaft is transferred to the thumb base, resulting in a fracture through the MC base. These fractures usually occur at the metaphyseal-diaphyseal junction and are called epibasal fractures

§ Thumb MC base fractures
- Usually transverse or mildly oblique
- Occur at metaphyseal-diaphyseal junction
- Epibasal
  - o Typically displaced with an apex dorsal angulation
    - § Pull of the adductor pollicis, flexor pollicis brevis and abductor pollicis brevis on the distal fragment
  - o If angulation is greater than 30°, closed reduction with percutaneous pinning is recommended. Open reduction is not necessary
- Apex dorsal angulation: distal fragment is adducted and flexed
- Amenable to closed reduction and cast immobilization

§ Bennett's fracture
- Fracture subluxation
- Generally considered unstable
- Intra-articular fracture of the base of the thumb (2 pieces)
- Mechanism of injury: axial load in partial flexion
- Anterior oblique ligament keeps fragment attached to the trapezium
- APL is the deforming force of the metacarpal shaft "fragment"
  - o Pulls the MC shaft radially, proximally and dorsally

§ Rolando's fracture
- Comminuted (>2 fragments) fracture of the base of the thumb
- Difficult to reduce

Note: Today's Powerpoint presentation will be posted to the following web site in the days following the ASHT conference: www.handtherapyhub.com. Click 2013 ASHT Conference.

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