Fractures
Cindy Glaenzer PT, CHT

Bony Anatomy
• Epiphysis
• Physis
• Metaphysis
• Diaphysis
• Periosteum
• Endosteum

Two Types of Bone
• Cortical bone – compact bone
  • Concentrated in diaphysis of long bone
  • Houses osteons (contain osteocytes)
  • 80% of skeletal mass

Two Types of Bone
• Cancellous bone – trabecular or spongy
  • 20% skeletal mass
  • Concentrated at epiphysis and metaphysis of long bones
  • Metabolic turnover is greater than for cortical; usually faster healing

Fracture
Definition: A break in the cortical continuity of the bone.
• Energy absorbed by bone
• Mechanical & structural failure
• Loss of Continuity of Bone
• Vascular disruption at fracture site

Fracture Classification
• Location in Bone
  • Diaphyseal
  • Metaphyseal
  • Articular
Fracture Classification:

- Depth of fracture: complete, incomplete
- Angle: transverse, oblique, spiral, longitudinal, stellate
- Complexity: simple, comminuted or crushed
- Closed versus Open
- Intra articular vs. extra articular
- Avulsion

Pediatric Fractures:

- Buckle or Torus fracture
- Greenstick fracture

Pediatric Fracture Classification: Salter-Harris

- Salter I - separation through growth plate (physis)
- Salter II - injury through physis with part of metaphysis attached - most common
- Salter III - injury through physis; longitudinal fracture through epiphysis

- Salter IV - longitudinal fracture
  - extends into metaphysis, physis, and epiphysis;
  - complete anatomical alignment necessary to restore articular surfaces
  - extent of physeal plate damage unknown

- Salter V - Crush injury to germinal cells of epiphysis; premature closure of physeal plate
Three Phases of Fracture Repair

**Inflammatory Phase**
- (0-2 weeks)
  - Accumulation of a hematoma between fracture ends under elevated periosteum
  - Bone necrosis (osteocytes lose nutrition)
  - Proliferation of fibroblasts and osteoblasts
  - Invasion of leukocytes and macrophages

**Reparative Phase**
- (1 – 8 weeks)
  - Hematoma organizes – forms fibrin scaffold for repair cells
  - External cartilaginous callous forms from periosteum and internal callus from endosteum
  - Gradual increase in stability toward clinical union
  - New bone and osteogenic cells bridge fracture site

**Remodeling Phase**
- (2 – 6 months)
  - Occurs over prolonged period of time
  - Continuous bone resorption/ bone formation
  - Influenced by forces of stress
  - Bone is remodeled as osteoclasts reabsorb callous

Fracture Repair

Bone Healing

**Primary Healing:**
- No Callus formation
- Direct apposition of bone ends with compression
- Rigid fixation (substitute for callus)

**Secondary Healing:**
- Callus formation
- Slight movement /micro motion

Factors Affecting Healing

- Patient’s age
- Complexity/Character of fracture
- Systemic Disease
- Bone Disease/metabolic bone disease
- Medications
- Nutritional factors, ETOH, tobacco use

Factors Affecting Outcome:

- Compliance
- Motivation
- Cognitive status
- Emotional status
- Extent of injury: tendon, nerve, soft tissue, multiple fractures
- Joint stability
- Infections
- Ability to achieve anatomic reduction
- Prior functional level
- Comorbidities
Goals

**Surgeon:** Obtain and Maintain Anatomic reduction of the fracture/s.

**Therapist:** Restore the upper extremity function with the best attainable ROM and strength of the shoulder, elbow, forearm, wrist, fingers and thumb, in as pain-free and timely manner as possible.

*Stability *Mobility *Function

Achieving the Anatomic Reduction

- Cast with closed manipulation
- Percutaneous pinning
- Internal fixation
- External fixation
- Combination

Conservative

- **Closed Reduction**
  - Indication: stable fracture
  - Immobilized with cast or splint

Conservative management of fractures

**Advantages:**
Less chance of infection
No incision/scar

**Complications:**
Lose reduction
Edema
No access to skin/wounds
Cast: Too tight/ uncomfortable/Too loose

Surgical Intervention: Open Reduction and Internal Fixation

- Indications
  - unstable fx’s
  - fx’s requiring early motion
  - fx’s w/ high incidence of non-union
  - avulsion fractures (e.g. Central slip or Jersey finger)
  - intra articular fracture
  - fractures with a step-off
  - Joint subluxation

Surgical Intervention: Types of fixation

- Percutaneous Pins-Kirschner wires: open or closed
- Screws
- Plates-dorsal, volar, radial
- Spanning bridge plate
- External Fixation
- Wires
- Intramedullary Nails
- Bone Grafts +/-
Advantages of ORIF

• If stable allows function.
• If stable can start early motion.

Complications of Internal Fixation:

• Soft tissue injury
• Hardware can cause irritation
• Tendon ruptures
• Adhesions
• Pin site infections

Common Complications of Fractures

• Edema
• Pain
• Joint stiffness
• Tendon adhesions
• Decreased strength
• Nonunion
• Malunion/Bone length/angle/rotation alteration
• Nerve entrapments or compressions
• Osteo Arthritis

Complications:

Acute Compartment Syndrome

• 4 P’s-Pain, Pallor, Paresthesias, Pulselessness

“Frozen Shoulder” - adhesive capsulitis

Chronic Regional Pain Syndrome- CRPS
Reflex Sympathetic Dystrophy- RSD

Therapy Considerations: Fracture Management

• Therapists should have an understanding of:
  • Fracture stability/alignment-access x-rays if possible
  • Operative procedures performed- get op report
  • Potential dysfunction at uninvolved joints
  • Appropriate timing for ROM, splinting, strengthening
  • Balancing act between protection and applying controlled stress for motion and strength
Good history, understanding patient, empowering the patient through education.

• *** Motion or stress to the bone promotes bone healing.

General Therapy for all Fractures

Fracture protection – maintain stability
• Pain management
• ADL assessment/training
• Edema management
• Prescribe Exercises-A/AA/PROM
• Joint mobilization
• Sensory assessment and desensitization
• Strengthening
• Splinting for protecting/maintaining motion or to improve PROM- dynamic or static progressive
• Patient education
FRACTURES OF THE WRIST

Wrist Fractures
• 15% of all fractures in the body
• Bimodal- Children and women age 60-70

Distal Radius Alignment
Normal Radius
• Radial tilt: 22 degrees average
• Articulates with scaphoid and lunate and ulnar head through the sigmoid notch

Distal Ulna Alignment
• Ulnar head articulates with radius at sigmoid notch
• Separated from proximal row by TFCC
• Radius rotates around fixed ulna

Distal Radius Alignment
• Palmar tilt: 11 degrees average
• Articulates with scaphoid and lunate and ulnar head at the sigmoid notch

Radius and Ulna load bearing
1. Ulnar variance = length of ulna relative to radius
2. Neutral
3. Ulnar plus (ulna is longer)
4. Ulnar negative (ulna is shorter)
   Before diagnosing compare to other wrist.
Ulnar Variance

Reduction in distal radius length alters the force distribution through the radius and the ulna to the proximal row.
- Normal 80% radius and 20% ulna
- The ulnar side of wrist is not intended to be the primary weight-bearing joint
- Positive ulnar variance has a greater chance of TFCC injuries
- Ulnar sided wrist pain

Distal Radius Fractures:

- Colles
  Fall on an outstretched hand-FOOSH
  - Extra-articular
  - Complete fx, of distal radius w/ dorsal displacement
  - 80% require reduction

Colles fractures often do not stay reduced and need surgery to maintain alignment.

Distal Radius Fracture Types:

- Smith’s:
  - Reverse Colles fracture
  - Distal radius with volar displacement
  - Mechanism of Injury is fall with wrist flexed
- Barton’s:
  - Displaced and unstable fracture subluxation of the distal radius with the carpus following the articular fragment
  - Displaced Articular Rim fracture of the distal radius with volar or dorsal displacement
- Chauffeur’s:
  - Oblique fracture of the radial styloid

Distal Radius Fracture Treatment

- Kirschner wires: open or closed
- Percutaneous Pins
- Screws
- Plates-dorsal, volar, radial
- Spanning bridge plate
- External Fixation
- Bone Grafts +/-

- Closed manipulation and casting/splinting

External Fixation:

- External Fixation-provides traction to prevent fx shortening or angulation

Distal Radius fracture and volar plate tray

Cindy Glaenzer PT, CHT
Post Wrist Fracture Complications

- Stiffness, swelling, pain
- Malunion/radial shortening
- Nonunion
- DRUJ dysfunction
- RSD/CRPS
- Median nerve compression
- Radiocarpal arthritis
- Weakness
- Carpal instability
- Shoulder stiffness

Distal Radius Fracture
Anatomical Complications

Radial shortening is the most common, disabling deformity:
- slight shortening changes axial forces across wrist
- > 6mm - affects flexion, UD, and pronation, and grip
- < 6mm - affects forearm rotation

Dorsal tilt >10° ↓’s wrist flexion

Treatment: Wrist Fractures

- Edema control
- Pain management
- Splinting for stability, protection, Range of Motion- shoulder to fingers
- Observe movement pattern- reestablish independent wrist extension, assess muscle length
- Function
- Modalities
- Patient education-anatomy, help patient accept responsibility for their part in the rehab process, pathology

Therapy Progression

- Strengthening and endurance training
- Dynamic or static progressive splinting
- Work simulation/hardening
- Work/sport/activity training and/or modification

Functional Wrist ROM

- Ryu (1991): 40 flex and ext, 40 combined RD/UD
- Brumfield (1983): 10 flex, 35 ext
- Palmer: 5 flex, 30 ext, 10 RD, 15 UD
- Gartland and Werley: 45 ext, 30 flex, 50 sup/pro

Moral of story- Functional ROM is not full/normal ROM.
COMMON CARPAL FRACTURES

Carpal Fractures - Frequency
- Occur 10x's less frequent as distal radius fractures
- Scaphoid: account for 60-70% of all carpal fractures
- Triquetrum/Lunate: second most common-account for 20% of all fractures
- Hamate fractures- both the hook and dorsal
- Others: combined account for only 7-10% of carpal fractures

Scaphoid Fractures:
- 90% occur from force applied with wrist in dorsiflexion (FOOSH)
- Vulnerable to injury
  - Spans both proximal and distal rows
  - Principle bone to block extreme wrist ext
  - Difficult to diagnose - often made based on clinical signs
  - Pain in snuff box
- Variable healing times according to fracture site

Healing Time: Scaphoid Fractures
- Distal 2/3: 10-12 weeks
- Proximal 1/3: 12+ weeks
- Poor vascular supply
- Direction of fracture affects healing- horizontal quicker than vertical

Conservative treatment
Immobilization of Scaphoid Fracture
- Thumb spica long arm cast then short arm cast- IP free with wrist slight extension and radially deviated
- Literature demonstrates that there is no difference between LAC, SAC thumb spica and a wrist cast without the thumb included.

Complications: Scaphoid Fractures
- Non-union
- Carpal ligament injuries
  - Carpal instability
- Delayed diagnosis
- Normal anatomical alignment not restored
- Persistent pain
Surgical Treatment:
ORIF with bone graft Herbert screw, Russe Technique
• Immobilize 4-16 weeks in cast or orthosis with IP free until bone union

Preizer’s
• AVN of the scaphoid
• Etiology is unknown
• Can cause carpal instability if untreated

Other Carpal Fractures:
• Triquetrum: 2nd most common. FOOSH
• Lunate: Central wrist pain
• Trapezium: often associated with fractures/dislocations involving thumb
• Pisiform/Hamate: trauma over ulnar/volar wrist, proximal hypothenar eminence
• Capitate: rare because this carpal is in a centrally located and protected position
• Trapezoid: rare; crush or high energy impact

Kienbock’s
• Avascular necrosis of the lunate
• Associated with negative ulnar variance
• Varying degrees of disability – central wrist pain, limited extension, weak grip
• Point tenderness over dorsal aspect of lunate

Carpal Fractures: Mobilization Post Healing
• Focus on wrist and thumb ROM, and composite flexion and extension, thumb flexion with ulnar deviation
• May require protective splint between exercise post cast removal
• Functional ADL’s encouraged

THERAPY FOR CARPAL FRACTURES
Carpal Fractures-
Healed
- Static progressive or dynamic splinting for wrist flexion and extension or composite motion
- Grip strengthening
- Wrist strengthening within pain free range
- Sport of hobby specific training
- Work hardening depending on RTW status

Metacarpal Fractures:
Frequency
- 40-50% all hand fractures
- Relatively Quick healing
- Commonly seen in 1st and 5th digits

Metacarpal Neck Fractures
- Most common site, is the weakest portion
- Caused by compressive force- (blow with closed fist)
- Boxer’s Fracture in 4th or 5th metacarpal
- Angulation (rotation deformity) can cause pain in palm, claw deformity, trapping of digits)
- Can protrude into palm

Anatomical Considerations
- If including the MP’s in the splint, the MP’s need to be immobilized in flexion to keep the collateral ligaments lengthened
- Goal is to achieve alignment without rotation or shortening
- Shortening of 3-5 mm can produce intrinsic/extrinsic imbalance
- Malrotation= finger overlap
- Angulation tolerated better in 4/5th MC

Operative Indications
- Multiple fractures
- Open fractures
- Comminuted fractures
- Displaced fractures
- Malrotation
- Multitrauma
  - i.e. head injury
- Spiral fractures
  - Tend to be unstable
- Oblique fractures
  - Tend to shorten
**Surgical management of MC fractures**
- Intramedullary pinning
- Cross pinning
- Bone grafting
- External Fixator

**Therapy Considerations: Metacarpal Fractures**

**Evaluation**
- Edema
- Scar
- ROM
- Muscle length - intrinsic, extrinsic
- Observe movement pattern
- Joint tightness
- Strength - manual muscle testing as well as grip and pinch strength

**Edema Management**
- MC fx’s can result in soft tissue damage
- Often excessive dorsal edema

**Extensor Tendon Adherence**
- Common because less soft tissue between extensors and MC's
- Result in MCP extension lags and extrinsic extensor tendon tightness
- Treatment: isolated EDC exercises, scar massage, retrograde massage, FES, combined wrist/finger flexion, modalities

**Limited MP flexion**
- MP joint contractures common w/metacarpal head and neck fractures
- Static progressive or dynamic MP flexion splinting
- Composite wrist and finger flexion
Proximal / Middle Phalangeal Fractures

Types of Fracture

- Type varies
  - Oblique, transverse, spiral
- Spiral/oblique tend to be unstable
- Often cause soft tissue adherence
- Comminution = more soft tissue damage

Management

- Reduction and Immobilization
- Remember that the Extensor tendons and FDS/FDP are in close proximity to the proximal phalanx. Tendon adhesions easily develop
- Surgery:
  - Percutaneous Pins
  - Screws
  - Plates

Complications:

- PIP flexion contracture
- Limited active PIP extension
- Tendon adherence at fx site

Proximal & Middle Phalanx-Treatment

- Edema control
- Splinting
  - Hand based
  - Buddy taping
- Motion:
  - AROM
  - AAROM
- Once Healed
- PROM/dynamic splinting
- Strengthening
- Functional activities

Proximal & Middle Phalanx with Internal Fixation:

- Can start motion earlier due to stability of fixation
- Addition of scar management
- Soft tissue involvement
Distal Phalanx

Frequency / etiology

- Account for 50% finger fractures
- Thumb/middle most commonly injured
- Crush common mechanism of injury
- Classified by location
- Heal w/out excessive treatment

Tuft Fractures

- Crush/comminuted fx of fingertip
- Painful- hematoma
- Soft tissue injury
- Rehab:
  - Restore DIP motion
  - Desensitization
  - Protective splinting to DIP

Distal Phalanx Base fracture with extensor tendon: Mallet Finger Fractures:

- Extensor tendon avulsion fx or dorsal intra-articular fx
- “Flexion drop” deformity
- Tx: Mallet splint
  - Slight hyperextension
- A/PROM to MP/PIP
- Check for laxity at the PIP joint

Mallet Finger

Mallet splint- 6-8 weeks continuous!
  - Slight hyperextension
  - Stax Splint
  - Custom splint for DIP
**Check for laxity at the PIP joint- may need to block PIP from hyperextending**
  - A/PROM to MP/PIP
  - Watch skin

Mallet Finger with Fracture:

- Once healed/stable, d/c daytime splinting with continued night splinting. (6-8 weeks is standard)
- Watch for extensor lag. (resume splint)
- Resume motion/normal activities.
  If splinting fails may need surgery.
Complications Distal Phalanx fx:
- Numbness
- Sensitivity or tenderness
- Limited DIP ROM
- Nail abnormalities

Fractures of the Thumb
- Follows similar guidelines as for digits
- Thumb spica splint for immobilization
- Special considerations:
  - Thumb joints can lose motion faster than in fingers
  - Motion at basal joint helps when MP joint motion is lost
  - Prevent 1st web space contracture

Thumb Fractures
- Bennett Fracture:
  - Most frequent
  - Fracture dislocation at CMC
  - Oblique intra-articular metacarpal fracture
- Rolando Fracture:
  - 3 part intra-articular fracture at base of metacarpal

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    - Chapter 26, Fractures of Metacarpals and Phalanges: General Principles of Surgical Management
    - Chapter 29, Hand Fracture Fixation and Healing: Skeletal Stability and Digital Mobility
    - Chapter 73, Rehabilitation of the Hand and Upper Extremity: Role of Early Mobilization
    - Chapter 76, Management of Carpal Fractures and Dislocations
    - Chapter 127, Functional Fracture Bracing

Bibliography:
  - Chapter 28, Fractures: General Principles of Surgical Management
  - Chapter 29, Hand Fracture Fixation and Healing: Skeletal Stability and Digital Mobility
  - Chapter 73, Management of Carpal Fractures and Dislocations
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  - Chapter 29, Management of Carpal Fractures and Dislocations
  - Chapter 127, Management of Distal Radius Fractures
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