Wrist Biomechanics and Instabilities
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Objectives

• Wrist Biomechanics
  – Essential anatomy of the wrist
  – Carpal Kinematics
  – Force Transmission
  – Proprioception
• Thoughts on Wrist Rehabilitation
  – Instabilities
    – CID
    – CIND
    – CIC

ESSENTIAL ANATOMY OF THE WRIST

Boney Anatomy

• Bones of wrist
  – Complex shapes
  – Intricate articulations with each other
  – Radius to carpus
  – Carpal bones with one another
• Grossly wrist motion is combination of motion at:
  – Radiocarpal Joint
  – Midcarpal Joint

http://upload.wikimedia.org/wikipedia/comm ons/f/f6/Carpus_%28left_hand%29_-_ animation02a.gif

Carpal Ligaments Extrinsic

Essential Anatomy of the Wrist

• Contributors to a functional stable wrist
  – Boney anatomy
  – Ligamentous structures
  – Proprioception
  – Muscle Contraction as a stabilizer
Extrinsic Ligaments

- **Palmar Radiocarpal**
  - RS (Radioscaphoid)
  - RSC (Radioscaphocapitate)
  - LRL (Long radiolunate)
  - SRL (Short Radiolunate)

- **Palmar Ulnocarpal**
  - UC (ulnocapitate)
  - Utq (ulnotriquetral)
  - UL (ulnolunate)

- **Dorsal Radiocarpal**
  - DRC (dorsal radial carpal)

Carpal Ligaments Intrinsic

- **DIC**
- **TqHC**
- **LT**
- **CT**
- **SL**
- **SC**
- **SRT**
- **TT**
- **DRC**

Intrinsic Ligaments

- **S-L**
  - Dorsal portion stronger
- **L-T**
  - Palmar portion stronger
- **DCR Interosseous ligs**
  - Very strong

- **Midcarpal**
  - DIC
    - Helps to stabilize LC joint
  - TqHC
    - Stabilizer of PCR
  - STT
    - Stabilizes scaphoid tuberosity
  - SC
    - Stabilizes scaphoid tuberosity

Carpal Ligaments Rich with Mechanoreceptors

- **DIC**
- **TqHC**
- **LT**
- **CT**
- **SL**
- **DRUL**
- **PRUL**

Carpal Kinematics

- Let’s review
  - 1. Which carpal row is more stable and acts as one unit?
  - 2. Which carpal row has more motion between the bones within that row?

Wrist Biomechanics

CARPAL KINEMATICS
Carpal Kinematics

- Answer 1 = DCR
  - DCR has very little motion between bones, moves as one
- Answer 2 = PCR
  - More motion between these bones
  - More variety of movements of bones when wrist motion occurs

Let’s Review again

- 1. What happens with wrist flexion/extension at the PCR?
- 2. What happens with wrist RD/UD at the PCR?
- 3. What do the bones of the PCR want to do and how do they stay balanced?

Wrist Kinematics

- Wrist Radial and Ulnar Deviation

  - More detail the triquetrum moves distally on the slope of the hamate
  - UD
    - PCR extends and UD
    - More detail the triquetrum now moves distally on the slope of the hamate (see you tube video on wrist kinematics can really visualize this)

Carpal Kinematics

- Answer 3
  - Scaphoid potential energy flexion, Triquetrum = extension
  - SL-LT ligs create balance between these forces
Force Transmission

• REVIEW
• Force travels through wrist from
  – 3rd MC
  – To CSL joint at Midcarpal joint
  – To Radiocarpal joint
  • RS 56.56%
  • RL 29.35%
  • UL 10.21%
• What would happen to force distribution with RD/UD??

Carpal Ligaments Rich with Mechanoreceptors/Proprioception

Proprioception

– Dorsal and Triquetral lig tend to be more densely innervated with mechanoreceptors
– Volar Radial ligaments stout collagen rich but lacking mechanoreceptors
  • Radial column of wrist accepts loading forces
  • Role to stabilize with force transmission

Proprioception

  – Discussed findings of innervation patterns in ligaments of wrist
  – Proposed how these findings can translate to therapeutic intervention in wrist injuries

"The field of wrist proprioception and rehabilitation is vast, and we need a collective contribution and collaboration between surgeons and therapists to further our knowledge in this realm."

Proprioception

• Basic Rehabilitation
• Proprioceptive awareness
• Joint Position Sense
• Kinesthesia
• Conscious Neuromuscular Control
• Unconscious Neuromuscular Control
Proprioception

Yeah it says oriole magic your in B-more

Muscles as Stabilizers

- Muscle Loading and Carpal Alignment
  - Contraction of certain muscles may improve carpal alignment
    - SL friendly = FCR, FCU, APL, ECRL; cause scaphoid supination and decreased stress to SL
    - LT friendly – ECU
      - MCI Friendly – FCR, ECU

Muscles as Stabilizers

<table>
<thead>
<tr>
<th>Muscles</th>
<th>Supinator</th>
<th>Pronator</th>
<th>SL</th>
<th>LT</th>
<th>MCI</th>
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<tbody>
<tr>
<td>FCR</td>
<td>X – But only for Scaphoid with partial SL injury</td>
<td>X</td>
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Dart Thrower’s Motion

- Widening of SL interval has been shown in 4D computed tomography study with DTM
- Wolfe, A. & Wolfe, S. raise the question in their article on SL rehabilitation: Is their a limited DTM range safe in the repaired SL?

Role of DTM

- Dart Throwing Motion (DTM)
  - Most functional tasks are performed in this plane of motion
  - With this motion more action is at midcarpal joint thus limiting stress to radiocarpal joint
  - Less motion of Scaphoid and Lunate
  - What next.... Implications for early motion protocols for fractures, SL injuries, and ligament repairs
    - Whoa wait still need to clarify things
Thoughts on Wrist Rehabilitation

• Let’s not just think of the wrist as motion and strength
• What do we need from our wrist?
  – Be able to accept and transfer force
  – Functional range
  – Protective reflexes

Thoughts on Rehabilitation

• What is functional Motion in the wrist?
  – *Palmer et al.*: 30 degrees ext., 5 degrees flexion, 10 degrees RD, 15 degrees UD
  – *Ryu et al.*: 40 degrees ext., 40 degrees flexion, 40 degrees combined rd/UD
  – *Garland and Werley*: 45 degrees ext., 30 degrees flexion, 15 degrees RD, 15 degrees UD and 50 degrees of each sup/pro

Thoughts on Rehabilitation

• Let’s get more sophisticated
  – Is there an arc of motion that limits stress to the injured structure?
  – Is there a muscle contraction that has been show to improve stability for injured structure?
  – How can we work on improving proprioception lost during immobilization?

Thoughts on Rehabilitation

• Consider what is the injured structure
• What are the established guidelines to promote healing of that structure
• What are the needs of your patient?
  – Athlete vs Knitting Guru
• What has happened to the protective proprioceptive reflexes due to immobilization?

INSTABILITIES
What Makes a Stable or Unstable Wrist?

CID vs. CIND
CID + CIND = CIC

• CID = carpal instability dissociative
• Instability between carpal bones in same row
• S-L and L-T tears
• CIND = carpal instability non-dissociative
• Instability between rows either radiocarpal or midcarpal
• Seen with patients with ligamentous laxity, trauma
• Mid carpal instabilities

Proximal Carpal Row (PCR)

• Scaphoids potential energy is for Flexion
• Triquetrum’s potential energy is for Extension
• This potential energy is facilitated by the SL and LT ligament
• The result in normal circumstances is a balanced lunate in the PCR.

Promiscuous Lunate

• Lunate goes with carpal bone that it is still connected with
  — Scaphoid flexes
  — Triquetrum extends

  — S-L disruption, lunate goes with triquetrum = extension of lunate = DISI
  — L-T disruption, lunate goes with scaphoid = flexion of lunate = VISI
Scapholunate Dissociation

- Most Common Carpal Instability
- History of a fall on extended and UD hand
- Wrist weakness and pain with loading

Scapholunate Dissociation – How Long??

- Timing is everything
  - Acute < 3 weeks
  - Healing potential
  - Sub acute 3-6 weeks
  - Chronic > 6 weeks
  - Reducible?
  - Arthritic changes?

Scapholunate Dissociation – What are the films telling us?

- Pre dynamic
  - Dorsal wrist pain
  - Positive Watson’s
  - No radiographic evidence of injury
  - CT, MRI, arthrography, or arthroscopy may show injury in instances of no radiographic evidence
  - Drive through sign – capitate head is seen through open SL interval during arthroscopy

Scapholunate Dissociation – What are the films telling us??

- Dynamic
  - Isolated complete or partial SL tear
  - Can be seen radio graphically with stress views
    - Clenched fist view

Scapholunate Dissociation – What are the films telling us??

- Static
  - Ruptured SL ligament
  - Ruptured palmar ligaments
  - Radio graphic evidence in non stressed views
  - What does that look like???
Radiographic Changes
SL Dissociation

- **PA VIEW**
  - Cortical Ring Sign - scaphoid flexes and tuberosity is superimposed on waist
  - Terry Thomas Sign
    - > 3mm, suspicious
    - > 5mm, diagnostic
  - Reduction in Carpal Height
  - Triangular Shape of Lunate

- **Lateral View**
  - Increased Scapholunate angle
  - Normal is between 30 and 60 degrees
  - **DISI = angle greater than 60**

S-L Tear

- 2 signs on this x-ray - what are they??

Radiographic Changes
SL Dissociation

**SL Provocative Test**

- Scaphoid Shift Test/Watson’s:
  - Patients wrist placed in ulnar deviation and slight extension. Examiner places thumb on tubercle of scaphoid and flexion of scaphoid is blocked as patients wrist is moved into radial deviation slight flexion.
  - Instability will cause scaphoid to sub lux dorsally.
  - When pressure is removed a painful clunk will be noted in a positive test.
  - There is a 30% rate of false positive.
  - False positives can be decreased by clenching fist during testing.
Scaphoid Shift/Watson’s Test
UD and slight extension to... RD and slight flexion

Treatment of SL Tears
Conservative
• Grade I and II
• Hold until stiff, stable – immobilize 3-12 weeks
  • Thumb Spica Orthosis
• Then immobilize intermittently (between exercises)

Treatment of S-L Tears
Conservative
• After immobilization period initiate gentle AROM
  – What arc of motion would be beneficial to start with?
• When to start PROM? Be judicious remember our goal is stability over mobility
• Strength
  – Isometrics DTM
    • FCR if incomplete SL – Why?
    • Be cautious with power grip strength – Why?

Surgical Treatment of SL Tears
• Scapholunate Ligament Repair
http://www.eatonhand.com/img/img00085.htm

Surgical Treatment SL Tear
• Dorsal Capsulodesis
  – Dynamic Instability
    • Augment ligament repair
  – Static instability
• B-L-B Grafts
  – Portion of SL joint cut out and a bone – tendon-bone graft placed here.
  • Common donor dorsal capitae-hamate ligament
• Tendon Weaves
  – Pulls carpal bones into alignment through tendon woven through the bones

Examples of Tendon Weaves
Surgical Treatment

• RASL (Reduction Association of Scaphoid and Lunate), Rosenwasser et al. 1997
  – Repair of what is left of SL then with Herbert screw join scaphoid and lunate to prevent capitate from pushing down into space. Screw is left in for up to a year to create fibrous union.
  – Caloia, M., Caloia, H., & Pereira, E. 2011- found success with arthroscopic RASL (ARASL) in a review of 9 wrists

Therapy Post S-L Repair or Reconstruction

• Knowledge is Power – find out what type of surgery was performed --- this may change your treatment
• Thumb spica cast or orthosis for 8 weeks
  – What happens to our proprioceptive reflexes during this time?
• Education – expected outcomes, might not have full motion that is OK
  – Goal = stability over mobility

Treatment SL Tear

• Rehab after Repair / Reconstruction
  – 8 weeks in a thumb spica cast or orthosis
  – Forearm Based thumb spica orthosis for another 4 weeks once therapy is started used intermittently.

Therapy Post S-L Repair or Reconstruction

• Early Mobilization Phase
  – Gentle AROM, emphasize DTM first
  – Proprioceptive training
    • DTM AROM
    • Joint Position Sense
    • Mirror box/Visual influence
  – Scar management

Therapy Post S-L Repair or Reconstruction

Variations in Rehabilitation Post SL Repair

• PROM
  – Starts a couple weeks after AROM
  – Be judicious and gentle ensuring not to destabilize repair
  – Could this be done in more stable arc of DTM?
• Strength
  – Pain free and good mobility
  – Start isometrics in DTM working to isotonics
  – Perturbation exercises eg. Gyroscope, mini baps board
  – Reactive muscle activation
• Dynamic or Static Progressive Orthosis – not really in the plan

• Dorsal Capsulodesis
  – AROM only, little or no passive flexion exercises except per MD
• B-L-B Grafts – Rehabilitation
  – One should avoid early loading which can cause failure
  – Return to normal functional use generally near 4-6 months
• RASL
  – Motion can begin early than SL repair
    • 4-6 weeks
Treatment SL Tear

- Options for Partial Wrist Fusions =
  - SL fusion
  - STT fusion
  - SC Fusion
  - SLC Fusion
  - RSL Fusion with excision of distal scaphoid
- Choice in fusion depends on location of arthritis within the carpus

Partial Wrist Fusions Rehab

- Long or short arm cast – until solid (6-12 wks)
- Pins removed after immobilization period (if this is the form of fixation utilized)
  - Patient usually referred to therapy at this time
  - Short arm thumb spica orthosis for an additional 2-4 weeks then wean

Partial Wrist Fusions Rehab

- A/AAROM of wrist 6 + weeks
- Gentle PROM after healed (8-10 weeks)
- Progress to strengthening at 10-12 weeks post operatively
- “Work Hardening” after 16 weeks

Partial Wrist Fusion Expectations

- Depends on type of fixation, bone graft, and healing rate
- Expect decreased ROM (40-60% loss)
- Goals: decrease pain, increase stability, and strength of wrist
- Changed carpal mechanics

Treatment SL Tear

- Salvage Procedures
  - Proximal Row Carpectomy
    - Non arthritic capitate – Why?
  - Scaphoid excision with 4 corner fusion
    - If there is capitate arthritis
  - Total Wrist Arthroplasty – low demand patient
  - Wrist Fusion

SLAC

- Scapholunate advanced collapse
- Progressive instability causing advanced arthritis
- Caused by S-L (DISI)
SLAC wrist

• Stages of SLAC
  • Stage 1 = styloid scaphoid DJD
  • Stage 2 = DJD of proximal scaphoid facet
  • Stage 3 = Capitulunate DJD
  • Stage 4 = Radiolunate/Pancarpal DJD

SLAC Wrist

• Characterized by pronounced impairment of pain increased with axial loading and RD.
• Degenerative changes between the scaphoid, lunate, capitate, and radius.
• Can result from scaphoid non union or SL tear. What would this be called from a non union???

SLACin Now What??
Proximal Row Carpectomy
Four Corner Fusion

Rehab of Proximal Row Carpectomy (PRC)

• Wrist AROM at POW 4
• Wrist PROM at POW 6
• Strength at POW 6
• Expectations:
  – 30-50% reduction in wrist motion
  – 20-50% reduction in grip strength (altered mechanics and length)

Four Corner Fusion
See Partial Wrist Fusions for Treatment

Moving on from all things SL lets check out the other side
LT Tears

- A complete tear of LT is not enough to produce static instability
  - Must include DRC
    - This allows the lunate to assume a flexed position
- Volar segment of the LT is the strongest
- High energy Trauma (perilunate dissociation)
- Most present later with ulnar sided wrist pain

LT Tears

- Convex outline of PCR is interrupted by a step off between the lunate and triquetrum

http://www.radiologyassistant.nl/en/42a29ec06b9e8

Volar intercalated segment instability = VISI
Angle = < 30

Tests for L-T involvement

- Shear Test
  - Kleinman:
    - Elbow on the table with forearm in neutral
    - Place thumb over dorsal aspect of lunate to stabilize the lunate
    - Then with opposite hand on volar surface of pisotriquetral joint provide a force volar to dorsal
    - This creates shearing force at LT
Tests for L-T involvement

- Ballottement Test/Reagan/Shuck
  - Stabilize the lunate with the thumb and index finger
  - With other hand rock (ballotte) the pisotriquetral unit, volarly and dorsally
  - Positive test is noted with pain, crepitus, and laxity.

Test for L-T Involvement

- Ulnar Snuffbox compression test/Linscheid’s Test
  - Compression is applied at the ulnar snuffbox
  - Compress the triquetrum against the lunate
  - This creates pain in a positive test

Treatment of LT Tears

- Non-operative (isolated tears without instability)
  - Rest, utilization of orthosis, injection, and anti-inflammatories
  - Acute Injury cast or orthosis for 3-8 weeks
    - Padding at PT complex and dorsal DR to improve alignment of PT complex with PCR
    - During initial rehab orthosis is used for 2-4 weeks
    - Strength begins after 2-4 weeks of mobilization with limited symptoms

Conservative Treatment L-T Tears

  - Found with contraction of ECU decreased supination and tension at LT interval
  - In cadavers, low numbers, needs further clinical trials but interesting

Treatment of LT Tears

- Partial Tear = debridement
- Direct Repair
- Ulnar Shortening (dynamic tears) = tighten ulnocarpal ligaments enough to eliminate symptoms

Treatment of LT Tears

- Rehabilitation after Debridement
  - Wrist orthosis is utilized for 1-3 weeks post operatively
  - Initiation is dictated by comfort and can start as early as week one
  - Progress to light loading and increasing functional use happens over time as tolerated
Treatment LT Tears

- Rehabilitation after Direct Repair
  - Short arm cast or orthosis for 8 weeks
  - After pin removal volar wrist orthosis for 4 more weeks
  - ROM initiated at time of pin removal
  - Impact loading should be avoided for 4-6 months

CIND

- Can be either
  - Radiocarpal – RA, madelungs, excessive distal ulna excision, pure radiocarpal dislocation
  - Midcarpal Instability (MCI)
    - Palmar MCI
    - Dorsal MCI
    - Extrinsic MCI

MCI

- This is difficult to diagnose because static imaging studies are often unremarkable.
- Most notable characteristic is the abrupt carpal shift that a clunk

CIND, We will focus on Palmar MCI

- If Palmar MCI instability develops:
  - Scaphoid flexion movement dominates
  - Proximal row collapses into VISI
  - Patients symptoms occur when a sudden shift occurs from a VISI position in radial deviation to physiologic position as moving into ulnar deviation
  - Patient will feel an abrupt clunk

Pathomechanics Palmar MCI

- TqHC, SC, STT ligaments prevent:
  - Flexion of the PCR when axial loads are applied
  - Abrupt transition from flexion to extension with UD
- Injury to these ligaments cause:
  - An inability to transfer loads without collapsing into a VISI pattern
  - Rotation of the proximal row from flexion to extension is not smooth during ulnar deviation
  - When the triquetrum and hamate meet with UD there is a violent shift of the PCR into extension
Mid carpal Instability Testing

- Mid carpal shift test/Catch up Clunk Test
  - Force is applied to the capitate palmarly as the wrist is moved from radial to ulnar deviation with an axial load
  - A positive test will result in a clunk and pain at a point just beyond neutral as the wrist moves into ulnar deviation.
  - Indicates instability but may also be heard with SL or LT instability as well.


Mechanism of Injury Palmar MCI

- Most common cause is hyperextension injury
- Hypermobility or ligamentous laxity
- Exact incidence is unknown
- Complaints of ulnar sided wrist pain
- Do not use their hand normally because afraid of sudden painful clunk
- Afraid to use hand functionally
- Loose grip when clunk occurs
- Avoidance and abnormal use occurs

Treatment of Palmar MCI

- Initially conservative treatment
  - Immobilization
    - Pisiform boost/midcarpal stabilization orthosis

Treatment Palmar MCI

- Orthosis
  - Pisiform boost orthosis

Conservative Treatment MCI

- Isometrics
  - FCR
  - ECU

Conservative Treatment MCI

- Strength/What to avoid initially
  - Isotonics
  - Power grip
  - Repetitive wrist motion
  - But Why???
  - Patient education, how does this translate into life
Treatment of Mid Carpal Instability

• Operative Management
  • Aims to prevent pathologic motion and stabilize PCR
    – Extra articular causes – joint leveling procedures
    – Arthroscopic palmar MC capsular shrinkage
    – Tendon reconstruction of ligaments
    – MC fusion
    – Radiolunate fusion

Moving on to CIC
http://www.wikem.org/wiki/Perilunate_and_Lunate_Dislocations

Etiology Perilunate Dissociation

• Young males 20’s-30’s
• Sport, traffic, or work accident (high velocity/force)
• 5% of all carpal injuries
• 2/3 involve transverse fracture through scaphoid

Greater and Lesser Arches

• Fractures associated with perilunate dislocations =
  – Prefix Trans
  – Greater Arch Injuries
• Pure perilunate dislocation without fractures = lesser arch injuries

Progressive Perilunate Instability

• Mayfield et al. 1976
  – Four Stages
    • Stage I (SL)
    • Stage II (calitolunate)
    • Stage III (triquetrolunate)
    • Stage IV (radiolunate)

http://radiographics.rsna.info/content/28/6/1771.full

Treatment Mid Carpal Instability

• Post Operative Rehabilitation
  – After Soft tissue repair/pinning = 8 weeks of immobilization
    • Volar wrist orthosis is used intermittently after this initial period of immobilization
  – Avoid heavy loading, power grip, and weight bearing for 6 months

http://radiographics.rsna.info/content/28/6/1771.full
Progressive Perilunate Instability

- Stage I
  - Hyperextension force to wrist
  - Scaphoid trapezium trapezoidal ligament becomes taut
  - Force for extension across Scaphoid
  - Lunate cannot extend as much as it is constrained by L & SRL
  - Scaphoid fracture or SLIL tear

- Stage II
  - If force of extension continues, distal row displaces dorsally
  - RSC avulsed from radial styloid
  - Tear in palmar wrist capsule
  - And defect occurs in space of poirer

- Stage III
  - IF force continues –
  - As capitate translates dorsally tension from TqHC creates increased extension of triquetrum and…..
  - LT dissociation and tearing of ulnotriquetral ligament

- Stage IV
  - Lunate is held in place by dorsal capsule, Palmar RL ligaments
  - Capitate is pulled palmarly pushing on lunate and..
  - Lunate dislocates into carpal tunnel

Perilunate Dislocation

- Postoperative Rehabilitation
  - 8 weeks long arm thumb spica cast
  - Thumb spica orthosis for an additional 4 weeks
  - Gentle AROM is first initiated then progressing to passive as appropriate

CIC

- Early mobilization
  - Early gentle proprioceptive training ideas
    - Joint position sense
    - Mirror therapy
    - Moving in the arc of motion that is natural for the wrist and protective which is................
CIC

- Later PROM can be initiated but judiciously – remember our goals
- Strength
  - Weighted ball DTM
  - Grip strength
- RMA
  - Perturbation training

Thank You!!!