REFERENCES TO OFF-LABEL USAGE(S) OF PHARMACEUTICALS OR INSTRUMENTS

- Nothing to disclose

DISCLOSURE OF RELEVANT FINANCIAL RELATIONSHIP(S) WITH INDUSTRY

- Nothing to disclose

TOPICS

- Anatomy
  - Epidemiology, Diagnosis, and Treatment
    - Fractures
    - Dislocation
    - Instability/Ligament Injury
    - Valgus extension overload
    - Muscle tendon injury
    - Olecranon Bursitis
    - Acute compartment syndrome

LEARNING OBJECTIVES

- Summarize the key anatomical landmarks and structures of the elbow and forearm that are commonly involved in sports related injuries
- Explain the etiology and epidemiology of musculoskeletal injuries of the elbow and forearm as they relate to the injured athlete
- Implement the appropriate diagnostic evaluation for traumatic and overuse injuries of the elbow and forearm in athletes
- Create a treatment plan for the athlete with the injured elbow and forearm
- Discuss the epidemiology evaluation and treatment of neurovascular injuries of the elbow and forearm in the injured athlete
ANATOMY – OSSIFICATION

- Elbow Ossification Centers appearance
  - Capitellum (1-2 years)
  - Radius (3-4 years)
  - Internal – medial epicondyle (5-6 years)
  - Tricipital (7-11 year)
  - Olecranon (8-11 years)
  - External – lateral epicondyle (10-11 years)
  - Medial epicondyle is last to close (18-20)

CASE

- 5 year old was sliding down banister before leaving the house for t-ball practice
- Fall unrestrained
- Mother heard a thud
- Patient initially seen at ER and diagnosed with radial neck buckle fracture
- 3.5 week follow-up radiograph

ANATOMY – ARTICULATIONS AND MOVEMENT

Humerus, Radius, & Ulna

Ulnohumeral
- Composed of olecranon of ulna with olecranon fossa of humerus
- Flexion – Biceps brachii, brachialis, and brachioradialis
- Extension – Triceps and anconaeus
- ~ 0-140°

Radiocapitellar
- Formed laterally by convex humeral capitellum with concave radial head
- Supination and pronation rotational movements at this joint
- ~ Pronation 75° and supination 85°

Radio-ulnar joint
- Lateral ulna and radius – radius rotates over top of stationary ulna
- Pronation – Pronator quadratus and pronator teres
- Supination – supinator, biceps brachii aid in supination
**ANATOMY – LIGAMENTS**

**Lateral elbow**
- Lateral collateral ligament complex:
  - Radial collateral, lateral UCL, & accessory collateral ligament
  - Annular ligament allows radial head rotation
  - Rarely injured

**Medial elbow**
- Primarily stabilized by ulnar collateral ligament
  - Anterior, posterior oblique, transverse
  - Flexor carpi ulnaris is primary muscle stabilizer of medial elbow

**ANATOMY – MUSCLES**

- **Flexion/Extension**
- **Wrist Flexion/Pronation**
- **Flexor Carpi Radialis, Palmaris longus, Flexor Carpi Ulnaris, Flexor Digitorum Superficialis**
  - Pronator tarsia (medial epicondyle and coronoid of ulna to lat mid radius)
- **FD Profundus & pronator quadratus originates from ulna**

- **Wrist extension/Supination**
- **Extensor Carpi Radialis Longus, Extensor Carpi Radialis Brevis, Extensor Digitorum, Extensor Digiti Minimi, Extensor Carpi Ulnaris**
  - Supinator (lat epicondyle and ulnar mid radius)

**ANATOMY – NERVES AND VESSELS**

- **Median**
  - Passes anteriorly, covered by bicipital aponeurosis
  - Splits between head or pronator tarsia and travels deep to FDS
  - AH–motor
- **Ulnar**
  - Passes posteromedially and through cubital tunnel under FCU
- **Radial**
  - Passes antecubital between brachialis and brachioradialis
  - Splits into PIN (between supinator muscle) & superficial radial nerve
<table>
<thead>
<tr>
<th>Sports</th>
<th>Common Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Racquet sports</td>
<td>Lateral epicondylitis with backhand</td>
</tr>
<tr>
<td>Golf</td>
<td>Medial epicondylitis on downward with trailing arm or lateral with leading arm</td>
</tr>
<tr>
<td>Basketball</td>
<td>Posterior impingement with follow through</td>
</tr>
<tr>
<td>Bowing</td>
<td>Flexor pronator synovitis</td>
</tr>
<tr>
<td>Football</td>
<td>Valgus stress with throwing, dislocation, hyperextension, and bursitis with trauma</td>
</tr>
<tr>
<td>Gymnastics</td>
<td>Radiocapitellar load with posterior impingement</td>
</tr>
<tr>
<td>Archery</td>
<td>Valgus stress with medial traction, lateral compression, and posterior impingement</td>
</tr>
<tr>
<td>Rock Climbing</td>
<td>Biceps tendinitis</td>
</tr>
</tbody>
</table>

**PHYSICAL EXAMINATION SKILLS**

- Many tests for many conditions
- "None of the described tests can provide adequate certainty to rule in or rule out a disease based on sufficient diagnostic accuracy."
- Combination of history and multiple exam maneuvers and knowledge of anatomy is key
- Article has nice description of exam maneuvers

<table>
<thead>
<tr>
<th>Condition</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total distal biceps rupture</td>
<td>Hook test</td>
</tr>
<tr>
<td>Passive forearm pronation (PFP) test</td>
<td></td>
</tr>
<tr>
<td>Supination/Pronation test</td>
<td></td>
</tr>
<tr>
<td>med/lateral belly squeeze test</td>
<td></td>
</tr>
<tr>
<td>Bicipital aponeurosis (BA) flex test</td>
<td></td>
</tr>
<tr>
<td>Biceps crease interval (BCI)</td>
<td></td>
</tr>
<tr>
<td>Biceps crease ratio (BCR)</td>
<td></td>
</tr>
<tr>
<td>Total triceps rupture</td>
<td>Triceps squeeze test</td>
</tr>
<tr>
<td>(triceps) belly squeeze test</td>
<td></td>
</tr>
<tr>
<td>Posteromedial impingement syndrome</td>
<td>Arm bar test</td>
</tr>
<tr>
<td>Posteromedial impingement test/valgus overload test</td>
<td></td>
</tr>
<tr>
<td>Medial collateral ligament (MCL) insufficiency</td>
<td>Moving valgus stress test</td>
</tr>
<tr>
<td>Valgus stress test/ligamentous instability test</td>
<td></td>
</tr>
<tr>
<td>Milking maneuver</td>
<td></td>
</tr>
<tr>
<td>Posterolateral rotatory instability (PLRI)</td>
<td>Table-top relocation test</td>
</tr>
<tr>
<td>Stand-up test/chair push-up test</td>
<td></td>
</tr>
<tr>
<td>Push-up test</td>
<td></td>
</tr>
<tr>
<td>Lateral pivot shift test (awake/under anaesthesia)/posterolateral rotatory apprehension test</td>
<td></td>
</tr>
<tr>
<td>Posterolateral drawer test</td>
<td></td>
</tr>
<tr>
<td>Lateral epicondylitis/tennis elbow</td>
<td>Cozen’s test</td>
</tr>
<tr>
<td>Polk’s test</td>
<td></td>
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<tr>
<td>Maudsley’s test/middle finger resistance/extension test</td>
<td></td>
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<tr>
<td>Mill’s test</td>
<td></td>
</tr>
<tr>
<td>Kaplan sign/test</td>
<td></td>
</tr>
<tr>
<td>Grip strength test (5%–8%–10% decrease)</td>
<td></td>
</tr>
<tr>
<td>Medial epicondylitis/Golfer’s elbow</td>
<td>Epicondylitis medialis (shear) test/Golfer’s elbow test</td>
</tr>
</tbody>
</table>

**FRACTURES**

- In pediatric patients remember the ossification centers
- Obtain AP, lateral at minimum
- Consider imaging of the CL side
- On lateral view radiocapitellar line and anterior humeral line bisect capitellum
- Baum’s angle assess carrying angle (compare to contralateral: normal ~0–25) varus deformity
- Posterior fat pad is an elbow effusion and likely sign of fracture
FRACTURES – SUPRACONDYLAR

- Most common pediatric elbow fracture
- Most commonly a result of a FOOSH
- Olecranon fossa relatively thin between condyles
- May be associated with neurovascular injuries with higher grade injuries
- Posteromedial displacement: brachial artery and median nerve
- Posterolateral displacement: radial nerve
- Compartment syndrome

FRACTURES – SUPRACONDYLAR

- Gartland Classification
  - Type I – Posterior splint/cast for 2-3 weeks, repeat x-ray in 1-2 weeks?
    Total duration no longer than 3 weeks - return to play 4-6 weeks
  - Type II & III – Likely surgical fixation
- Complications – cubitus varus, Volkmann ischemic contracture

FRACTURES – RADIAL HEAD/NECK

- Approximately 30% of all elbow fractures
- Majority a result of a FOOSH (pronated forearm)
- Pain over lateral elbow, assess for crepitus and pain with pron/sup
- Diagnosis usually made via x-ray AP
- Modified Mason Classification
  - Type I – Nondisplaced fractures (displacement ≤2 mm)
  - Type II – Displaced fracture
  - Type III – Comminuted fracture
  - Type IV – Radial head fracture with associated dislocation
FRACTURES – RADIAL HEAD/NECK

Treatment
- Type I – Brief immobilization with cast or sling and early ROM
- Type II-IV (>2 mm, comminuted, or associated dislocation)
  - Likely surgical consultation – ORIF, surgical excision, prosthetic replacement
  - Return to play for type I usually 6 or more weeks, longer for others

Modified Mason Classification

FRACTURES – OLECRANON

- Mechanism: Direct blow to the proximal humerus or FOOSH with elbow in flexion (triceps avulsion)
- Exam is tenderness to palpation, swelling, and pain with triceps activation/extension
- Diagnosis usually seen on Lateral radiograph
- Classification & Treatment
  - Type I – Nondisplaced (<2 mm) with stable elbow. Immobilize in long arm cast
  - Type II – Displaced with stable elbow, requires ORIF
  - Type III – Displaced and unstable, requires ORIF
  - Type B would be comminuted

FRACTURES – MEDIAL & LATERAL EPICONDYLE

Medial
- M/C than lateral
- Can be associated with posterior dislocation or throwing
- Fat pad sign may be absent since extracapsular
- Assess varus stability & ulnar nerve
- Treatment based off degree of displacement (5-15 mm)
- Generally less than 5-10 mm can be treated non-operatively LAC for 2-6 weeks

Lateral
- M/C in children (6-10 yo)
- FOOSH

Treatment
- Weeks Type I with <2 mm displacement → monitor carefully and non-operatively
- Type II – >2 mm, <4 mm displacement, intact articular cartilage (closed reduction/fixation)
- Type III – >4 mm or cartilage disrupted – ORIF

Image: wikicommons
FRACTURES – RADIUS/ULNA MIDSHAFT

- M/C in children
- FOOSH
- Close neurovascular examination
- Orthopedic surgery referral
- Child w/ non-displaced and non-angulated-LAC for 6-8 weeks with close monitoring (weekly x-rays for 3 weeks)

MONTEGGIA

- Fracture of the proximal third of the ulna with radial head dislocation

FOREARM STRESS FRACTURES

- Ulnar stress fractures
  - Weightlifter
  - Softball player
- Recurrent loading with bicep curls and bench or underhand pitching
- Treatment – rest and avoidance of activity
- Gradual return to sport in approx. 6 weeks
### DISLOCATION

- Wrestling, football, gymnastics, weightlifting
- FOOSH, MVC posterior dislocation (can be posterolateral, posteromedial, etc)
- Simple = no associated fracture, Complex w/ fracture
- Check N/V structures before and after reduction
- Reduction – countertraction humerus (posterior pressure from front) with longitudinal traction to forearm, thumbs behind olecranon
- Post-reduction radiographs to assess for fracture (med epicond m/c)
- Immobilized in posterior long-arm splint/cast for 1 week with early ROM, return to play ~ 4-6 weeks
- If fracture, recurrent or unstable surgical referral

### NERVE IMPINGEMENT

- Radial tunnel syndrome
  - Radial nerve
  - Wraps distally around humerus
  - Out of deep lateral elbow pain with paralysis in radial nerve distribution
- Posterior Interosseous Nerve (PIN) Syndrome
  - Distal motor portion of radial nerve
  - Arcade of Frohse
  - Often confused with lat epicondylitis
  - Most have weakness with resisted extension of middle finger
- Cubital Tunnel syndrome
  - Ulnar nerve
  - Arcade of Struthers, arcuate ligament
  - Medial elbow pain, worse with overhead movement, 4th & 5th finger
  - Tinel
  - Froment sign
- Profunda syndrome
  - Median nerve
  - Tinel, 4th & 5th finger
  - Pronator synrome
  - Median nerve
  - Tinel, 4th & 5th finger
  - Anterior interosseous nerve (AIN) syndrome
  - Motor branch of median nerve
  - Gantzer muscle
  - OK sign

### LIGAMENT INJURY
LIGAMENT INJURY – UCL

• Mechanism: Acute traumatic valgus stress or chronic repetitive valgus stress UCL (anterior bundle)
  - Late cocking or early acceleration phase of throwing
  - May feel “pop”
• Examination: Swelling likely, tender over UCL (best palpated with elbow flexed between 50-70), + valgus stress, milking maneuver, and moving valgus stress test
  + test pain between 70-120

Imaging
- X-ray may show calcifications, MRI or US can confirm diagnosis

Treatment
- Overhead athletes or more severe injuries – operative reconstruction with 80-90% able to return to pre-injury function, RTP ~ 1 year
- Non-throwers or mild injury can consider non-operative treatment with rest + hinged elbow brace, rehabilitation
  - Ensure to assess kinetic chain and correct deficits during rehabilitation
- Associated conditions on throwers include ulnar nerve subluxation, snapping triceps, and others

Annual Number of UCL Reconstructions in Professional Baseball from 1974 to 2016

- All levels
- MLB pitchers

Annual Number of Revision UCL Reconstructions from 1995 to 2016

Redrawn from: Journal of Shoulder and Elbow Surgery May 2018
LIGAMENT INJURY – UCL

- Mid-substance, proximal, or distal, high grade, avulsion or complete tear
- Non-operative vs repair vs reconstruction
- Humeral side tears do better
- Overhead athletes with full thickness likely operative
- Partial tear – many options

Dr. Christopher Camp
Proximal Versus Distal Partial Non-Op Guidelines

<table>
<thead>
<tr>
<th>Proximal</th>
<th>Distal</th>
</tr>
</thead>
<tbody>
<tr>
<td>+/- PRP</td>
<td>+/- PRP</td>
</tr>
<tr>
<td>Rest X 2 weeks</td>
<td>Rest X 4-6 weeks</td>
</tr>
<tr>
<td>Shoulder rehab</td>
<td>Shoulder rehab</td>
</tr>
<tr>
<td>Kinetic chain</td>
<td>Kinetic chain</td>
</tr>
<tr>
<td>Throwing 7-12 weeks</td>
<td>Throwing week 13</td>
</tr>
</tbody>
</table>

MAGNETIC RESONANCE IMAGING PREDICTORS OF FAILURE IN THE NONOPERATIVE MANAGEMENT OF ULNAR COLLATERAL LIGAMENT INJURIES IN PROFESSIONAL BASEBALL PITCHERS

<table>
<thead>
<tr>
<th>Association With Likelihood to Fail Nonoperative Management</th>
<th>Unadjusted OR (95% CI)</th>
<th>P</th>
<th>Adjusted OR* (95% CI)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>0.83 (0.58-1.20)</td>
<td>0.334</td>
<td>0.81 (0.45-1.46)</td>
<td>0.489</td>
</tr>
<tr>
<td>High-grade tear</td>
<td>19.12 (2.92-125.32)</td>
<td>0.002</td>
<td>12.40 (1.50-102.73)</td>
<td>0.020</td>
</tr>
<tr>
<td>Chronically changed</td>
<td>0.09 (0.02-0.52)</td>
<td>0.007</td>
<td>0.18 (0.02-1.48)</td>
<td>0.113</td>
</tr>
<tr>
<td>High-grade and distal tear</td>
<td>35.00 (3.32-368.54)</td>
<td>0.003</td>
<td>4.69 (0.07-337.75)</td>
<td>0.479</td>
</tr>
</tbody>
</table>

Distribution of MRI Characteristics by Ultimate Treatment

- Distal tear
- High-grade tear
- Chronic changes
- High-grade and distal

SUMMARY

- High grade tears worse than low grade
- Ulnar sided injuries worse than humeral sided injuries
- Overhead athlete with distal tear likely recommend surgery
- Overhead athlete with low grade proximal partial tear definitely worth trial at non-op
- Stuff in between is worth discussing
- PRP needs more research to strongly support
LIGAMENT INJURY
POSTEROLATERAL ROTARY INSTABILITY

- Mechanism: Injury to the lateral collateral ligament complex results in rotary subluxation of the radius and ulna posteriorly.
- Signs and symptoms: Painful elbow locking and popping with instability, possible previous elbow dislocation.
- Diagnosis:
  - Prone push-up test, chair push off, or Positive lateral pivot shift test
  - Start in extension, → supination/valgus/axial force and flex
  - MRI can confirm diagnosis
- Treatment:
  - Conservative, rest, bracing and PT
  - Surgical if failed conservative for reconstruction


VALGUS EXTENSION OVERLOAD SYNDROME

- Mechanism: High valgus stress with rapid extension during throwing results on posteromedial impingement between olecranon and fossa
- Exacerbated by UCL insufficiency
- Signs/Symptoms: Pain typically worsen during acceleration and follow-through
- Pain during valgus stress and extension over posteromedial elbow
  - Positive armbar test → full pronation with arm on shoulder extended and apply downward pressure
- Treatment:
  - Non-operative: Rest, and throwing program
  - Operative: Assessment of UCL and excision of osteophytes and exploration of loose bodies with rehab

PREVENTION CONSIDERATIONS

Quantity of pitching
- Pitches per outing
- Days rest
- Months off
- Multiple teams
- Catching
- Fatigue

Pitch type
- Fastball, curveball, slider, etc

Others (genes, mature, etc)

Biomechanics

Davis, JT. The Effect of Pitching Biomechanics on the Upper Extremity in Youth and Adolescent Baseball Pitchers. AJSM 2009
PITCHING RECOMMENDATIONS (USA BASEBALL)

Pitch Count Limits and Required Rest Recommendations

It is important for each league to set workload limits for their pitchers to limit the likelihood of pitching with fatigue. Research has shown that pitch counts are the most accurate and effective means of doing so. See required rest recommendations below.

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Hours of Rest 0 Days</th>
<th>Hours of Rest 1 Day</th>
<th>Hours of Rest 2 Days</th>
<th>Hours of Rest 3 Days</th>
<th>Hours of Rest 4 Days</th>
<th>Required Rest</th>
</tr>
</thead>
<tbody>
<tr>
<td>9-10</td>
<td>1-20</td>
<td>21-35</td>
<td>36-50</td>
<td>51-65</td>
<td>66-80</td>
<td>NA</td>
</tr>
<tr>
<td>11-12</td>
<td>25</td>
<td>26-40</td>
<td>41-60</td>
<td>61-75</td>
<td>76-95</td>
<td>NA</td>
</tr>
<tr>
<td>13-14</td>
<td>30</td>
<td>31-45</td>
<td>46-60</td>
<td>61-75</td>
<td>76-95</td>
<td>NA</td>
</tr>
<tr>
<td>15-16</td>
<td>35</td>
<td>36-45</td>
<td>46-60</td>
<td>61-75</td>
<td>76-95</td>
<td>NA</td>
</tr>
<tr>
<td>17-18</td>
<td>40</td>
<td>41-45</td>
<td>46-60</td>
<td>61-75</td>
<td>76-95</td>
<td>81-105</td>
</tr>
</tbody>
</table>

Pitch Count Limits and Required Rest Recommendations

Muscle/Tendon Injury

DISTAL BICEPS

- Mechanism: Eccentric load to the biceps
- Signs/symptoms: Pop, anterior elbow pain, swelling and ecchymosis
- Examination: Positive hook test
- Imaging: MRI and US to confirm diagnosis
- Treatment: Partial tear may be non-operative but otherwise OPERATIVE REPAIR

MUSCLE/TENDON INJURY

MEDIAL AND LATERAL EPICONDYLIITIS (OPTHY) (GOLFER'S & TENNIS)

- Mechanism: Usually an overuse/ degenerative process affecting the tendon
  - Think ECRB with lateral
- Signs and symptoms: Elbow pain (med or lat) with pain on passive stress or active resistance, tender distal to epicondyle
- Imaging: US or MRI can confirm
- Treatment:
  - Non-operative: Rest, ice, counterforce brace, PT (eccentric loading), equipment modification (grip size, string tension), ESWT, injections
  - Percutaneous ultrasonic tenotomy (Tenex) appears safe and may provide some relief, more research needed. Operative in recalcitrant cases
Compared with PLA

<table>
<thead>
<tr>
<th>Treatment</th>
<th>WMD with 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>CS+PEP</td>
<td>0.02 (-2.13 to 2.15)</td>
</tr>
<tr>
<td>CS</td>
<td>0.12 (-0.65 to 0.90)</td>
</tr>
<tr>
<td>PEP</td>
<td>0.62 (-1.27 to 2.51)</td>
</tr>
<tr>
<td>AB</td>
<td>1.18 (-0.65 to 2.49)</td>
</tr>
<tr>
<td>AB+PEP</td>
<td>1.35 (-0.54 to 3.24)</td>
</tr>
<tr>
<td>PRO+PEP</td>
<td>1.56 (-1.95 to 4.33)</td>
</tr>
<tr>
<td>PRO</td>
<td>3.60 (1.07 to 6.15)</td>
</tr>
<tr>
<td>HYA</td>
<td>5.80 (3.53 to 8.10)</td>
</tr>
</tbody>
</table>

LATERAL EPICONDYL/ITIS/ALGIA/OPATHY

- Steroids not recommended the remainder likely requires more research but may provide benefit

MUSCLE/TENDON INJURY

TRICEPS TENDINITIS

- Mechanism: Overuse elbow extension
- Tender over distal triceps, pain exacerbated by resisted elbow extension
- Treatment: Rest, ice, PT

OLECRANON BURSITIS

- Mechanism: Often traumatic with acute hemorrhagic, chronic associated with repetitive trauma or movement
- Signs and symptoms: Pain olecranon and swelling extra-articular
- Treatment:
  - Non-operative compression, ice, NSAIDS, splinting/padding
  - Aspiration can be considered in acute, corticosteroids used for subacute or chronic with some increase risk of infection
  - Infectious bursitis requires abx
  - Surgical excision rarely required
COMPARTMENT SYNDROME

- Chronic can be seen in rock climbers
- Traditionally acute as result of trauma (forearm or humerus)
- Diagnosis – compartment pressure testing
- Treatment – forearm fasciotomy

5 Ps

1. Pain
2. Paresthesia
3. Paralysis
4. Pulse
5. Pallor

QUESTIONS & DISCUSSION

THANK YOU FOR JOINING US IN THIS COURSE

Rochester, Minnesota
Phoenix, Arizona
Jacksonville, Florida