Anatomy and Injuries of the Elbow

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Pediatric MSK Imaging: Beyond the Basics Reloaded Course 2016
Disclosure of Commercial Interest

Neither I nor my immediate family have a financial relationship with a commercial organization that may have a direct or indirect interest in the content.
Learning Objectives

• Review normal MR elbow anatomy
• Develop a systematic approach to evaluating the elbow
• Describe the effects of mechanical stressors on the elbow in children
• Recognize MR imaging appearance of common sports-related elbow injuries in the young athlete
• Discuss imaging pitfalls
Imaging acquired in a standardized planes
Axial images are perpindicular to the long axis of the humerus
Sagittal images are scanned perpindicular to the coronal scan

Sequences

Coronal
PD TSE
T1 SE
T2 TSE FS
3D Gradient

Sagittal
T2 TSE FS

Axial
PD TSE FS

T1
Marrow
Anatomy

FS FSS
Marrow
Ligaments
Tendons
Muscle

Gradient
Ligaments
Cartilage
Loose Bodies
Image Quality

Coil selection and patient positioning

Scan the elbow with the arm by the side & off-set the child in the scanner - to bring the elbow closer to iso-center

Depending on patient size: Large or small 4-channel flex coil

Casted patients? In flexion, scan the patient prone with the arm extended - large flex coil on top and spine coil on the bottom
MR Arthrogram

**Indications:**
- UCL in throwing athletes
- Osteochondral lesions
- Loose bodies

Lateral approach with patient prone & arm flexed 90 degrees overhead

Trend – posterior approach into the olecranon fossa
Systematic Approach

- Inside-Out Approach
  - Bones
  - Ligaments
  - Tendons
  - Nerves
  - Muscles
  - Other Soft tissues

- Compartment Approach
  - Medial
  - Lateral
  - Posterior
  - Anterior
Anatomy

Functions

Hinge joint at the humeroulnar and radiocapitellar

Provides rotation of the forearm at the radiocapitellar level

11-year old girl
Medial Elbow

Medial Collateral Ligament Complex
Anterior Ulnar Collateral Ligament
Posterior Ulnar Collateral Ligament
Transverse (oblique)

Main restraint to valgus stress

Anterior bundle of the UCL is the primary passive stabilizer to valgus stress

Anterior bundle tethers medial epicondyle to the sublime tubercle
Younger patients = striated pattern at the epicondylar insertion due to high elastin content and low type 1 collagen

(FDP = flexor digitorum profundus)
Posterior band forms the floor of the cubital tunnel & ulnar nerve is just superficial

(AM = anconeus muscle, FCU = flexor carpi ulnaris muscle)
Lateral Elbow

Lateral Collateral Ligament Complex
Radial collateral ligament *
Lateral band of the ulnar collateral ligament (LUCL)*
Annular ligament

*Main restraints to varus stress

Radial Collateral Ligament

Arises from the lateral epicondyle, just deep to the attachment of the common extensor tendon, extends distally and blends with the annular ligament

(Husarik et al. Radiology 2010; 257(1): 185-194.)


(SM = supinator muscle)
Lateral band of the UCL (LUCL)

LUCL - most important posterolateral stabilizer of the elbow joint
Originates deep to the CET and swings down behind the radial head and attaches to the supinator crest of the ulna
Not consistently seen (85%*); oblique imaging planes


(CET = common extensor tendon)
Annular ligament encircles the radial head and inserts on the posterior and anterior aspects of the ulnar at the radial notch.

(AM = anconeus muscle, BM = brachialis muscle, BT = brachialis tendon)
Tendon Attachments

Biceps tendon – radial tuberosity

Brachialis tendon – coronoid process
Pathology

• Substantial increased number of children participating in organized, competitive sports

• Children subjected to injury:
  – Not enough rest time between practices
  – Inadequate preparation & training
  – Increased intensity of play
  – Incomplete physical maturation

• Differ from adults?
  – Vulnerability of the growth plate
Overuse Injuries

• Result from repetitive stress without sufficient recovery time
  – *Unconditioned athlete*: periods of rapid increases in training
  – *Elite athlete*: training at a consistently high level

• More common in adolescence
  – Rapid physical growth & imbalance between muscle strength & flexibility
Overuse Injuries

Repetitive traumatic overload of the muscle-tendon-bone unit where mechanical forces are transmitted to tissues of varying consistencies & tensile strengths

Microavulsions with secondary inflammatory changes

Weakest part

Young athlete: *physeal cartilage*
Increasing maturity: *tendon insertion sites*
Injury Patterns: Young athletes

Age-related stage of elbow development & Sport-specific mechanism of injury

<table>
<thead>
<tr>
<th>Site</th>
<th>Appearance</th>
<th>Epiphyseal fusion</th>
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</thead>
<tbody>
<tr>
<td>C Capitellum</td>
<td>0-2 years</td>
<td>14 years</td>
</tr>
<tr>
<td>R Radial head</td>
<td>4-5 years</td>
<td>16 years</td>
</tr>
<tr>
<td>I Medial epicondyle (Internal)</td>
<td>6-7 years</td>
<td>15 years</td>
</tr>
<tr>
<td>T Trochlea</td>
<td>8-10 years, multiple and irregular</td>
<td>14 years</td>
</tr>
<tr>
<td>O Olecranon</td>
<td>10 years</td>
<td>14 years</td>
</tr>
<tr>
<td>E Lateral epicondyle (External)</td>
<td>11 years</td>
<td>16 years</td>
</tr>
</tbody>
</table>

Trilaminar appearance:

Zones of cartilage
Provisional Calcification
Primary spongiosa
Prior to appearance of the secondary center of ossification, increase in free water & increased cellular volume lead to T2 prolongation that can be appreciated as foci of high signal intensity on T2fs.
Little Leaguer’s Elbow (LLE)

1960: Brogdon & Crow
2 Little league baseball pitchers with medial elbow pain and abnormal radiographs of the medial epicondyle

Today:
General term referring to chronic valgus stress injuries in skeletally immature (throwing) athletes

Baseball pitcher, tennis serve, football pass, javelin throw, gymnasts
Pitching

Stages: Windup, early cocking, late cocking, acceleration, deceleration, and follow-through

Children develop normal stages of throwing by age 9

Late cocking and acceleration: valgus forces cause compression of lateral elbow & distraction of the medial elbow

Valgus Extension Overload (VEO)

Distraction *medial* elbow restraints

- Younger adolescents; affects medial epicondylar physis and apophyseal cartilage
  - Traction medial epicondyle apophysitis
  - Repetitive microavulsions at the apophyseal-cartilage interface

As the physis begins to close, injury shifts to the ulnar collateral ligament & common flexor tendon proper

- UCL injuries, medial epicondylitis

Valgus Extension Overload (VEO)

Compression on the *lateral* articular surface

- Capitellum & Radial head
  - Panner’s Disease & Osteochondral lesions
- Extension overload on the *lateral* restraints

Deceleration phase:
valgus extension shear force - posterior elbow compartments

Medial Compartment Injuries
Medial Compartment Injuries

Overhead throwing/ sidearm throwing in young children

- Affects medial epicondylar physis & leads to traction medial epicondylar apophysitis
- Repetitive microavulsions at the weak apophyseal-cartilage interface due to tugging by the UCL

As the physis begins to close, injury shifts to the ulnar collateral ligament & common flexor tendon proper

- UCL injuries
- Medial epicondylitis

Widening of the medial epicondylar physis.

Contralateral imaging can be invaluable to solidify diagnosis.

Initial radiographs normal up to 85% cases

Follow-up

Medial Epicondylar Apophysitis

Abnormal apophyseal physeal widening with periphyseal edema

Treatment: Rest, PT, reinforcement of proper throwing mechanisms
If left untreated - progress to non-union

13 year-old boy
Medial Epicondylar Apophysitis

14 year-old boy

Chronic traction injury with periphyseal edema without physeal widening in a slightly more mature elbow nearing maturity (Subtle!)

TIP: Apophyses should contain confluent fat marrow w/o bright signal
Older Child – UCL vulnerable

17 year-old girl
Medial Epicondyle Fracture

Most common acute fracture seen in the adolescent throwing athlete (7-15 y)

- Acute valgus stress with violent flexor-pronator muscle contraction
  - Tensile force > strength of the medial epicondyle apophysis
  - Fall on outstretched hand or chronic overuse
- Fragment becomes entrapped
- UCL is rarely ruptured

*Sometimes subtle* -- contralateral views or stress views
Medial Epicondyle Fractures

Management is controversial
Traditionally, casted for 4 weeks

Surgical Recommendations:
Open fractures
Incarcerated fragments
> 5mm displacement
High level of stress on elbow during athletics

Medial Epicondyle Fracture

12 year-old boy

Entrapped medial epicondyle apophysis within the joint space
Tip: If radiographs do not reveal a medial epicondyle in its expected location in a child older than 6 or 7 years, close inspection of the joint is warranted.
Chronic microtrauma with avulsion fracture of inferior medial epicondyle

Chronic injury to physis, small pieces of bone are avulsed from underside or inferior surface of medial epicondyle by the UCL

Avulsion involve the chondro-osseous junction of spherical growth plate
15 year old boy (pitcher) with chronic traction injury to the medial epicondyle – avulsion of the inferior aspect of the apophysis with abnormal signal in the UCL
14 year-old boy

Acute on Chronic Medial Epicondylar Injury
Lateral Compartment Injuries

www.helpful-baseball-drills.com
Thrower’s Elbow - Lateral

- Throwing - large hyperextension & valgus force
  - Lateral compressive force centered on the developing capitellum
  - Pattern of injury depends on the state of maturation of the capitellum
- Panner’s Disease
  - < 11 years of age
- Osteochondral lesions
  - > 12 years of age
  - Spectrum of same disease

Iyer et al AJR 2012; 198: 1053-1068.
Panner’s Disease: Osteochondrosis

- Cause: injury to the tenuous vascularity of the capitellum
  - Supplied by small posterior perforating-end arteries traverse a pliable and compressible epiphyseal cartilage

- Disordered ischemia of the ossific nucleus leads to disordered endochondral ossification
  - Involves the entire ossification center

Dull pain or stiffness
Panner’s Disease

Demineralization with irregularity, fragmentation and sclerosis of the capitellum

Loss of normal sharpness of the cortical margins

Symptomatic

7 year-old pitcher

Asymptomatic

Treatment: Rest & NSAIDs
Prognosis = excellent!
Loss of normal fatty marrow signal within the capitellum

Presumptive stages – ischemia & necrosis followed by revascularization & re-ossification
Overlying cartilage should be unaffected and osteochondral loose body formation does not occur.

Osteochondral lesions

- After 11-12 years, OCD is the main manifestation of lateral compression injuries
- Repetitive microtrauma, shear injury
  - Vascular insufficiency
- Lesion is at the periphery (anterior and lateral) of the ossifying epiphysis and deep to the articular surface
- Occurs when ossification is near complete

*Tip: Lucency in capitellum is never normal*
Osteochondral Lesion Progression

- Flattening of subchondral bone w/ intact cartilage
  - Subchondral bone fragments and collapses
    - Disruption of articular cartilage
      - Loose bodies, articular defects & incongruent joint surfaces
        - Pain, limited ROM & arthritis
Treatment - Stability

Arthroscopy:
Fragments that can be displaced by intraoperative probing

Imaging:
Radiographic, CT & MRI
Several different staging systems

*Children have a higher likelihood of having stable OCD lesions and have higher rates of healing*
Osteochondral lesions

- Lesion is usually anterolaterally positioned
  - Low in T1 with variable T2 signal
- Younger patients; lesion is at the periphery of the ossifying epiphyses
- Treatment – *depends on stability*

12 year-old softball pitcher. Subcondral edema within the anterolateral aspect of the capitellum
  - Overlying cartilage is intact
  - Small joint effusion
**OCD - Criteria for instability**

*MRI criteria for instability:*
- High T2 signal fluid interface with subchondral bone and breaks in the subchondral bone plate

**OCD - Criteria for instability**

**MRI criteria for instability:**
- High T2 signal fluid interface with subchondral bone and breaks in the subchondral bone plate.
- Irregular step-off involving the articular surface contours.

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**MRI criteria for instability:**
- High T2 signal fluid interface with subchondral bone and breaks in the subchondral bone plate
- Irregular step-off involving the articular surface contours
- Displaced osteochondral fragment

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**MRI criteria for instability:**

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- Irregular step-off involving the articular surface contours
- Displaced osteochondral fragment
- Fluid filled osteochondral defect

**MRI criteria for instability:**

- High T2 signal fluid interface with subchondral bone
- Irregular step-off involving the articular surface contours
- Displaced osteochondral fragment
- Fluid filled osteochondral defect
- Surrounding “cysts” (cartilage rests)

OCD - Treatments

**Stable lesions**
NSAIDS, PT, Rest*

No improvement 6 months - surgery

**Unstable lesions**
Debridement
Abrasart chondroplasty
Removal of loose bodies
Excision of lesion +/- subdchondral drilling
Fragment fixation
Replacement articular cartilage
OATS – osteochondral autograft transfer system

No consensus on preferred intervention and long-term prognosis
11 year-old with medial epicondyle pain. Lacks full extension.

Debridement until viable bleeding of subchondral bone to promote vascularization for healing response – scar cartilage to fill the defect & maintain congruent articular surface.

Arthroscopic images provided by Dr. Ted Ganley
Osteochondral lesion

10 year-old girl, cheerleader with lateral elbow pain
Loose bodies hide in natural recesses of the joint: Olecranon and condylar fossae
• Characterizing the OCD lesion, ligaments should be closely assessed

• Overuse injury- associated injuries are common
  – Lateral compressive forces coexist with high medial tensile forces
Lateral Trochlear Osteochondral Lesion

Occurs in a relative vascular watershed (posteriorly)

Mild fraying to delayed presentation of trochlear avascular necrosis

15 year-old boy, football injury

"Trochlear Hole"

Posterior trochlear Osteochondral Lesion

14 year-old with left elbow locking. Baseball injury 2-3 months prior
Pseudolesions

• Normal posterior tapering of capitellum at its inferolateral margin

• Can lead to erroneous diagnosis of osteochondral lesion

Fishtail Deformity

- Delayed complication of distal humeral fractures
- Likely avascular necrosis of the trochlear cartilage
  - Fishtail or chevron-like deformity of the distal humerus - lateral trochlea does not ossify & is resorbed

Narayanan et al. Peditr Radiol 2015; 45: 814-819
Fishtail deformity

11 year-old football player with elbow pain

Bone loss at lateral trochlea causing a chevron appearance of the distal humerus
7 year-old girl with prior history of injury
13 year-old boy, elbow pain
12 yo boy with pain after trauma

Common radiology pitfall!
Posterior Elbow Injuries
Olecranon Apophysitis

Traction injury to the olecranon apophysis; akin to adult avulsive triceps injuries
Acute injury – entire olecranon apophysis may detach

15 year-old boy with posterior elbow pain. Chronic traction injury of the olecranon physis with periphyseal edema

17 year-old baseball player with diffuse elbow pain
Chronic traction injuries of the olecranon and medial epicondyle
Triceps Pathology

9 year-old gymnast with elbow pain
Myotendinous strain of the triceps

8 year-old gymnast; triceps tendinopathy & apophysitis
Take Home Points

• In the young athlete, the weakest part of the musculoskeletal system is physeal cartilage
• Little Leaguer’s elbow comprises a wide spectrum of injuries dictated by skeletal maturity
• MRI is useful in avulsion injuries – degree of displacement and integrity of ligaments
• Osteochondral lesions can be subtle radiographically; MRI is useful for assessing signs of instability