Pediatric Upper Extremity Sports Injuries
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Sternoclavicular Fracture Dislocations

Anatomy
- Diarthrodial joint with intra-articular disc
- Medial physeal plate last secondary ossification center to close (age 22-25)
- Ligaments
  - Capsular – ant and post (posterior most important for AP stability)
  - Interclavicular
  - Costoclavicular

Mechanism of injury/epidemiology/
- 5% of all clavicle fractures
- Compression of shoulder toward midline
- Typically Salter-Harris type I or II physeal injuries
- True dislocations significantly less common – but do exist

Clinical Findings
- Posterior displacement – potential symptoms associated w/ impingement
  - Dysphonia (Trachea) / Dysphagia (Esophagus)
  - Distended neck veins (Venous congestion)
  - Diminished pulses (Arterial compromise)
- Anterior displacement
  - Usually a palpable mass over medial end of clavicle

Radiographs
- “Serendipity” view- underlying thoracic injury
- 40° cephalic tilt/ Both clavicles on same film
- May demonstrate morphology, medial physis, degree of displacement, underlying thoracic injury
- CT scans - highly effective in delineating position/”gold standard”

Treatment
- Anterior displacement
  - Injury may be chronic – associated w/ ligamentous laxity
  - Observation if asymptomatic
  - Excision if chronic and painful
  - May also be acute – Football/weightlifters/fall from height
  - Consider repair in acute injuries/high impact athletes
- Posterior displacement
  - Can be an emergency  (see symptoms assoc/ w/ impingement)
  - Reduction under general anesthesia
  - Thoracic surgery standby recommended
Posterior dislocation summary:
Displaced fracture dislocations
  Unstable – role of open repair
  Avoid hardware that can migrate
  Late persistent dislocations and malunion - more difficult to treat

Clavicle Shaft Fractures

Introduction: Clavicle Function/Epidemiology
  Functions as a strut linking axial skeleton to upper extremity
  Contributes to overall upper extremity motion
  Protects/retracts/rotates and elevates
  Attachment for pectoralis major and deltoid
  8 to 15% of pediatric fractures

Clavicle Shaft fractures
85% of all clavicle fractures
Mechanism of injury
  Fall onto shoulder
  Direct trauma during contact sports

Findings
  Pain, tenderness over the clavicle
  Limited range of motion and deformity over fracture site

Radiographs: AP
  15% posteroanterior view
  Apical lordotic view - perpendicular to the AP view
    Taken lateral with shoulder abducted 130°
  CT Scan- For re-assessment of displacement and fx union.

Treatment:
Non displaced fractures - nonoperative treatment
  Figure-of-eight bandage or Sling for 4 to 6 weeks

Displaced fractures in preadolescents +
  Most displaced fractures in adolescent patients
    Most fractures heal readily with a shortened malunion
    Preadolescents have ability to remodel over time
    Commonly remodel w/in a year of injury for those < 10y/o
    Nonunion rare - can be treated with orif, and bone grafting

Operative Treatment - Established indications
  Open fractures / Neurovascular compromise
  Concomitant displaced scapula fractures (acromion, coracoid)
  Severely displaced/irreducible fractures that threaten skin integrity

Operative Treatment
  Literature has swung pendulum in Adults toward operative treatement
  Applicability to adolescents / older adolescents - debated

  Traditional thought for middle third clavicle fractures
    Fracture union = good result / nonunion = poor result
    Neer, JAMA. 1960 - Midshaft clavicle fractures
2,235 pts – 3 nonunions/surgery – higher nonunion rate
Rowe, Corr. 1968;58:29-42 - Clavicle fractures
566 patients – 4 nonunions

Issues assessed in current literature
- Shortening / malrotation / Malunion
- Shoulder function / dysfunction
- Patient related outcome scores

DASH=Disabilites of the Arm/Shoulder/Hand
Constant Score / Return to play

225 fractures / 25 year follow up
185 asymptomatic / 39 with some symptoms
1 poor / 7 nonunions
“Few pts require surgery” / Shortening – no clinical significance

52 patients / 8 (15%) nonunions
16 (31%) unsatisfied
13 w/ some pain / 15 w/ brachial plexus symptoms
28 w/ cosmetic complaints

McKee et al, JBJS Am. 2006;88:35-40.
Deficits following nonop tx of displaced midshaft clavicle fx’s
Used patient outcome measurements and strength testing
30 pts – non op tx - displaced midshaft clavicle fractures
“Substantial residual disability”
80% w/ reduced strength
Constant shoulder scores 71 (p = .01)
DASH 25 (p = .02)

Systematic review of midshaft clavicular fractures
Nonunion rate –
Nonoperative treatment – 15.1% (24 of 159)
Operative treatment – 2.2% (10 of 460)

Canadian Orthopedic Trauma Society; JBJS 2007;89:1-10
Multicenter prospective randomized controlled trial
*Skeletally Mature Patients*
Midshaft displaced clavicle fractures
Nonunion – sling group - 7 of 65, operative group - 2 of 67
Symptomatic malunion –sling group-9 of 65, operative-0 of 67
Operative –also better time to union,
Better patient satisfaction - DASH/Constant
Complications – 23 of 62
wound infxn/hardware irritation/transient plexitis

“Based on these studies surgeons should consider operative
treatment for displaced fractures in older adolescents.”

Prospective Randomized Controlled Trial
60 patients / Elastic Nail Nail vs Nonoperative treatment
Operative group
  > Dash/Constant /faster return to activity
  Hardware complications / no nonunions
Nonoperative group
  3 nonunions / 2 malunion

IM Nailing/midshaft clavicle fxs w/ TEN/problems/complications
Ages 16-74 /34 patients / 26 male, 8 female / Davos Hospital
TEN only group (N = 19) / TEN + end cap group (N = 15)
Results – 62% of procedures required formal open reduction
38% – TEN passed w/o incision at fracture site
Operating time - 44 minutes / Floouro time-9 min
Complications – minor + significant in 70%
  Medial/lateral perforations/Hardware irritation 7/7/7
  Elastic nail breakage/Elastic nail dislocation 1/1
  Endcap significantly reduced medial migration/pain

39 athletes / Displaced clavicle shaft fxs / age 17-34
  90% radiographic union a@ 12 wks
Complications / wound infection, hardware refracture in 2

Summary: For combined ped/adult as well as adult literature
  Operative treatment:
    > rate of union/<strength deficits quicker return to training/sports
Disadvantages:
  Risk of infection / migration / refracture / hardware removal

References

**Physeal fatigue – Epiphysiolysis – “Thrower’s Shoulder” Fracture**

**Etiology**
- Joint Laxity / Open epiphyseal plates
- Underdeveloped musculature / Strength and muscle imbalances

**Differential Diagnosis**
- Glenohumeral instability/subluxation
- Rotator Cuff Tendonitis
- Osteochondroma arising from proximal humerus

**Biomechanics**
- Throwing results in force components capable of causing
  - Humeral retrotorsion
  - Epiphysiolysis
- Cartilage is stronger in tension 10-15 MPa, than in shear 1.4 MPa
- Pitching - Distraction force (215 N) = 5% of cartilage strength
  - Shear stress via torsion (18 N) = 400% cartilage strength

**Clinical Evaluation**
- Nonspecific, pain, aching and tenderness at proximal humerus

**Imaging**
- Radiographs – widening, demineralization, metaphyseal sclerosis
- Comparison views can prevent confusion
- MR – Physeal widening - T1 & gradient echo (coronal/saggital images)

**Management**
- Tenderness, no widening - 4 wks of rest, then PT and a gradual return
- Physeal widening – refrain from throwing for 3 months
- May take 2-12 months to reossify
Options – return to sports when symptoms resolved vs. when reossified

Prevention
Strengthening and interval-throwing program
Monitor for changes in throwing mechanics, which may suggest fatigue
Limit # of pitches/game, pitches/practice – AOSSM, USA Baseball

Proximal Humerus Fracture
4 -7% of all epiphyseal fractures
Peak age at 10 – 14 yrs
¾ of these fractures occur through unicameral bone cysts
Proximal humeral growth accounts for 80% of length of humerus
Proximal fragment flexes and externally rotates due to pull of rotator cuff
Distal fragment pulled proximally by deltoid and adducted by pectoralis major muscles

Displaced fractures
Children younger than 11 yrs treated nonoperatively
Beaty advises:
children < 5y/o
up to 70° angulation, 100% displacement
children > 12y/o
up to 40° angulation, 50% displacement

Reduction
Traction, abduction and external rotation

Unstable fractures
Treated in cast; “statue of liberty” position
Percutaneous pinning
Open reduction
Glenohumeral dislocation
Vascular injury
Interposition of biceps tendon

References

**Panner’s Disease/Osteochondritis of the Capitellum**

**Panner’s Disease**

**Growth and Development**
- Ossification center - 6 months
- Ossification nucleus full grown - 12 years
- Fuses to metaphysis - 14 years (♀) 17 years (♂)

**Blood Supply - Panner’s and Osteochondritis Dissecans**
- Descending extraosseous branches from the brachial artery
- Chondral vessels supply the osseous nucleus
- Osseous nucleus supplies chondroepiphysis
  - Lack of communication can lead to necrosis
  - Vulnerability diminishes with physeal closure

**Clinical presentation** - Ages 4-10 years (median 7)
- Mechanical pain
- Limitation of flexion and extension
- Synovitis - palpable effusion, fat pad sign
- X-ray
  - ↓ size of ossific nucleus fragmentation, erosion, lysis, sclerosis

**Treatment**
- Sling for several weeks
- Stop all offending activity
- ROM exercises

**Prognosis**
- Full recovery expected 12-18 months
- Noncompliance - deformity and overgrowth
- Bilateral Lesions - rule out other condition
  - Hemophilia and variants
  - Multiple epiphyseal dysplasia
  - Autoimmune vasculitis
  - Steroids

**Osteochondritis Dissecans of the Capitellum**

**Background/Key Facts**
- Vascular compromise in nearly fully developed ossific nucleus
- Ages 10-17 years, median 14
- Franz Konig 1889 - “A portion of cartilage was dissected free by a low grade subchondral inflammatory response”

**Clinical Presentation**
- Mechanical Pain
- Mechanical dysfunction – grinding, clicking, locking
- Pain on palpation of radial-capitellar joint
- Flexion and extension deficits
- Synovitis

**Radiographs**
- Overgrowth from stimulation
- Cystic changes
- Subchondral lysis, flattening or separation
  - MRI
  - Bone edema
  - Synovitis
  - Lysis and cystic changes
  - Subchondral and cartilage separation - Pill, Ganley (17)
MRI in Elbow OCD
- 11 lesions
- Accurate with size, loose bodies
- Guided treatment - Bowen

Treatment

Cartilage intact
- Nonoperative treatment
- Rest until symptoms resolve
- ROM
- Follow-up through resorption/reconstitution phases

Nonoperative Treatment of 24 patients
- Age 13.3 years, follow up 5.2 years
- 5/11 early lesions failed to heal
- 4/4 advanced lesions failed to heal - Takahara

Cartilage intact but persistent pain and swelling
- Arthroscopic evaluation, search for loose bodies
- Consider drilling of lesion to stimulate further healing

Cartilage fractured
- Nonsurgical treatment
  - High risk of clinical failure
  - Potential for
    - R-C joint degenerative changes
    - Loose body formation
    - Persistent motion loss

Arthroscopic assisted debridement
- C.P.M., PT after 6 weeks
- Return to sports @ 6-12 months - Pill, Ganley (1)

Arthroscopic debridement - 12 patients
- Age 14.5 years, follow up 3.2 years
- Contracture improvement 23° to 10°
- 11/12 highly satisfied – Ruch

Arthroscopic debridement – 10 patients
- Age 13.8 years, follow up 3.9 years
- Outcome poorly correlated with lesion grade
- 4/10 back to baseball – Byrd

Arthroscopic debridement – 16 patients
- Age 13.8 years, follow up 4 years
- Contracture improvement by 14°
  3/14 gave up throwing/gymnastics – Baumgarten

Closing Wedge Osteotomy
- 7 patients, “Thrower’s Elbow”
  - Capitellum revascularized in 7/7 @ 6 months
  - Back to throwing - Kiyoshige

Pull out Wiring and Bone Grafting – 11 patients
- 11 patients, 14.7 years, follow up 4.8 years
- Throwing @ 6 months
- 10/11 back to throwing - Takeda

**Dynamic Staples and Bone Graft – 4 patients**
- 4 patients, follow up 7.5 years average
- 4/4 back to throwing - Harada

**Prevention**
- Training
- Intensity
- Practice time – Ganley, Spiegel

**Education**
- Patients/parents/families
- Coaches/athletic trainers/therapists
- Gatekeepers – primary care, nurses, orthopaedists

**References**


**Medial Epicondyle Humerus Fractures**

**Background/Key facts**

- **A Traction Apophysis** – tension forces across the physeal plate
  - Part of the distal humeral epiphysis in early ossification
  - Later separated from the total distal humeral epiphysis

- Medial epicondylar apophysis located on the posterior distal humerus
  - May be difficult to visualize on the AP x-ray

- **Ossification**
  - Appears at 5 to 6 years of age / Fusion occurs at 15-18 years of age

- **Soft tissue attachments**
  - FCR/FCU/FDS/Palmaris longus/Pronator teres
  - Capsule (in younger patients)
  - UCL - anterior and posterior bands

- **Mechanism of injury**
  - **Direct blow** – Rare
  - **Trauma**
    - Avulsion and extension – Fall on an outstretched hand
    - Isolated muscle avulsion
  - **Overuse**
    - Chronic Tension Stress Injuries

- **Incidence**
  - 14% of pediatric distal humerus fractures
  - 12% of all pediatric elbow fractures
  - 30-50% association with elbow dislocation
  - Ages 9-14 most common
  - 80% occur in boys
  - 20% in girls

**Operative vs Nonoperative treatment – Opinions Vary**

- **Cast**
  - 90 + % good to excellent results
  - 0-90% radiographic union rate

- **ORIF**
  - 80-90% good to excellent results
  - 95% radiographic union rate
Non-operative indications
Advantages of non-operative treatment
- Good functional results in many series
- Potential for non-union

Operative indications
Advantages of operative treatment
- Allows early motion
- Union likely

Operative indications (absolute)
- Intra-articular entrapment of fracture fragment
- Ulnar nerve entrapment
- Gross instability of elbow

Operative indications (relative)
- Fractures displaced > 5 mm
- Stable elbow required for athletics
  - Throwing athlete dominant arm
  - Upper extremity weight bearing athlete (gymnast)
- Ulnar nerve symptoms
- Medial epicondyle fx + Ulnohumeral dislocation

Contraindications
- Infection / Medical risks which prohibit surgical treatment
- Non-displaced fractures

Clinical Evidence
Studies yet to show equivalence or superiority using validated outcome tools
Few have referenced throwing athletes and their ability to return to sport

- Displaced Medial Epicondyle Fracture Treatment and Return to Sport in Teens
  To evaluate the outcome of operative vs. non operative treatment
  Clinical outcome of overhead athletes
  - 44 patients w/ medial epi fx / 24 did not meet criteria
  - 20 patients – 3.6 yrs follow up
  - 14 patients (7 baseball pitchers, tennis, and quarterbacks)
  - Overhead and thrower athletes returned to sport (next level) and both groups and completely satisfied
  - DASH score (validated tool) was slightly higher in the non op group
  - Potentially statistically but not not clinically relevant since both treatments associated with good clinical outcomes (sports/satisfaction)

  Lawrence, Flynn, Ganley

- Why don’t we have “The Final Answer”
  - Perhaps our measurement techniques are not perfectly reliable
  - Perhaps displacement may not predict stability – Stress testing

- Agreement in the Measurements of Displaced Medial Epicondyle Fractures
  - To assess both Intra and Interobserver agreement
  - 2 residents, 1 fellow, 2 attendings
  - Correlation coefficient for interobserver agreement .80 for anteroposterior radiograph measurements
Disagreement between reviewers 54% of the time .24 for lateral radiograph measurements .62 for the oblique radiograph measurements
-Intraobserver agreement varied among the reviewers.
-Agreement was best for the anteroposterior radiographs
- Study suggests that there are questions whether amount of perceived displacement should be used as criteria for choosing op vs. non op treatment.  

Pappas, Lawrence, Donegan, Flynn, Ganley

- Operative versus non-operative management of pediatric medial epicondyle fractures
  -Systematic Review - 14 studies met inclusion criteria / 498 patients
  -Union Rates – Difference statistically significant
    Operative treatment
    One study 6 of 14 (43%) went on to union
    All other studies – union rate 84.6-100%
  - Non-operative treatment - Between 0 and 90
  - Odds ration of union with surgery 9.33 times non-op tx (p<.0001)
  - Pain at final follow up – Difference Not statistically significant
    Operative – 15% (37 of 246)
    Non-operative – 8.7% (10 of 115)
  - Odds ratio - Pain at f/u w/surgery 1.87 times non op tx (p=0.73)
  - Ulnar Nerve symptoms – Difference Not statistically significant
    Operative – 4.5% (13 of 287)
    Non-operative – 2.5% (3 of 122)

  CHOP / PENN study

- Algorithm of treatment for medial epicondyle fractures
  Medial epicondyle fracture in a child
  Fracture open – Irrigation and debridement
  Marked instability/incarcerated fragment – Joint exploration and ORIF
  Suspected ulnar nerve entrapment – Nerve exploration, ORIF, +/- nerve transposition
  Fragment >5mm displaced, instability on EUA, stability needed for athletics (throwers, etc) – ORIF
  Discussion of risks/benefits of both treatments with patient/family for a shared decision making process

Operative Techniques
  Tourniquet/ image intensifier/radiolucent table
  Incision slightly anterior
  -Partially threaded 4.5 mm screw in teens
  -Place screw in medial column with washer
  ★ Be aware of ulnar nerve position during screw placement
  -Posterior splint – Early/immediate motion

References