The Throwing Shoulder

UCSD MSK Fellow Presentation
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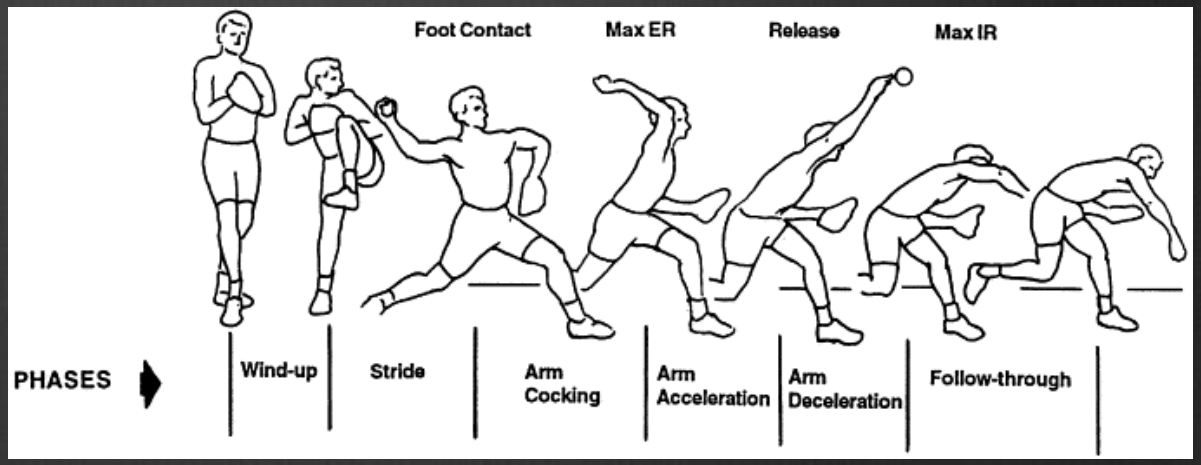
Objectives

- Throwing Motion
- Dead Arm
  - Posterosuperior Impingment
  - GIRD – Pathologic Cascade
- Humeral Retroversion
- Bennett Lesion
- Anterosuperior Impingement
- Little Leaguer's Shoulder

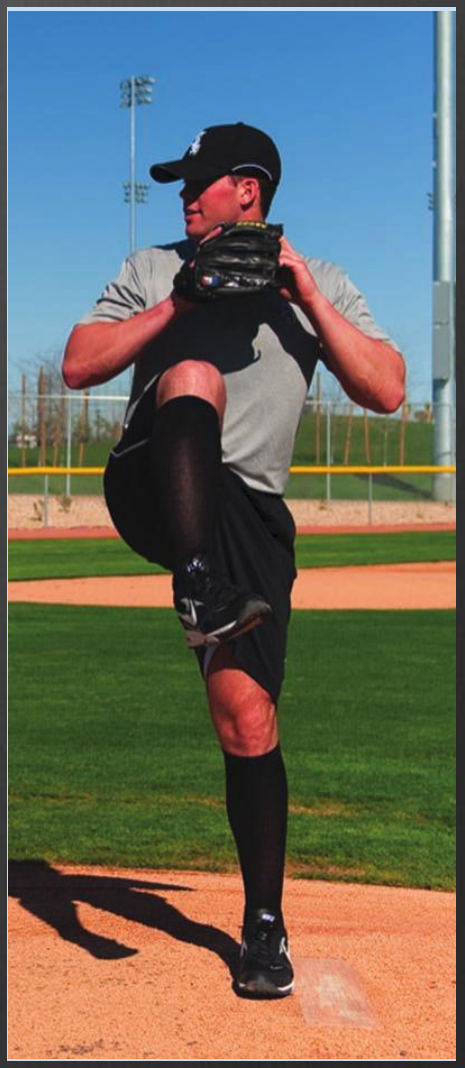
Throwing Motion

- 6 phases (Fleisig, et al. 1996)
- 1) Windup
- 2) Early cocking / Stride
- 3) Late cocking
- 4) Acceleration
- 5) Deceleration
- 6) Follow through



Windup

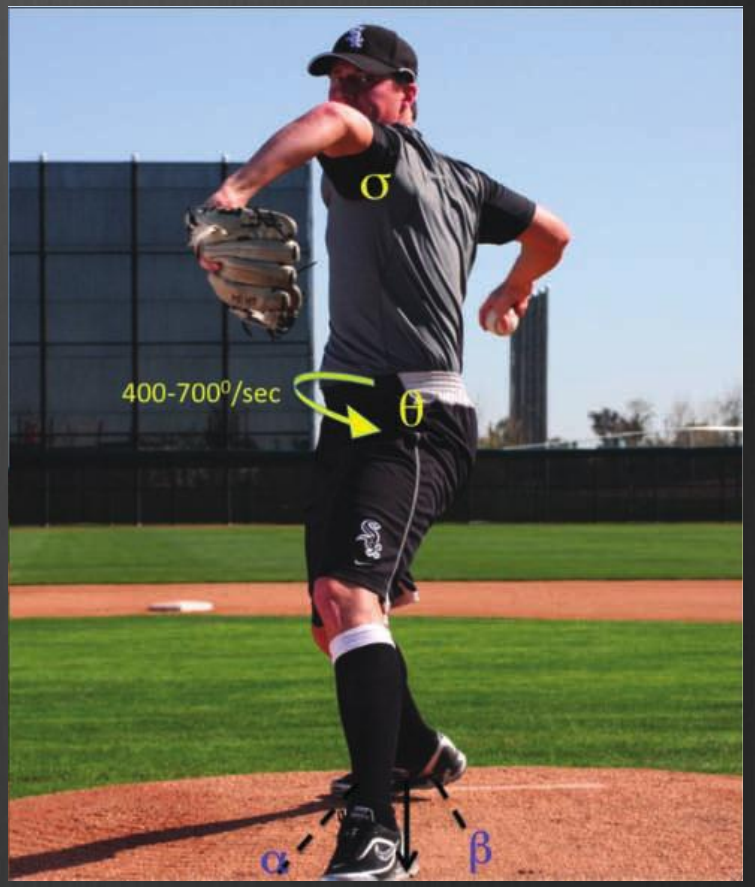
- Elevation of lead leg to highest point
- Separation of throwing and glove hands



Seroyer et al. 1999

Early cocking and stride

- Begins at lead leg max height and ends at stride foot contact
- Early shoulder abduction and external rotation



Seroyer et al. 1999

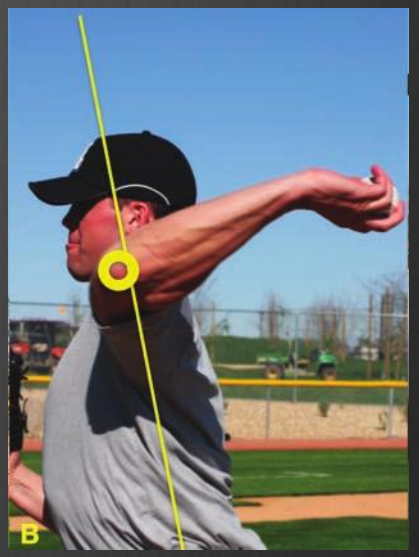
Late cocking

- Begins with foot contact
- Ends with maximal abduction and external rotation of the shoulder

Seroyer et al. 1999

Acceleration

- Between maximum external rotation and ball release
- Rapid horizontal adduction and internal rotation of the humerus
- Internal rotation velocities up to 7000°/sec (Fleisig et al 1994)
  - Possibly fastest motion in all of sport



Seroyer et al. 1999

Deceleration

- Most violent phase
- Between ball release and maximum humeral internal rotation
  - Arm outstetched towards home plate
- Biceps and brachialis
  - Decelerating elbow extension
- Large distraction forces on posterior soft tissue structures of the glenohumeral joint
  - Up to 80% of body weight

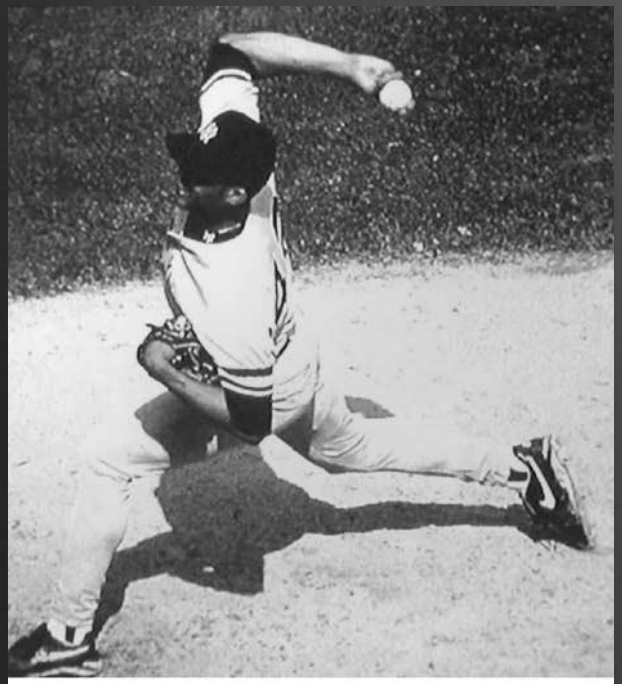
Seroyer et al. 1999

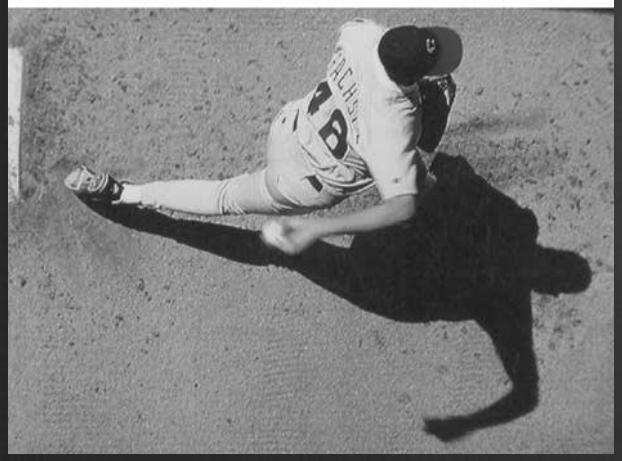
Follow Through

- Between maximum adduction and internal rotation and arm coming to rest
- Ends with pitcher in the fielding position

Seroyer et al. 1999

External Rotation Set Point





- Pitch velocity
  - Proportional to internal rotation velocity of the humerus during acceleration phase
- Increased maximum external rotation during late cocking phase
  - Increased distance for accelerating forces to act
- "The slot"
  - Proprioceptive sense of the external rotation set point needed to obtain maximum velocity

External Rotation Set Point

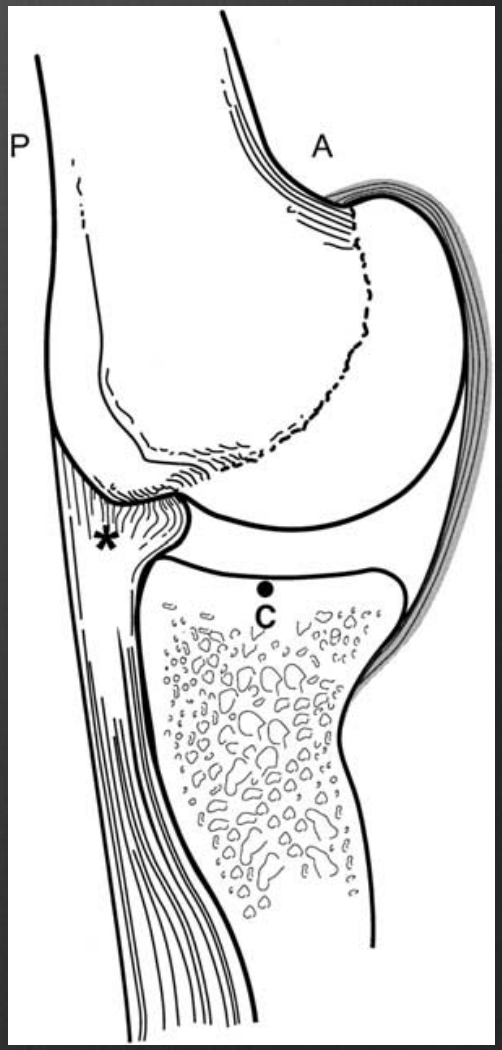
- Soft tissue and osseous adaptations allow increased external rotation in late cocking
- Evenutally some of these adaptations may lead to pathology and “dead arm”

Dead Arm

- "Any pathologic shoulder condition in which the thrower is unable to throw with preinjury velocity and control because of a combination of pain and subjective unease in the shoulder." (Burkhart et al 2003)
  - Discomfort typically late cocking/early acceleration phase
  - Sudden sharp pain and arm "goes dead"
- Mysterious etiology
  - Psychopathology, posterior glenoid calcs, acromial osteophytes, CA ligament impingement, rotator cuff, biceps tendon, AC joint, microinstability, internal impingement, SLAP

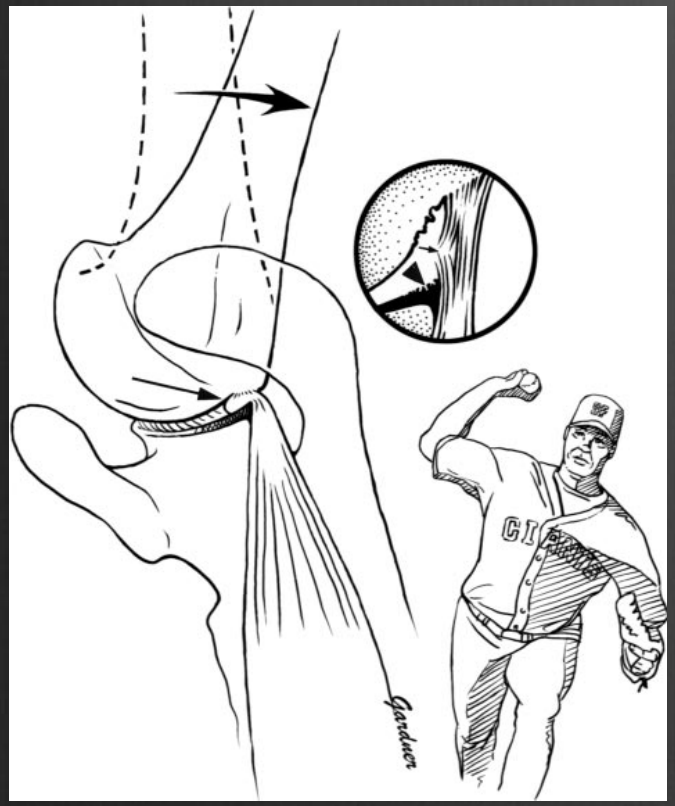
Posterosuperior impingment

- Walch et al first described impingement of undersurface of posterosuperior rotator cuff between greater tuberosity and posterosuperior glenoid and labrum with ABER.
- Contact can be physiologic in ABER
- Spectrum of pathologic findings
  - Undersurface tears of the posterior supraspinatus and anterior infraspinatus where impingement occurs
  - Posterosuperior labral tears
  - Cystic changes and sclerosis posterior greater tuberosity and posterosuperior humeral head and posterior glenoid



Burkhart 2003

Posterosuperior impingment



Halbrecht et al 1999

- Jobe applied this concept to throwing shoulder
  - Repetitive ABER in late cocking phase
  - Proposed stretching of anterior capsuloligamentous structures in throwers leads to progression

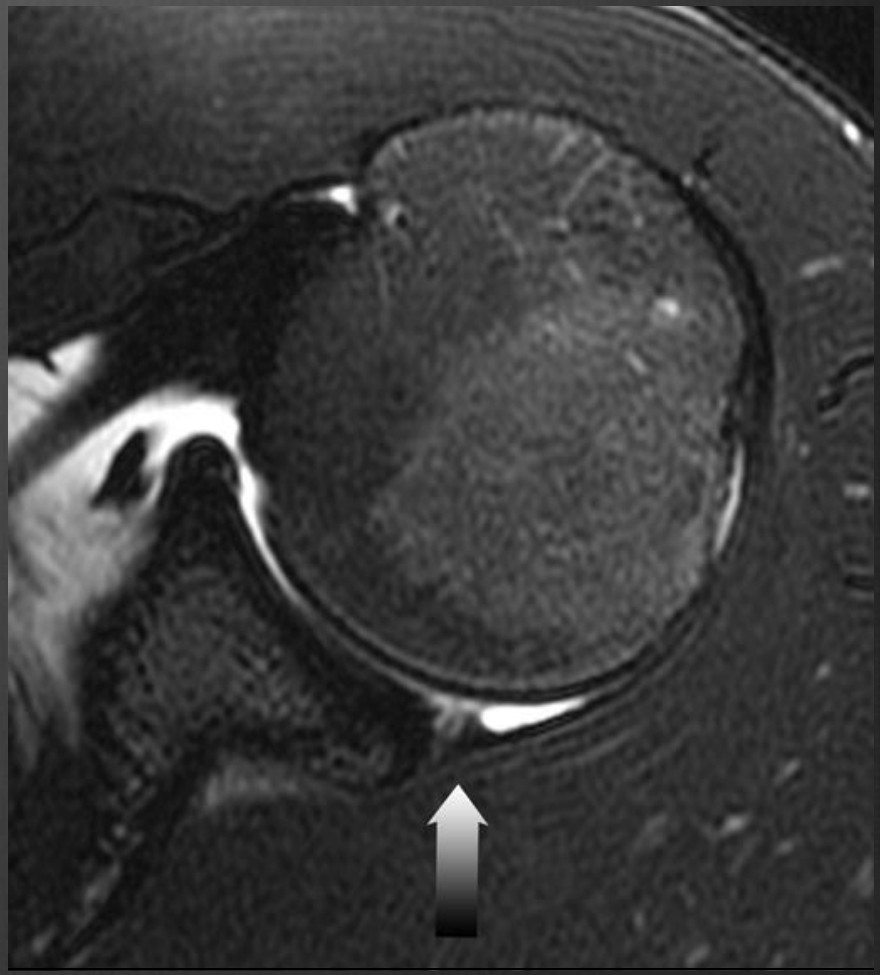
Posterosuperior impingment

- Halbrecht et al. 1999
  - 10 asymptomatic college baseball players
  - Bilateral shoulder MR arthrograms
  - Contact between cuff undersurface and posterosuperior labrum in ABER
    - Throwing and non-throwing shoulders
    - Likely physiologic
  - Throwing shoulders only
    - 3 posterosuperior labral tears
    - 2 cuff tears and 2 others with tendinosis
    - 2 posterosuperior humeral head and posterior glenoid cystic changes
  - No correlation with anterior instability

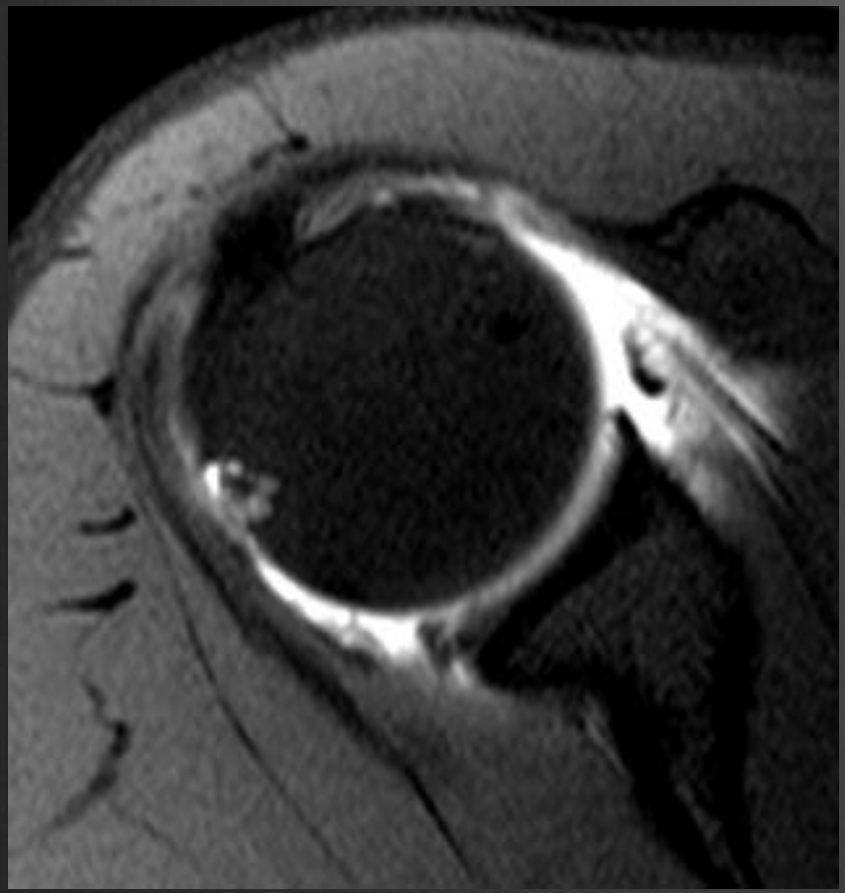
Halbrecht 1999

MRI of Posterosuperior impingment

- Giaroli et al, AJR 2005
  - 6 patients surgically confirmed PSI
    - 4 baseball, 1 tennis, 1 swimmer
  - 15 control patients
  - 100% cases
    - Abnormal PS labrum vs 13% controls
    - Abnormal cuff undersurface vs 27%
    - Cyst like changes in humeral head vs 27%
  - Cyst like changes
    - More posterior than typically seen with cuff pathology



MRI of Posterosuperior impingment



Courtesy of Brady Huang, MD

22 year old professional pitcher with stiffness and normal pitching velocity

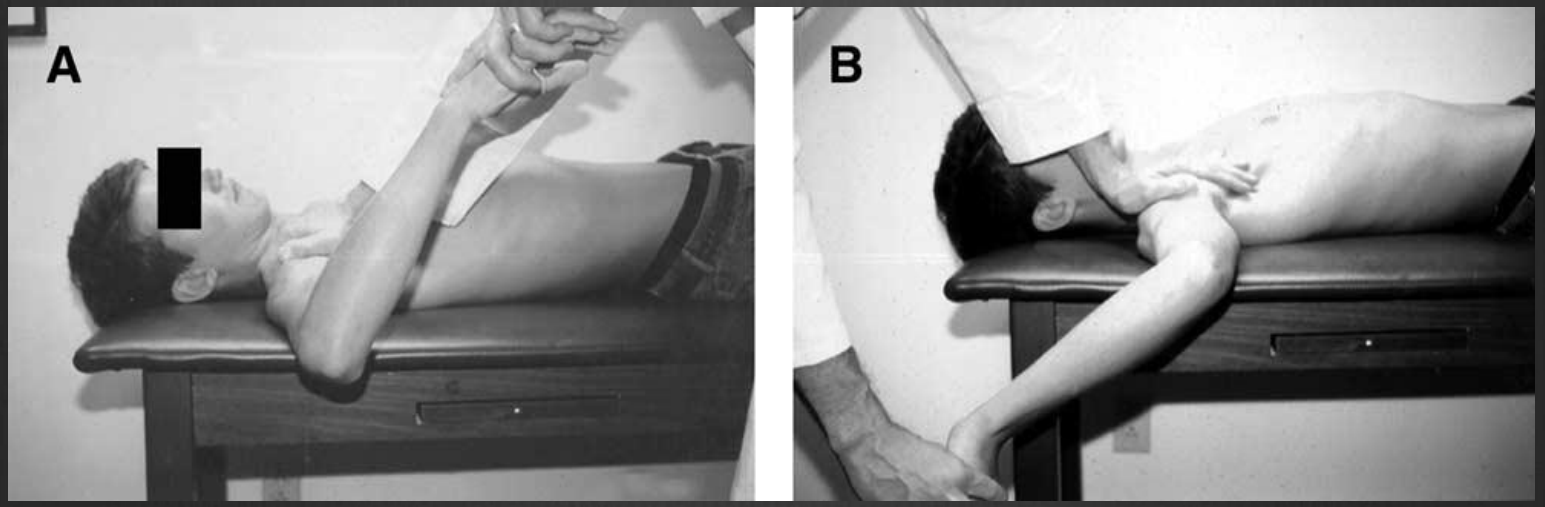
MRI of Posterosuperior impingment

Courtesy of Brady Huang, MD

16 year old female swimmer

GIRD

- Glenoid internal rotation deficit
  - Loss in degrees of glenohumeral internal rotation compared with the non-throwing shoulder
  - GIRD in symptomatic shoulders generally > 25^{o}
  - Loss of internal rotation far exceeds gain in external rotation
- Caused by posteroinferior capsular contracture
- Burkhart favors GIRD as initiating a cascade eventually leading to SLAP lesions and dead arm



Burkhart et al 2003

GIRD

- Clinical evidence
  - 60% of 39 professional pitchers with at least 35° GIRD developed shoulder problems requiring them to stop pitching (Verna 1991)
  - Morgan treated 124 pitchers with arthroscopically proven SLAP 2 lesions – all had severe GIRD
  - Kibler found severe GIRD in all 38 overhead athletes treated for proven Type 2 SLAP
  - Donley and Cooper found asymptomatic ptichers only 13° GIRD preseason and 16° GIRD posteseason
  - Kibler found decreased GIRD and 38% decrease in shoulder injuries in a group of tennis players who performed daily posterior capsular stretching compared with control group
- PSI normal phenomenon and is not etiology of dead arm

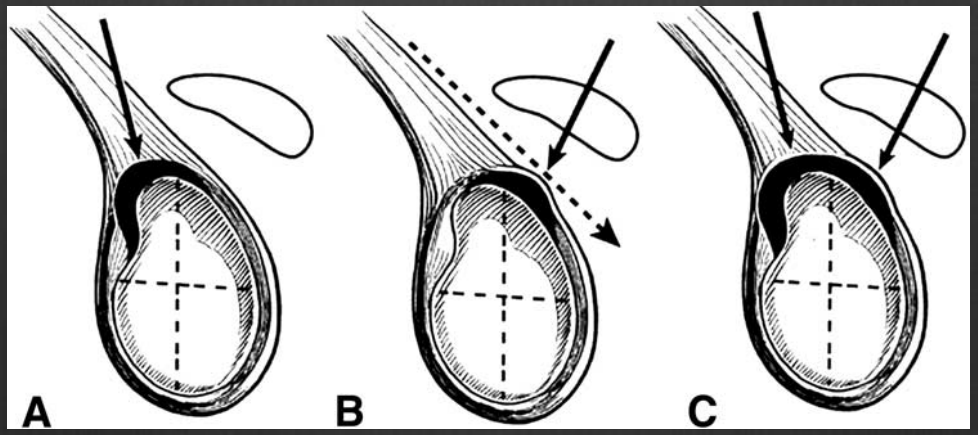
Pathologic Cascade

- Posteroinferior capsular contracture – GIRD
- Shift glenohumeral contact point in ABER
- Hyper-external rotation in ABER
- Increased shear forces on the biceps anchor and posterosuperior labrum
  - Peel back mechanism
  - Type II SLAP tear
- Increased shear and torsional stress on posterosuperior cuff
  - Undersurface rotator cuff tears

Burkhart et al 2003

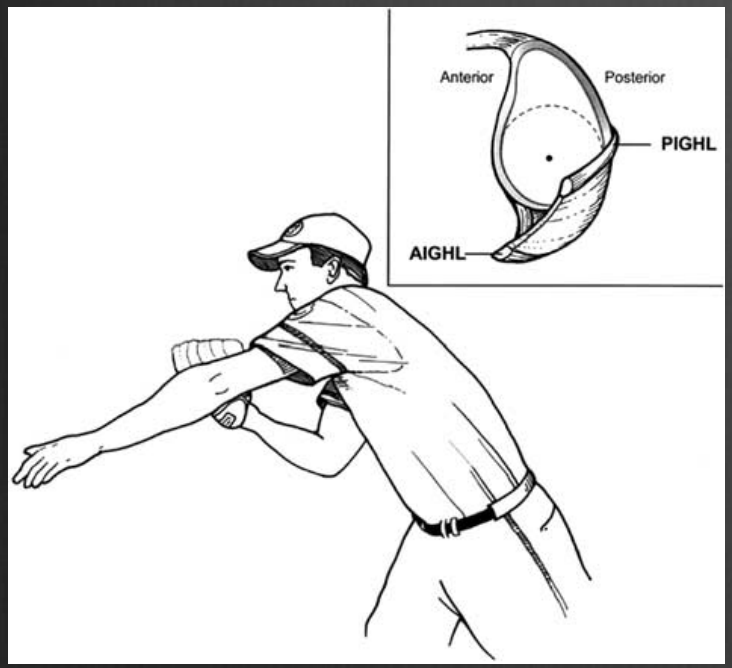
SLAP Tear

- Superior Labrum anterior to posterior
- Snyder Classification
  - Type I: Fraying
  - Type II: Tear of biceps labral complex
  - Type III: Bucket handle tear
  - Type IV: Bucket handle tear with extension to Biceps
- Morgan Type II subtypes
  - IIA: anterior extension
  - IIB: posterior extension
  - IIC: anterior and posterior extension



Burkhart et al 2003

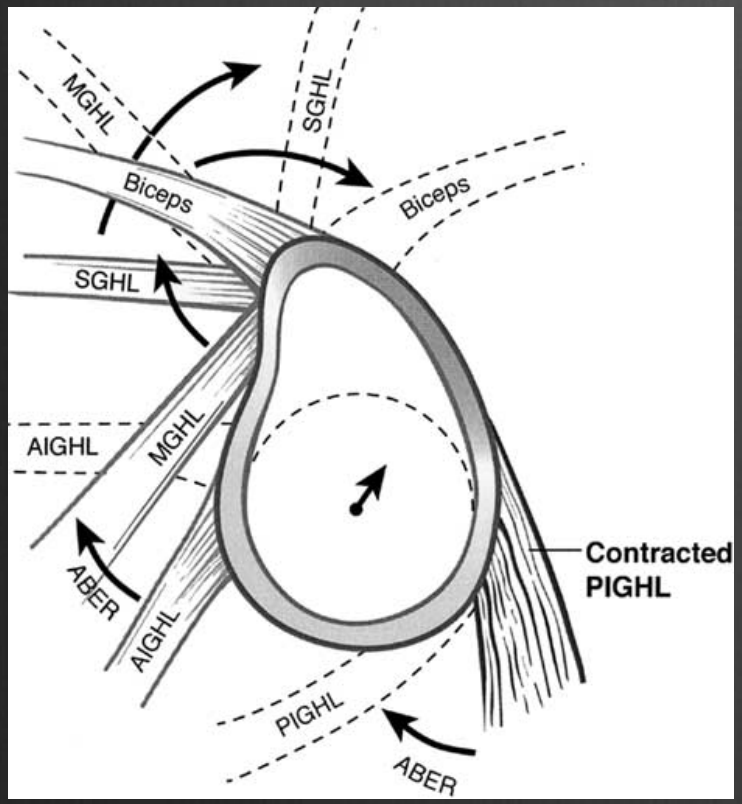
Posteroinferior Capsular Contractrion



- Large distraction forces on posteroinferior capsule during deceleration (750N, 80% BW)
- Repetitive tensile loading leads to posteroinferior capsular hypertrophy
- GIRD results

Burkhart et al 2003

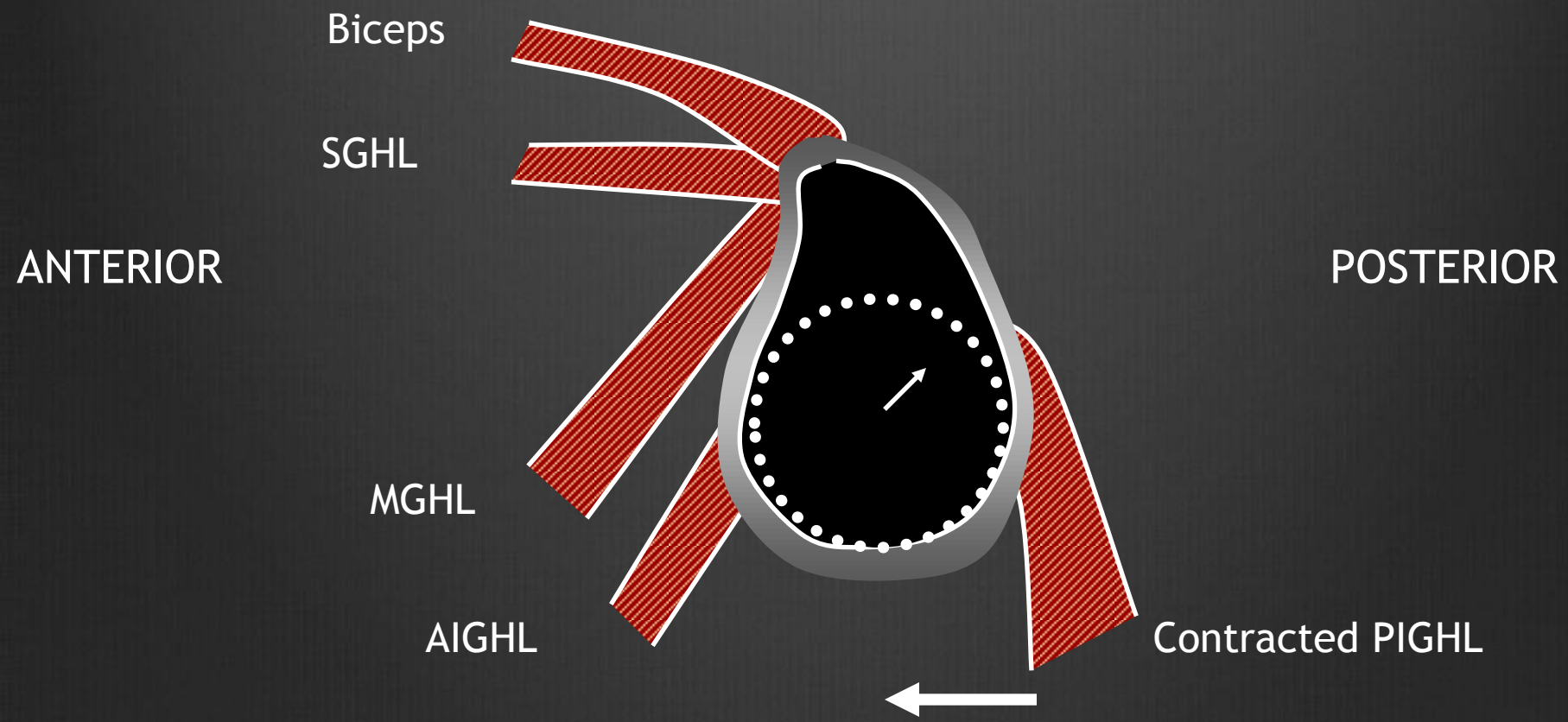
Contact point shift



- PIGHL shifts under humeral head during ABER
- Contracted PIGHL exerts posterosuperior force on humeral head
- Posterosuperior shift of the GH contact point

Burkhart et al 2003

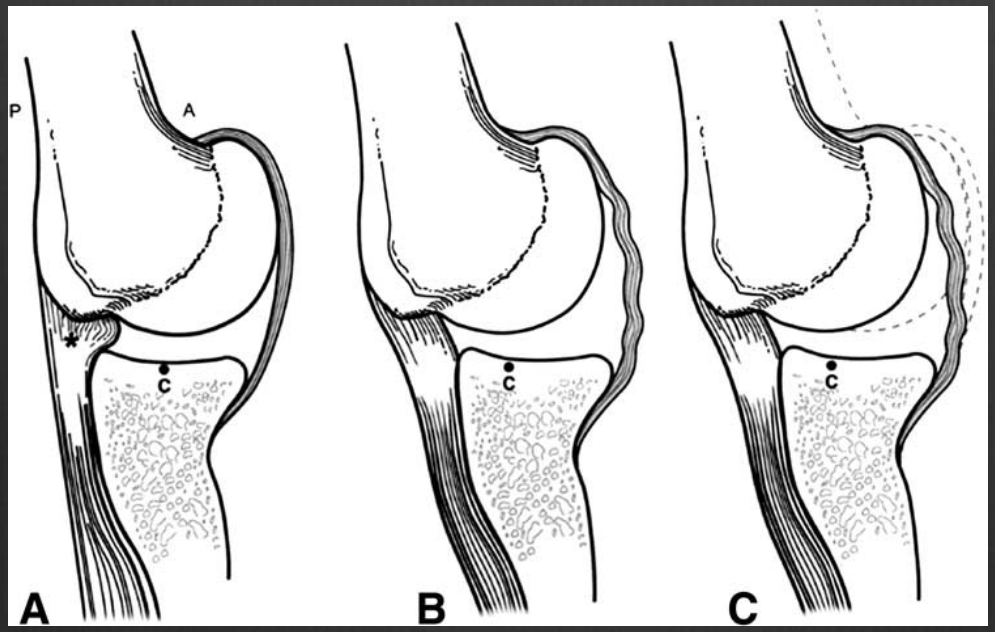
Posteroinferior Capsular Contracture



Courtesy of Brady Huang, MD

Hyperexternal Rotation

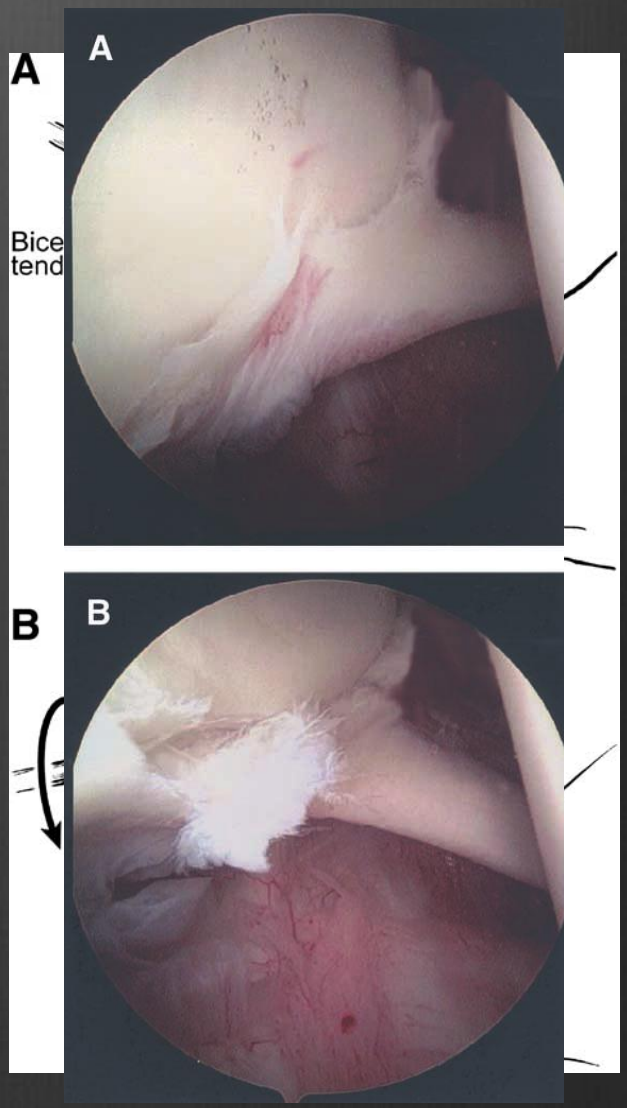
- Contact point shift allows hyperexternal rotation via 2 mechanisms
- Increased clearance of the greater tuberosity before internal impingement
  - Greater arc of external rotation
- Decreased CAM effect of humeral head and proximal humeral calcar on anterior capsule
  - Relative redundancy of anterinferior capsule



Burkhart et al 2003

Increased Shear force on Labrum

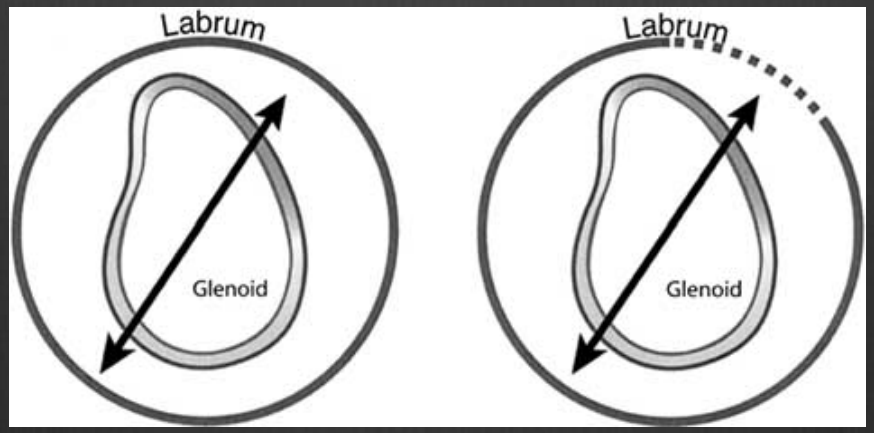
- Twisting of biceps tendon with hyperexternal rotation
- Shearing force directed to posterosuperior labrum
- Type II SLAP tears
  - Predominantly Type IIb or IIc
- Peel back
  - Biceps root will shift medial to supraglenoid tubercle
- This is likely cause of “dead arm”



Burkhart et al 2003

Pseudolaxity

- Anterior instability reported in dead arm
  - Positive drive through sign at arthroscopy
  - Scope driven from top to bottom of GH joint without resistance
- Burkhart suggests this is due to pseudolaxity not true instability
- Decreased CAM effect – capsular redundancy
- Circle concept
  - Break in labral ring (from SLAP tear) allows channeling of apparent laxity to opposite side of ring where there is disruption.



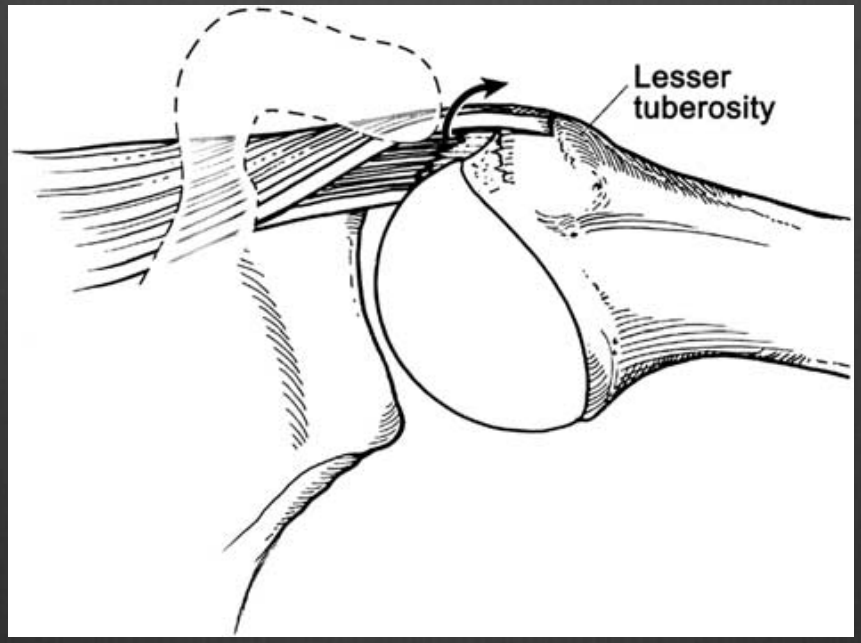
Burkhart et al 2003

Acceleration vs Deceleration

- Andrews et al (1985) initially proposed deceleration mechanism of thrower's SLAP tear.
  - High tensile load on long head biceps tendon with deceleration
- Cadaver model (Kuhn et al) supports acceleration model
  - Type 2 SLAP in 90% of specimens from loading biceps in ABER
  - Type 2 SLAP in only 20% of specimens loaded in follow-through
  - 20% less force needed in ABER
- Most thrower's recall late cocking/early acceleration phase as position of injury (Burkhart 2003)

Increased shear force on cuff

- Hypertwist from hyperexternal rotation
- Torsional and shear overload of cuff undersurface leading to tears



Burkhart et al 2003

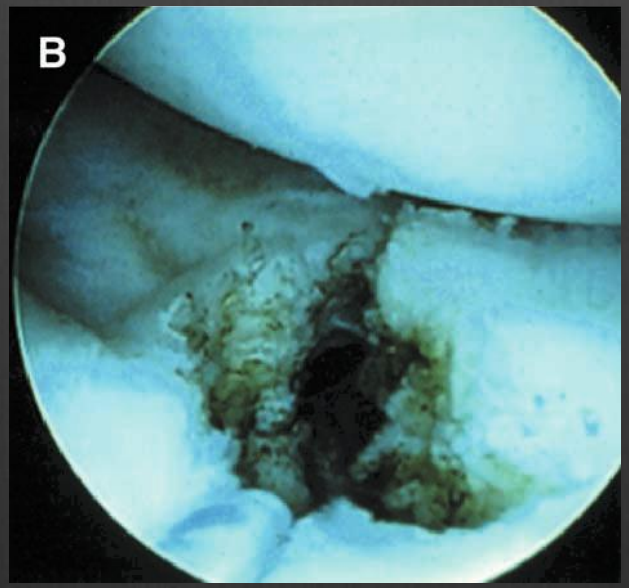
Burkhart Cascade Caveats

- Anterior instability
  - Not part of the inciting pathology of dead arm
  - Anterior capsular failure may be tertiary problem
  - Increased tensile stress on AIGHL with repetitive hyperexternal rotation
- Posterosuperior impingement
  - Not primary pathology in dead arm
  - May be seen in older elite thowers
    - Hyperxternal rotation in late cocking in excess of 130^{o}

Burkhart et al 2003

GIRD Treatment

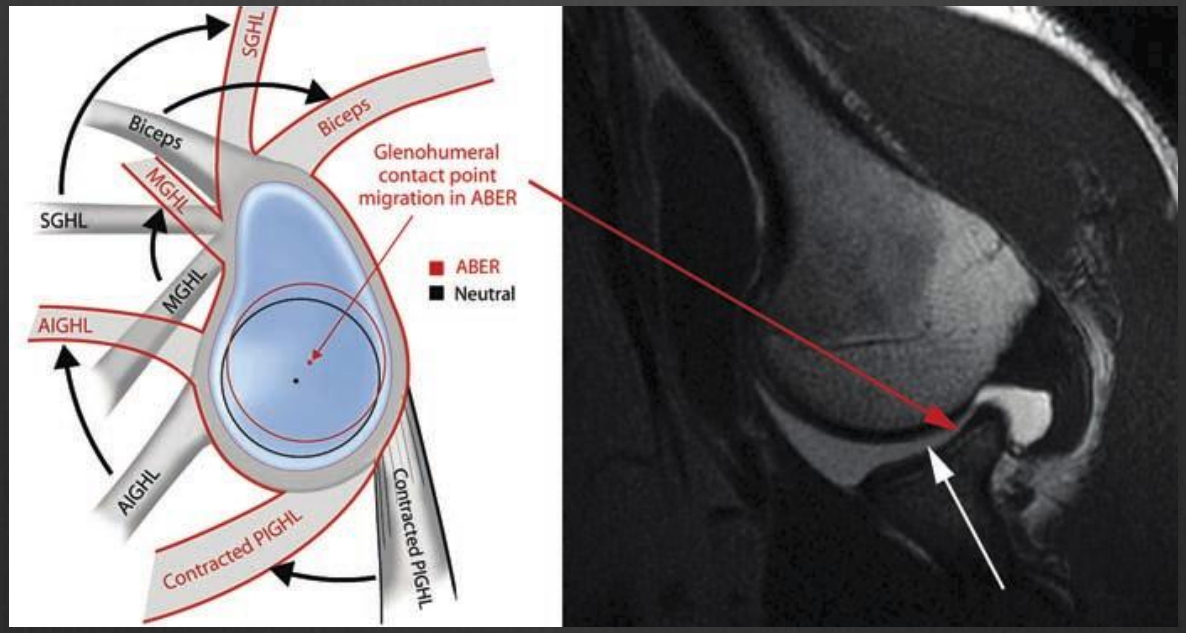
- Most respond to posterior capsular stretching
- SLAP repair
  - Morgan and Burkhart report 87% return to preinjury level of performance and velocity
- Selective posterior capsulotomy in stretch non-responders



Burkhart et al 2003

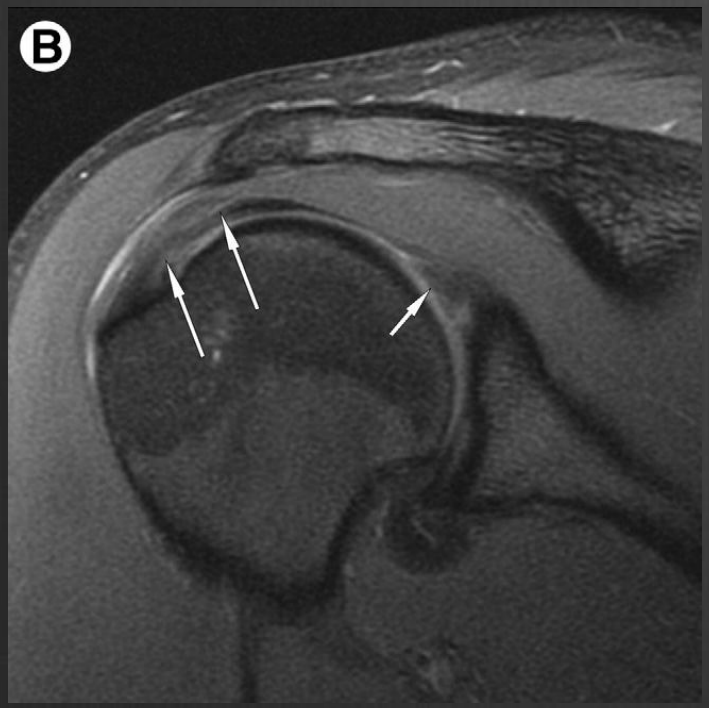
Imaging of GIRD

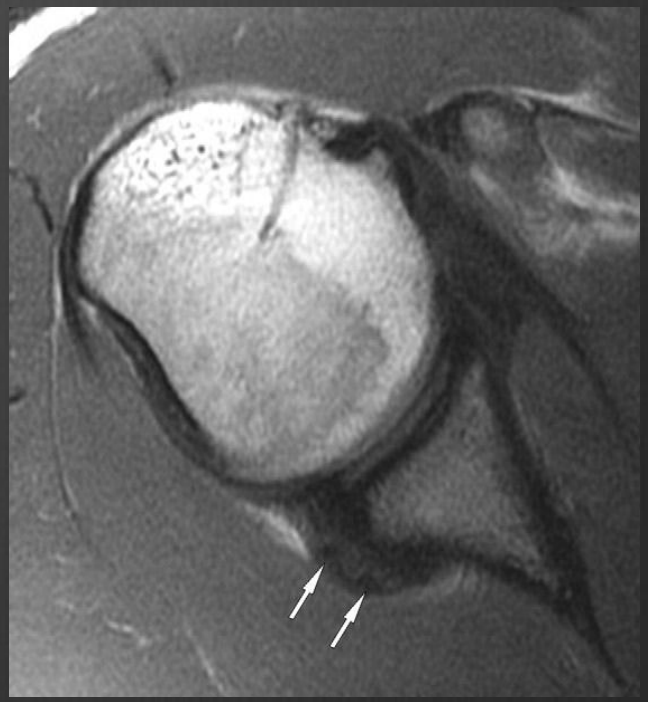
- Saleem et al AJR 2008 – Pictoral essay
  - Usefullness of the Abduction and external rotation views in shoulder MR arthrography
- ABER view may recreate decentering of humeral head with GIRD



Imaging of GIRD

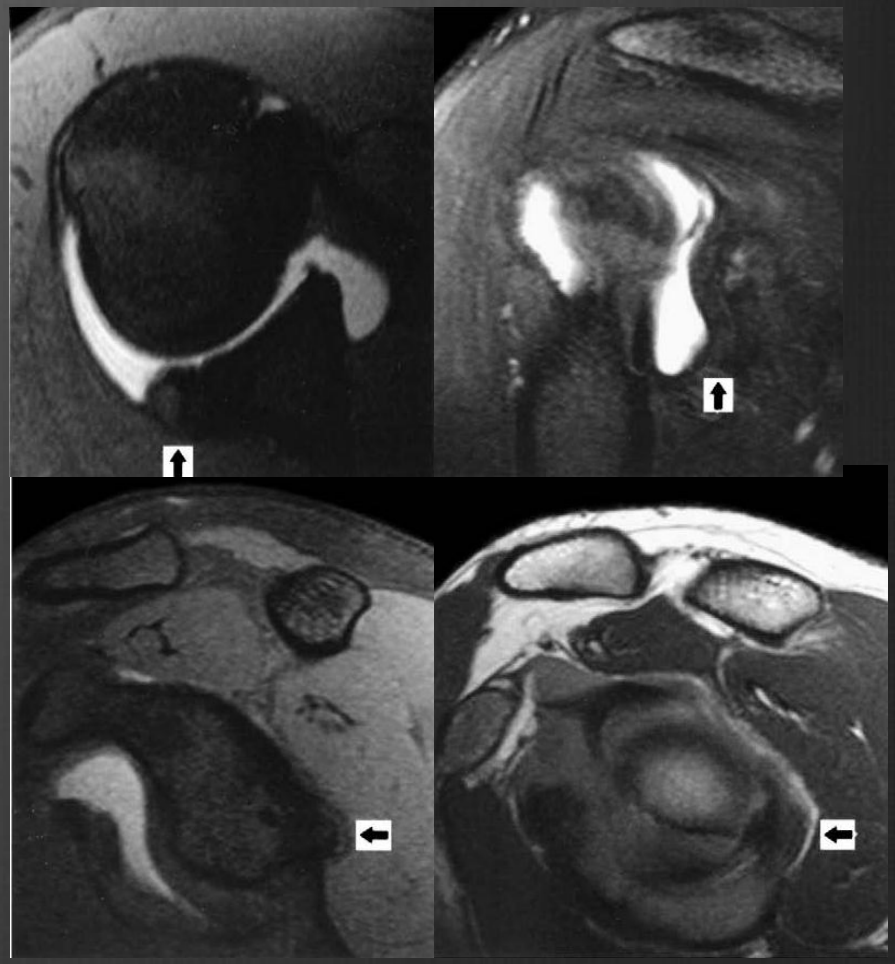
- Sanders, Zlatkin, and Montgomery, 2010
  - Imaging of Glenohumeral Instability (review)
- 18 year old baseball pitcher with GIRD
  - Marked thickening of the posterior capsule





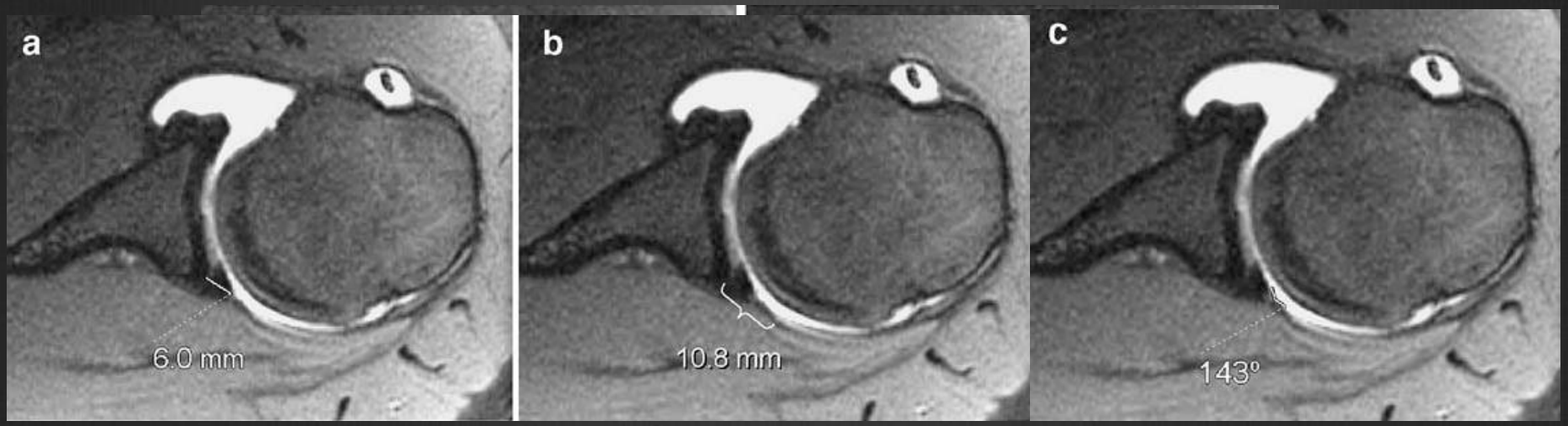
Imaging of GIRD

- Tehranzadeh, Fronek, and Resnick (Clinical Imaging, 2007)
  - Retrospective study of MR arthrograms in 6 professional pitchers with symptomatic GIRD
  - 5 with arthroscopy
- All with undersurface rotator cuff tears
- 4 SLAP tears, 2 posterior labral fraying
- Subjective posteroinferior capsular thickening
  - No standard at the time for measurement



Imaging of GIRD

- Tuite et al – Skeletal Radiology 2007
  - 26 overhead athletes with GIRD and internal impingement
  - 26 asymptomatic controls
- Attempt to diagnose and quantify posterior capsular thickening
  - Labral length at 8 o'clock – subchondral bone to labral tip
  - Posterior recess angle
  - Thick - capsule labral length
    - If capsule inserted near labral tip
    - Subchondral bone to where capsule "thinned out to become 1-2mm thick"



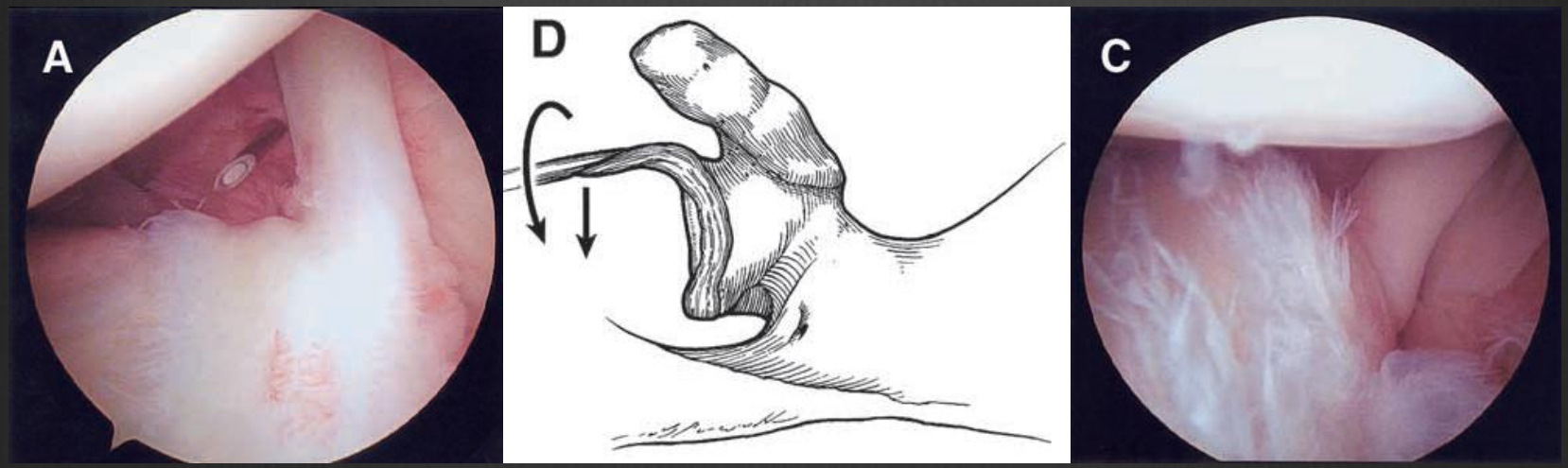
Tuite et al

	Labral Length (mm)	Thick capsule – labral length (mm)	Posterior recess (°)
GIRD	6.4 (2.9- 12.5)	8.8 (2.9-16.5)	94 (18-160)
Controls	4.9 (2.3-9.5)	5.4 (2.3-11.7)	65 (28-148)

- All differences statistically significant
- Limitations
  - PIGHL difficult to separate from capsule near labral attachment
    - Labral measurement used as surrogate
  - Glenoid shape differences not controlled for
    - i.e. hypoplasia with thick posterior labrum
  - Somewhat arbitrary thick capsule-labral length end point
  - Developmental variations in capsular attachment not accounted for
    - Park et al, AJR 2000 showed variable posterior capsular attachment
      - 60% type 1 – directly onto labrum
      - 31% type 2 – junction of labrum and glenoid
      - 9% type 3 – Medial to glenoid
  - Overlap of measurements
  - Technical differences – Patient positioning, amount of contrast
  - Overhead athletic participation as children not controlled for

Imaging Posterosuperior Labral Peel Back

- Borrero et al, Skeletal Radiology 2010
  - 34 patients surgically confirmed labral tear with peel back in ABER
  - 29 controls with no peel back
- Attempt to describe MR appearance and determine reliability of MR for prospective diagnosis of posterosuperior labral peel back
  - Position of posterosuperior labrum with respect to glenoid on ABER



Burkhart et al 2003

Labral Peel Back – Borrero et al

- Posterosuperior labrum = "Reverse C" shape
- Three point grading system
  - 0 - Apex of reverse C clearly lateral and craniad to glenoid tangent line
  - 1 - Apex flush with glenoid tangent line
  - 2 – Apex clearly medial and caudal to glenoid tangent line on at lease 1 image

Grade 0

Grade 1

Grade 2

Labral Peel Back – Borrero et al

- Grade 0 and Grade 1 considered negative
- Grade 2 considered peel back
- 2 blinded readers: excellent inter-rater agreement – Kappa coefficient of 0.9
- Sensitivity 73%, Specificity 100%, PPV 100%, NPV 78%

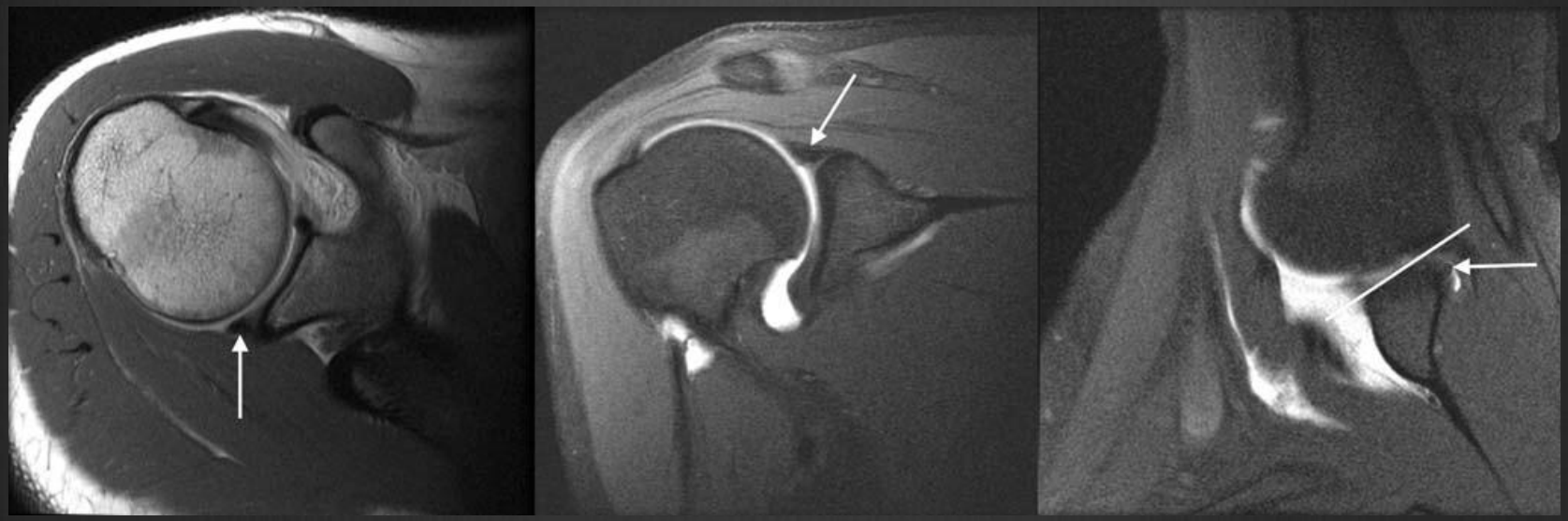
Grade 0

Grade 1

Grade 2

Labral Peel Back – Borrero et al

- Additional analysis of value of ABER for diagnosis of SLAP
- 5 of 34 patients
  - SLAP tear only evident on ABER
  - No labral tear evident on standard sequences



Humeral Retroversion

- Posteromedial angle between the axis of the elbow and the axis through the center of the humeral head
- Normal values range from 10º-40º
- Increased retroversion
  - Seen in dominant arms of overhead athletes
  - Allows increased external rotation before humeral head contrained by anterior capsule

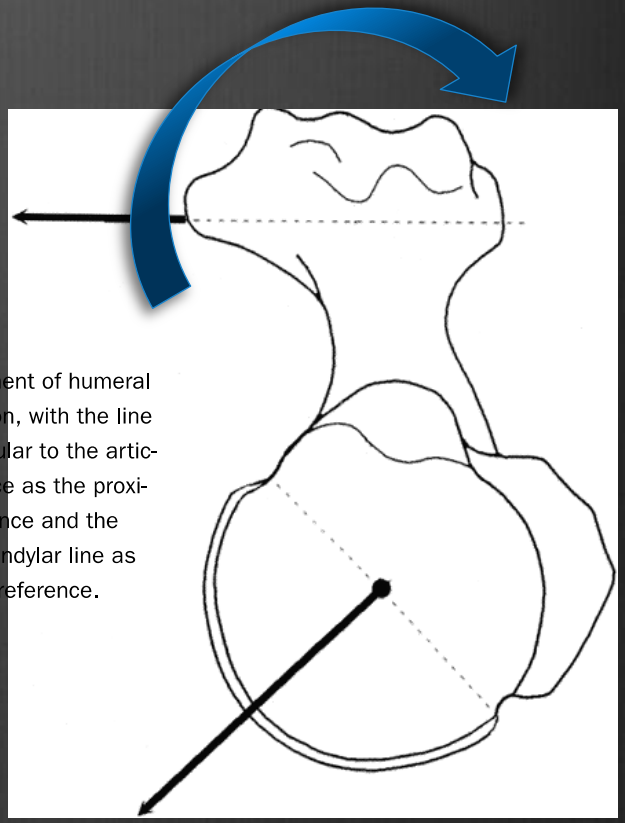


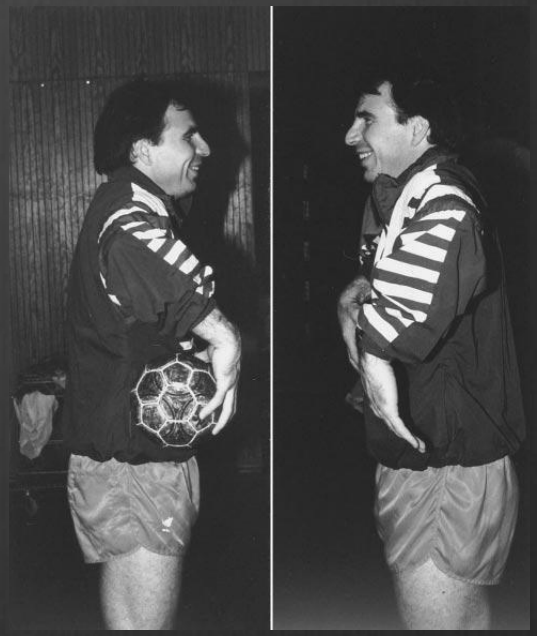
Fig. 1
Measurement of humeral retroversion, with the line perpendicular to the articular surface as the proximal reference and the transepicondylar line as the distal reference.

Hernigou 2002

Reagan et al. 2002

Humeral Retroversion

- Pieper, AJSM 1998
  - 51 professional handball players
    - Retrotorsion angle average of 9.4° greater on dominant side
    - No side to side difference in retroversion of controls
  - Players with chronic shoulder pain - no side to side difference
  - Increased retroversion adaptive response allowing more external rotation before excessive strain on shoulder soft tissues

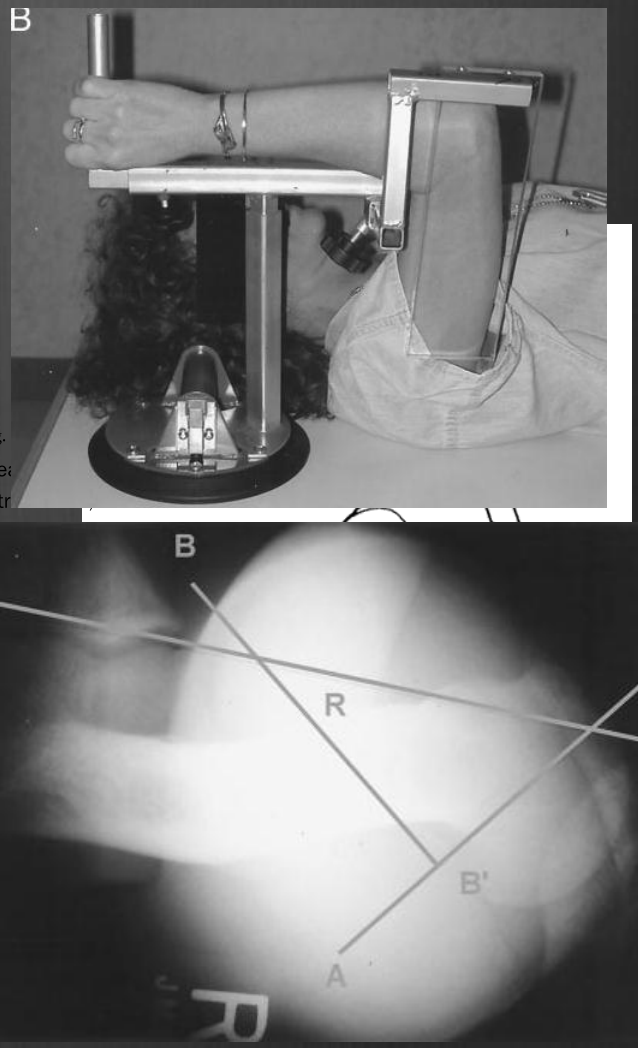


Humeral Retroversion

- Crockett et al, AJSM 2002
  - 25 professional pitchers vs 25 controls
  - Retroversion in dominant arm of pitchers – 40^{o}
    - Significantly greater than non dominant arm (23^{o})
    - Significantly greater than dominant arm of nonthrowers (18^{o})
  - Nonthrowers
    - No significant difference between dominant (18^{o}) and nondominant (19^{o})
- Reagan et al, AJSM 2002
  - 54 asymptomatic college baseball players
  - Significantly greater retroversion in dominant arm
    - Dominant arm – 36.6^{o}
    - Nondominant arm – 26^{o}

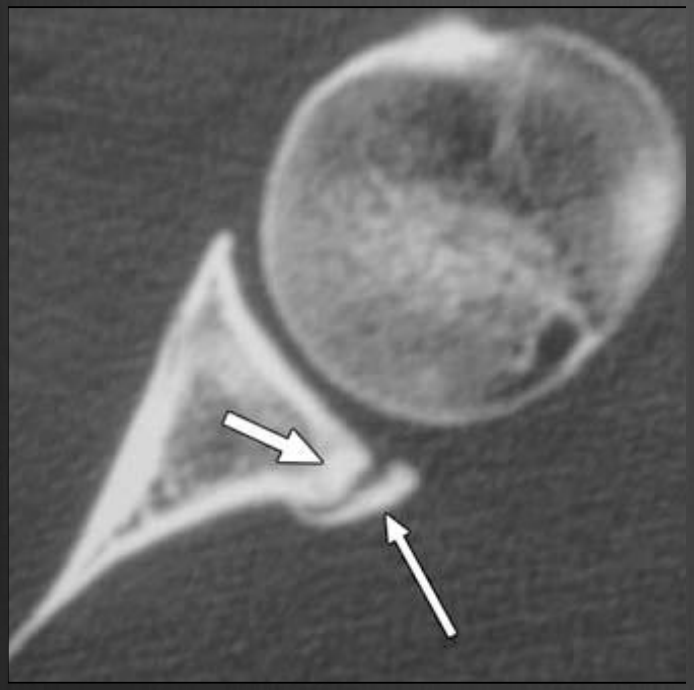
Humeral Retroversion Measurement

- Multiple different techniques
  - Radiographic techniques complicated
  - CT preferred method
- CT Reference lines
  - Line perpendicular to the proximal articular surface of the humeral head
  - Distal reference Line
    - Transepicondylar line
    - Trochlear tangent line
    - Forearm axis



Reagan et al. 2002

Bennett Lesion

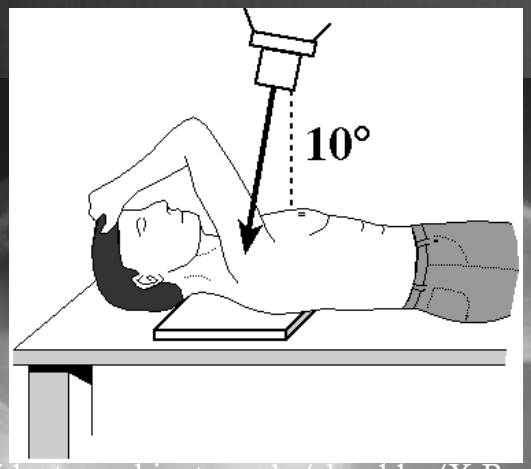


Shah and Tung 2009

- Ossification near the posteroinferior glenoid in overhead athletes
- Bennett (1941) originally believed traction injury at attachment of the long head of the triceps
- Generally accepted as traction injury of posteroinferior capsule and PIGHL

Imaging of Bennett Lesions

Stryker Notch View

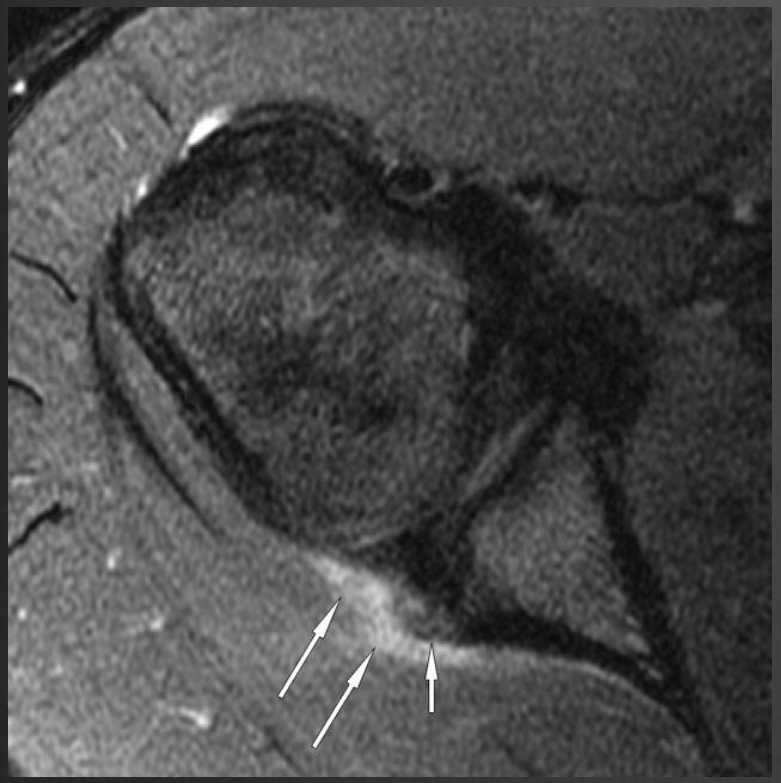


http://depts.washington.edu/shoulder/X-Rays.htm

Meister et al 1999

- Best evaluated by CT and radiographs
- Extra-articular crescentic calcification/ossification near the glenoid attachment of PIGHL
- Special radiographic views may be helpful
  - Bennett or modified Bennett view
    - ABER with beam angled 5° cephalad
  - Stryker notch view
    - Hand on head with elbow straight up
    - Beam angled 10° cephalad

MRI of Bennett Lesions



Sanders et al 2010

- Low signal abnormality within capsule
- May contain high T1 signal from marrow
- Possibly associated with capsular thickening
- Pericapsular edema
  - More acute injury?

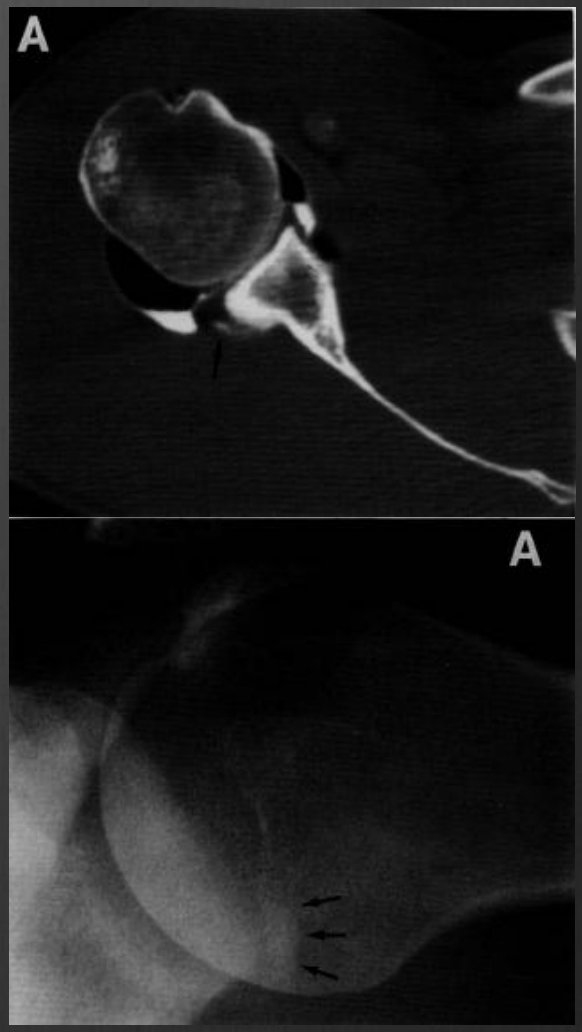
Chung CB and Steinbach LS. MRI of the upper extremity: elbow, wrist, and hand. 2009. (Anecdotal data per Dr. Chung)

Bennett Lesion

- Controversial clinical significance and treatment
- Associated with posterior shoulder pain
  - ABER position – late cocking/early acceleration
  - Adduction/internal rotation – follow through/deceleration
- Frequently seen in asymptomatic overhead athletes
  - 12 of 55 (22%) asymptomatic MLB pitchers (Wright et al 2004)
- Frequently associated with other intra-articular pathology
  - Posterior and posterosuperior labral tears
  - Undersurface rotator cuff tears
- Variable results for surgical excision

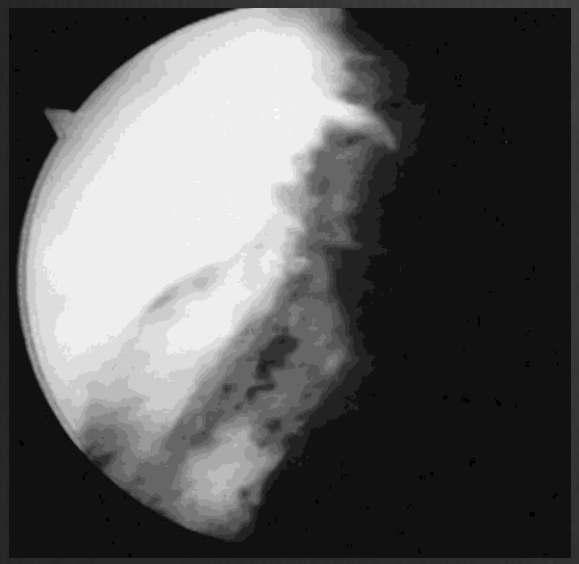
Bennett Lesion

- Lombardo et al, AJSM 1977
  - 3 pitchers with open excision of exostosis and posterior labral debridement
  - All 3 returned to pre-injury level of performance
- Ferrari et al, AJSM 1994
  - 7 baseball players with shoulder pain and Bennett's lesion
  - 6 labral tears and 6 undersurface rotator cuff abnoramlities repaired
  - Bennett lesion not treated
  - 6/7 returned to preinjury level



Ferrari et al, 1994

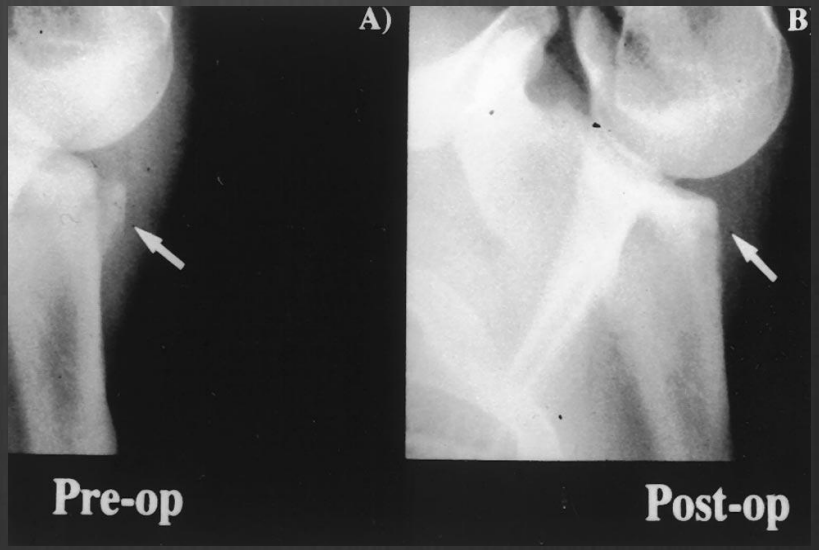
Bennett Lesion



- Meister et al, AJSM 1999
  - 22 overhead athletes with shoulder pain and Bennett's
  - 11 patients - exostosis debrided
  - 21 patients - undersurface cuff tears debrided
  - 20 patients - Labral "fraying" debrided
    - 15 posterior, 4 anterior, 1 superior
  - 10 of 18 patients with follow up returned to preinjury level > than 1 year
    - Exostosis debridement no effect on return
  - Still recommended excision of large exostosis in patients with posterior shoulder pain

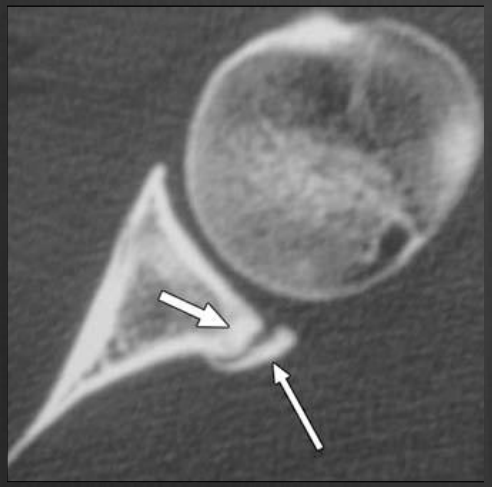
Bennett Lesion

- Yoneda, et al 2002
  - 16 baseball players with arthroscopic resection of symptomatic Bennett's
    - Posterior shoulder pain with throwing
    - Pain with throwing reduced by lido injection into Bennett's
    - Posteroinferior GH joint tenderness
  - 11/16 returned to preinjury level of performance
  - Many associated abnormalities also treated
    - 6 articular sided cuff tears debrided
    - 4 posteroinferior labral tears repaired
    - 4 "biceps and labral complex injuries" repaired or debrided

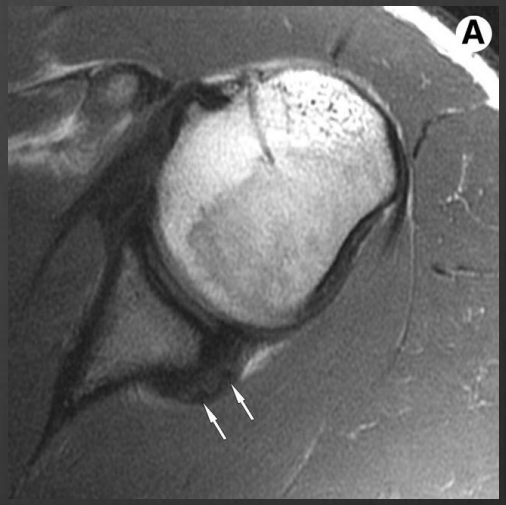


Bennett Lesion and GIRD?

- Both involve PIGHL
- PIGHL thickening sometimes seen with Bennett lesion
- Tuite et al, Skeletal Radiology 2007
  - Different response to same repetitive injury ?
  - Spectrum of injury where some with GIRD go on to Bennett's?
- Meister et al, AJSM 2002
  - "An asymmetric loss of internal rotation and increased external rotation was noted in all 22 patients"



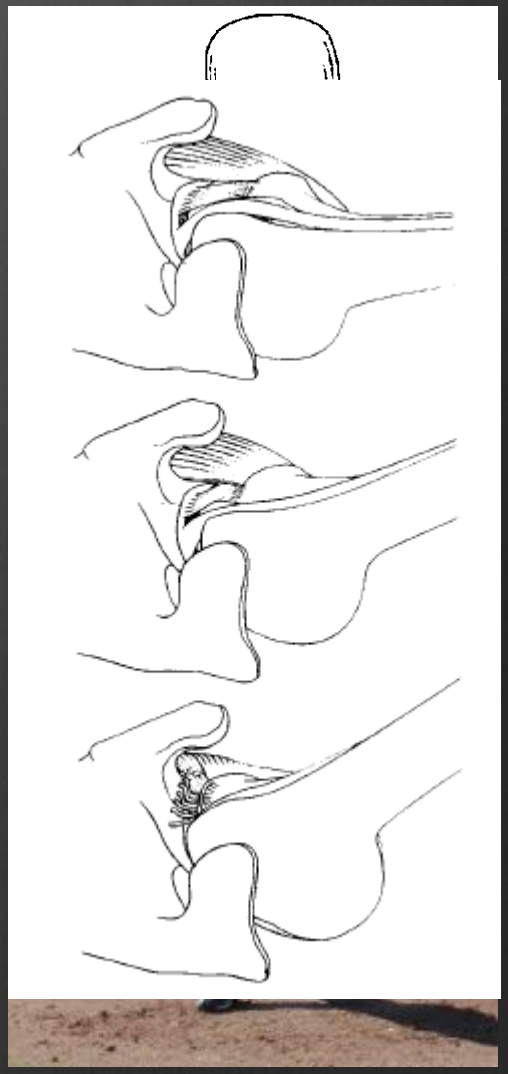
Shah and Tung 2009



Sanders et al, 2010

Anterosuperior Impingment

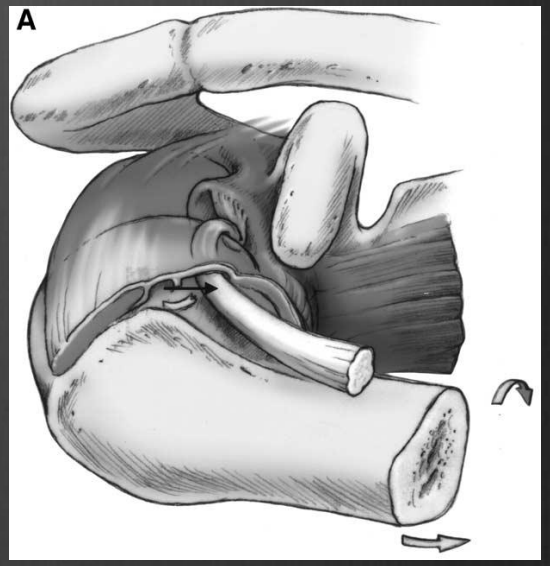
- Impingment of undersurface of biceps pulley and subscapularis tendon against anterosuperior glenoid rim with adduction and internal rotation
- Gerber and Sebesta, 2000
  - 16 pts c/o pain with anterior elevation and internal rotation
  - 12/16 in overhead professions (masonry)
  - 3 isolated pulley lesions
  - 10 pulley lesions + undersurface tears of upper fibers of subscap
  - 3 intact pulley with undersurface subscap
  - 16/16 impingment with horizontal adduction and internal rotation at arthroscopy
  - Likely from repetitive overhead movements

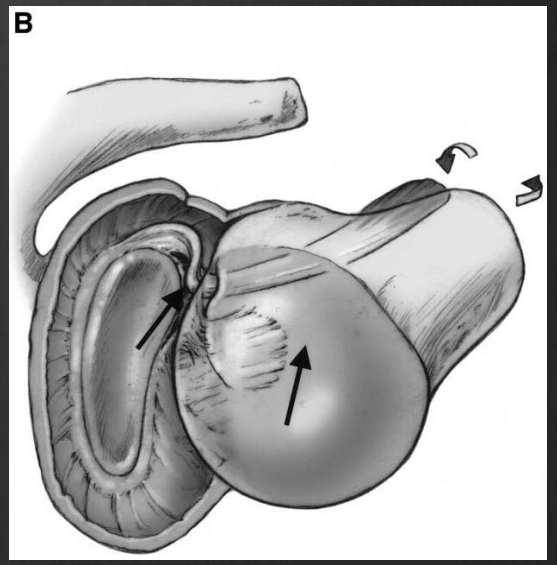


http://mlbblogger.files.wordpress.com/2013/03/maestri-follow-through.jpg?w=555&h=312

Anterosuperior Impingment

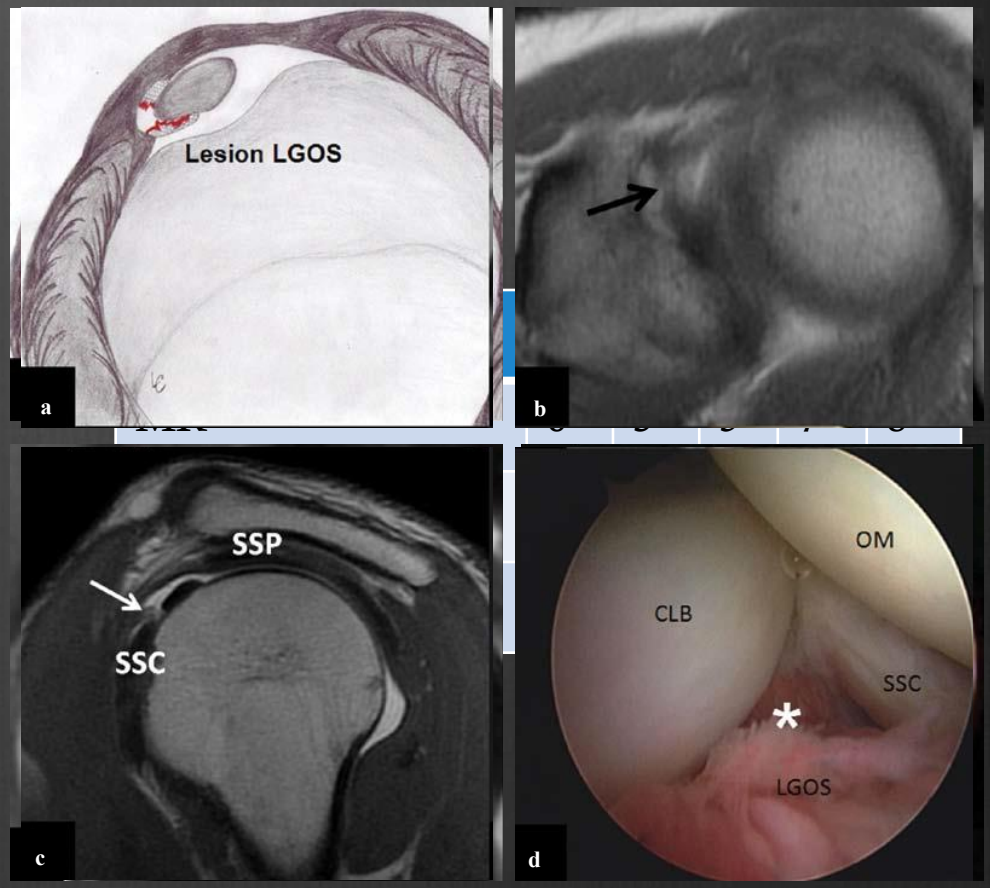
- Habermeyer et al 2004
  - 89 Patients with pulley lesions
  - 4 groups (% with ASI at arthroscopy)
    - 1. Isolated pulley lesion (26.9%)
    - 2. Pulley + deep surface supra (19.1%)
    - 3. Pulley + deep surface subscap (59.1%)
    - 4. Pulley + deep surfaces SS + SSC (75%)
  - Role of subscap tears
    - Increased ASI with Subscap involvement
    - LHB loses stabilizing effect on GH joint
    - Anterosuperior humeral head translation → Increased ASI
  - Pulley lesion
    - Degenerative
    - Traumatic – forcefully stopped overhead throwing motion





Anterosuperior Impingment

- Very little in radiology literature
- Barile et al 2013
  - 23 overhead athletes with suspected pulley lesions
  - Excellent correlation with Arthroscopy
    - 2 downgraded from I to normal
    - 2 upgraded from III to IV
  - Increased ASI with subscap involvement
  - MR less accurate for AS Labrum
    - Type 4: 6 MR vs 10 Arthro
    - Type 3: 2 MR vs 4 Arthro



Little Leaguer's Shoulder

- Proximal humeral physis overuse injury
  - Rotational stress during overhead throwing
- Gradual onset of shoulder pain with throwing and tenderness at lateral aspect of shoulder
- Most commonly in early to mid teenage years
  - Physis vulnerable during period of rapid growth
- Mechanism of injury
  - Injury to metaphyseal vessels supplying physis
    - Necessary for chondrocyte death and cartilage mineralization
    - Prolonged chondrocyte survival and extension into metahpysis

Fleming et al 2004

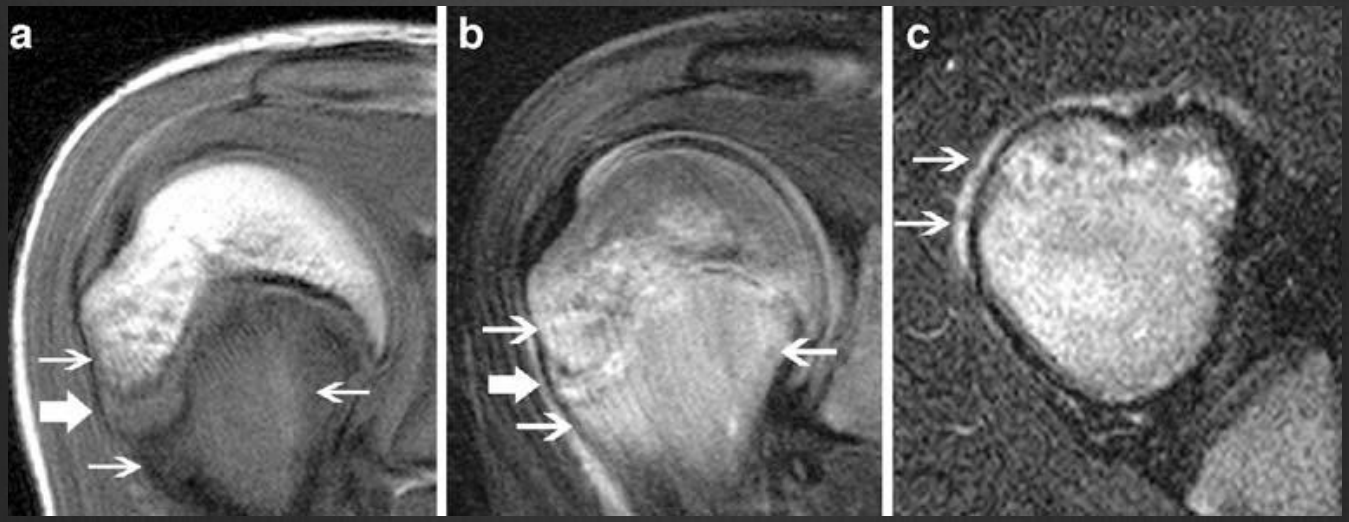
Little Leaguer's Shoulder

- Radiographic findings
  - May be normal if symptoms less than 10 days
  - Proximal humeral physeal widening
  - Less common findings
    - Metaphyseal demineralization or sclerosis
    - Fragmentation or cystic changes lateral aspect of the proximal humeral metaphysis

Carson and Gasser 1998

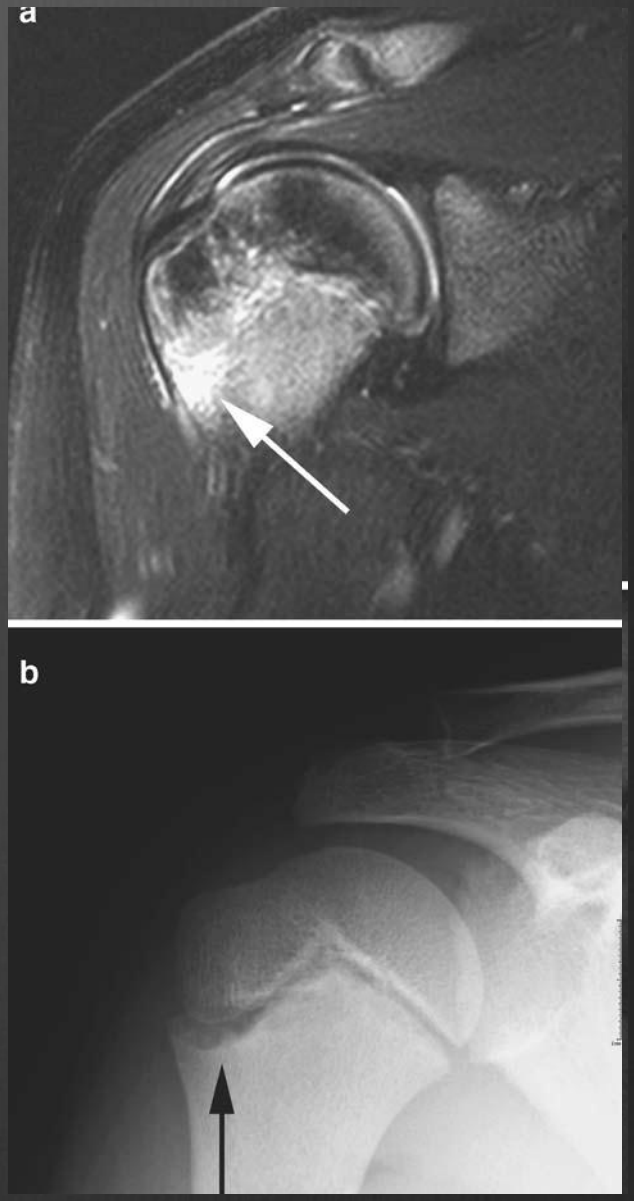
MRI of Little Leaguer's Shoulder

- Hatem et al, 2007
  - 4 pitchers age 12-14 with MRI for shoulder pain
  - 3/4 widened physis
    - Possibly related to imaging early after symptom onset in 1 patient (3 weeks)
  - 4/4 metaphyseal bone marrow edema
  - 3/4 epiphyseal marrow edema
  - 2/4 periosteal edema



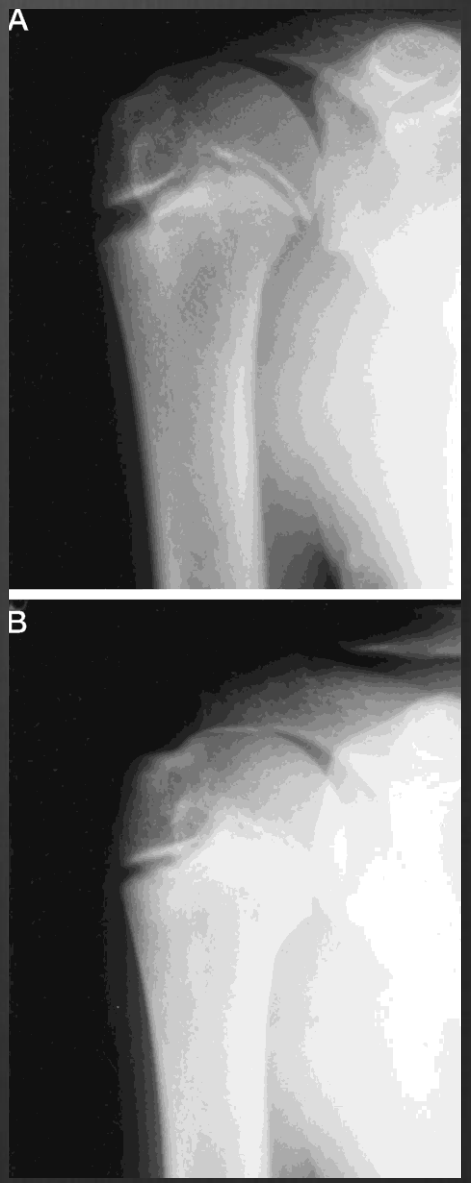
MRI of Little Leaguer's Shoulder

- Obembe et al, 2007
  - 4 adolescent overhead athletes (11-15)
  - Extension of physeal signal into metaphysis
  - Metaphyseal bone marrow edema
  - No epiphyseal abnormalities
  - No periosteal edema



Little Leaguer's Shoulder Treatment

- Conservative management
- Rest / throwing restriction
- Gradually resume throwing
- Carson and Gasser, 1998
  - 21/23 patients returned to throwing after average rest of 3 months
  - 2 patients still resting at time of publication
  - Radiographic appearance lags behind clinical response



Carson and Gasser, 1998

Conclusion

- The throwing shoulder is an evolving and controversial subject
- GIRD initiating the pathologic cascade to SLAP tear is the leading current theory to explain “dead arm”
- Knowledge of injury patterns specific to the throwing shoulder can help the radiologist identify the total spectrum of abnormalities and provide more relevant clinical insight to the treating orthopedic surgeon.

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