Anatomy and Pathology of the Rotator Interval

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Historical perspective

- Term “rotator interval” used by shoulder surgeons to describe coracoid perforation of the anterior rotator cuff; a triangular interval results
  - Attributed to Neer (1970)
- Role in
  - Glenohumeral instability
  - Stabilization of the long head biceps tendon
  - Inflammatory capsular conditions (adhesive capsulitis)

Overview

- Normal anatomy
  - Borders
  - Contents
- Biomechanics
  - Anatomic (cadaveric)
  - Clinical
- Pathology
  - Rotator cuff tears
  - Biceps sling
  - CHL, SGHL, long head biceps tendon
  - Capsular inflammation (adhesive capsulitis)

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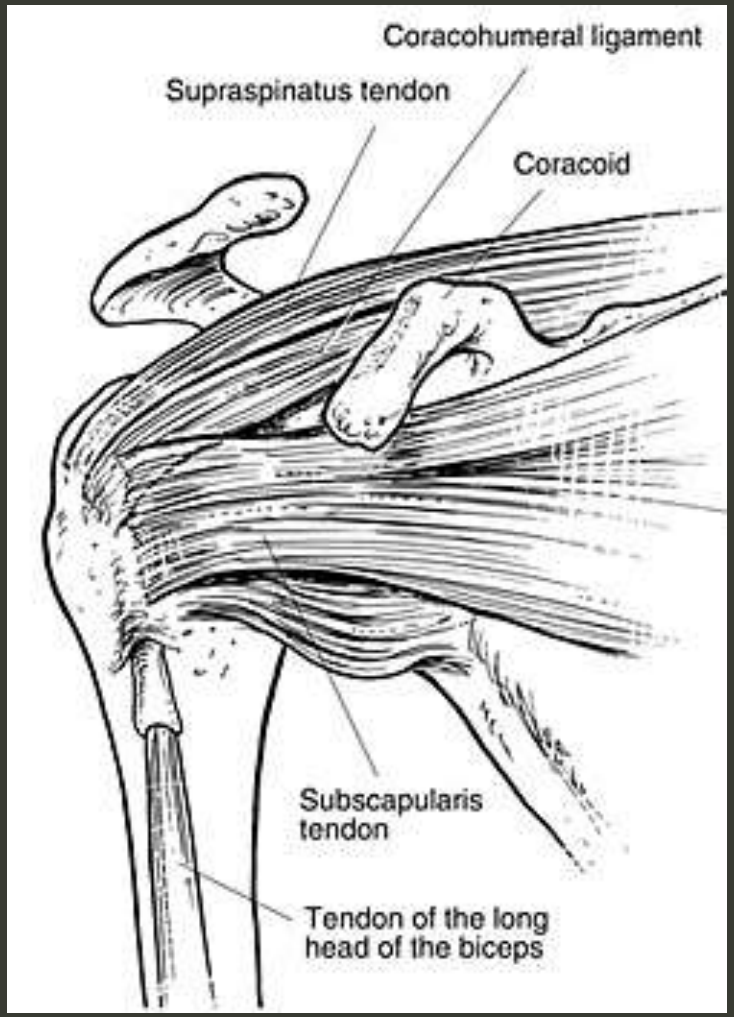
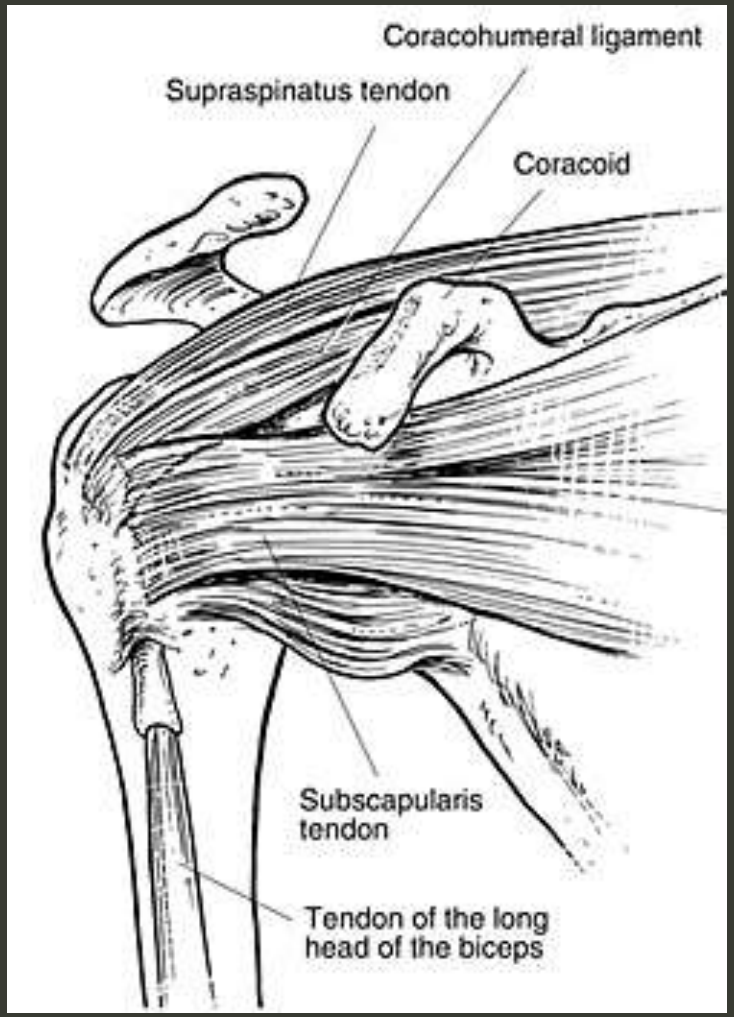
Rotator interval



- Triangular space created by interposition of the coracoid process between the supraspinatus and subscapularis muscles

Hunt SA, Kwon YW, Zuckerman JD: The Rotator Interval: Anatomy, Pathology, and Strategies for Treatment. J Am Acad Orthop Surg 2007:15;218-227.

Rotator interval



- Borders of the rotator interval
  - Superior: anterior margin of the supraspinatus muscle
  - Inferior: superior margin of the subscapularis muscle
  - Apex: intertubercular groove
  - Base: coracoid process

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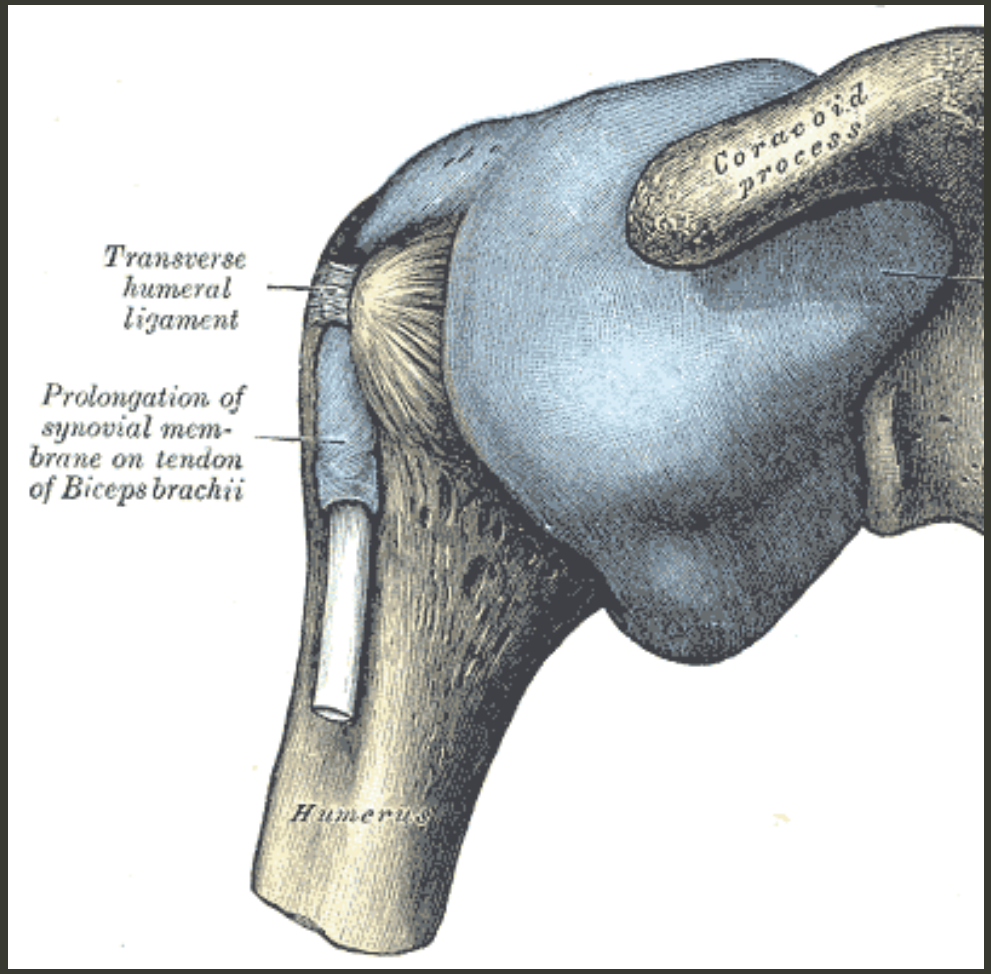
Transverse humeral ligament

Gray's (1901):

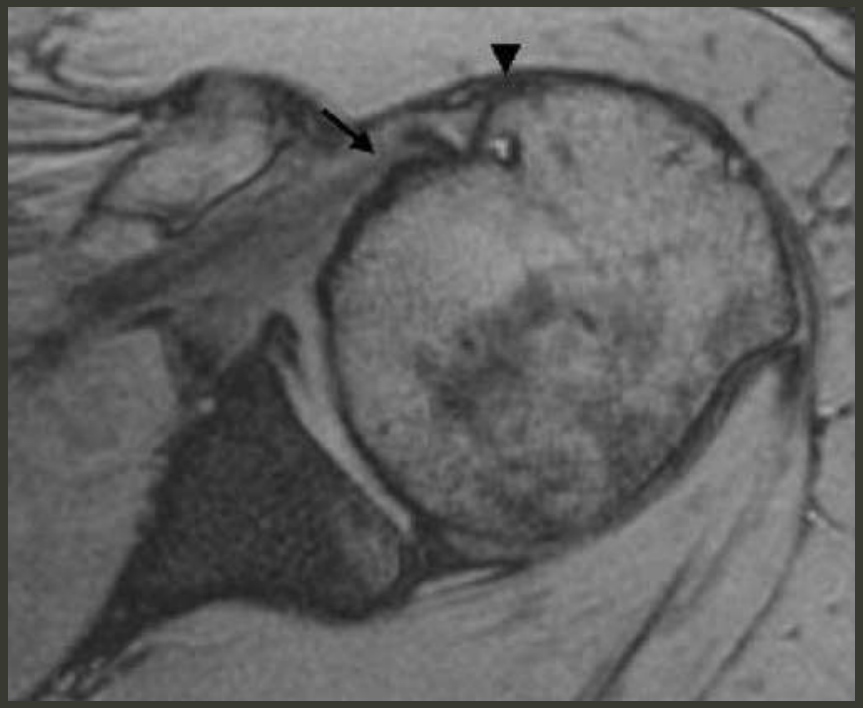
"The transverse humeral ligament is a broad band passing from the lesser to the greater tubercle of the humerus, and always limited to that portion of the bone which lies above the epiphysial line. It converts the intertubercular groove into a canal, and is the homologue of the strong process of bone which connects the summits of the two tubercles in the musk ox."



Transverse humeral ligament?

- Meyer (1920s): 2 observations
  - In shoulders with biceps tendon dislocation, the tissue described as THL was intact
  - Biceps dislocation was consistently medial (underneath or into the subscapularis tendon substance)
- Others (Slatis and Aalto, 1979; Krief 2004) have suggested that coracohumeral ligament disruption is necessary for biceps tendon dislocation
  - No clear anatomic or histologic description of the THL

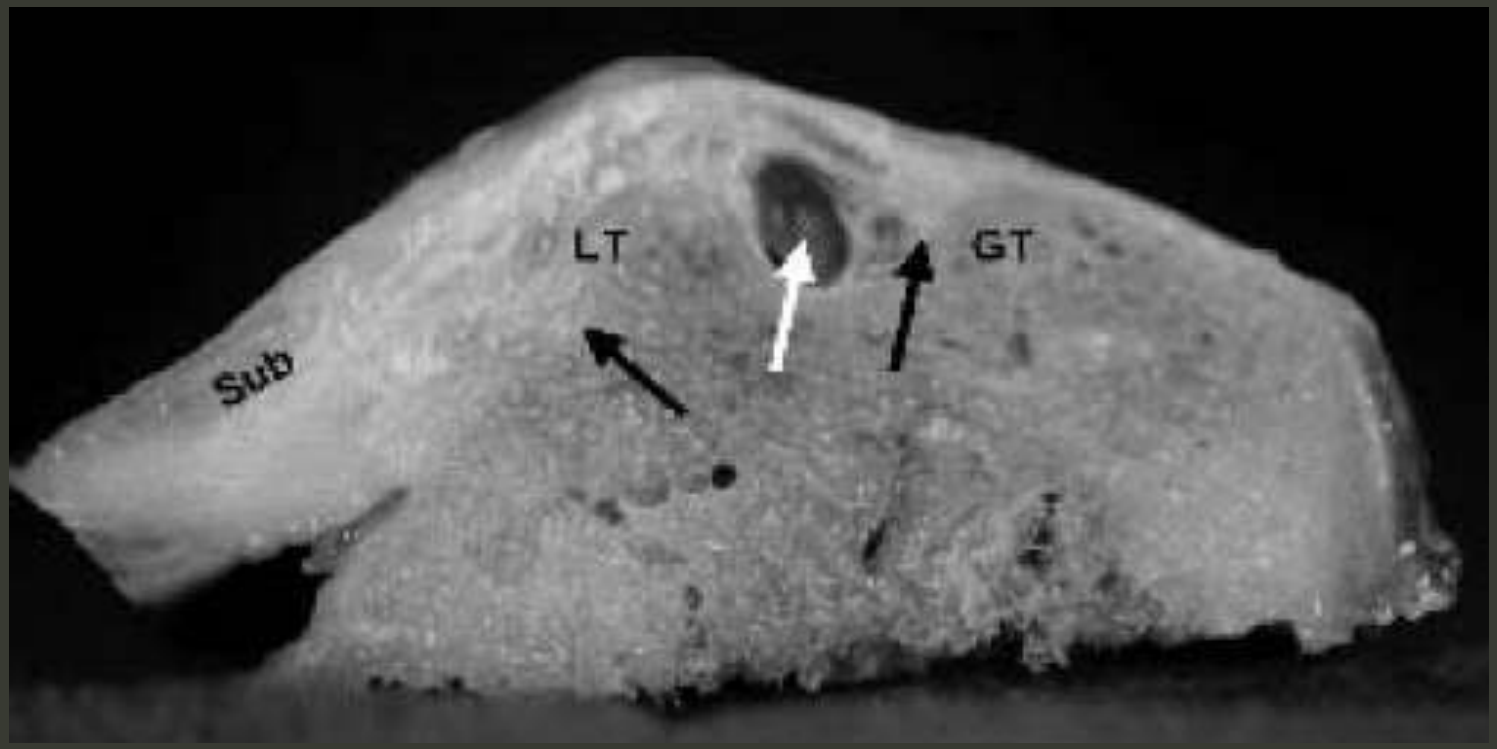
Transverse humeral ligament?



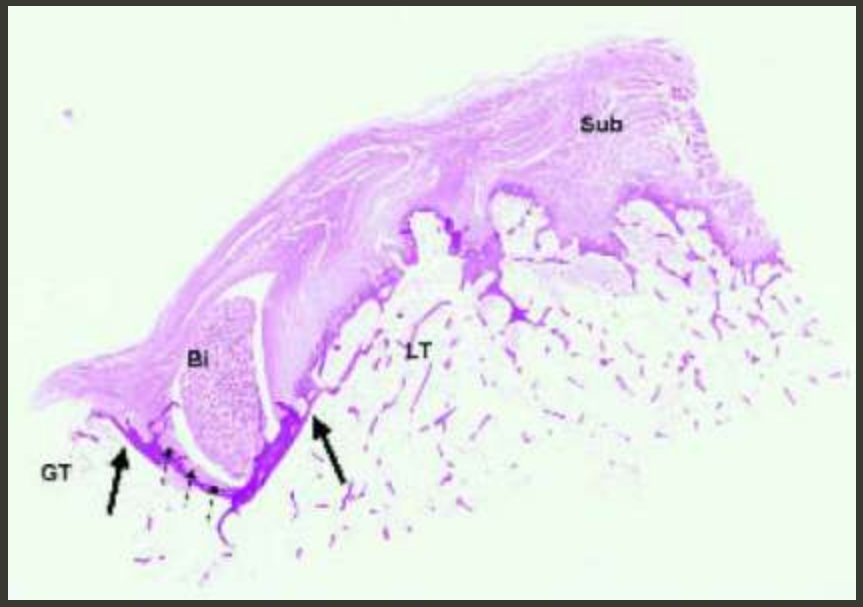
Ax T2 GRE

- Gleason et al. (2006)
  - 14 shoulders in 7 matched pairs
  - MR imaging, gross dissection, histologic findings were concordant

Transverse humeral ligament?

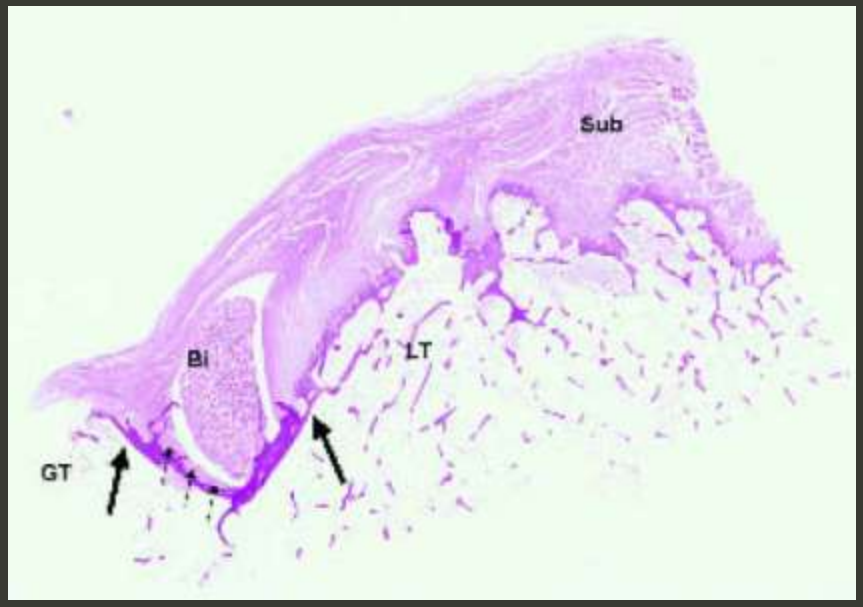


Transverse humeral ligament?



H+E

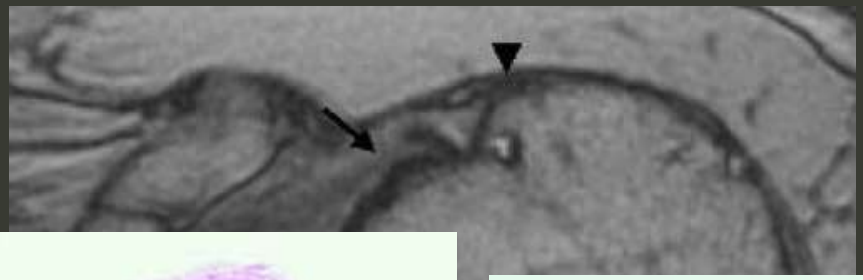
Transverse humeral ligament?

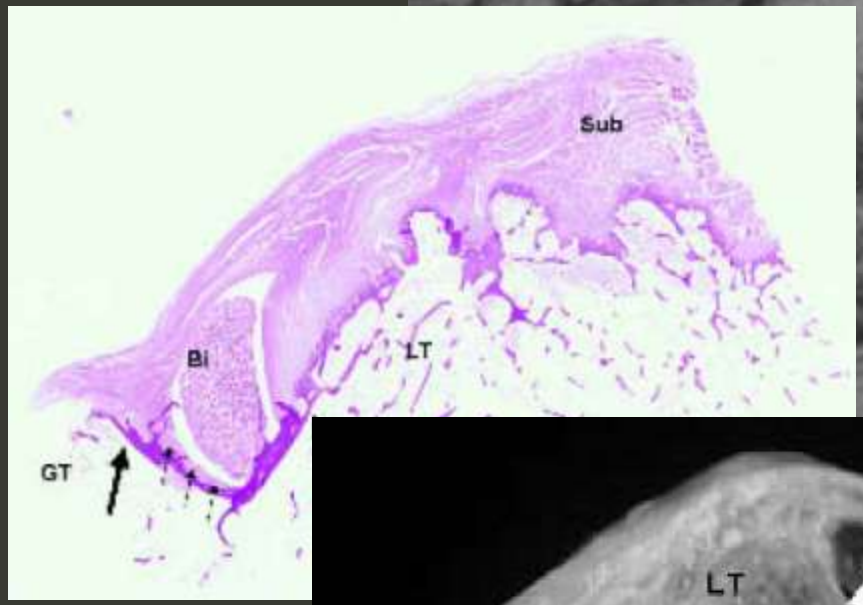


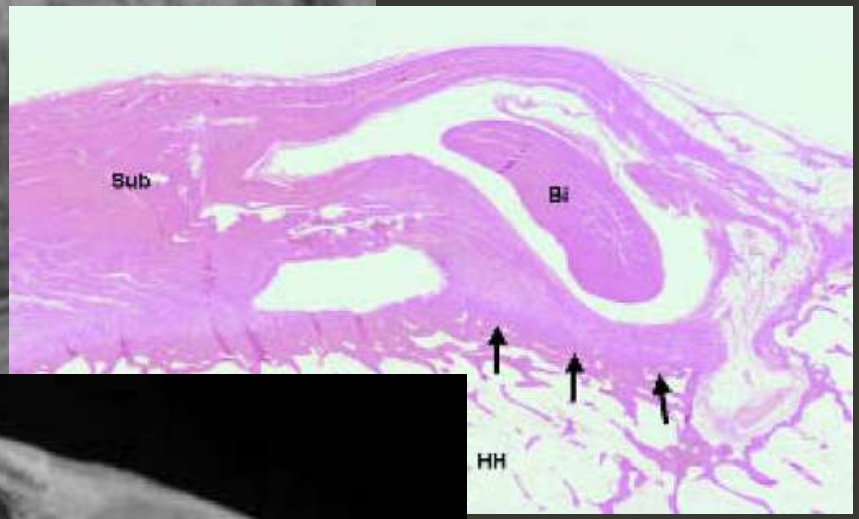
H+E

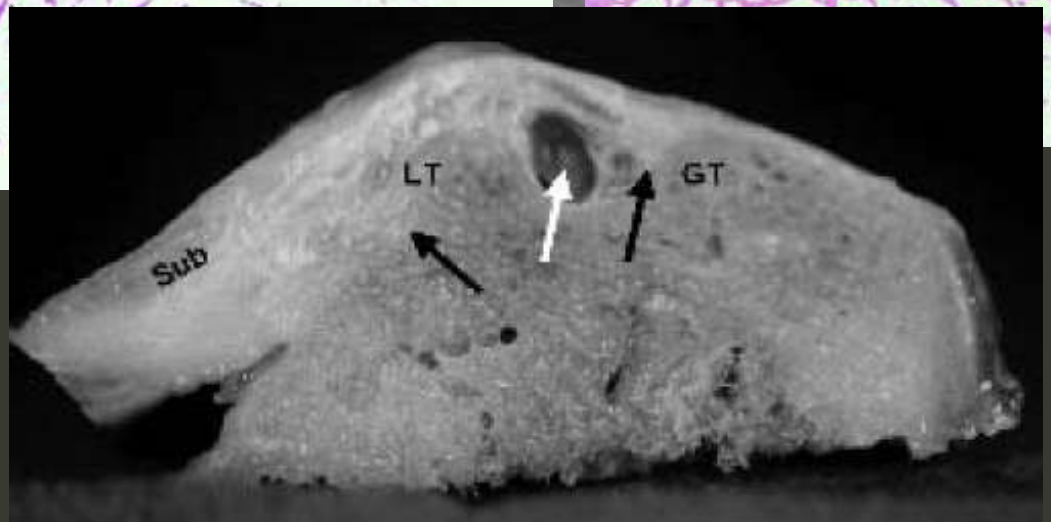
Elastin stain

Separate “THL” not confirmed









H+E

Rotator interval contents

- Coracohumeral ligament
- Superior glenohumeral ligament
- Biceps tendon, long head

- Reinforced by, confluent with overlying capsule

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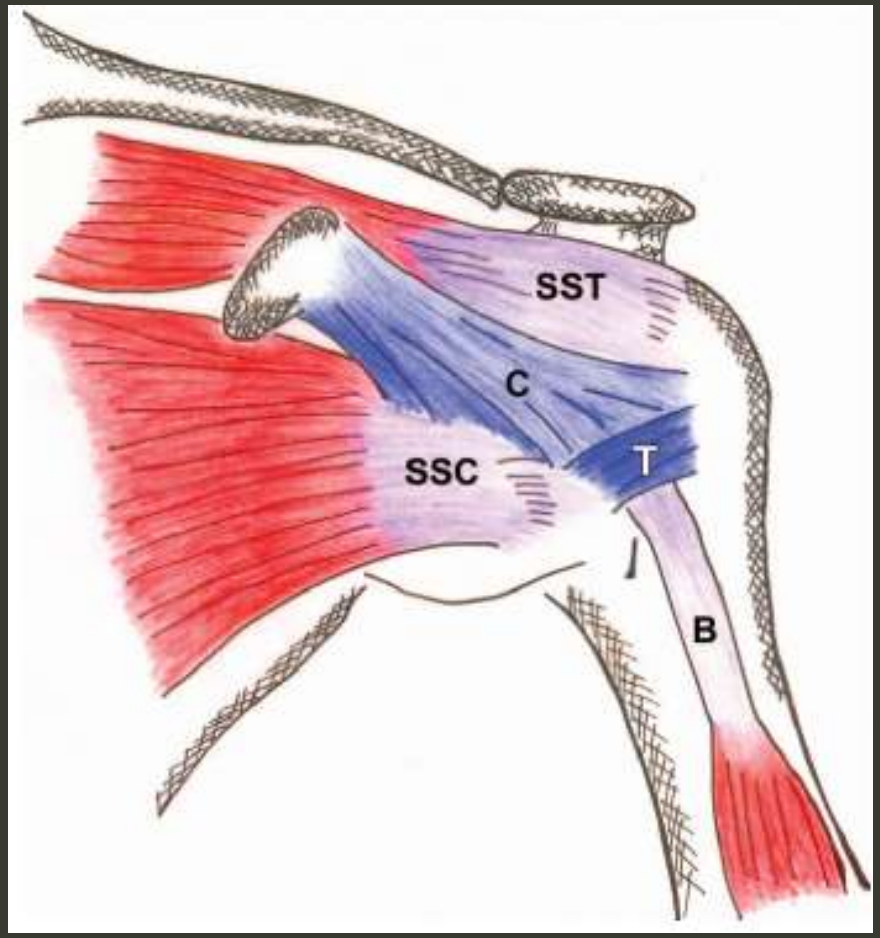
- Coracohumeral ligament
- Superior glenohumeral ligament
- Long head biceps tendon

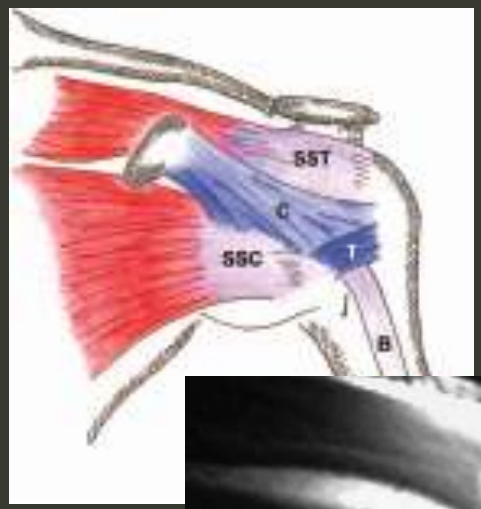
Coracohumeral ligament

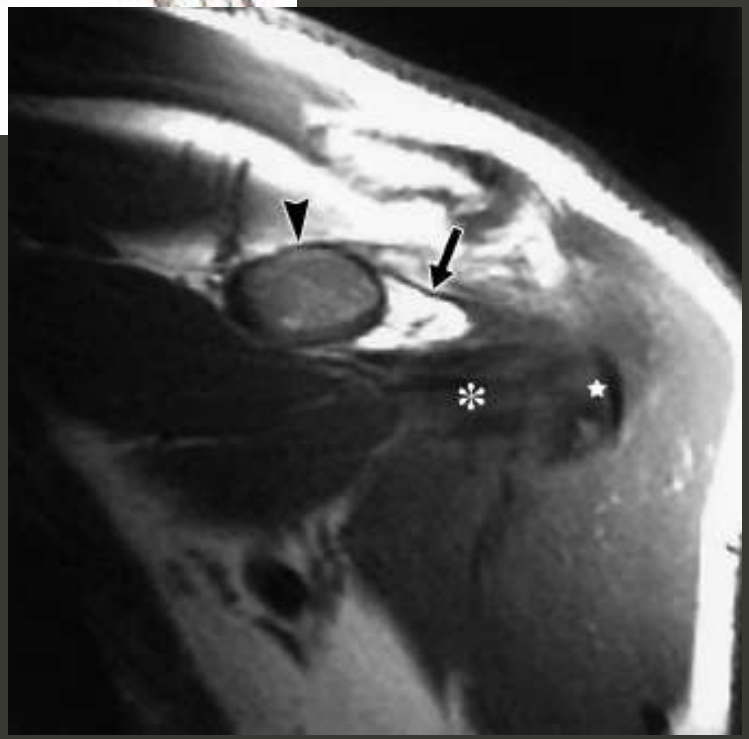


- Origin: lateral aspect of the coracoid base

Morag, Y et. al. (2005)

Coracohumeral ligament

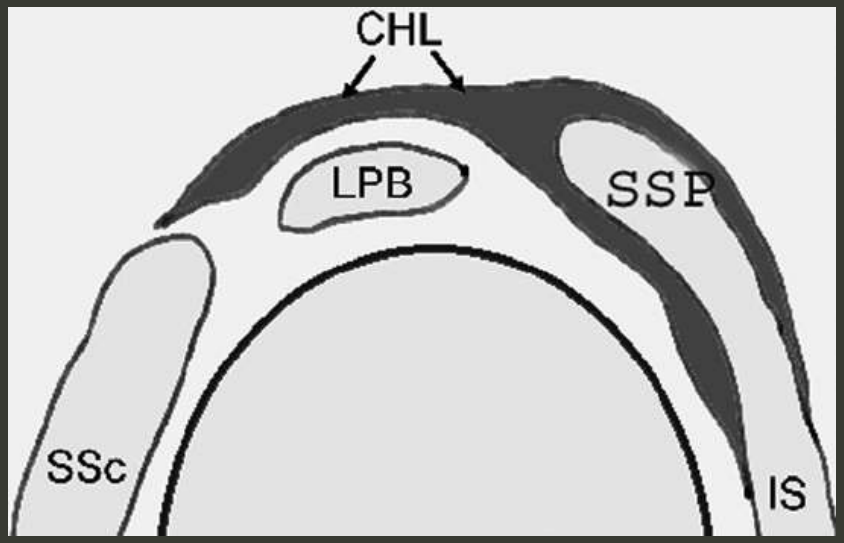


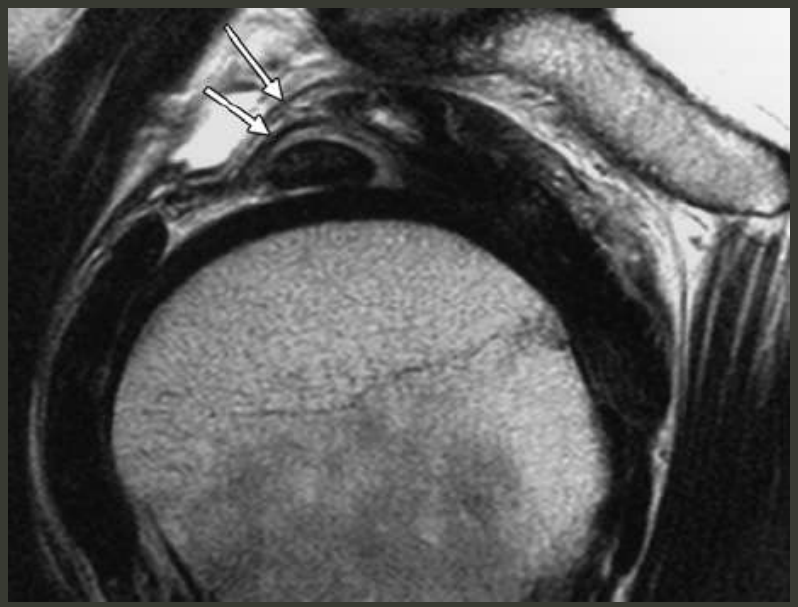


- Origin: lateral aspect of the coracoid base
- Distally, forms two bands
  - Smaller, medial band crosses over the IA biceps tendon to insert on the lesser tuberosity, superior fibers of the subscapularis tendon

Morag, Y et. al. (2005)

Coracohumeral ligament





Krief, AJR 2005

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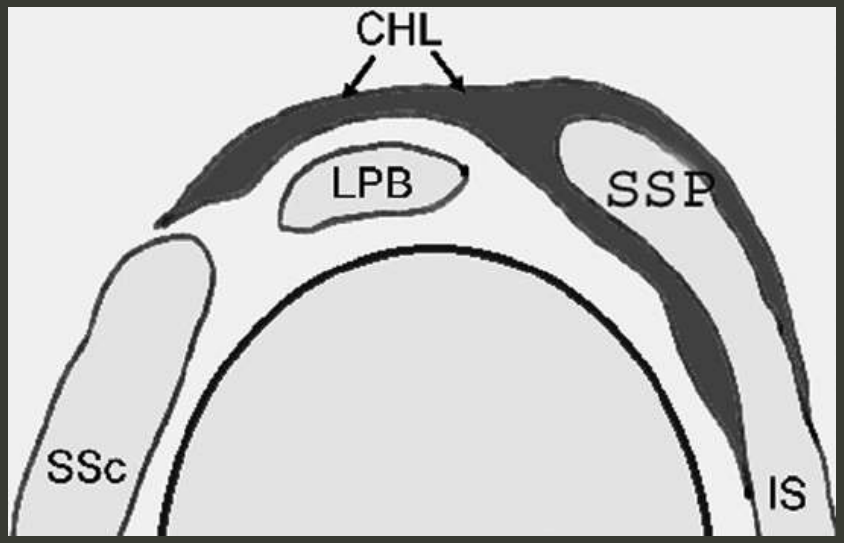
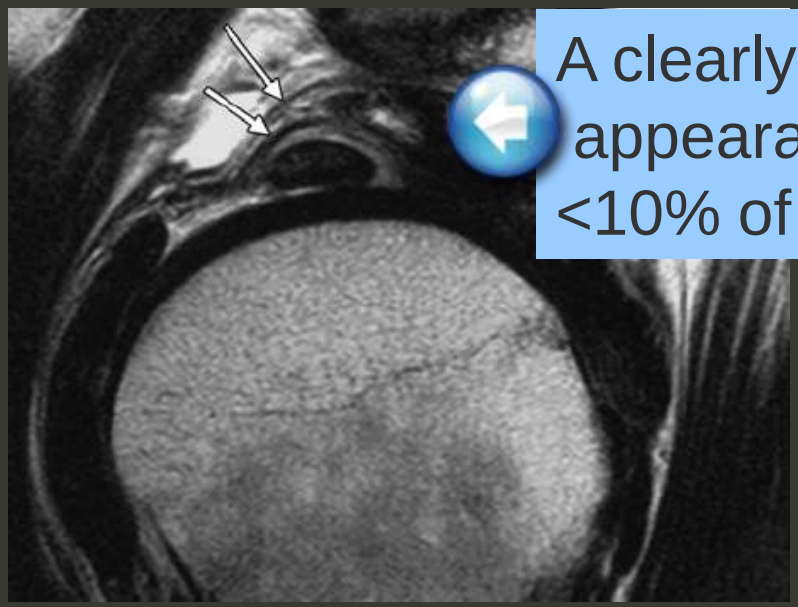
  - Larger, lateral band inserts on greater tuberosity and anterior supraspinatus tendon

Coracohumeral ligament





A clearly multilayered appearance is seen in <10% of cases

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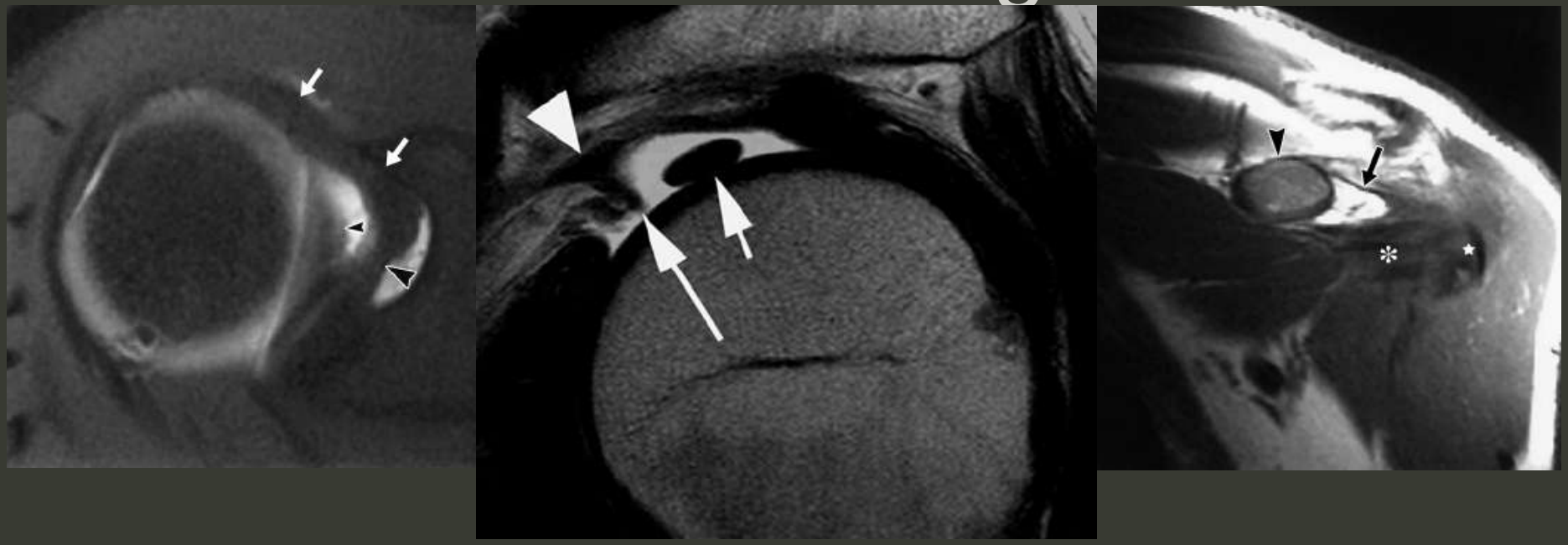
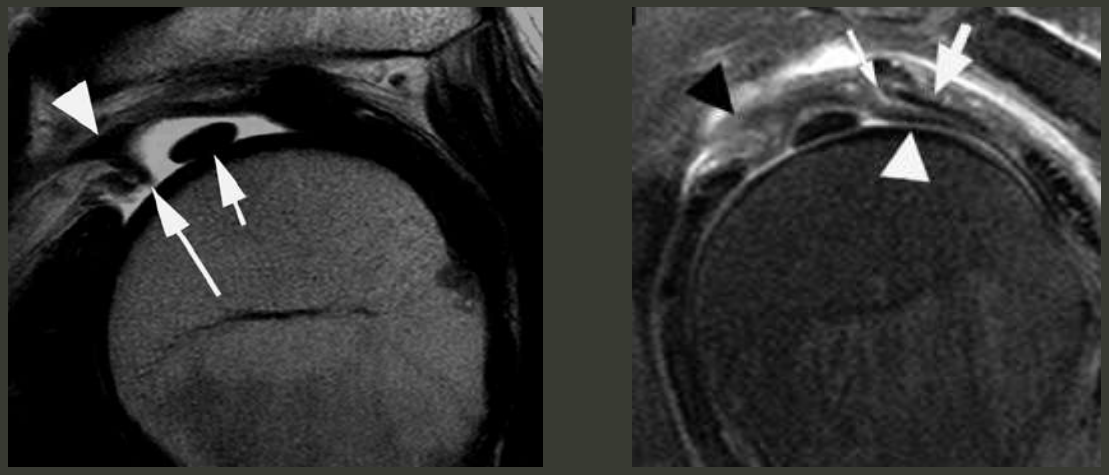
Coracohumeral ligament



- MR imaging
  - Homogeneous, low signal on all sequences
  - Sagittal oblique plane optimal but should be able to see in all three planes
  - Well seen in its midportion
  - Cannot be differentiated from supraspinatus, subscapularis tendon fibers where fused

Coracohumeral ligament



Krief, AJR 2005

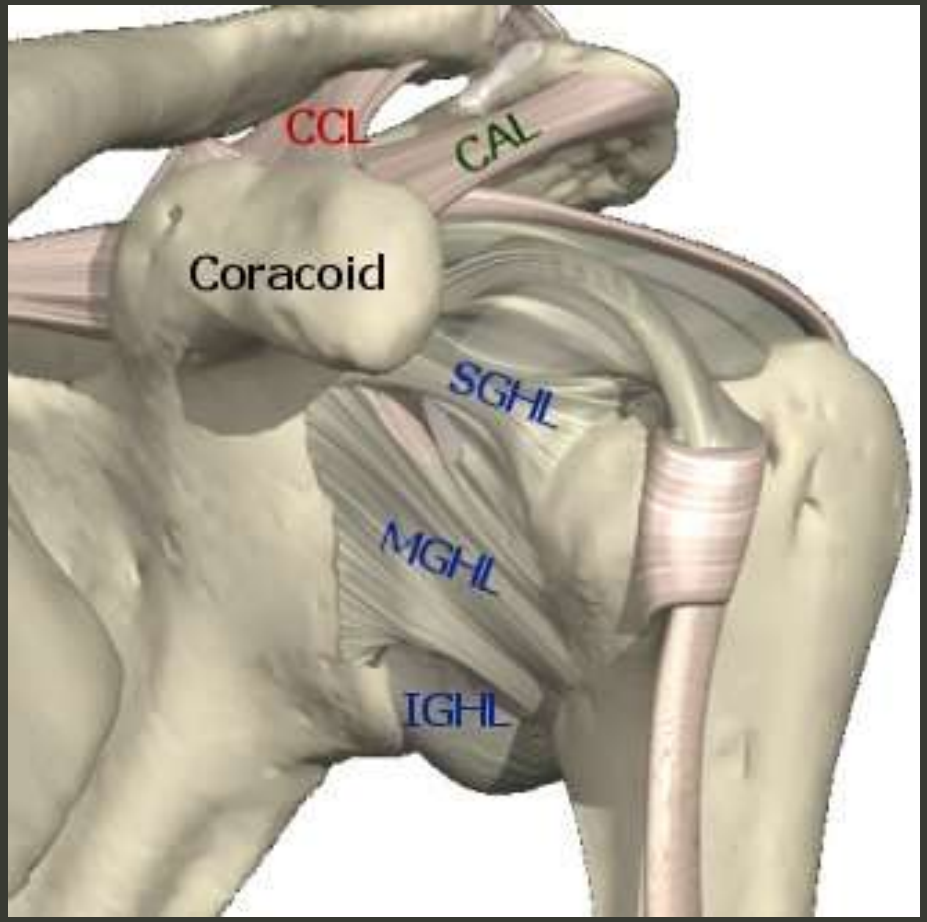
- MR
  - Without fluid in the glenohumeral joint, the superior glenohumeral ligament may be difficult to differentiate as a separate structure
- Histologically, more similar to capsule
  - ? Focal capsular thickening
  - At least contributes to the capsular roof of the RI

Rotator interval contents

- Coracohumeral ligament
- Superior glenohumeral ligament
- Biceps tendon, long head

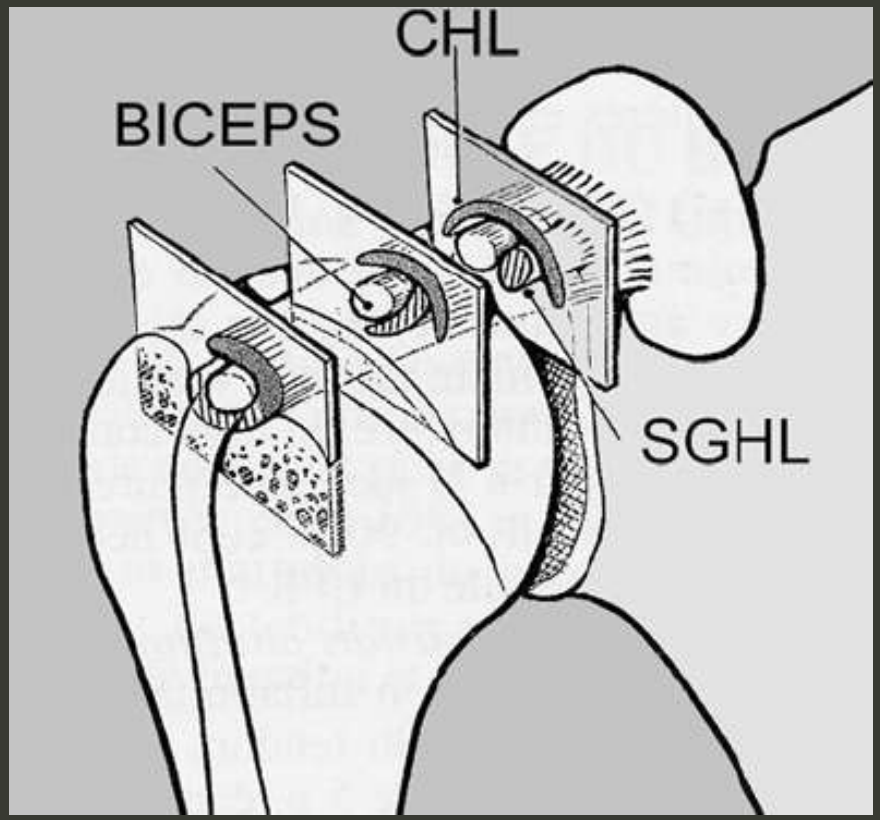
Superior glenohumeral ligament

- Origin: superior tubercle of the glenoid (anterior to the biceps tendon)
- Insertion: superolateral lesser tuberosity (deep to superior border of subscapularis tendon)



www.yess.uk.com/images/anatomy/ghj_ligs.jpg

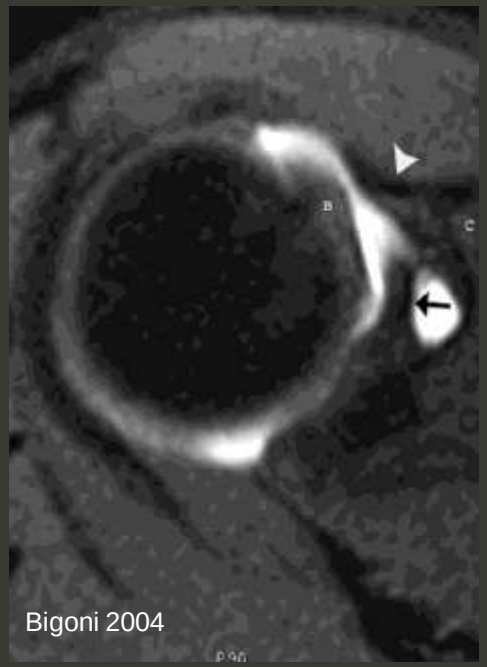
Superior glenohumeral ligament

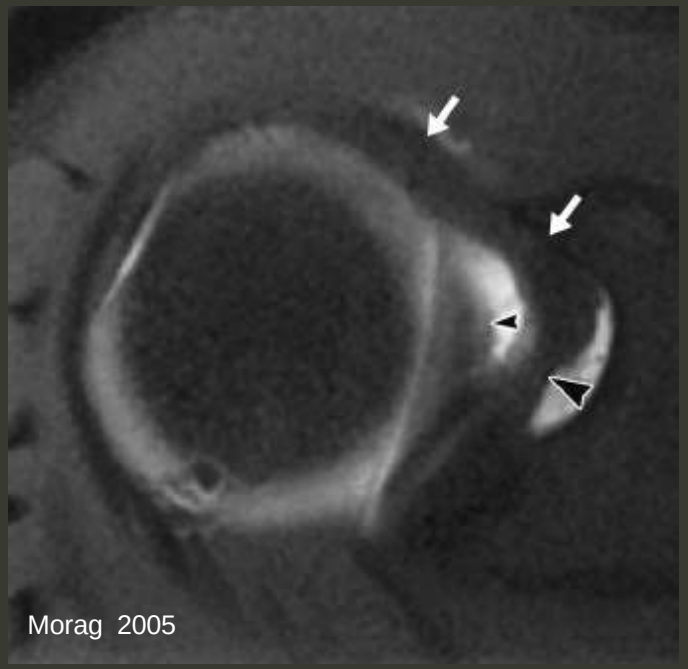


- Changes morphology medial to lateral
  - Proximal: tubular, anterior to long head biceps tendon
  - Midportion: flattened anteriorly; T-shaped extension to CHL
  - Lateral: fuses with CHL to form a sling around the long head biceps tendon

Krief, AJR 2005

Superior glenohumeral ligament


Bigoni 2004


Morag 2005

- MR
  - Uniform low signal intensity
  - Anterior to long head biceps tendon on axial images
  - Cannot differentiate from CHL where fused distally
  - Best seen in the presence of intraarticular fluid

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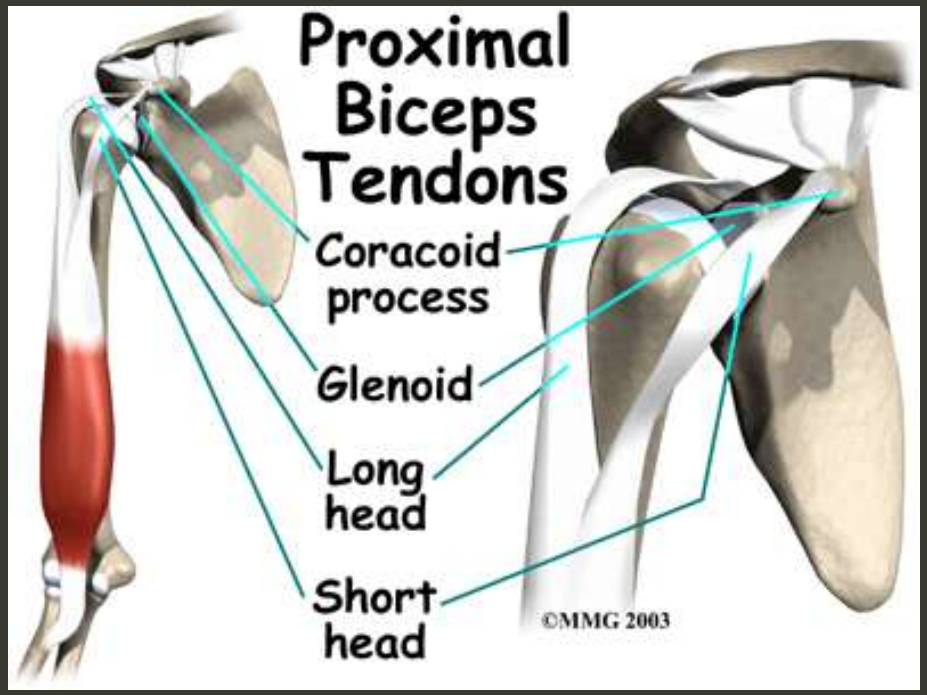
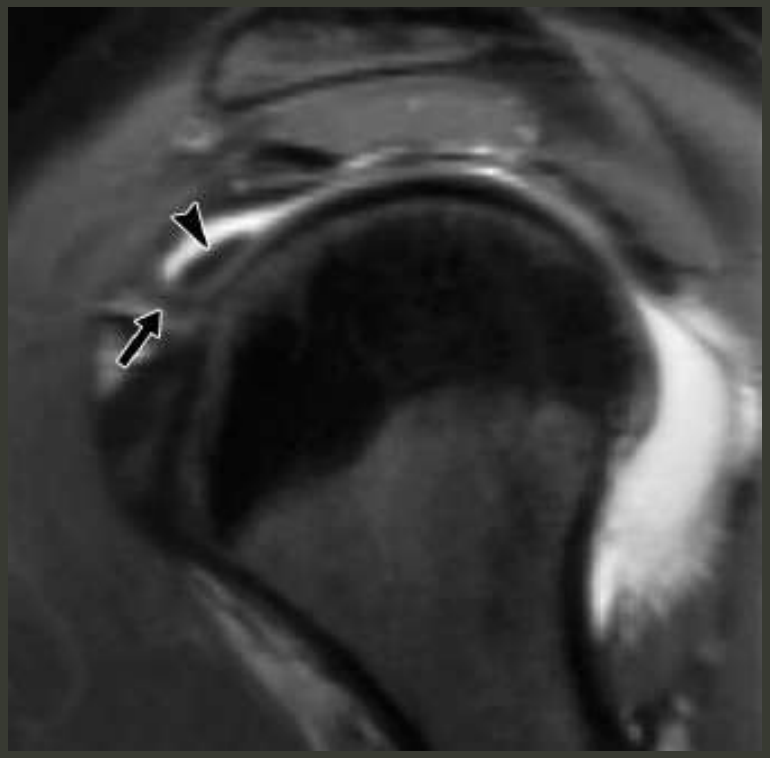
Biceps tendon, long head



www.eorthopod.com/.../distal_biceps_rupture.html

- Origin: superior glenoid labrum; supraglenoid tubercle, rotator cuff, joint capsule, coracoid base
  - Intraarticular
    - Traction zone: intraarticular, extrasynovial; tendon histology
    - Sliding zone: contacts humerus, fibrocartilage histology
  - Extraarticular (bicipital groove)
- Exits the glenohumeral joint through the apex of the RI

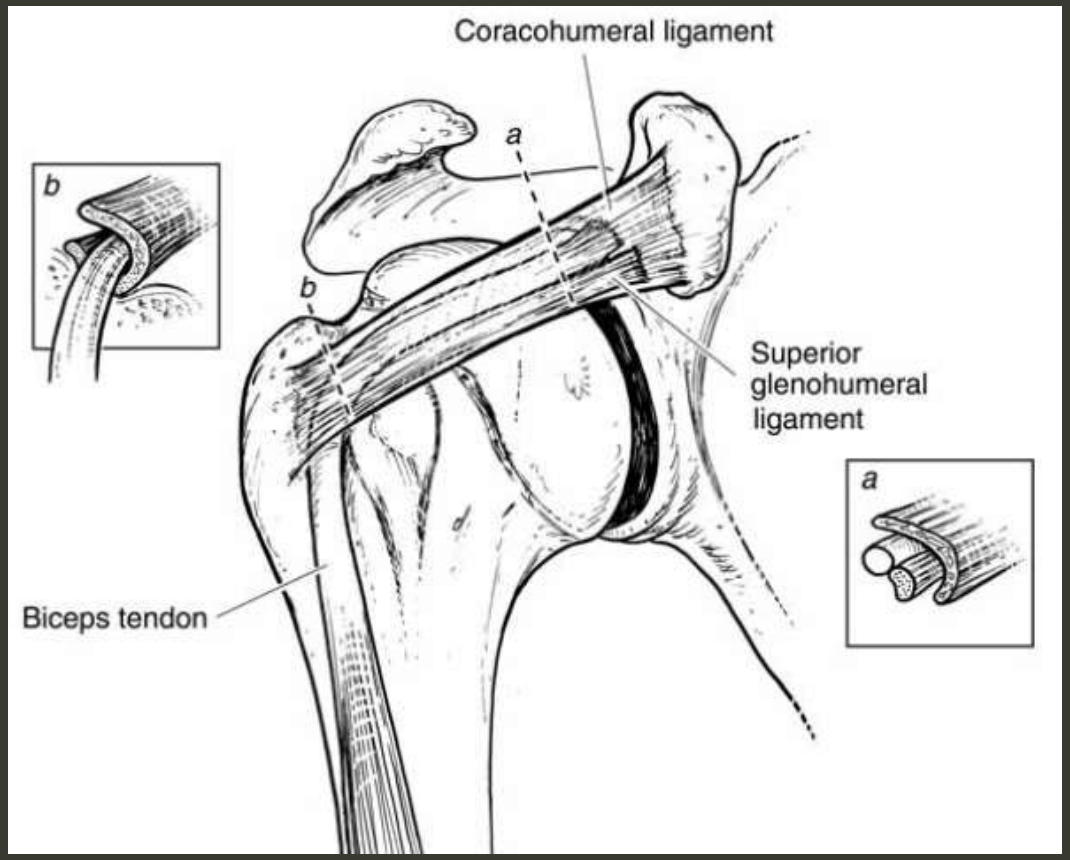
Biceps tendon, long head



- MR
  - Uniform low signal intensity

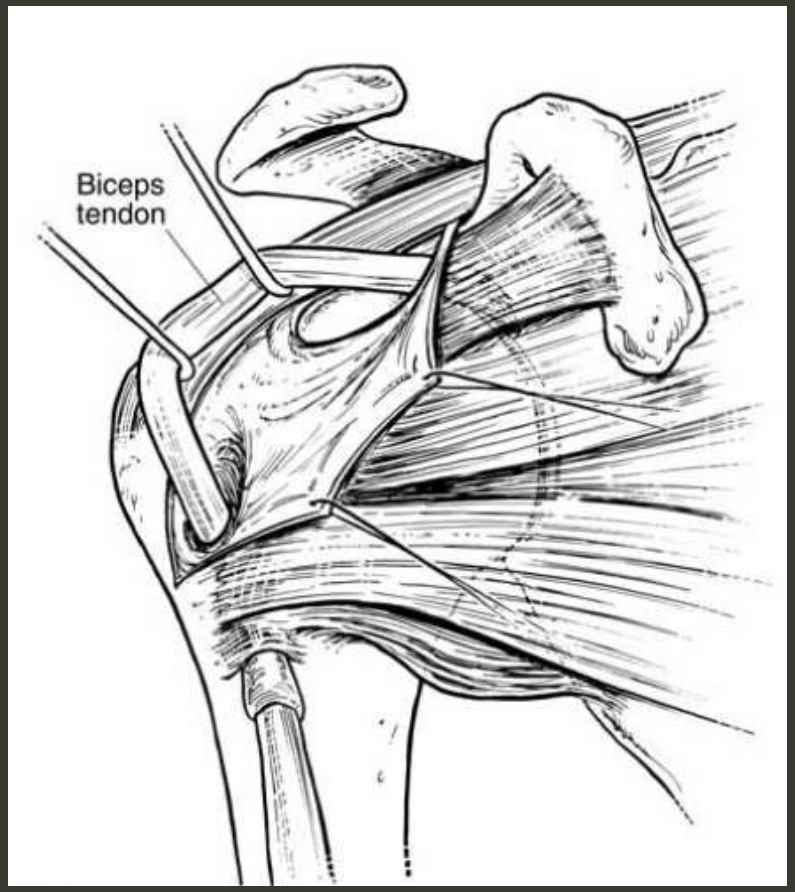
Biceps tendon, long head

- Biceps pulley (sling)
  - CHL and SGHL fuse distally
  - Prevents subluxation of the LHBT over the anterior ridge of the intertubercular groove



Hunt 2007

Biceps tendon, long head

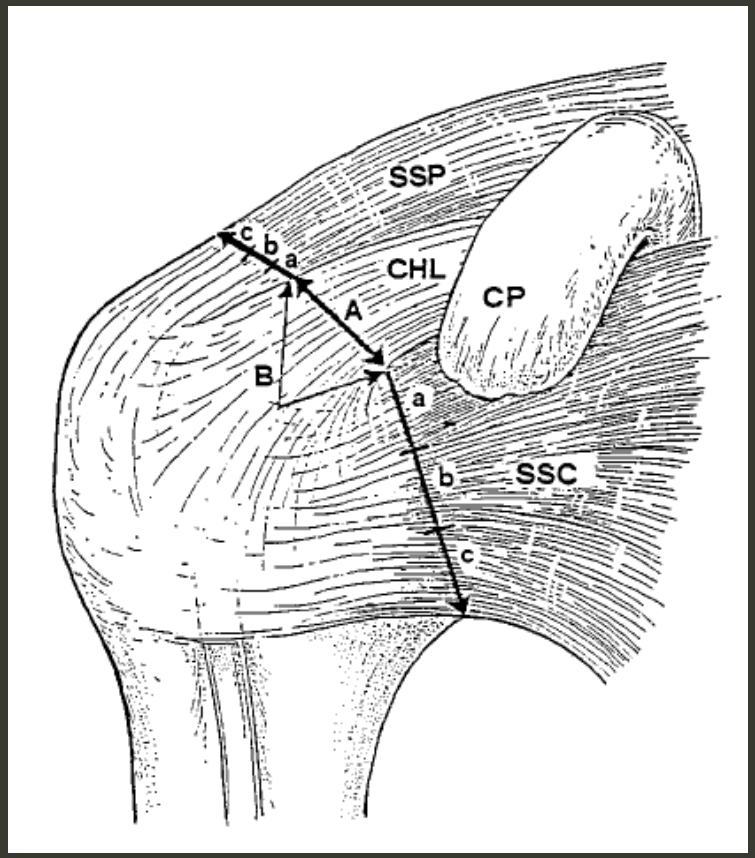


Hunt 2007

Biceps pulley (sling)

- Anterior fibers of the RI incised, retracted

Alternatively: Rotator interval layers



Jost, Koch, and Gerber. Anatomy and functional aspects of the rotator interval. J Shoulder Elbow Surg 2000; 9(4);336-341.

- RI divided into two parts at the cartilage/bone transition of the humeral head (medial: cartilaginous)
  - Medial: 2 layers
    1. CHL
    2. SGHL, joint capsule
  - Lateral: 4 layers
    1. Superficial CHL
    2. Supraspinatus, subscapularis fibers (cross/blend)
    3. Deep CHL (insertions)
    4. SGHL, joint capsule

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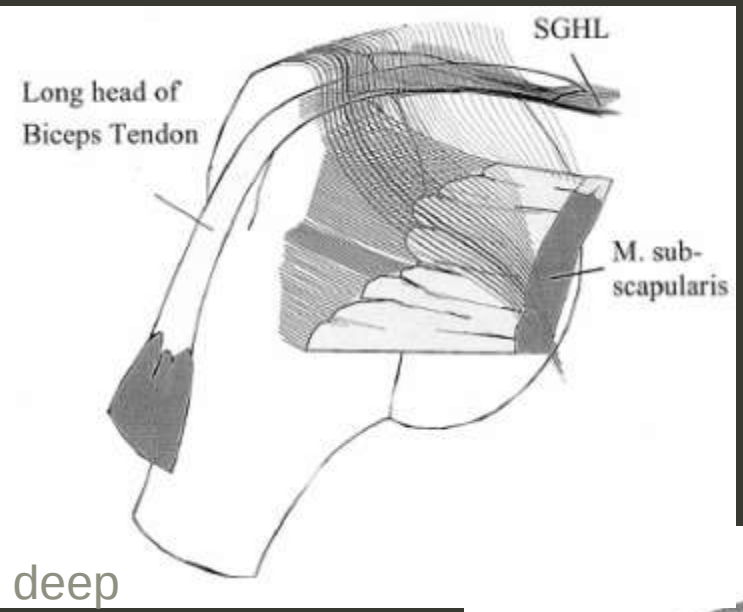
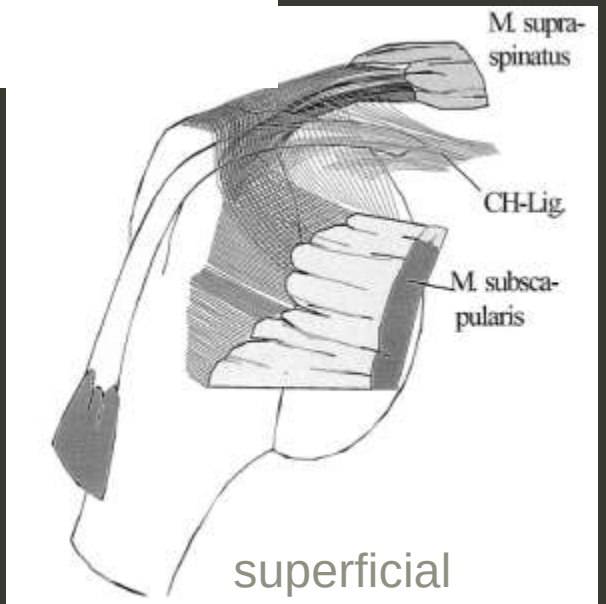


deep



superficial

Werner et al 2000

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Shoulder biomechanics

- Negative intraarticular pressure
  - Most important in neutral passive position
  - Minimal contribution to stability
- Obligate translational movements
  - Controversial: extremes of motion versus end range passive motion
  - Capsular constraint mechanism (Harryman et Al 1990): obligate translation occurs when a portion of capsule is under tension
- Concavity-compression
  - Dynamic compression of the humeral head into the glenolabral socket by the rotator cuff musculature +/- long head biceps tendon
  - Center the humeral head into the glenoid, counteracting oblique forces across the face of the glenoid
- Proprioception

➔ Not a literal ball-in-socket;
potential tangential forces acting upon the GH joint

Contribution of RI to shoulder stability

- SGHL, CHL posses similar roles
  - Resistance to inferior and posterior translation of the humeral head
  - Relative importance of each – controversial

Contribution of RI to shoulder stability

- CHL
  - Ovesen and Nielsen (1985) sequentially sectioned the CHL and SGHL; former resulted in greatest inferior translation of humeral head on x-ray
  - Boardman et. Al (1996) CHL has greater stiffness, greater load before failure
- SGHL
  - Warner et. Al (1992) SGHL greater restraint to inferior translation

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Most surgical interventions treat both ligaments (similar functions)

Contribution of RI to shoulder stability

- Long head biceps tendon
  - Observation: anterior shoulder subluxation in biceps tendon rupture
  - Cadaveric studies => long and short head tendons contribute to anterior glenohumeral stability with the arm in abduction/external rotation
  - May increase resistance to torsional forces (EMG studies conflicting)

Harryman et al. (1992)

- Perhaps the first comprehensive cadaveric study to evaluate RI function
- Sectioning the RI capsule (CHL/SGHL) increased the ranges of flexion, extension, adduction, external rotation
  - Humeral head tended to translate posteroinferior wrt glenoid after sectioning
- Imbrication decreased these ranges of motion
- (Abduction, internal rotation relaxed the RI capsule; sectioning/imbrication did not alter)

Harryman et al. (1992)

- Conclusions
  - RI checks against excessive flexion, extension, adduction, external rotation (multidirectional instability)
  - Stabilizes against inferior translation of the humeral head in the adducted shoulder
  - Stabilizes against posterior translation of the humeral head in the flexed or abducted /externally rotated shoulder

Harryman et al. (1992)

- Clinical application: adhesive capsulitis
  - Fibrosis of the RI → limited ROM *and* obligate anterosuperior translation of the humeral head at extremes of motion
  - Abnormal translation may contribute to impingement of the humeral head against the coracoid process (subcoracoid impingment)

Clinical approach

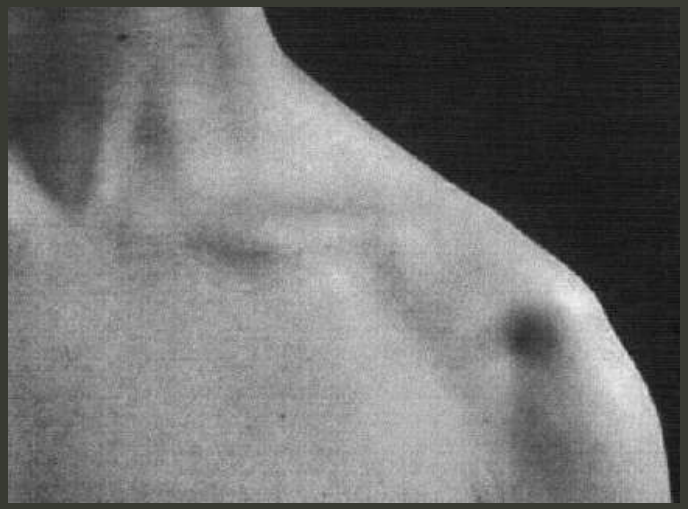
- Nobuhara and Ikeda (1987)
  - 106 shoulders with RI lesions
    - Type I: superficial post-inflammatory contraction of the CHL and subacromial bursa following injury to the RI; contraction, no instability
    - Type II: instability; inflammation in the deeper soft tissues of the RI

Clinical approach

- Nobuhara and Ikeda (1987)
  - 106 shoulders with RI lesions
    - Type I
      - Restriction of passive external rotation or forward flexion of the shoulder
      - Adhesive capsulitis; postoperative tightness

Clinical approach

- Nobuhara and Ikeda (1987)
  - 106 shoulders with RI lesions
    - Type I
    - Type II
      - Inferior translation of the humeral head with the arm at the side (“sulcus” sign)



Sulcus sign should disappear with external rotation (which places the RI under tension). If it persists, suspect RI failure.

Nottage 2003

Nobuhara and Ikeda (1987)

Following surgical closure of the RI in their patients:

TABLE 3. Follow–up Evaluation of 78 Joints

		Number	*Percent (%)*
Pain	Relieved	31	40
	With overuse	44	56
	With motion	3	4
Range of motion	Complete	70	91
	Slightly decreased	7	9
	Limited	1	0
Muscle strength	Normal	58	74
	Slightly decreased	20	26
Activities of daily living	Normal	55	70
	Slightly decreased	20	26
	Limited	3	4
Stability	Good	55	70
	Slightly decreased	20	26
	Poor	3	4

Summary of clinical findings

- Rotator interval too tight (fibrosis)
  - Alterations in glenohumeral obligate translation
  - Superior cuff complaints, pain (internal impingement)
- Rotator interval too loose (defect)
  - Posteroinferior glenohumeral instability, pain

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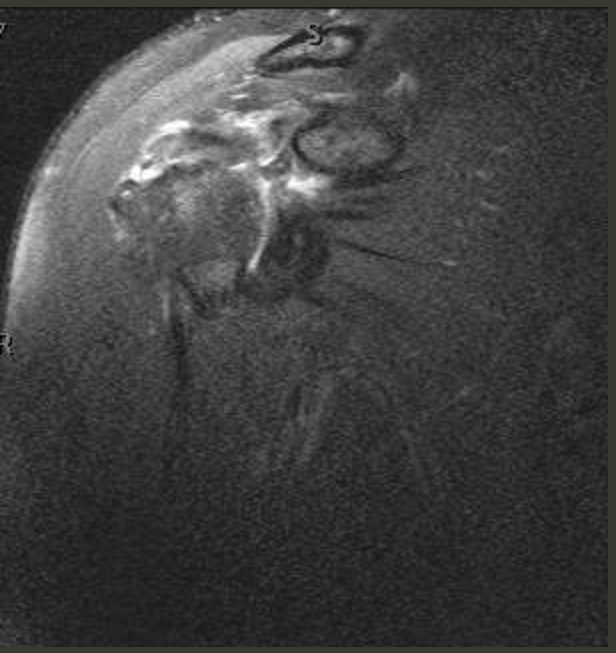
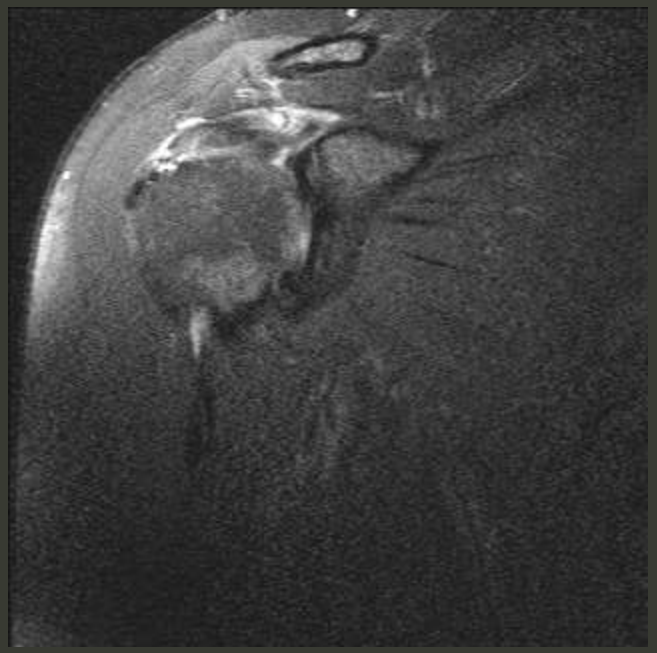
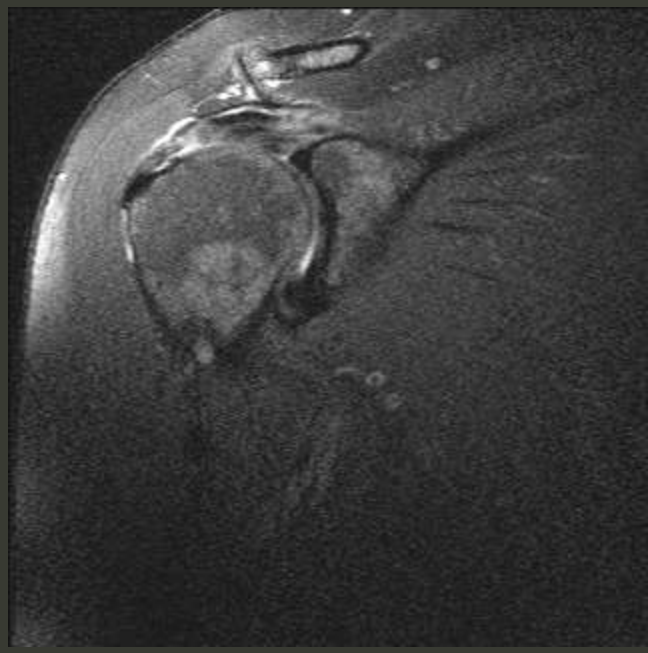
RI pathology

- Includes:
  - Extension of rotator cuff tear
    - Anterior supraspinatus tendon
    - Superior subscapularis tendon
  - Long head of the biceps tendon, intraarticular
  - Coracohumeral ligament
  - Superior glenohumeral ligament
  - RI capsule

RI and rotator cuff tear

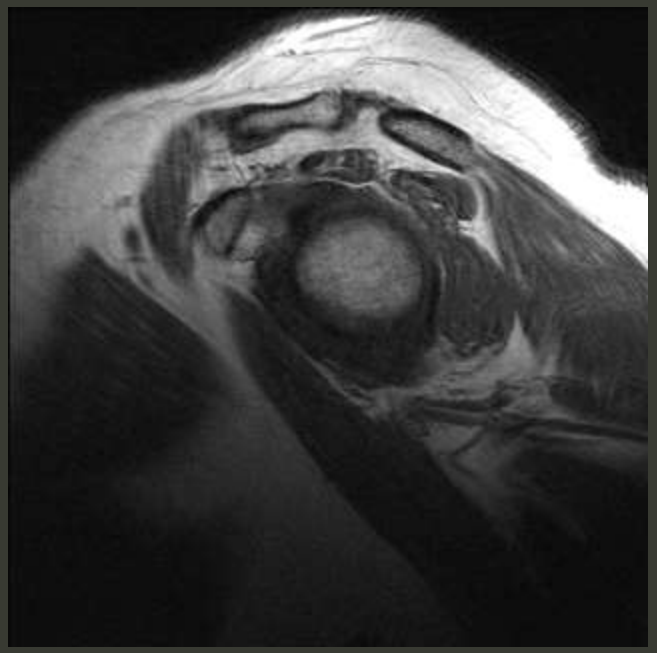
- Anterior extension of a supraspinatus tendon tear can involve the rotator interval
  - If involves the coracohumeral ligament, can also result in biceps tendon subluxation

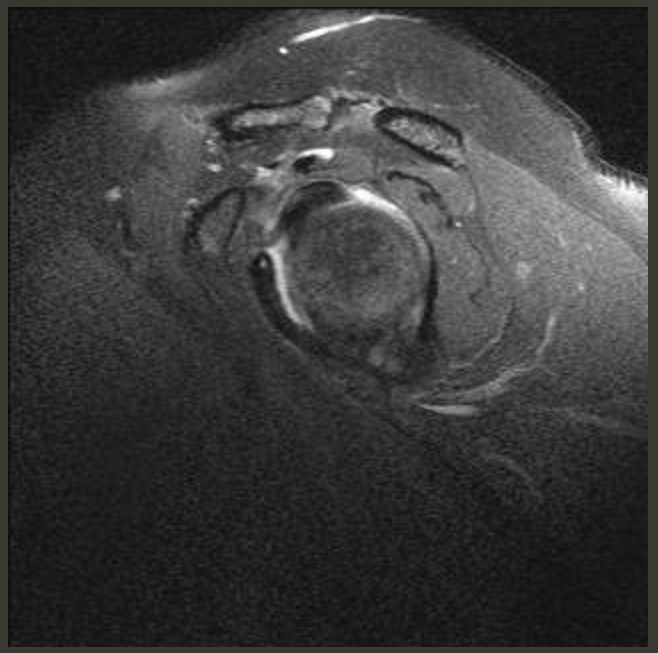
RI and chronic rotator cuff tear

70 yo F with chronic shoulder pain
Supraspinatus/infraspinatus/subscapularis tendinosis
FTT anterior supraspinatus tendon

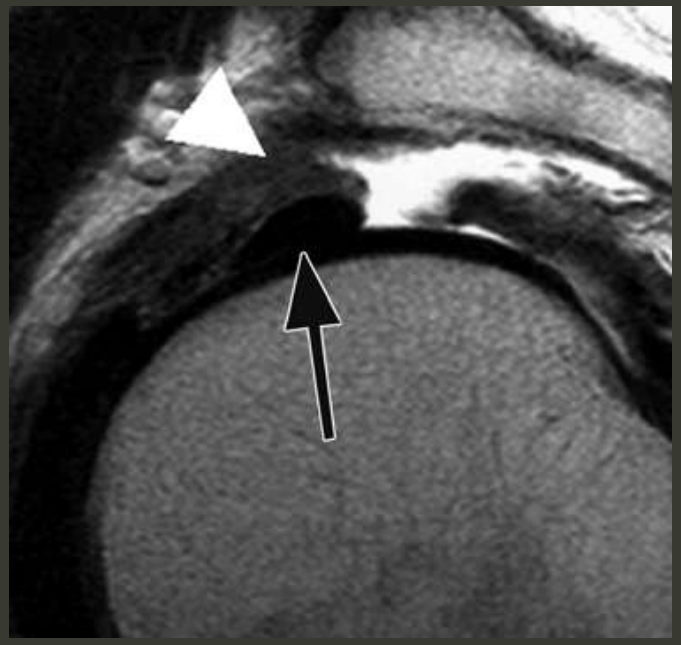
RI and chronic rotator cuff tear



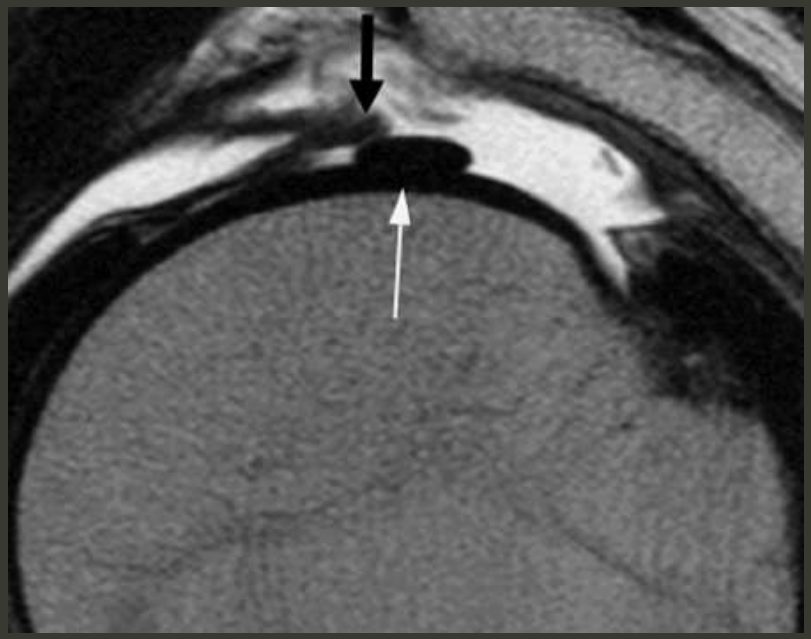


. . . and low signal material in the RI c/w fibrosis

RI and rotator cuff tear



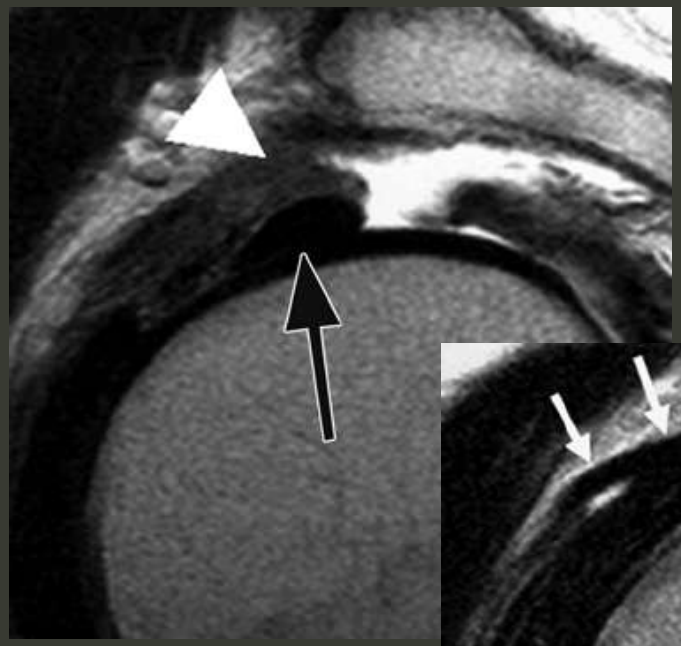
FTT supraspinatus
CHL intact (biceps t remains covered)



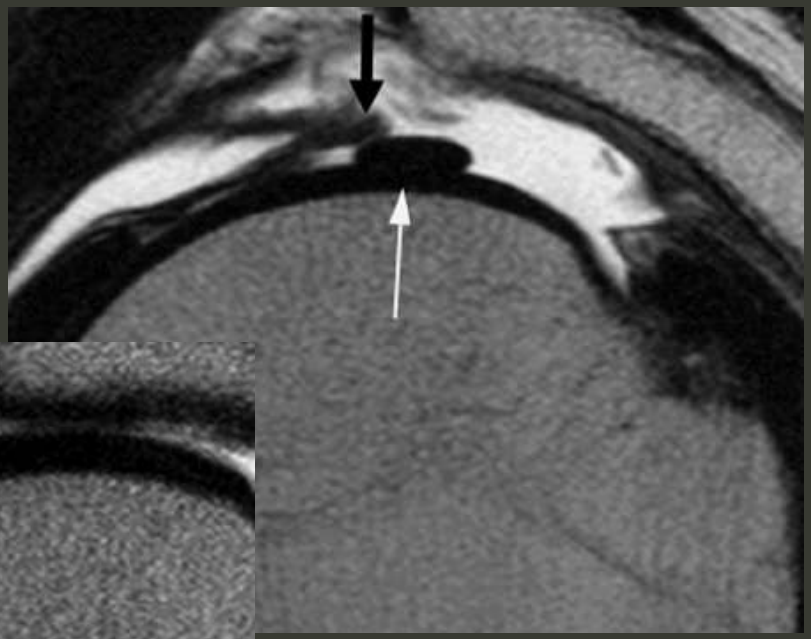
FTT supraspinatus
Extends into CHL
Biceps t not covered; flattened

Krief 2005

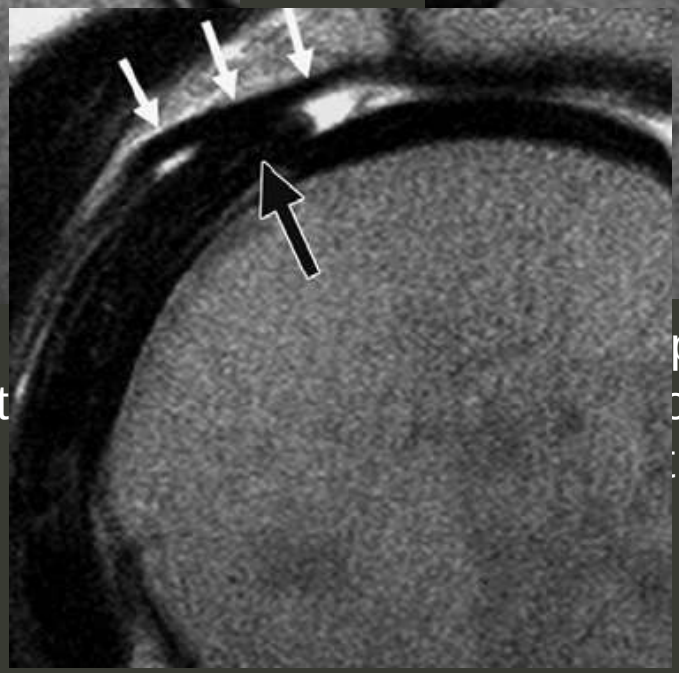
RI and rotator cuff tear



FTT supraspinatus
CHL intact (biceps t
covered)



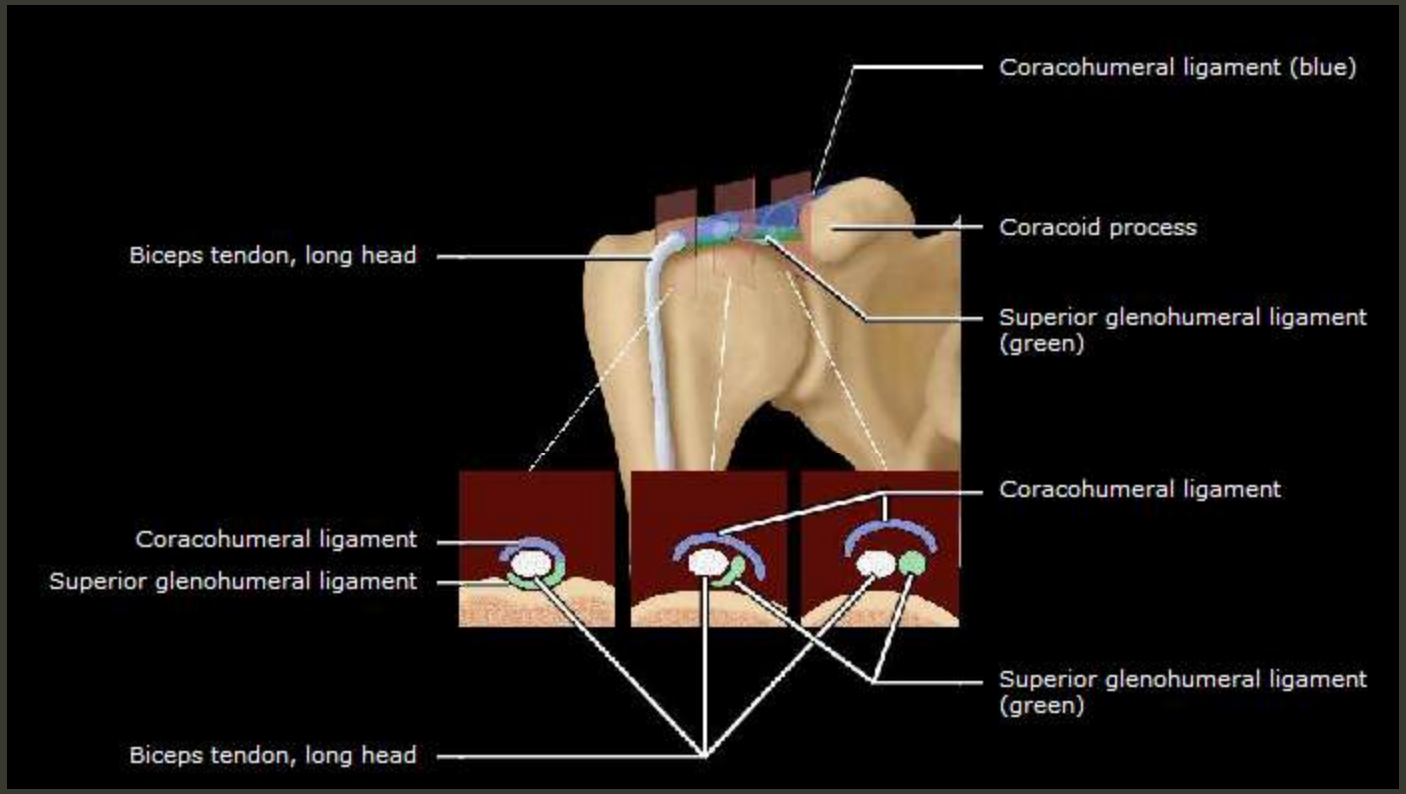
pinatus
o CHL
covered; flattened



Biceps impingement may result

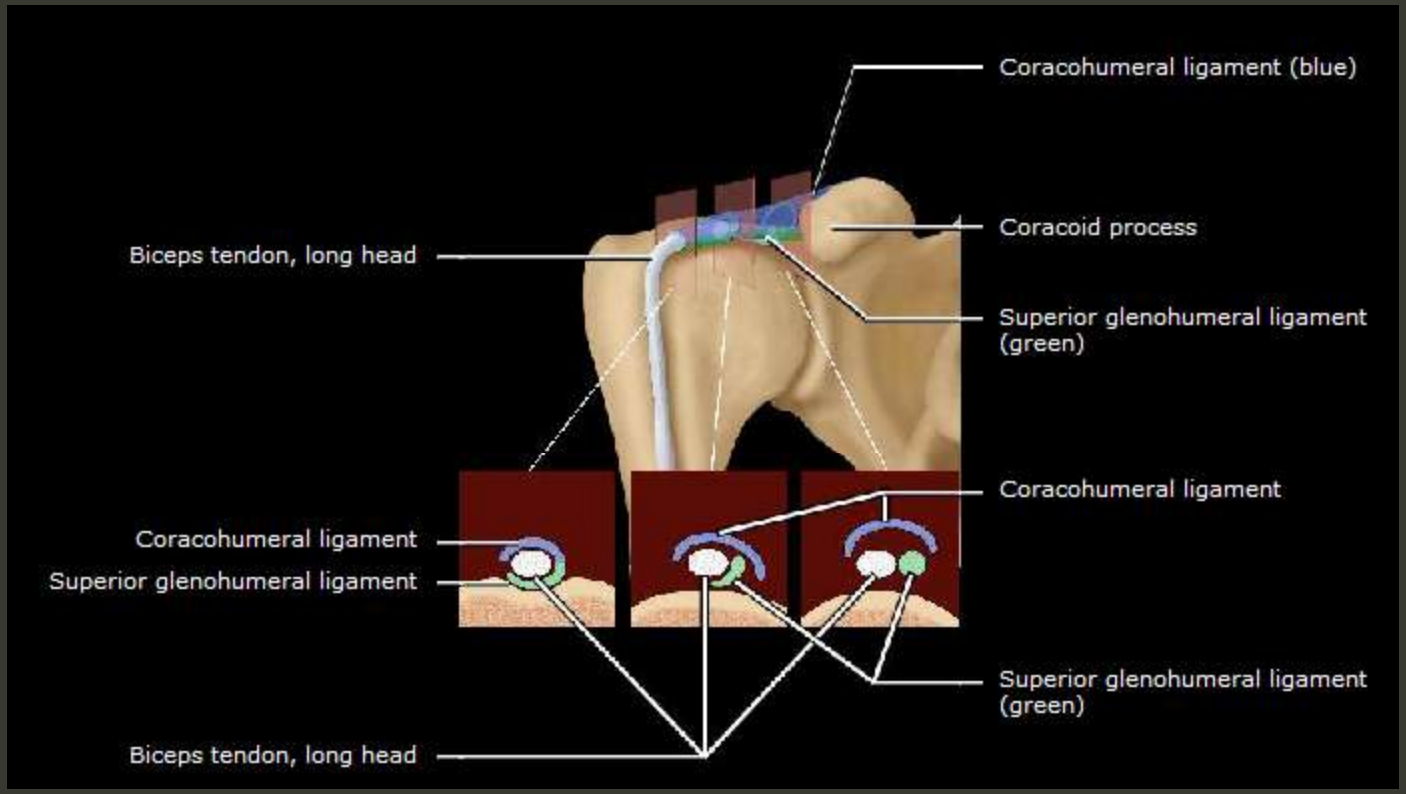
Krief 2005

Biceps pulley lesions



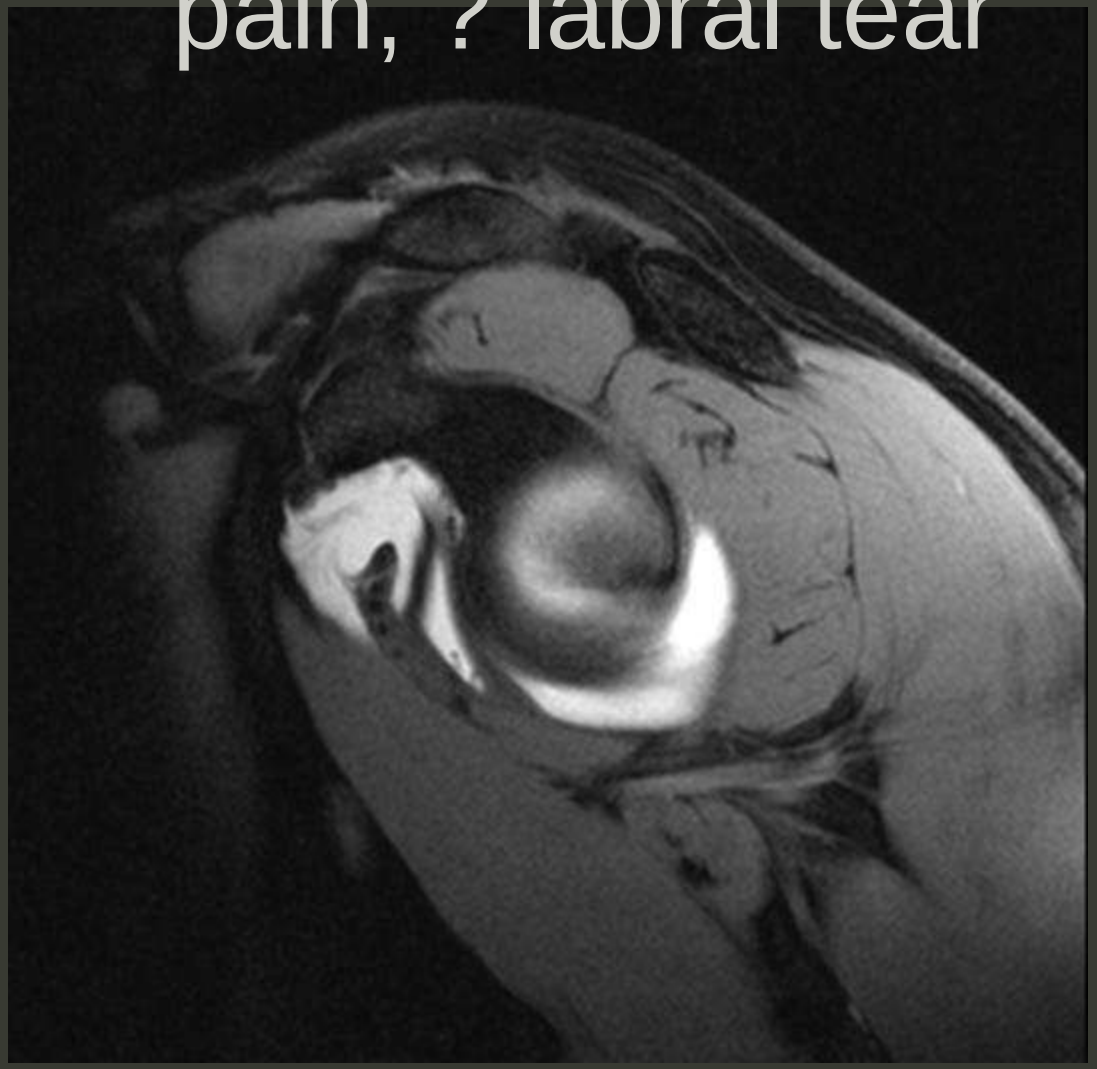
• Extension of a supraspinatus tear into the rotator interval can involve the biceps pulley, leading to biceps tendon subluxation
• “Hidden” lesion: on anterior arthroscopy, superficial subscapularis tendon intact; may not see the underlying biceps subluxation/dislocation into or behind the subscap tendon substance

Biceps pulley lesions

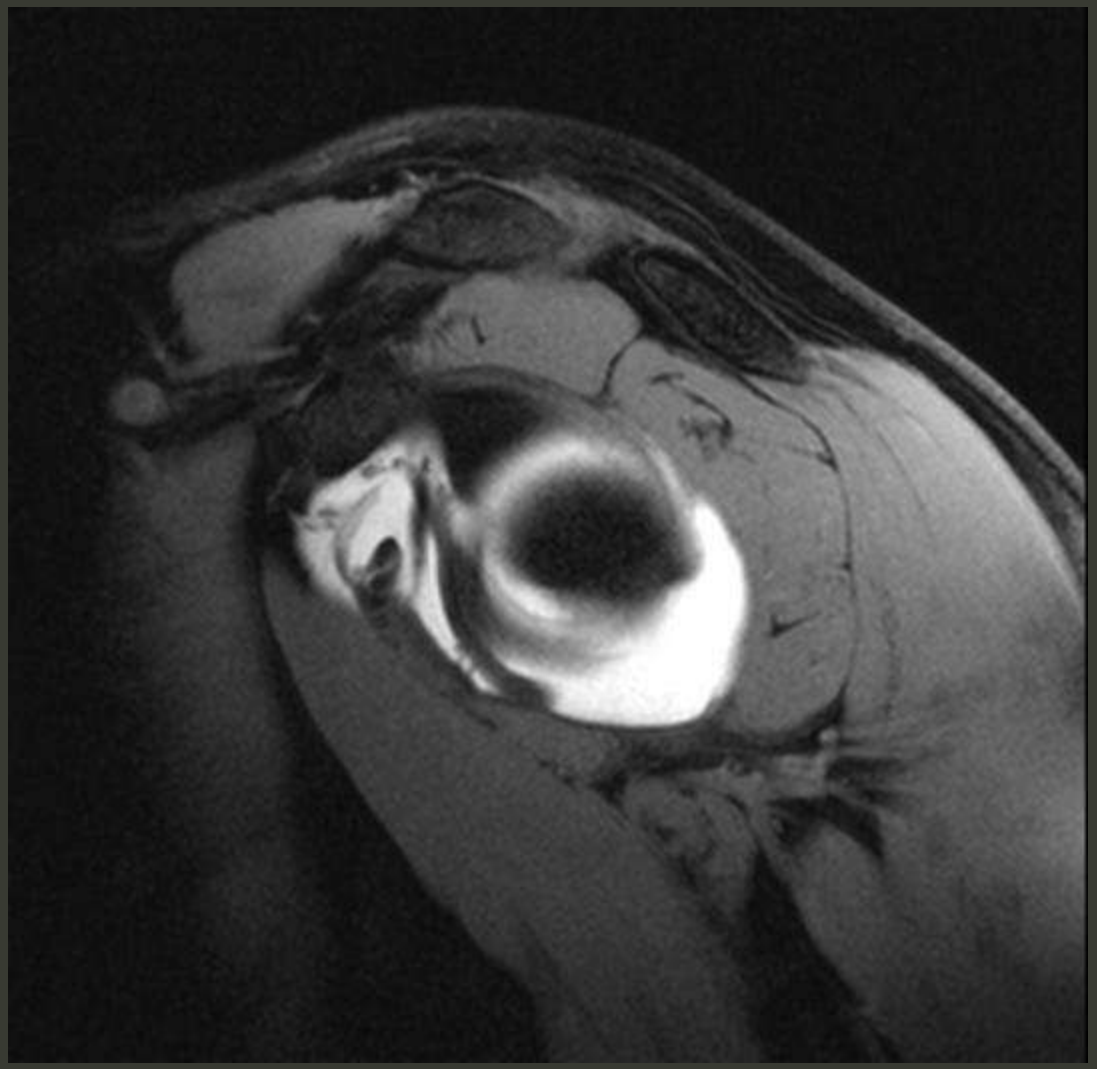


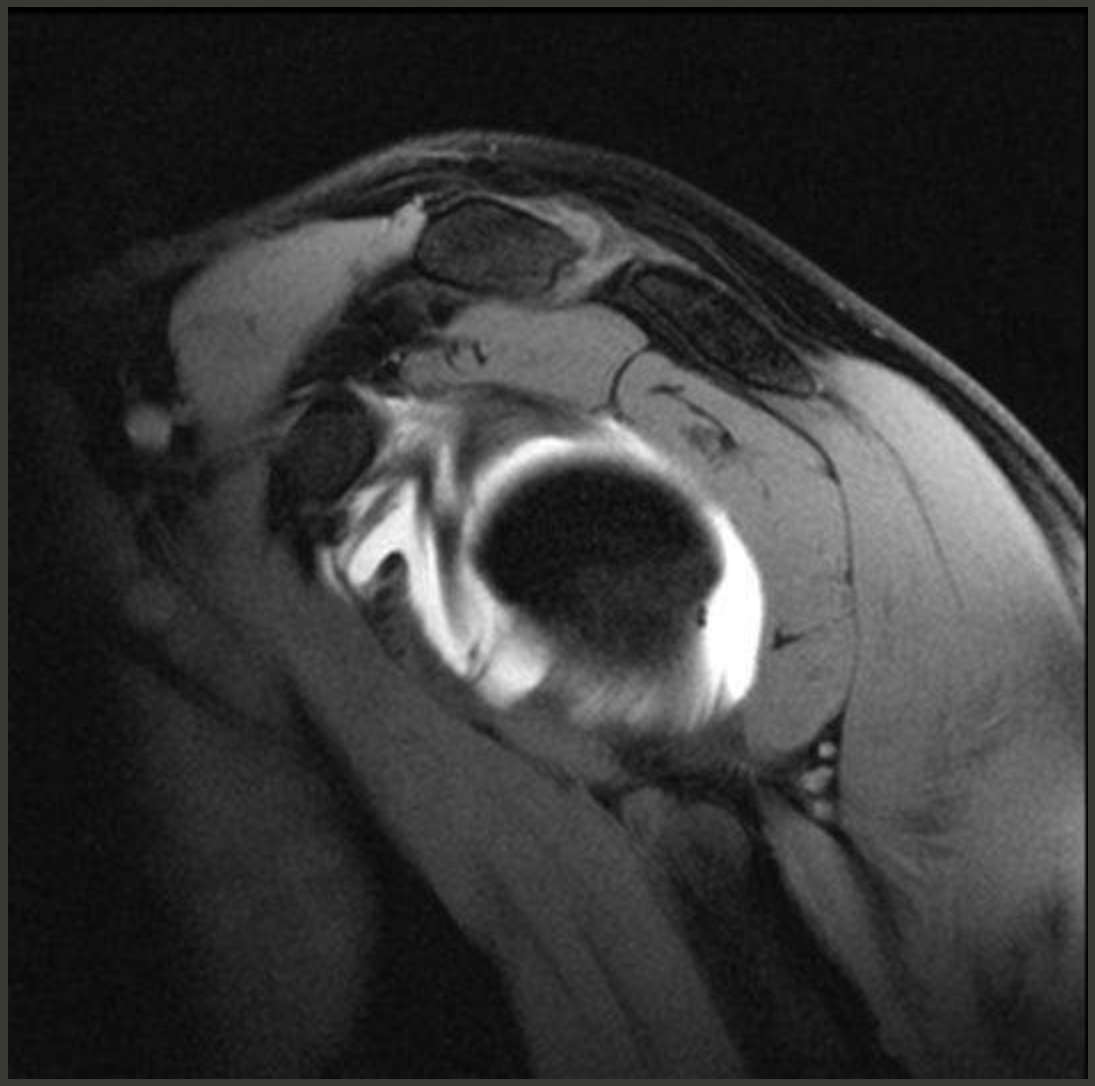
- Extension of a supraspinatus tear into the rotator interval can involve the biceps pulley, leading to biceps tendon subluxation
- "Hidden" lesion: on anterior arthroscopy, superficial subscapularis tendon intact; may not see the underlying biceps subluxation/dislocation into or behind the subscap tendon substance

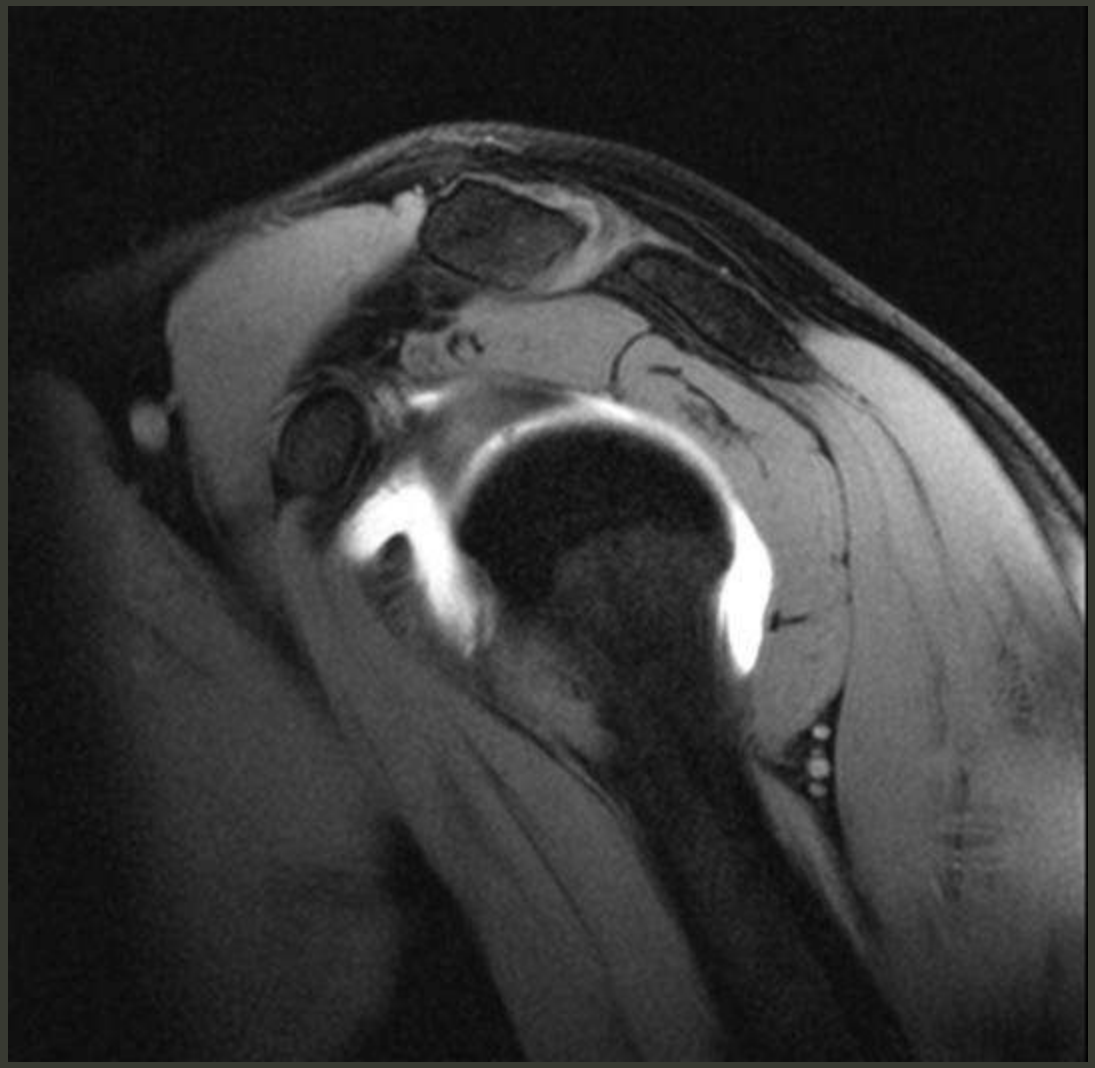
23M hockey player with shoulder pain, ? labral tear

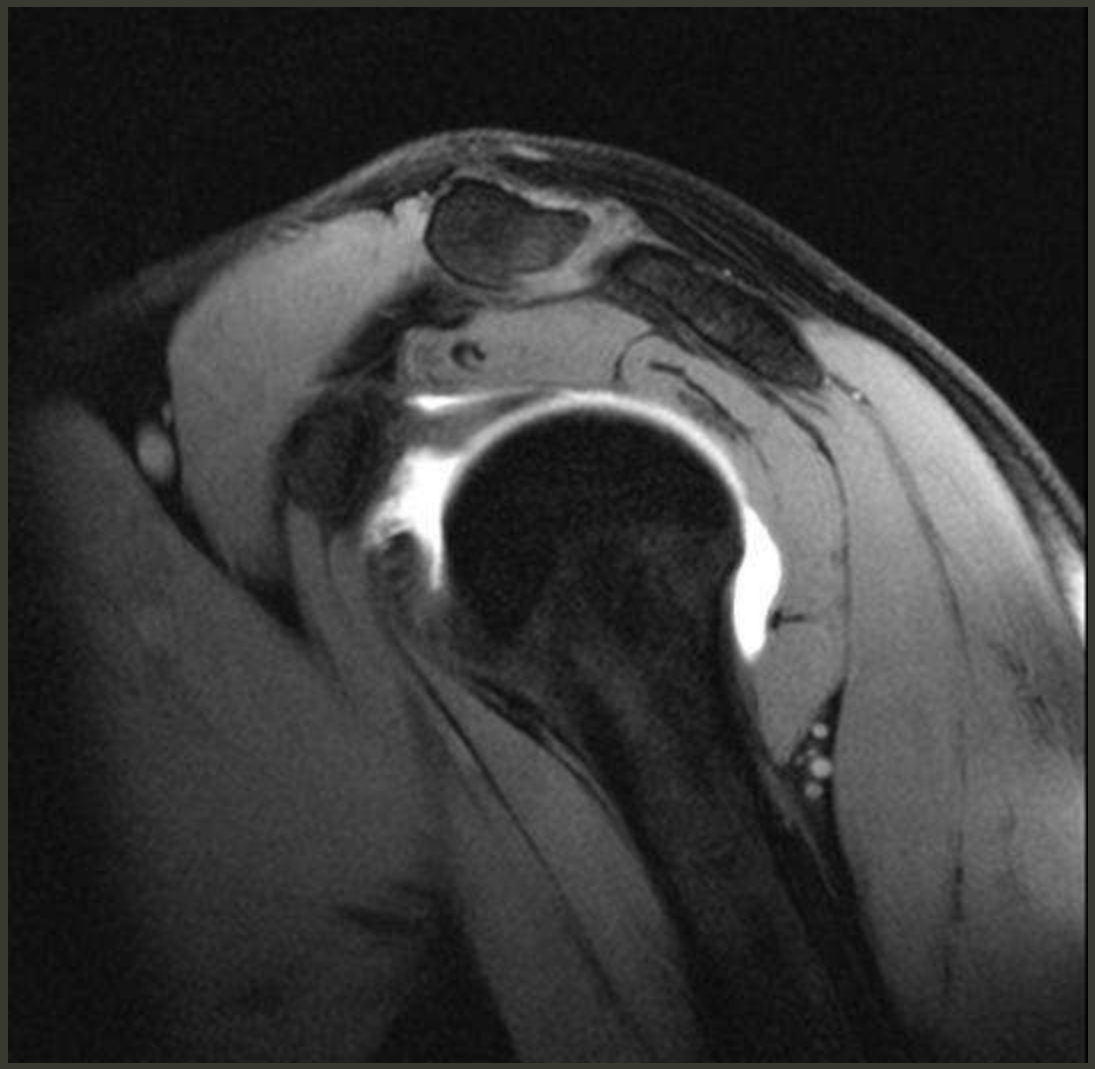


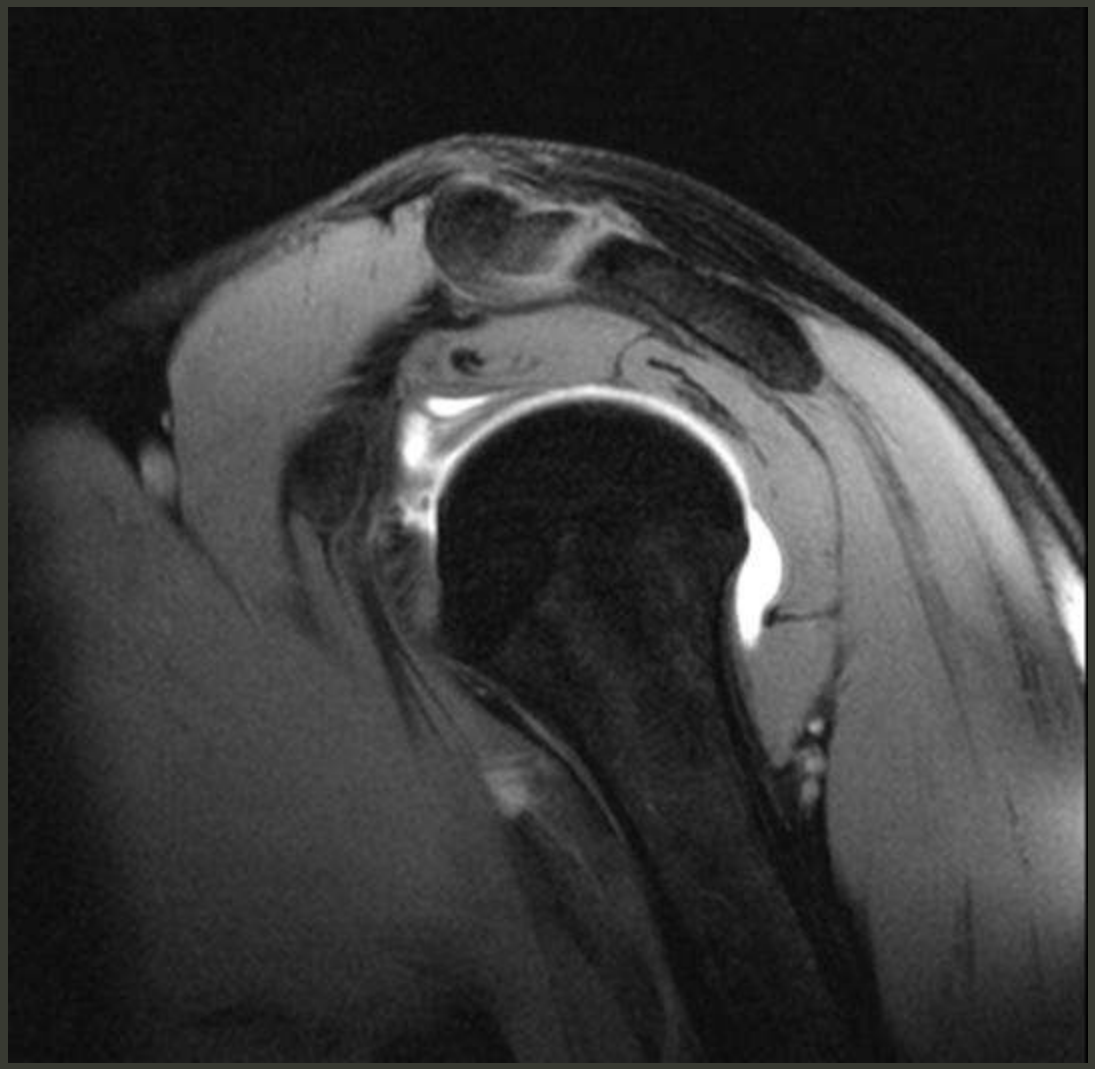
Images courtesy of C. Chung

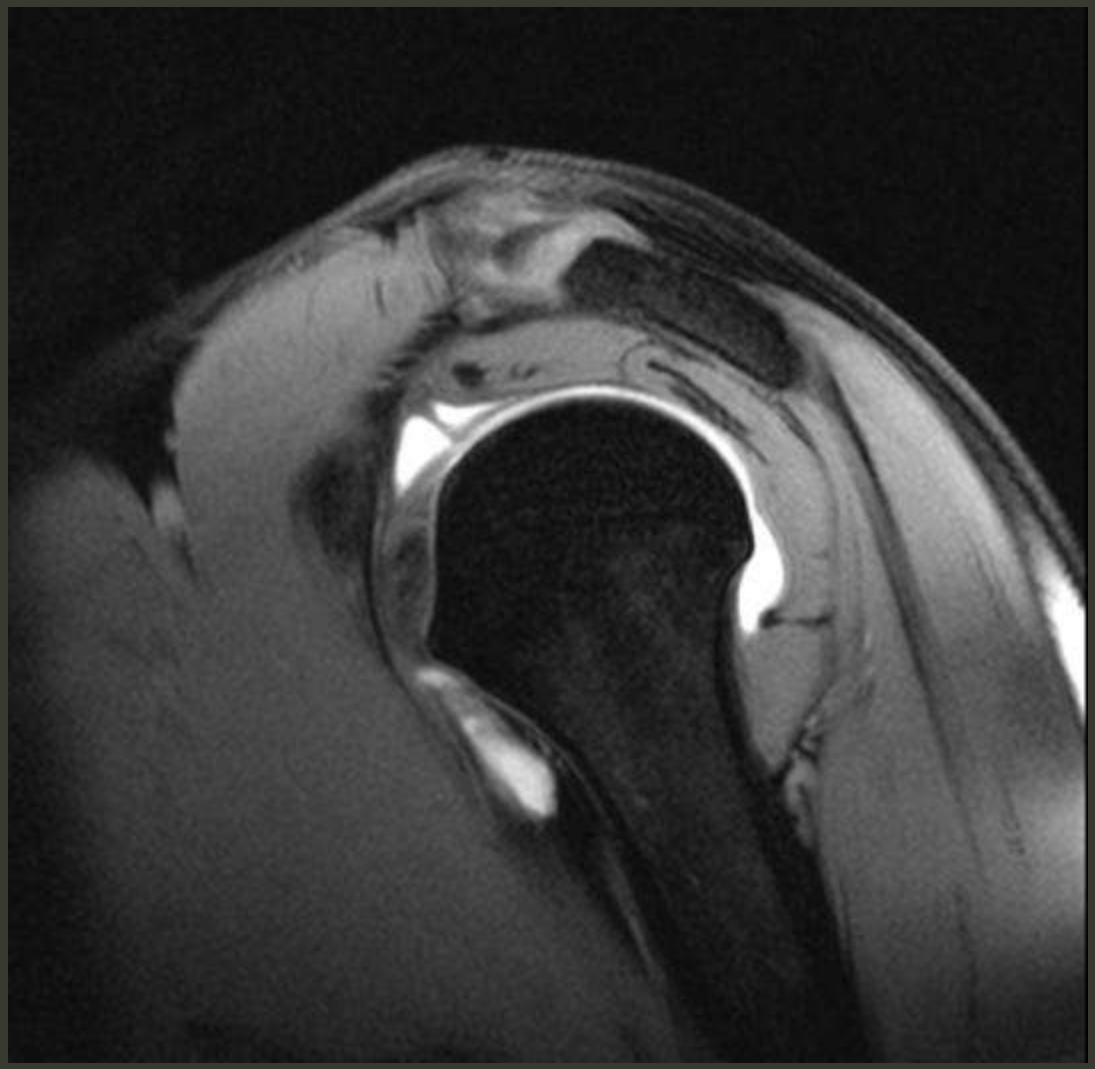


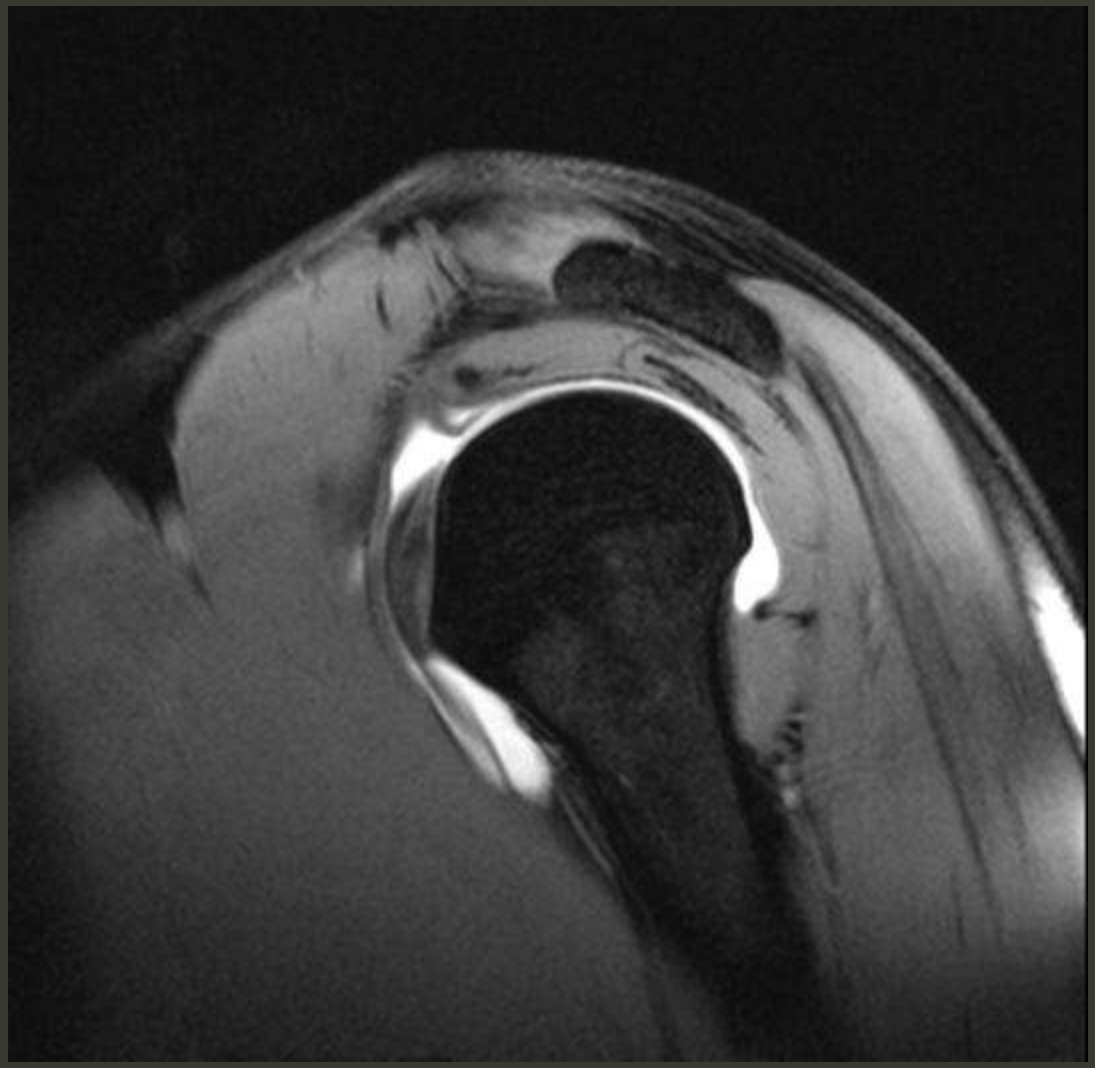


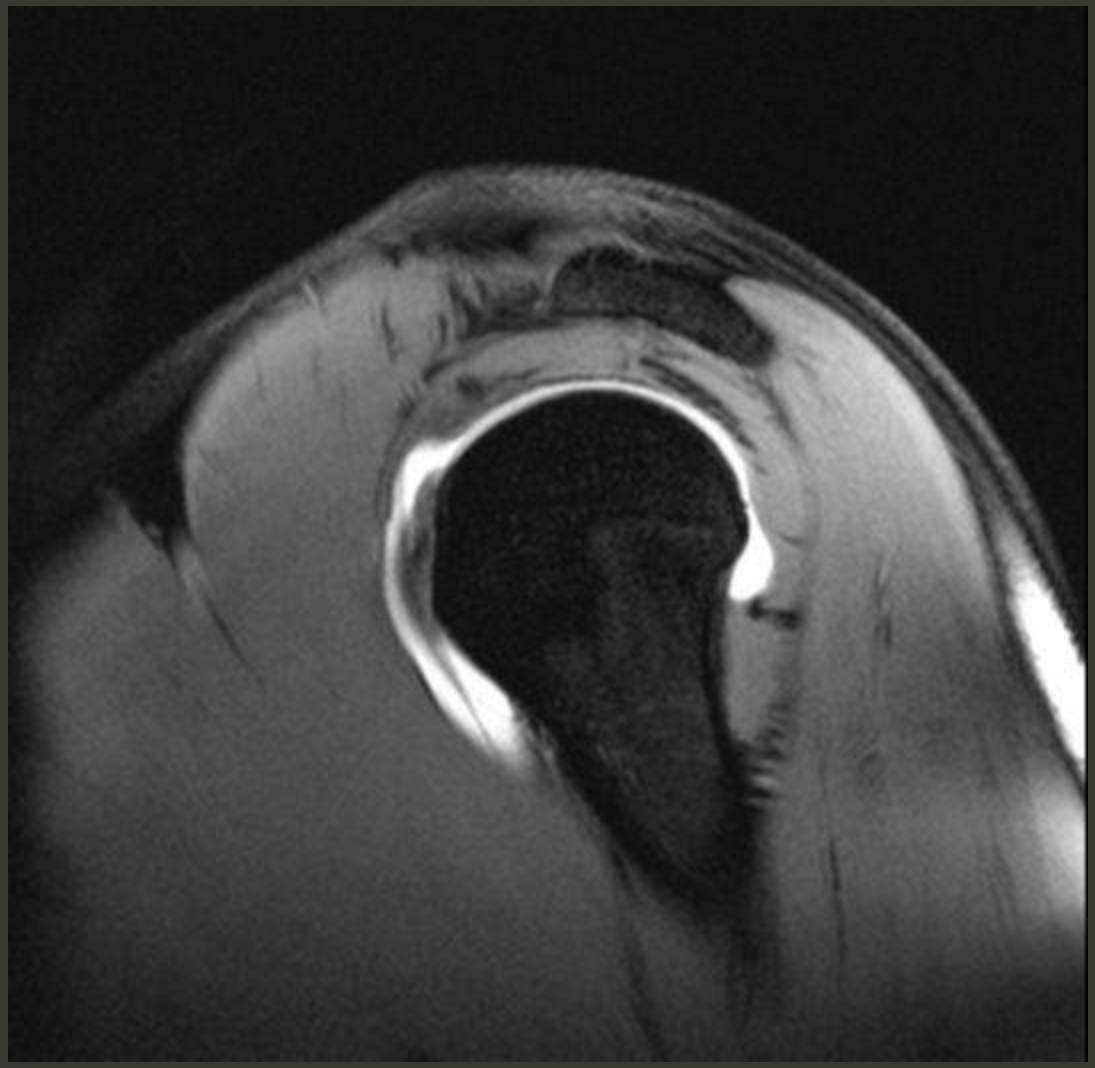


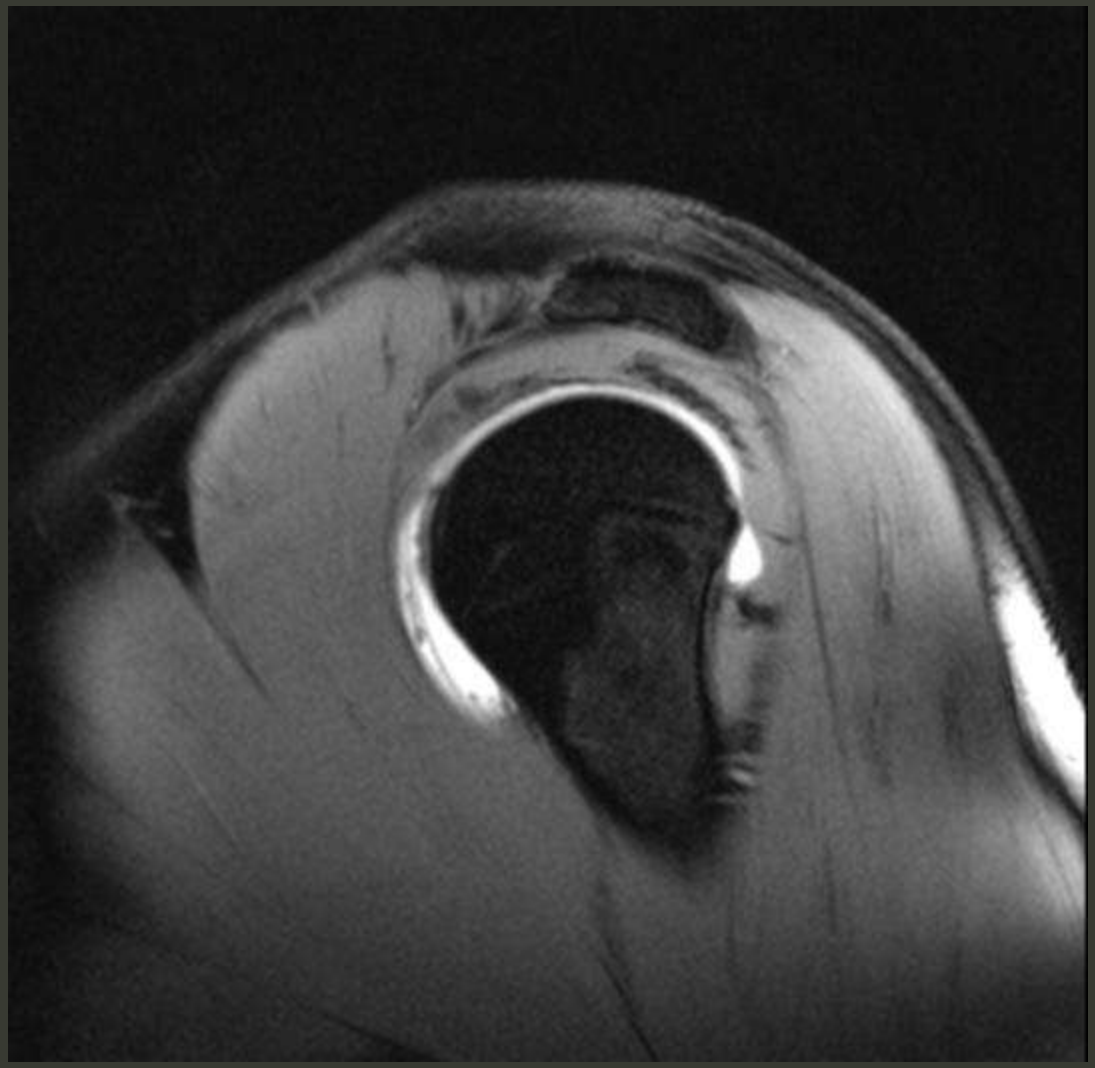


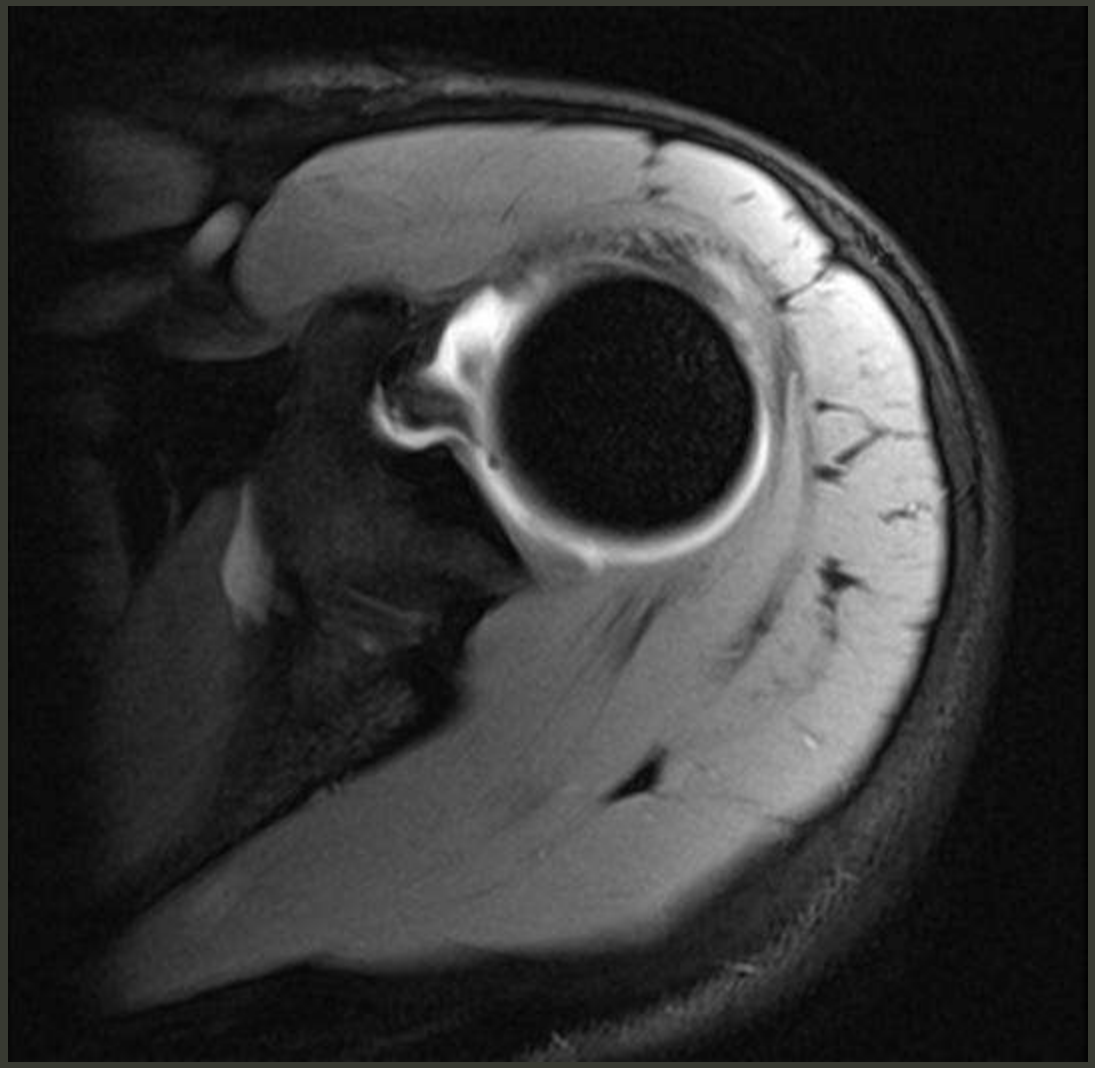


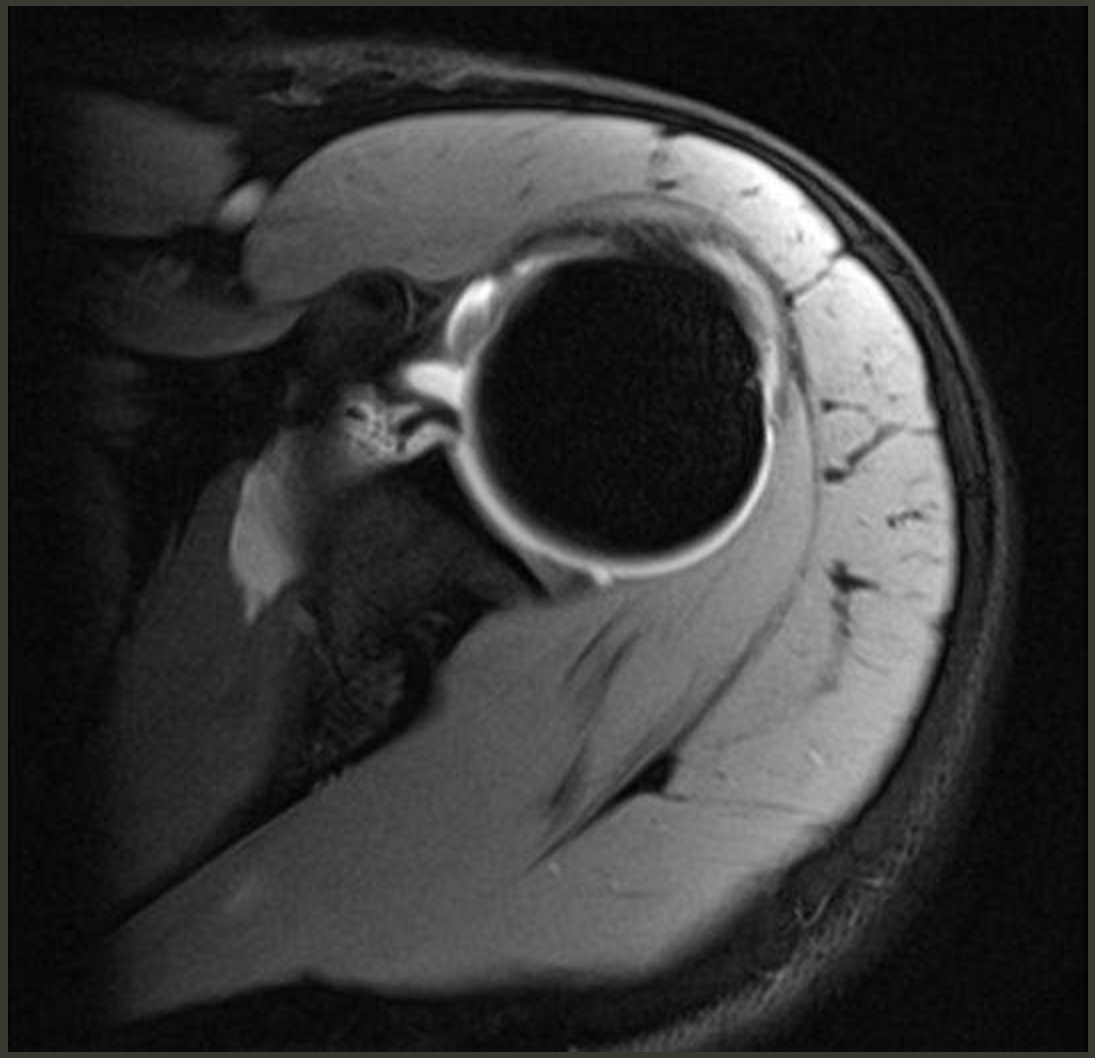


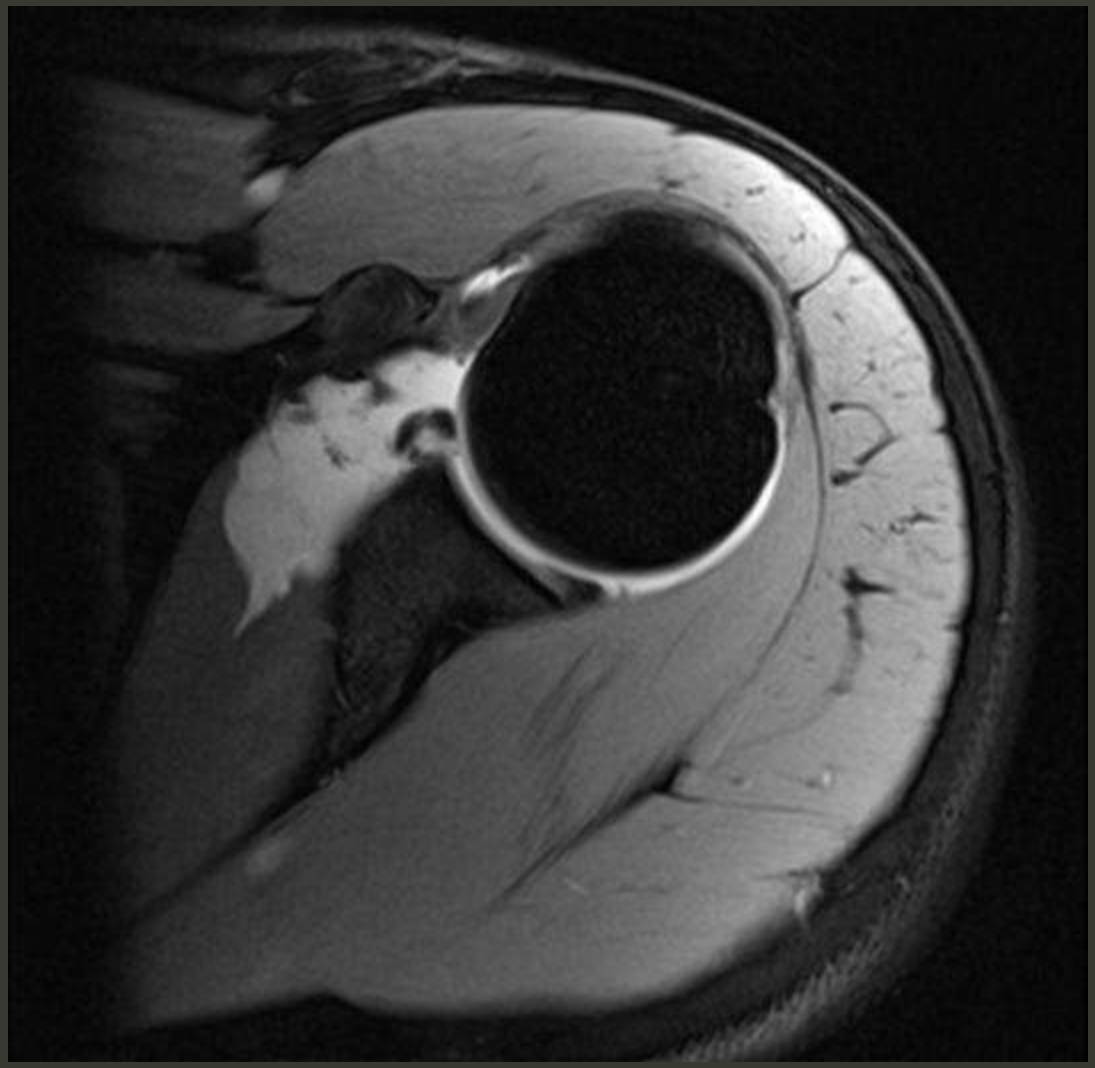


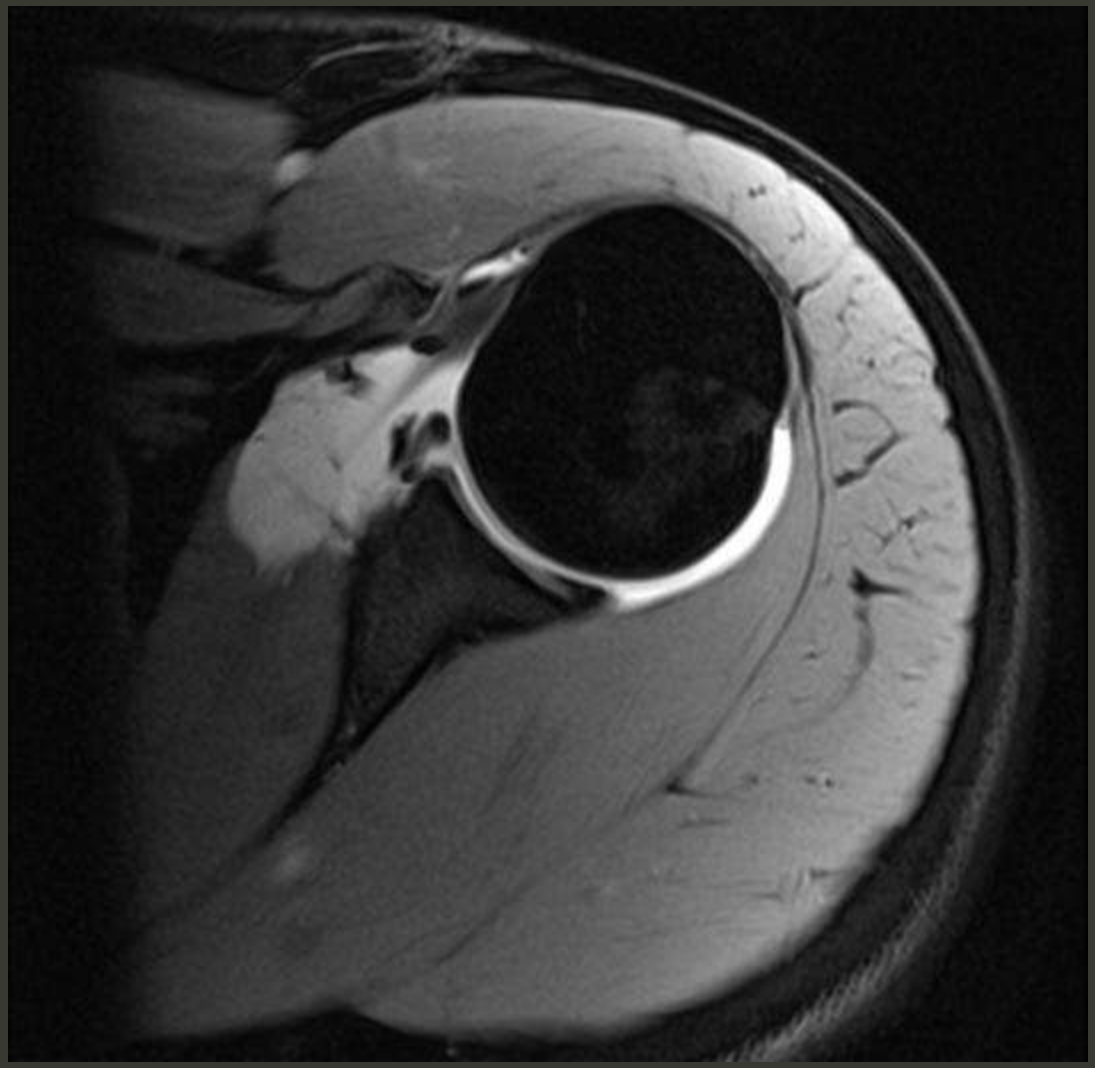


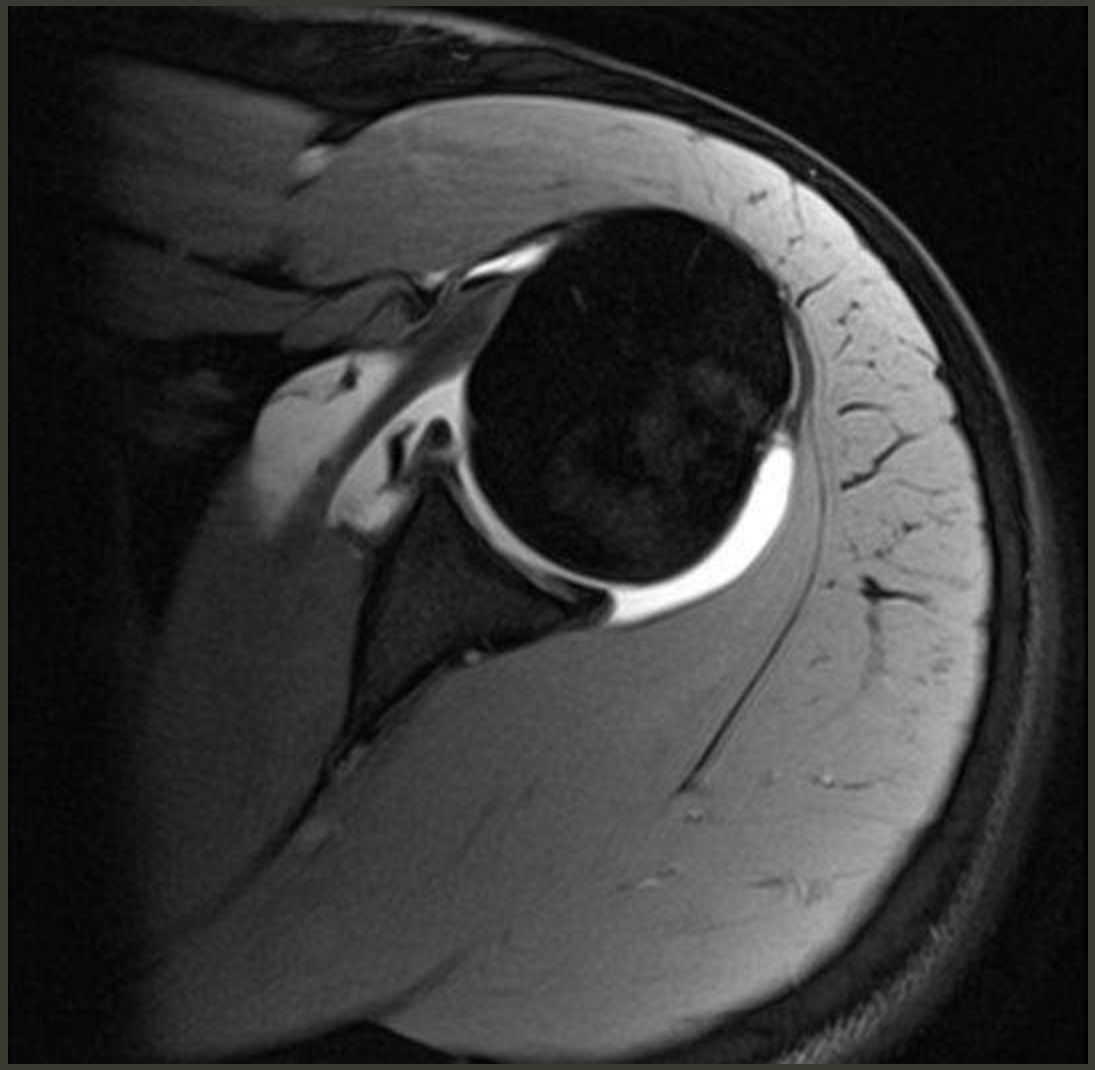




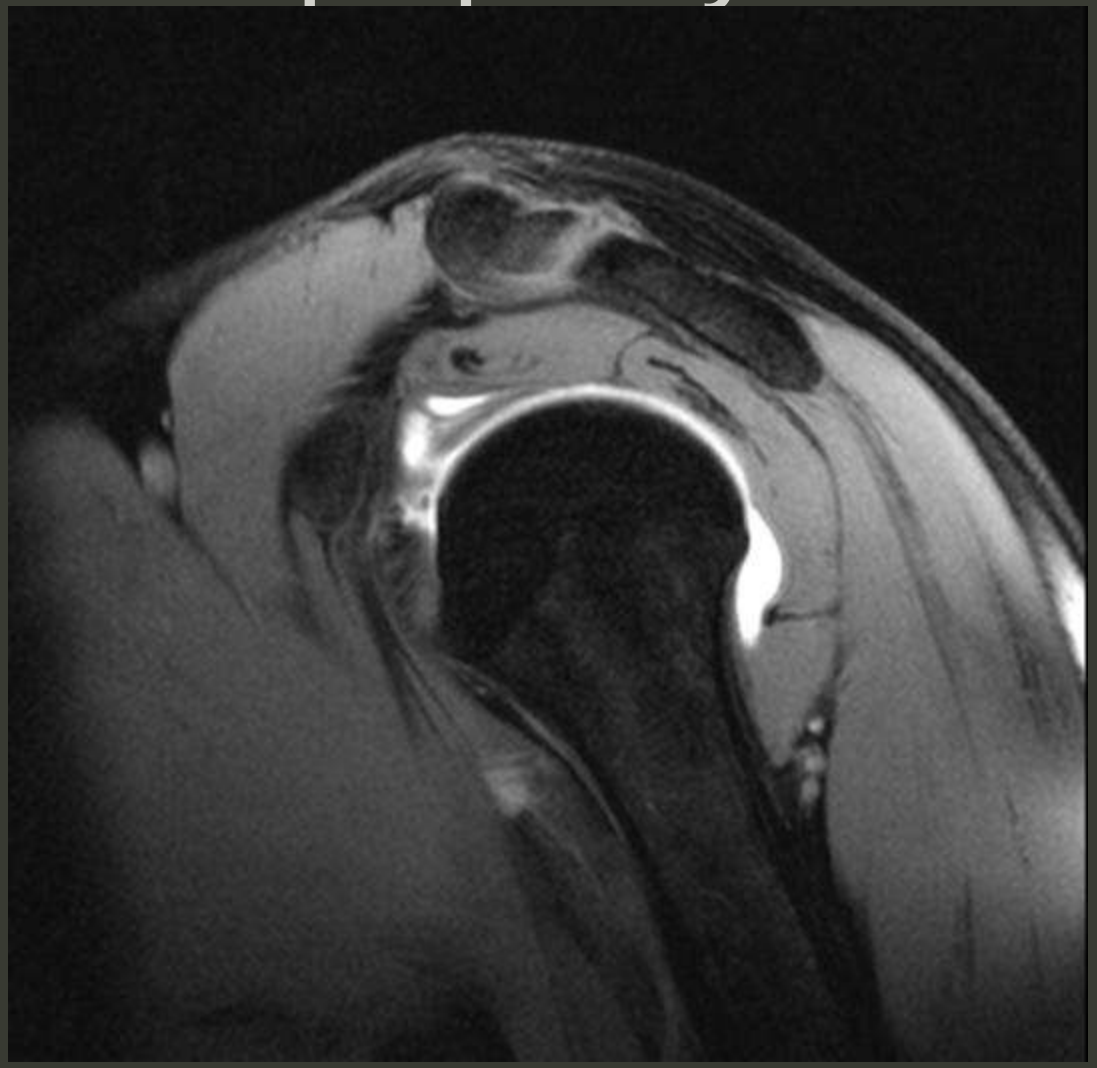




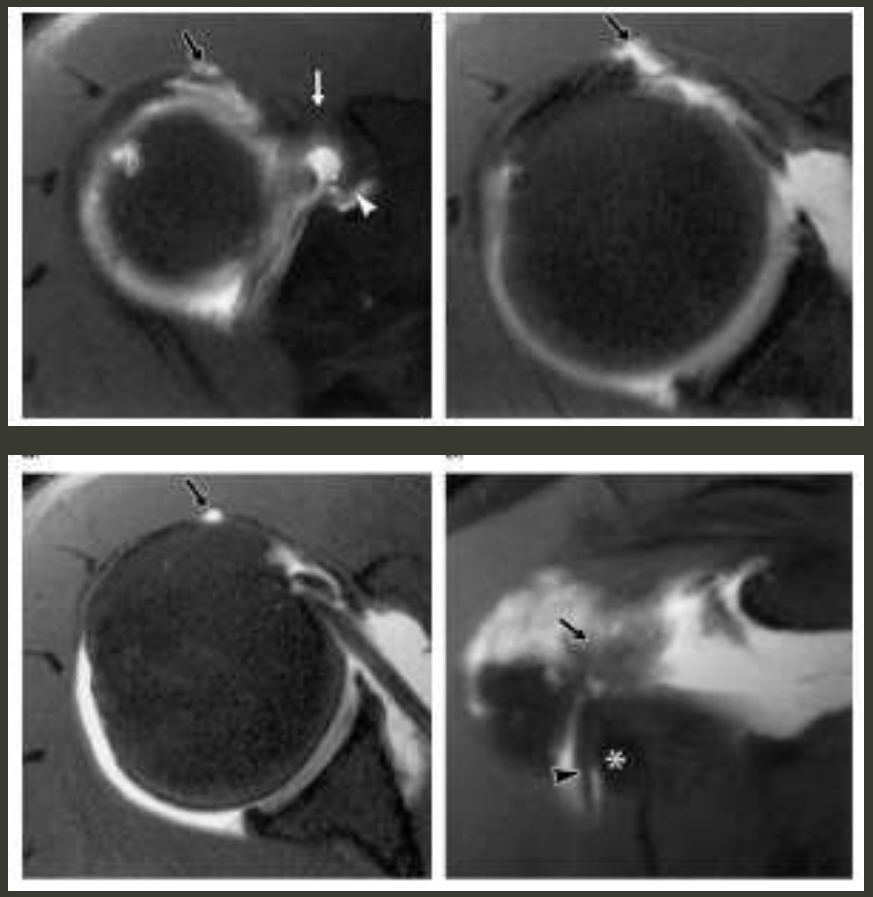




Biceps pulley lesion



Biceps pulley lesion



- Arthroscopically proven partial tear of biceps sling
- Thickened, irregular, disrupted (contrast extravasation)

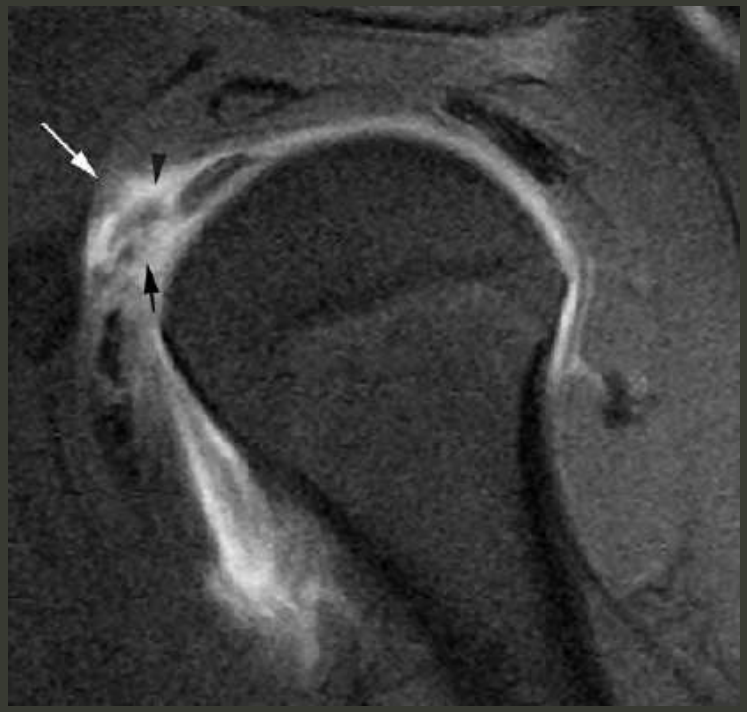
Morag 2005

Biceps pulley lesion

- Arthroscopically proven bicipital sling injury
- Intact subscapularis tendon

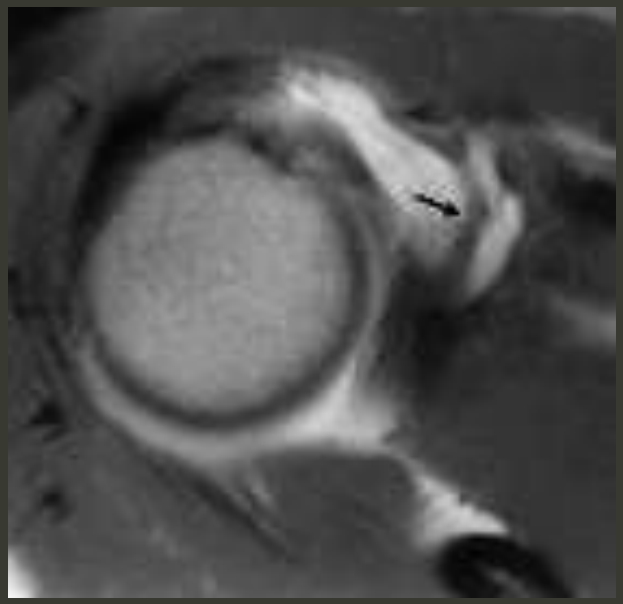
Morag 2005

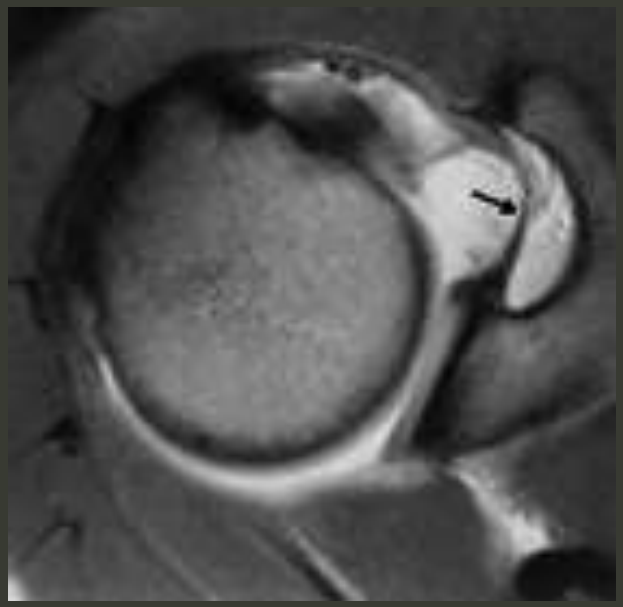
RI lesion and SLAP tear

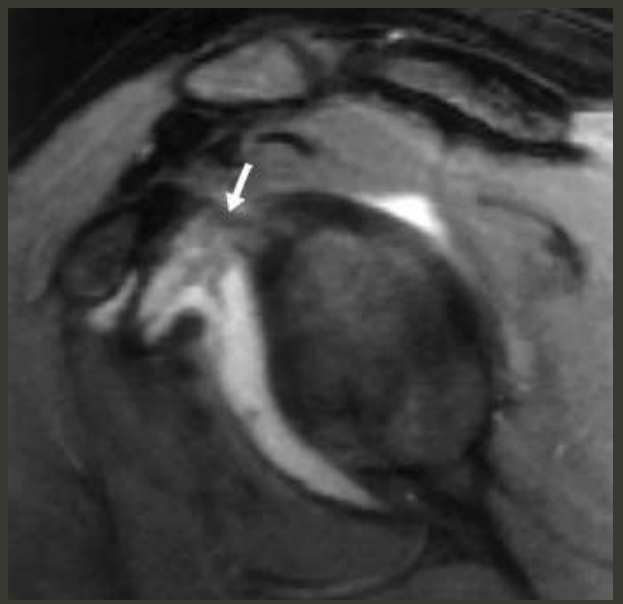


Beltran and Kim 2003

SGHL partial disruption



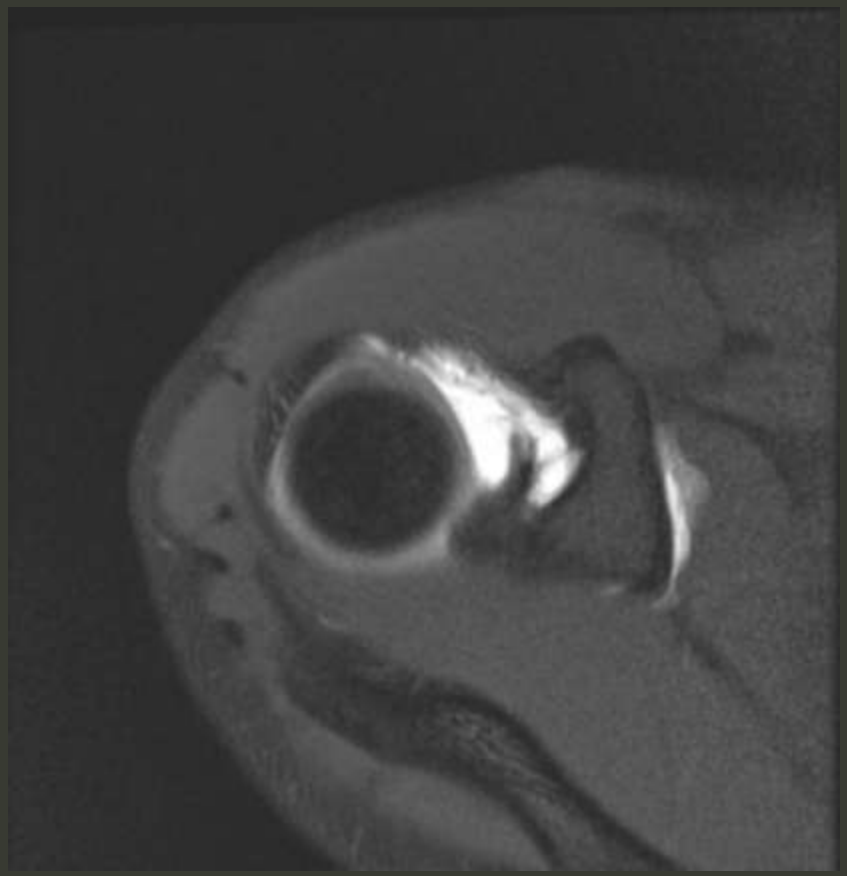


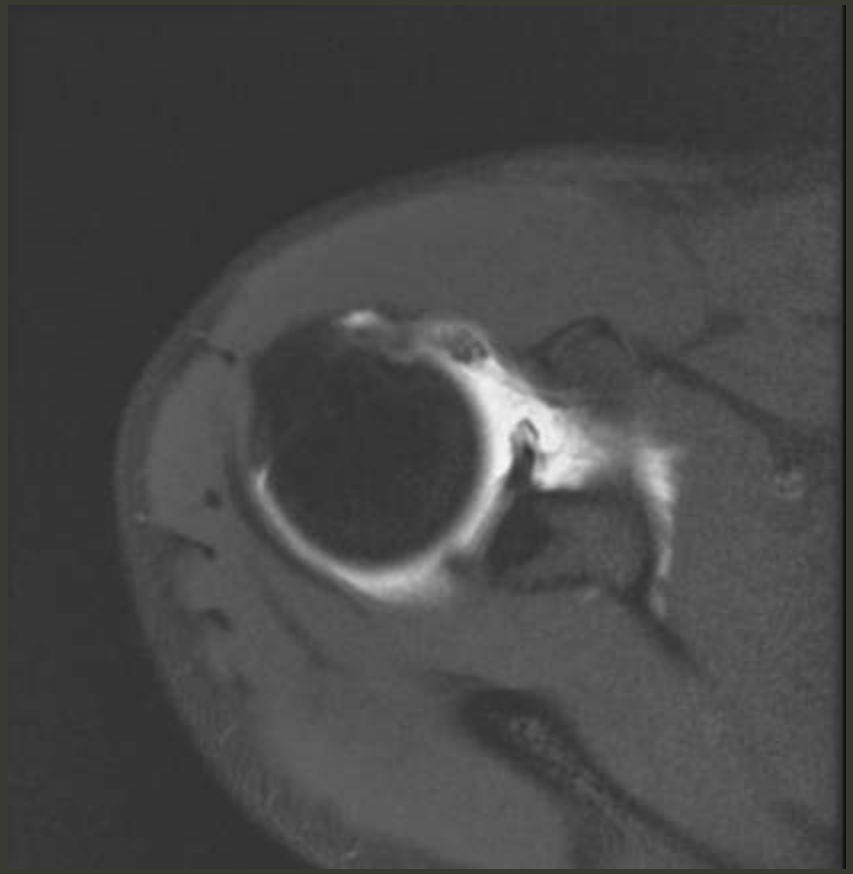


Attenuated, irregular

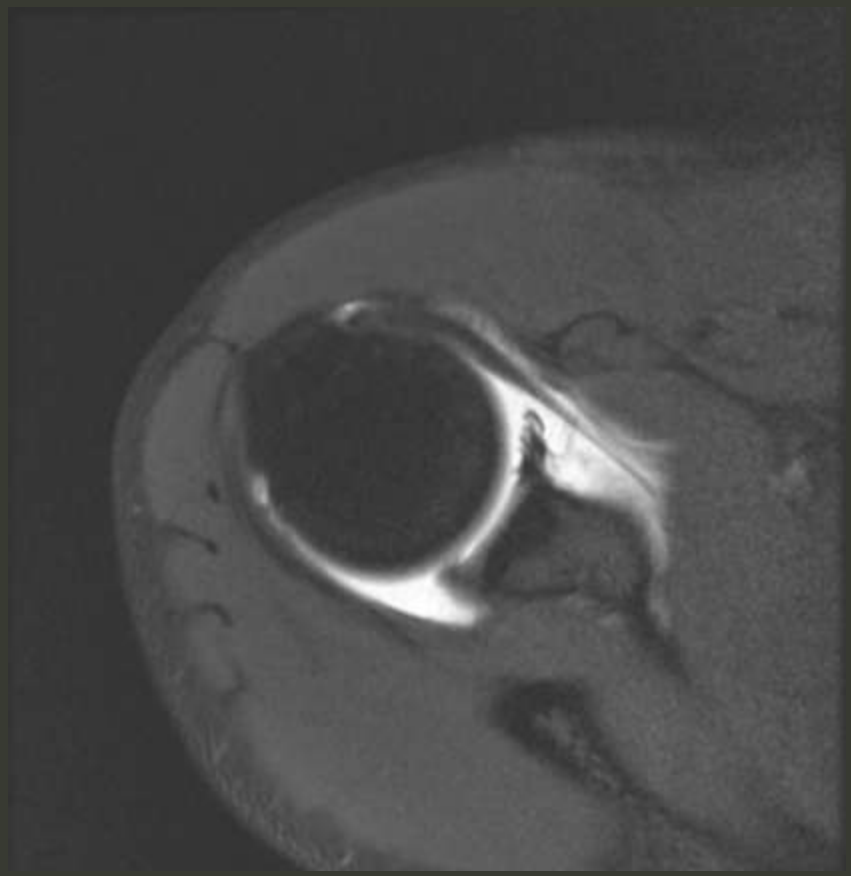
Morag 2005

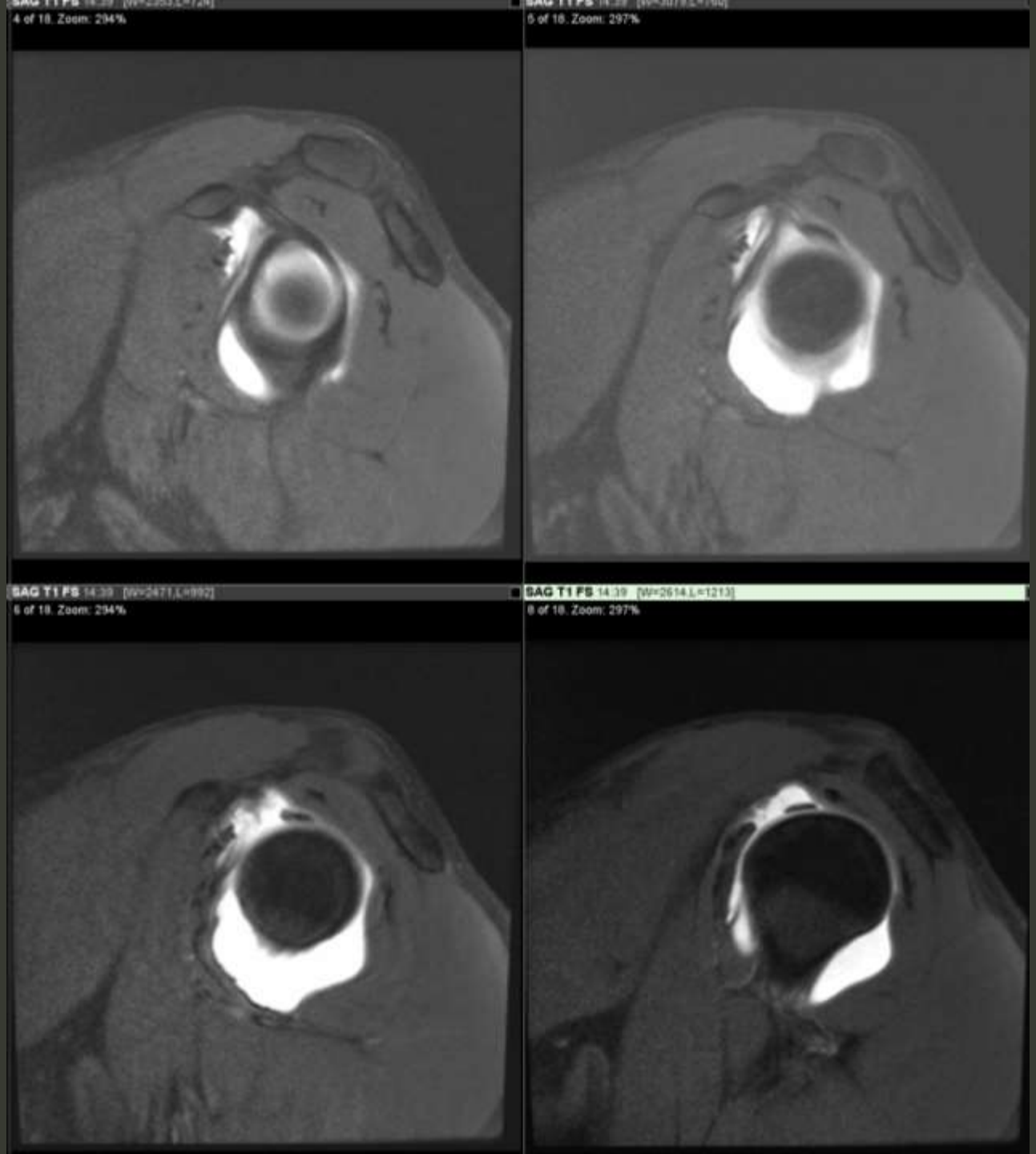
17 yo baseball player, r/o labral tear

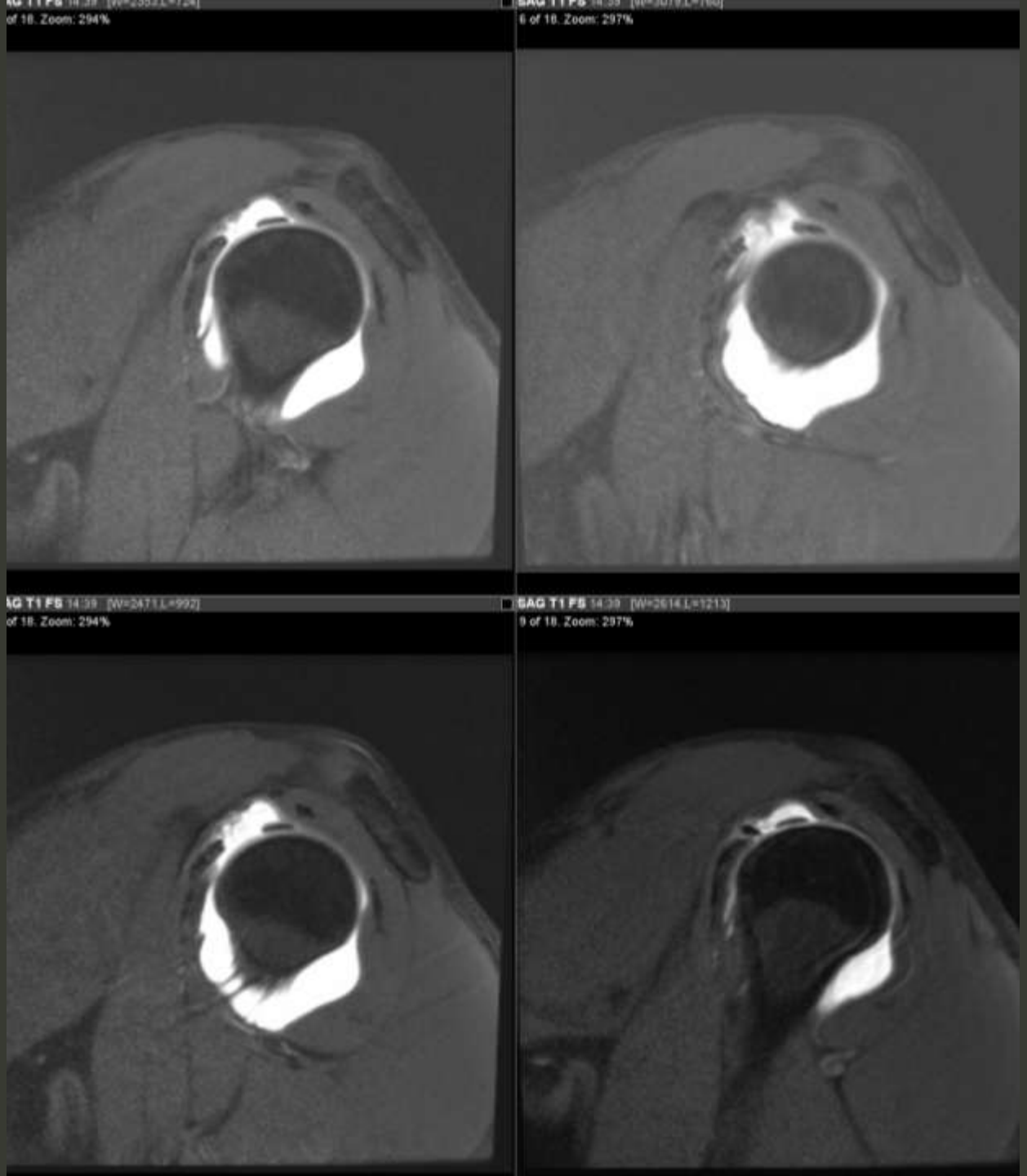




SGHL tear




4 of 18. Zoom: 294%
5 of 18. Zoom: 297%
SAG T1 FS 14:39 [W=2471,L=992]
6 of 18. Zoom: 294%
SAG T1 FS 14:39 [W=2614,L=1213]
8 of 18. Zoom: 297%


of 18. Zoom: 294%
6 of 18. Zoom: 297%
of 18. Zoom: 294%
9 of 18. Zoom: 297%

RI lesions in the throwing shoulder

- Multiple repetitive motions
- Generate significant forces around the shoulder
- Well documented that repetitive overhead motions lead to stress on static and dynamic restraints to glenohumeral motion
- D/Dx is wide (impingement syndromes, macroinstability, microinstability, tendonitis, RCT, labral tears, biceps disorders, radiculopathy, thoracic outlet syndrome)

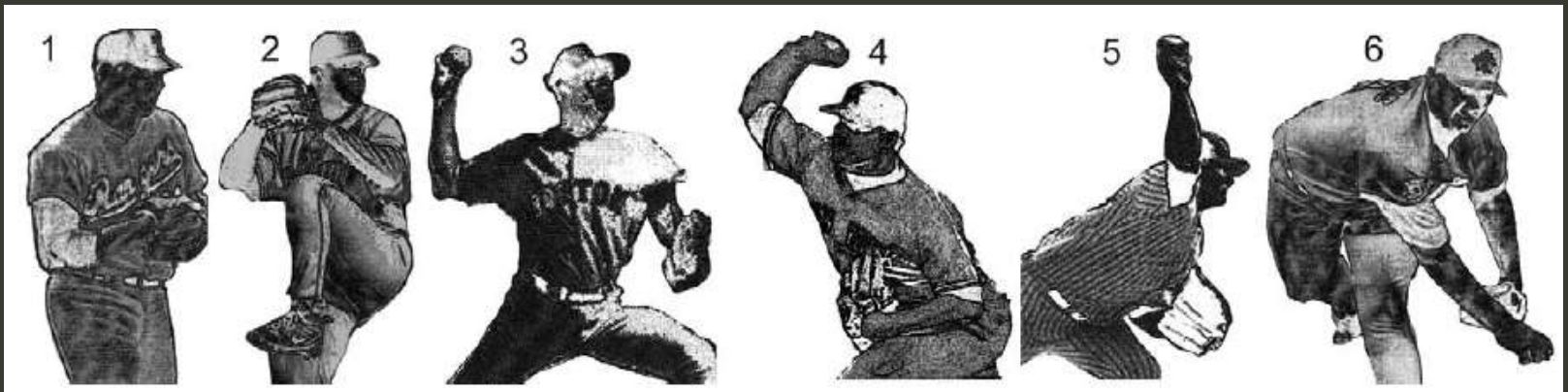
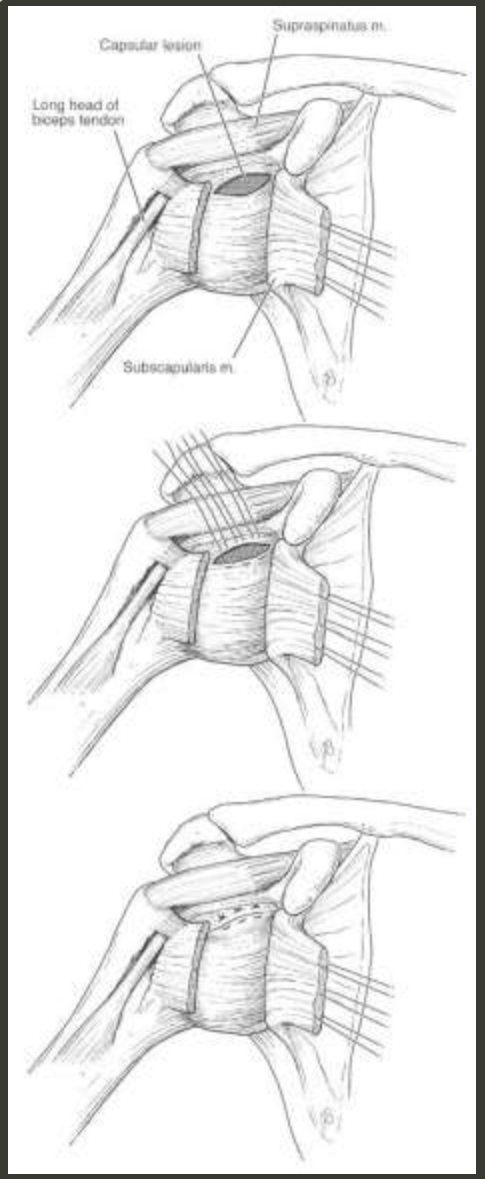


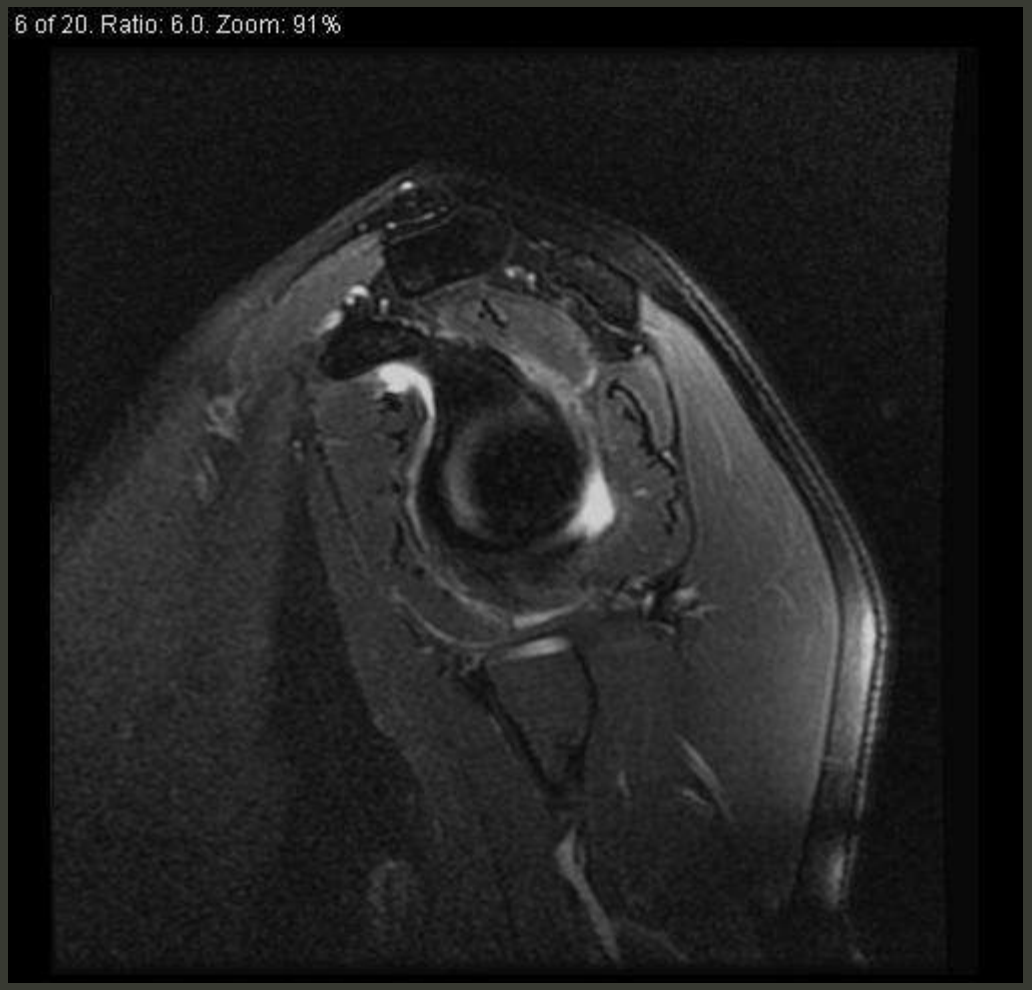
Fig. 6. The six basic positions of a baseball pitch. Positions 1 and 2 are the wind-up phase. Note that the shoulder is in internal rotation and mild abduction at the end of the wind-up phase, in position 2. Position 3: Early cocking phase. The shoulder is in 90 degrees of abduction and 15 degrees of horizontal abduction. Position 4: Late cocking phase. Shoulder in maximum external rotation at 90 degrees of abduction and 15 degrees of horizontal adduction. Position 5: Acceleration phase. Shoulder in 90 degrees of abduction, rotating from external rotation to internal rotation. The ball is released. Position 6: Deceleration and follow-through phases. Shoulder in internal rotation, horizontal adduction, and moving from abduction to adduction.

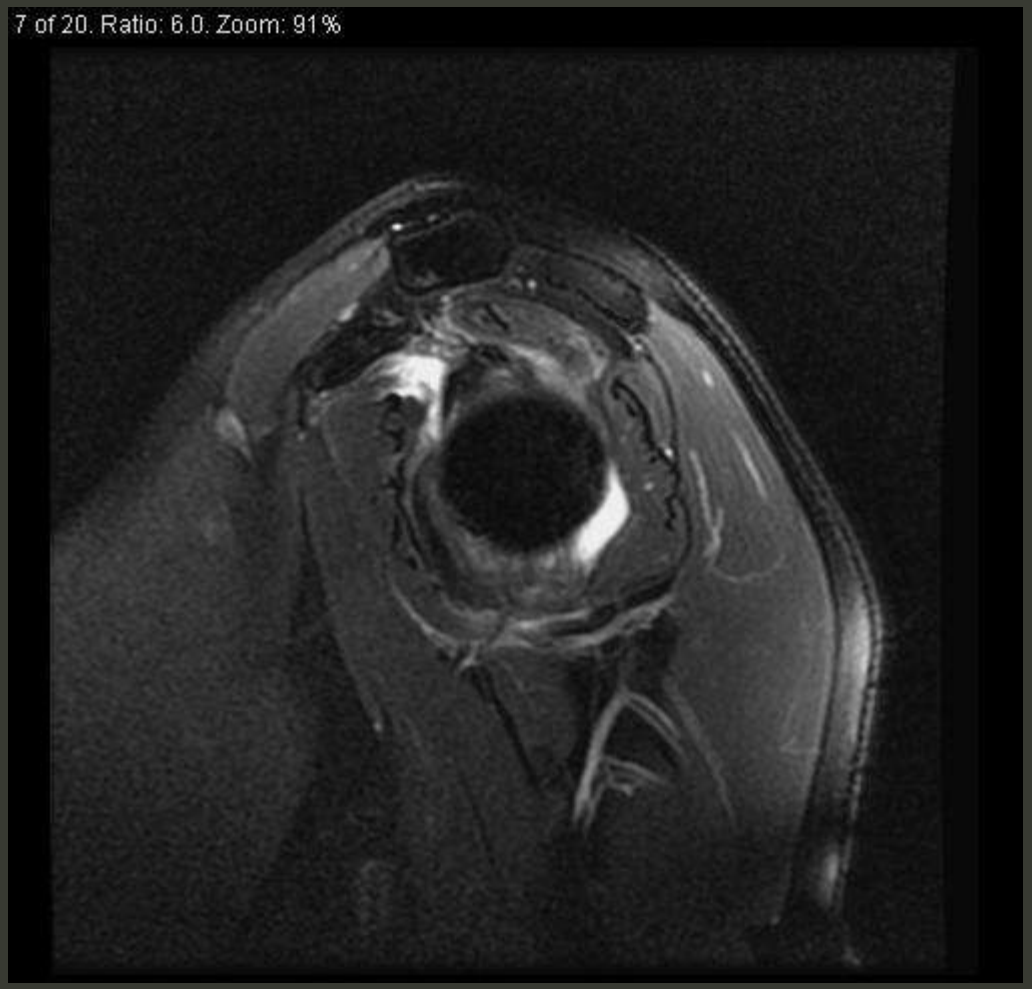
RI lesions in the throwing shoulder

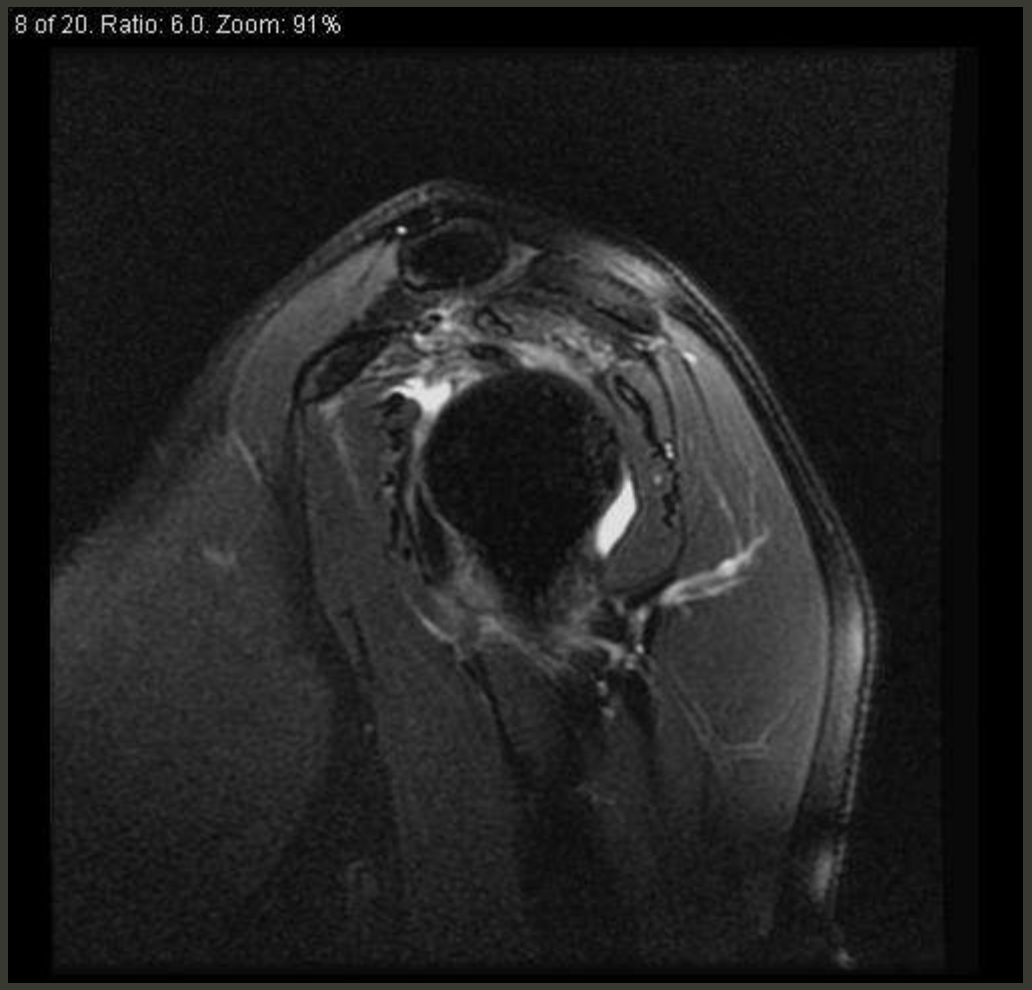
- FT tears in the RI may present with pain, instability
  - Often cannot recall single traumatic incident
  - Pain, apprehension most severe when in 90 deg abduction and maximal ext rot
  - Frequently demonstrate instability on exam
- Tx: closure or imbrication of the defect
  - Usually performed in conjunction with a stabilization procedure (rarely alone)

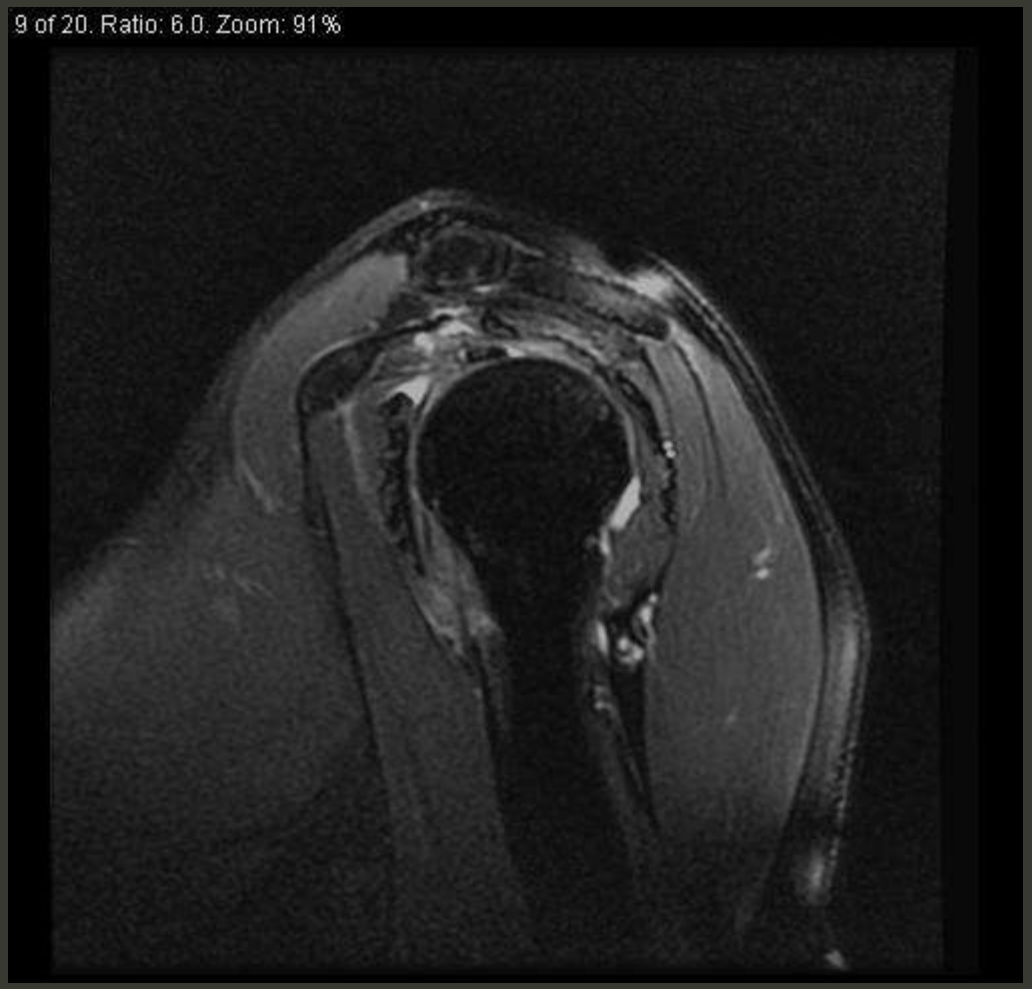


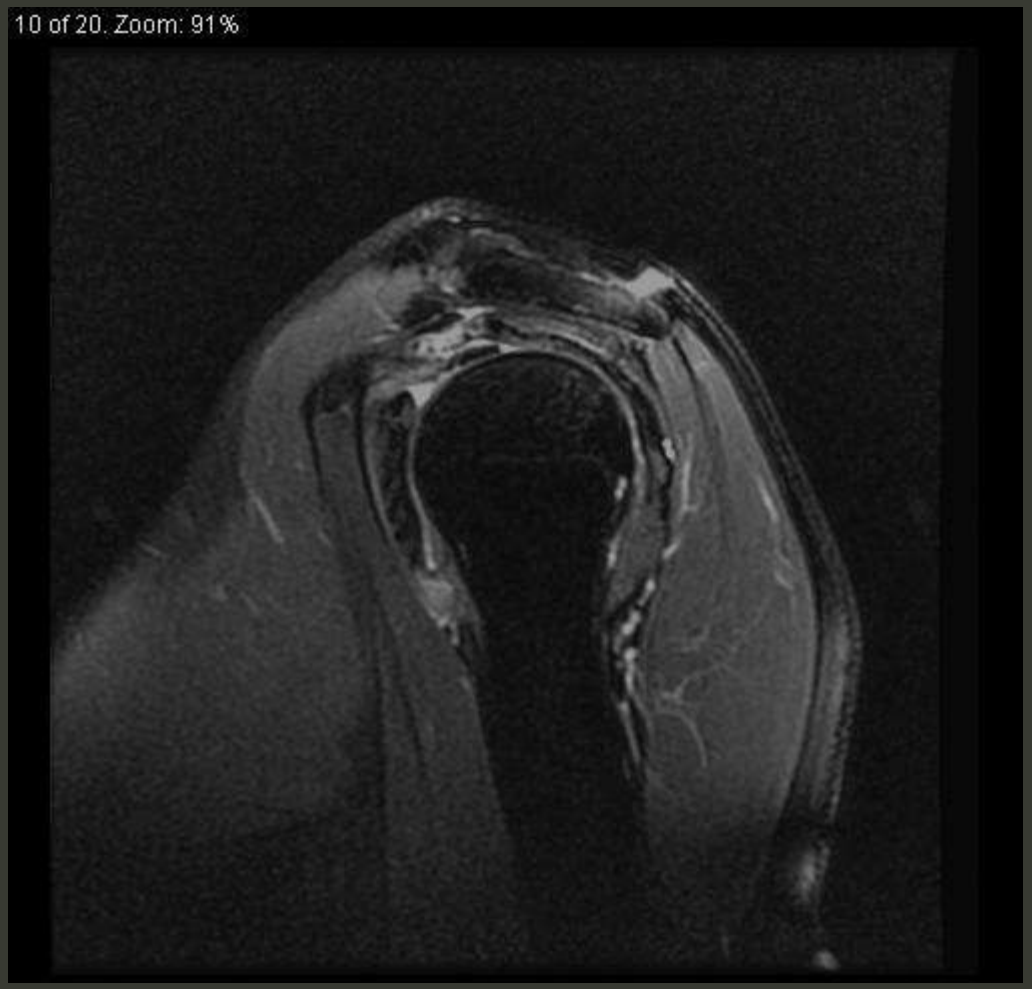
Shoulder pain, decreased ROM

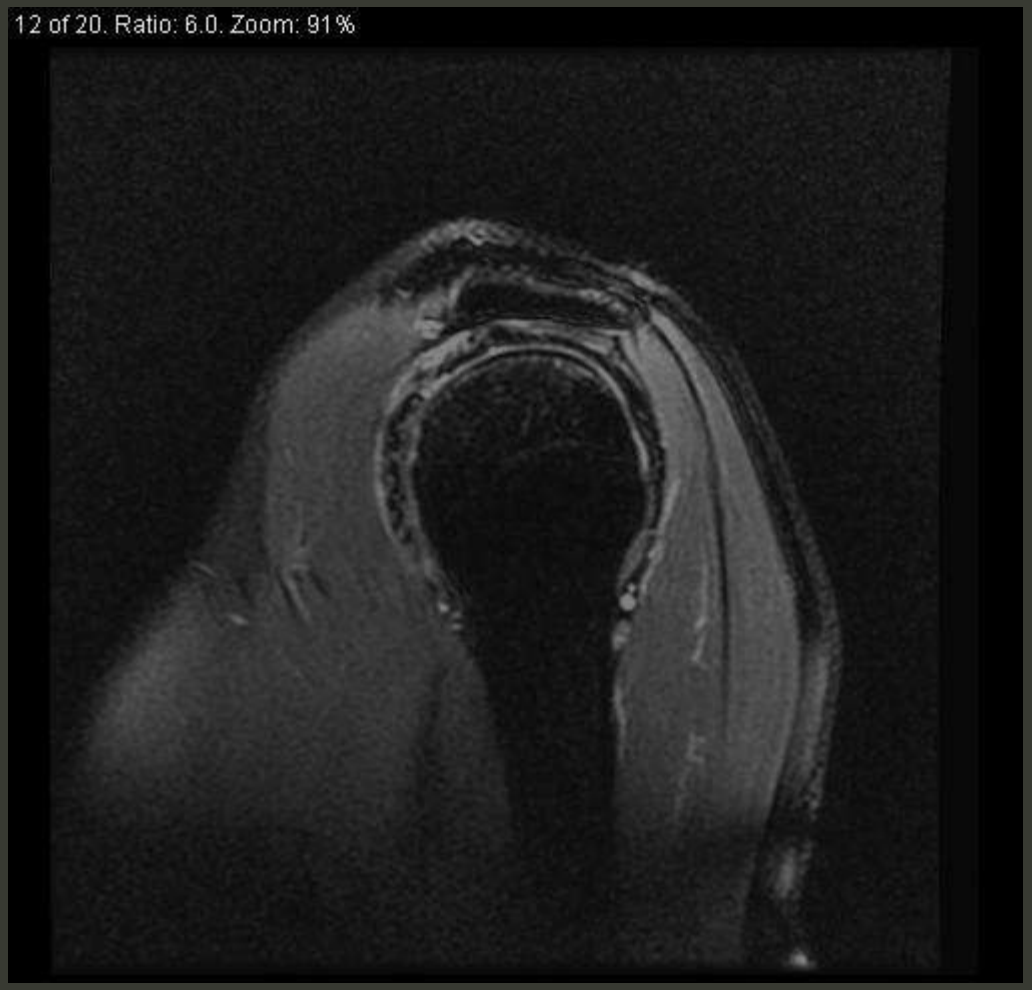



7 of 20. Ratio: 6.0. Zoom: 91%

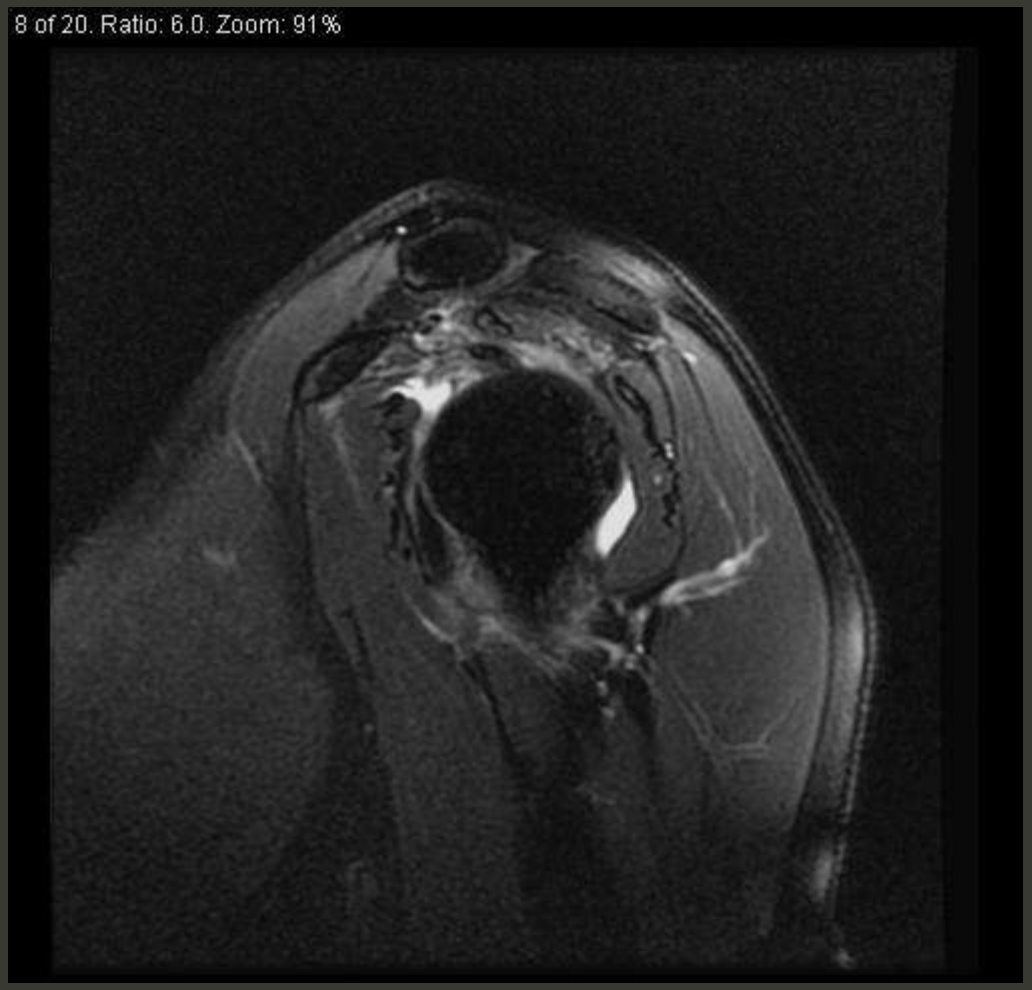

8 of 20. Ratio: 6.0. Zoom: 91%


9 of 20. Ratio: 6.0. Zoom: 91%


10 of 20. Zoom: 91%


12 of 20. Ratio: 6.0. Zoom: 91%

Adhesive capsulitis



MR findings in adhesive capsulitis

- Mengiardi, et al. 2004

Normal CHL
Subjacent fat maintained

MR findings in adhesive capsulitis

- Mengiardi, et al. 2004

Normal CHL
Subjacent fat maintained

57 yo man with frozen shoulder
Partial obliteration of fat

MR findings in adhesive capsulitis

- Mengiardi, et al. 2004

Normal CHL
Subjacent fat maintained

57 yo man with frozen shoulder
Partial obliteration of fat

55 yo pt with frozen shoulder
Complete obliteration of fat (subcoracoid triangle sign)

MR findings in adhesive capsulitis

- Mengiardi, et al. 2004

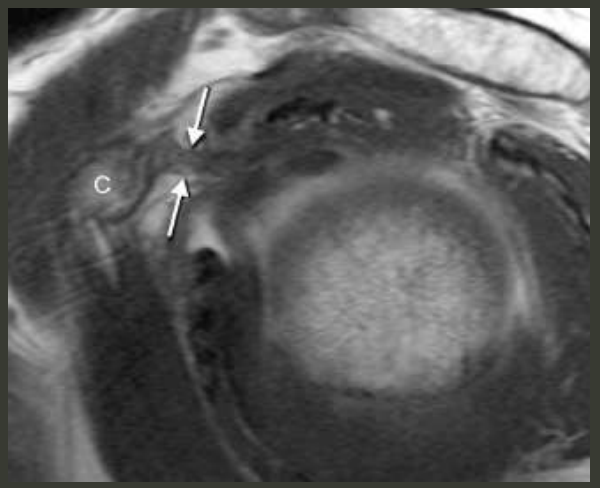


TABLE 3
Diagnostic Value of Significant Quantitative and Qualitative Criteria for Diagnosis of Frozen Shoulder

Criterion	Sensitivity		Specificity	
	Percentage*	95% CI (%)	Percentage*	95% CI (%)
Quantitative†				
≥4-mm thickness of CHL	59 (13/22)	36, 79	95 (21/22)	77, 100
≥7-mm thickness of capsule in rotator cuff interval	64 (14/22)	41, 83	86 (19/22)	65, 97
Qualitative				
Abnormality of CHL‡	82 (18/22)	60, 95	45 (10/22)	24, 68
Obliteration of subcoracoid fat triangle				
Present (partial or complete)	77 (17/22)	55, 92	59 (13/22)	36, 79
Complete	32 (7/22)	14, 55	100 (22/22)	85, 100
Synovitis-like abnormality at superior border of subscapularis tendon	59 (13/22)	36, 79	77 (17/22)	55, 92

Note.—CI = confidence interval.
* Numbers from which percentages were derived are given in parentheses.
† See Figure 1 for method of measurement.
‡ Abnormality was characterized by signal intensity change and/or contour irregularity.

Ozaki et al. 1989

- 365 pts with adhesive capsulitis who failed conservative treatment
- Surgical release of the contracted rotator interval

Ozaki et al. 1989

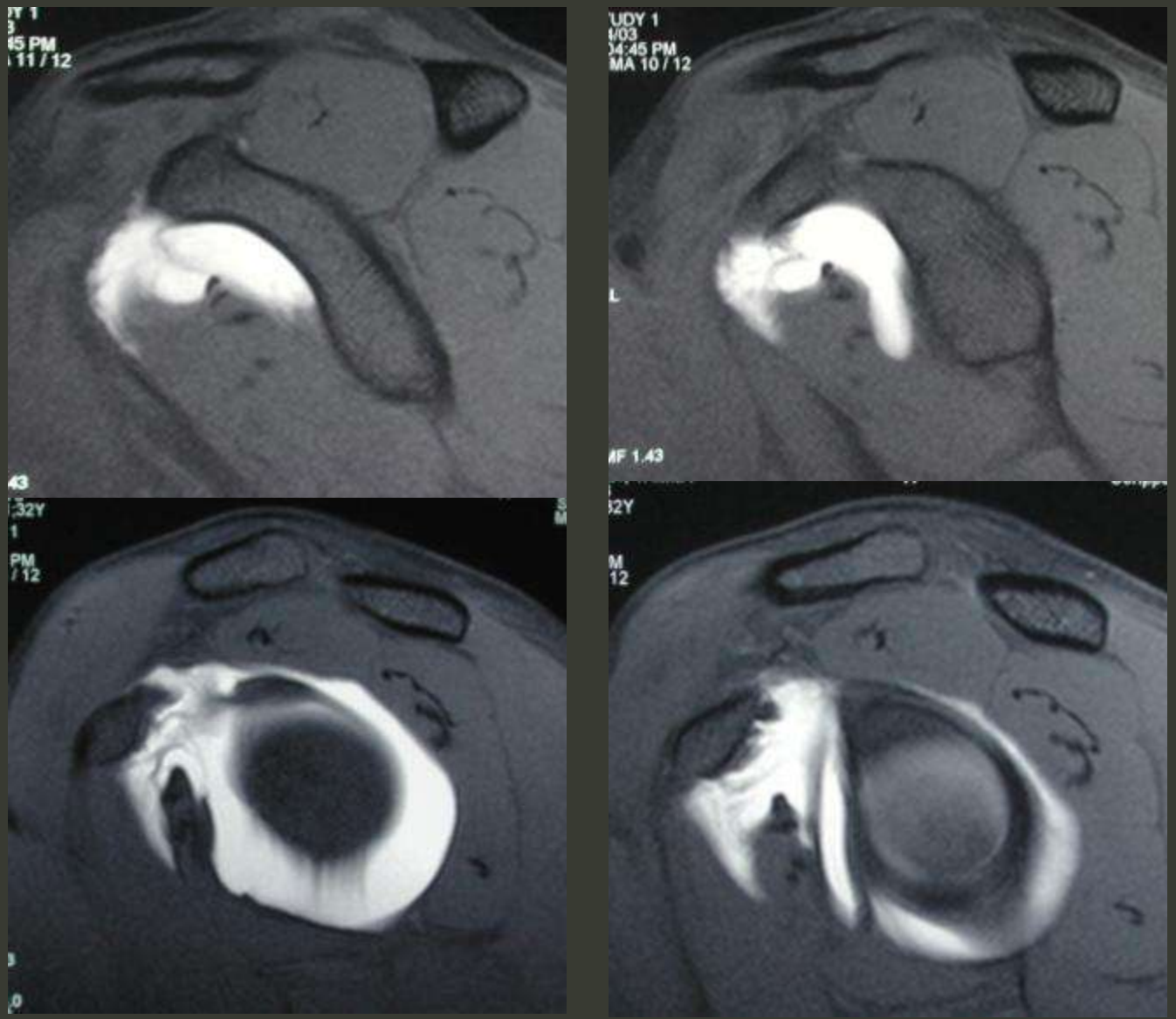
- 365 pts with adhesive capsulitis who failed conservative treatment
- Surgical release of the contracted rotator interval

TABLE I

RESULTS AT FOLLOW-UP EVALUATION

	Patients	
	No.	Per Cent
Pain		
Relieved	16	94
With overuse	1	6
With motion	0	0
Range of motion		
Complete	16	94
Slightly decreased	1	6
Limited	0	0
Muscle strength		
Normal	17	100
Slightly decreased	0	0
Limited	0	0

Unknown case



Images courtesy of C. Chung

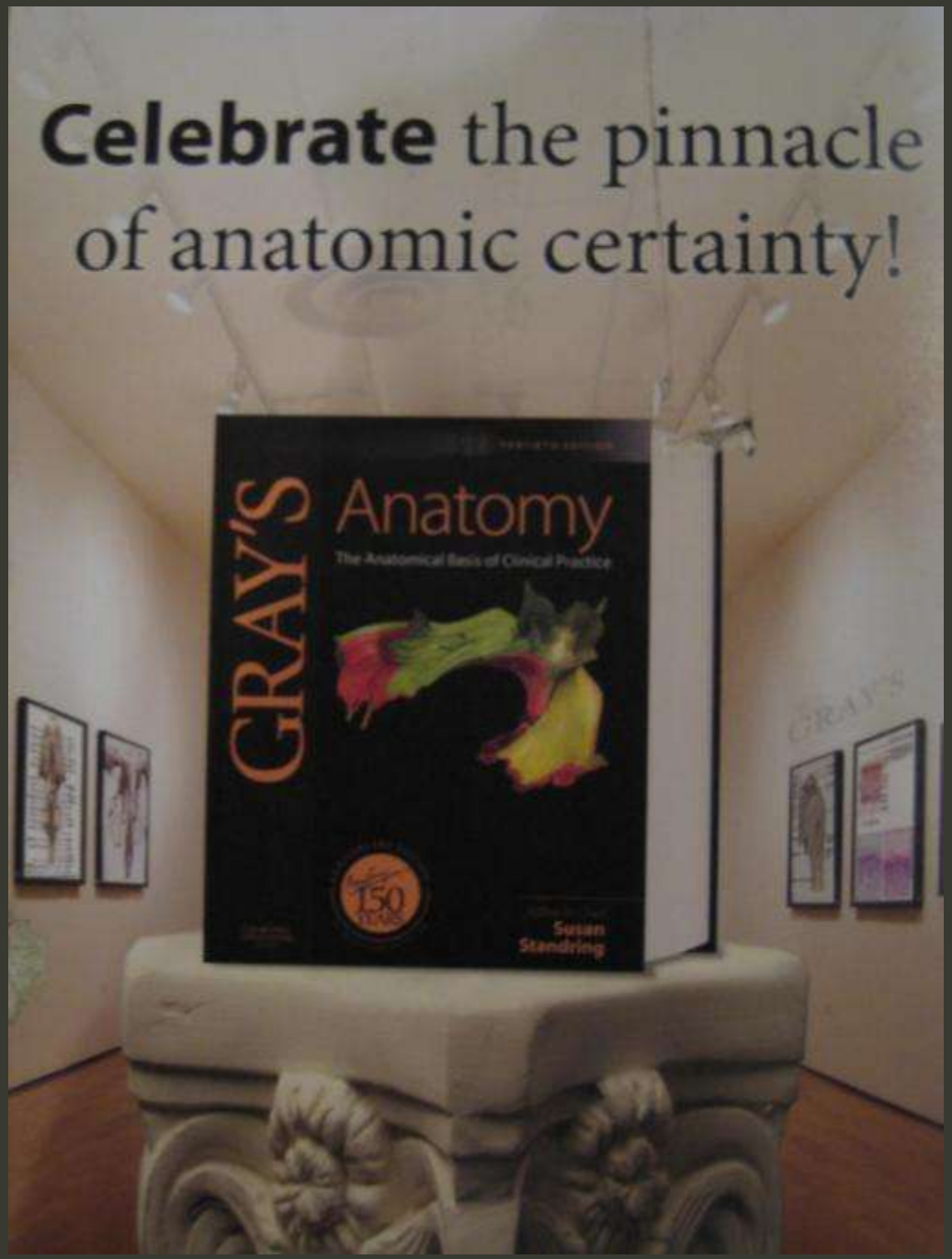
Shoulder arthrogram, rotator interval approach

Iatrogenic RI “lesion”

- Concept is also of significance with arthroscopy
  - RI is regularly used as the anterior portal in shoulder arthroscopy
  - But capsulorraphy without RI closure in a pt with RI defect can result in recurrent postoperative symptoms

Summary

- Normal anatomy controversial
- Biomechanic significance controversial
- Pain, instability can result from RI pathology
- RI lesions often in association with other shoulder pathologies (eg RCT, SLAP)
- “Hidden” lesions can potentially be seen with MR
- Missed RI lesion can have clinical repercussions (inadequate surgical repair → recurrent pain/instability)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