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DIAGNOSTIC IMAGING OF THE THROWING ATHLETE'S SHOULDER

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ABSTRACT

The diagnostic capabilities of advanced imaging have increasingly enabled clinicians to delineate between structural alterations and injuries more efficiently than ever before. These impressive gains have unfortunately begun to provide a reliance on imaging at the loss of quality in the clinical examination. Ideally, imaging of the shoulder complex is performed to confirm the provisional diagnosis developed from the history and clinical exam rather than to create such. This clinical commentary will provide the framework for both basic and advanced uses of imaging as well as discussion of evolving modalities.

Keywords: Throwing athlete, shoulder pain, imaging, diagnosis

Level of Evidence: 5

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INTRODUCTION AND IMPLICATIONS OF THROWING

The activity of throwing is accomplished through the use of the entire body to enable the distal portion of the upper extremity to be the final portion of the "whip" – propelling the ball at high velocities in a controlled fashion. To be a successful throwing athlete requires years and many hundred thousand repetitions to develop the mature throwing pattern. Significant loading to shoulder structures results in both soft tissue (rotator cuff and capsulolabral structures) and bony (humerus and scapula) changes – consistent with years of on-going demands.

The throwing athlete takes the most mobile joint complex in the body (composed of a true complex of both bony and soft tissue articulations) and alters the basic presentation of restraints and functional patterns to facilitate throwing. The thrower must maximize the desired ranges of motion to enable enhanced throwing while systematically providing high loads, which make these soft tissues respond negatively to mechanical stresses and may place them at risk of injury – especially over long-term exposure. One can view the throwing shoulder much like a thoroughbred horse – very finely tuned and trained but always vulnerable to injury. A very apt description is that the throwing athlete must possess the required increase in external rotation at the glenohumeral joint to be an efficient thrower, yet still have the stability required for maintenance or control of throwing mechanics. Obviously, the shoulder compromise is focused on control throughout a large range of motion for the throwing motion and not joint stability in the thrower.

Imaging of the glenohumeral joint and its periarticular tissues remains a challenge primarily related to the multiple layers of overlapping soft and bony tissues. Rather than cleanly reflecting an individual structure, tissue overlap or structure superimposition is the rule. This has led clinicians to create numerous "special" radiographic projections, which attempt to better isolate the desired structure. Over time and with the evolution of imaging technology, clinicians have increasingly begun to use magnetic resonance imaging (MRI) as a more definitive modality to allow visualization of tissue changes, particularly of the soft tissues.

The initial decision to image must be predicated on a complete physical examination. Ideally in the thrower, throwing history and athletic context are reviewed prior to the actual examination. One of the hallmarks of the physical exam is the well appreciated change in range of motion seen in the thrower.[1] The throwing athlete requires the examiner to not use the non-involved extremity for strict contrast as the throwing side should exhibit significant hypertrophy, altered range of motion (increased external rotation with a concomitant loss of internal rotation – typically referred to as glenohumeral internal rotation deficit – GIRD) and changes in scapular position. The clinician's physical examination closely correlates the phases of throwing (wind-up, cocking, acceleration, ball release, and follow through) and the corresponding tissues that are loaded in each phase, in order to best delineate injury and, thus, the indication for imaging. When imaging is to be used, the introductory radiographic imaging is to clear bony components (humerus, scapula, and clavicle) and additional imaging may be required for soft tissues.

BASIC SCREENING IMAGES

The screening images are a series of radiographic views taken to enable relationships and structural assessments of the bony structures and at a minimum include the Anterior-Posterior in Internal Rotation (AP-Int Rot), Anterior–Posterior in External Rotation (AP- Ext Rot) and Axillary (True Lateral view) (Figures 1, 2, 3). Descriptions of the positions for screening views are A-P internal rotation (supine with forearm and palm down across abdomen), A-P external rotation (supine with external rotation of the humerus-palm up) while the Axillary requires the beam be directed from inferior to superior with the arm abducted approximately 60-90 degrees. In external rotation, the greater tuberosity is in profile as the most lateral projection while in internal rotation, the lesser tuberosity is in profile on the medial aspect of the humeral head against the glenoid. The Axillary view enables assessments of overall positions of the bony structures. These views give an overall appreciation of the proximal portion of the humerus, the lateral aspects of the clavicle, the acromioclavicular (AC) joint as well as the upper portions of the scapula.

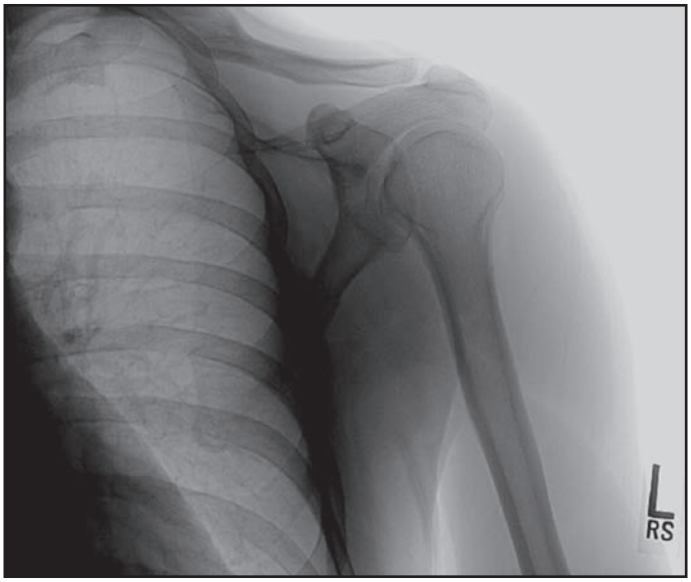

Figure 1. *An anterior-posterior radiograph of the shoulder. Note the prominence of the lesser tuberosity near the glenohumeral joint line.*

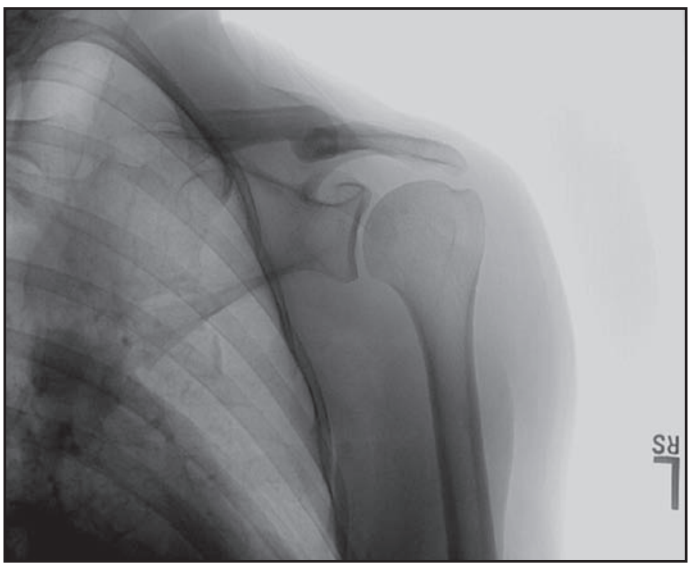

Figure 2. *An anterior-posterior radiograph of the shoulder. Observe the glenohumeral joint line and the prominence of the greater tuberosity laterally. This view is sometimes referred to as a Grashey view and is made with the patient's trunk rotated approximately 30 degrees to obtain a true A-P of the scapula and profile the glenohumeral joint.*

Some clinicians add one or two supplemental views as a part of their "throwing shoulder" screening films. These include the West Point (inferior to superior modified axillary designed to enable review of the anterior/inferior glenoid rim) and/or Stryker (anterior to posterior view with the arm in external rotation and approximately 90 degrees of abduction

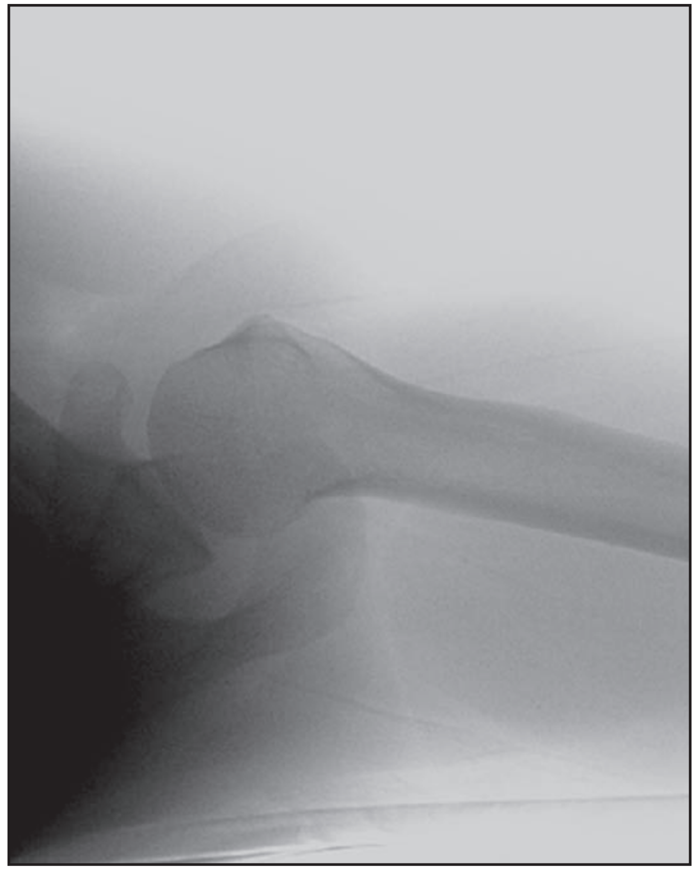

Figure 3. *In this supine axillary view, the normal relationship of the humeral head and glenoid fossa are easily appreciated.*

designed to expose Hill-Sachs humeral head lesions associated with instability). Since instability is a common issue with athletes, these additional views can be useful in better delineation of bony changes seen in these patients. The diagnostic power of other imaging modalities, principally MRI, has diminished the use of these supplemental angles as accompanying soft tissue injury may also be revealed.

These imaging selections are in keeping with the American College of Radiology (ACR) Appropriateness Criteria®. An overview of recommended imaging procedures for the diagnostic process shows that radiographs are often followed by MRI and occasionally augmented with direct injection of intra-articular contrast and subsequent imaging, known as magnetic resonance arthrography (MRA). In addition to radiography and MRI/MRA, the recent revisions in these guidelines have elevated the recommended uses of diagnostic ultrasound for examination of the rotator cuff. These guidelines include multiple presentation specific considerations, referred to as "variants." Additional information is available on the ACR web site for current versions of these criteria and to understand the imaging modality selection within the variants described (http://www.acr.org/Quality-Safety/Appropriateness-Criteria). Variants 1 through 4 have the greatest applicability to the throwing athlete and warrant particular attention.[2]

The use of MRI has become the pre-eminent test for examining athletes with shoulder pathology as it enables assessment of both soft tissue and bony structures. It also does not expose the patient to ionizing radiation, however, it is expensive. Ideally, MRI is used to plan surgery, clarify conditions when radiographs are not definitive and the manual examination is equivocal (Figure 4). Additionally, MRA can increase the definition of intra-articular structures particularly as the contrast medium fills small tears or disruptions in articular structures or distends the capsule and labrum in order to reveal defects (Figures 5 & 6).

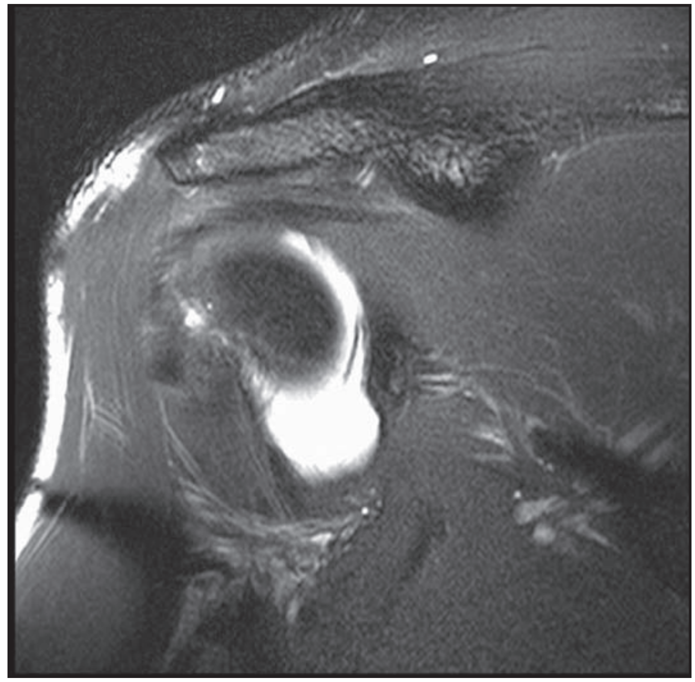

Figure 5. *In this coronal-oblique slice MRA, observe the linear fragment of labral tissue visible against the intra-articular contrast distending the capsule.*

In the recent past, computed tomography (CT) has become a much more widely used modality. It includes the ability to assemble 3-dimensional reconstructions, which reflect the contours and bony edges with remarkable detail. It has excellent value in trauma when fractures are being considered (Figures 7 & 8). One issue in the use of CT as a routine procedure is the exposure level of ionizing radiation, which is particularly worrisome with younger patients.[3,4]

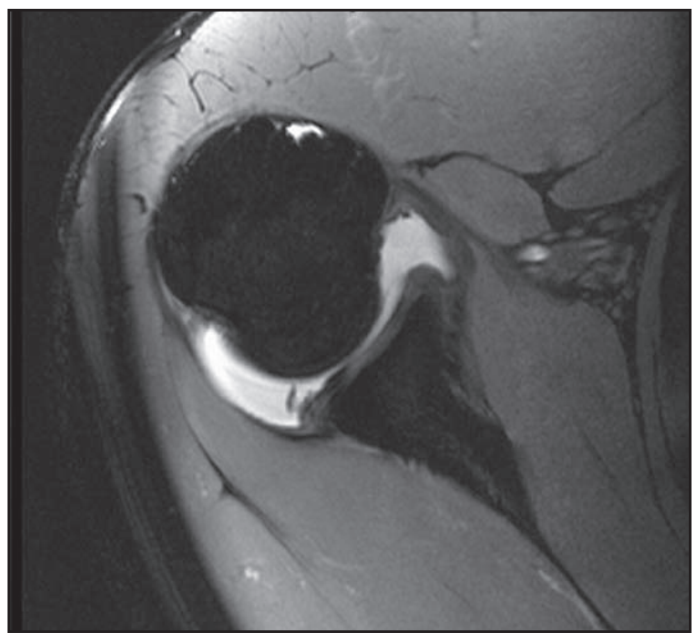

Figure 6. *In this axial slice of the same patient as Figure 8, the small labral fragment is again revealed posteriorly as the contrast distends the capsule, allowing greater visualization of labral discontinuity.*

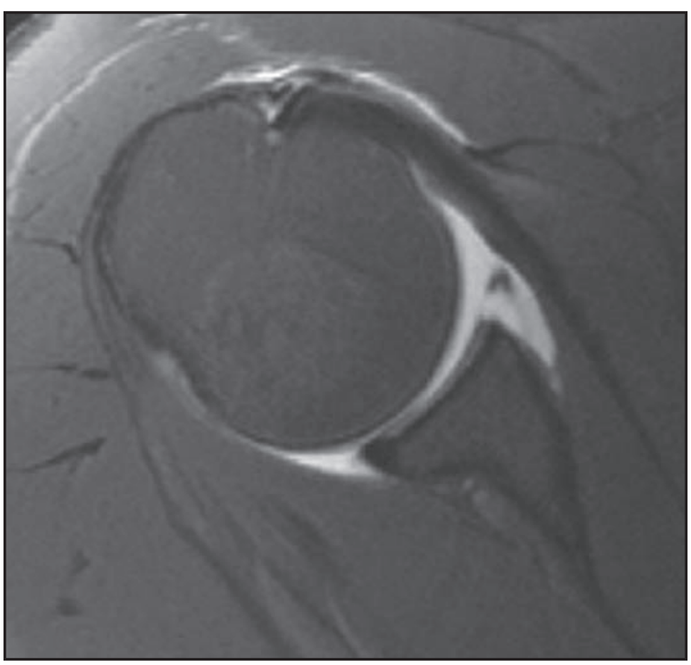

Figure 4. *An axial slice MRI demonstrating a Bankart lesion. Notice the labral fragment at the anterior aspect of the joint line.*

Figure 7. *In this axial slice CT, a fracture of the scapula is evident. This type of injury, difficult to appreciate on radiography, is more readily revealed with the multiplanar views and clear delineation of cortical bone margins visible on CT.*

Figure 8. *The advances in CT in recent years include three-dimensional imaging, which can allow remarkable demonstration of the bony anatomy.*

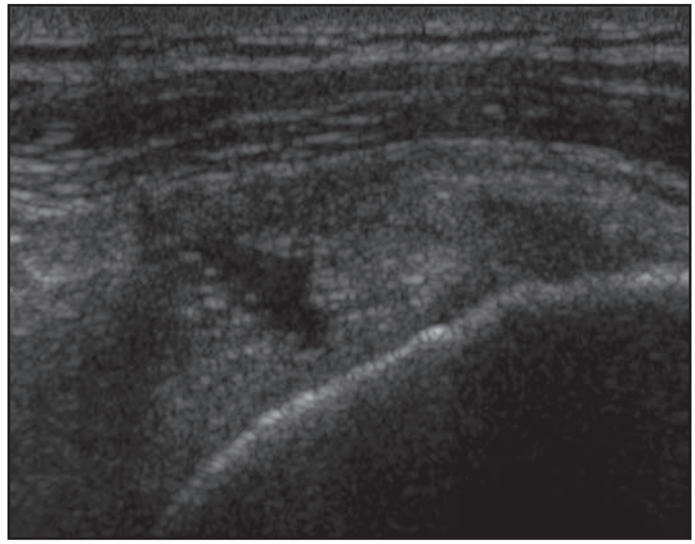

Figure 9. *In this longitudinal view of the supraspinatus muscle and tendon overlying the humeral head, observe the focal hypoechoic area within the tendon (darker), consistent with a tear.*

An emerging modality for shoulder imaging is musculoskeletal ultrasound (US). At this time, US can be used primarily for assessment of the rotator cuff tendons and general structural alignments. It is more user dependent and limited in acceptance in most settings, but may be useful in skilled hands (Figure 9).[5]

Specific Throwing Shoulder Assessments

Traumatic versus an atraumatic onset plays a significant role in the use of imaging use. The majority of throwing injuries are not trauma per se, but rather associated with the highly demanding repetitive "controlled violence" of throwing. This is exemplified by the loss of motion and strength seen after a pitcher completes a "start" – where he typically throws considerably more than the reported/recorded pitches as that number only reflects pitches thrown to hitters. Most pitchers require 4 or 5 days to fully recover which is consistent with most teams scheduling of starting pitchers.[6,7]

If there is a traumatic onset, the initial screen of radiographs normally is sufficient to delineate whether occult fracture or gross instability is present when combined with manual assessment. Instability is quite common in the adolescent and young adult age group and normally is defined by presentation (either dislocated or significant event where the athlete had a reduction process). Much more common is the vague onset associated with minimal changes to shoulder restraints, described as soft tissue (capsular) laxity. When required, to clearly define these structures, MRI or MRA are often used (Figures 10 & 11). This leads to a common problem associated with shoulder dislocations as the capsule is unable to re-attach to the underlying glenoid as the labrum has insufficient vascularity to support healing. The classic tear is Anterior/Inferior and is called a Bankart lesion and if it includes a glenoid bony separation it is called a Bankart fracture. Traditionally, the radiologist had used an arthrogram to demonstrate these lesions but today MRI and its greater specificity has supplanted the earlier techniques. CT is still used for suspected fractures particularly of the glenoid rim. Thus, when dislocations have been ongoing, the surgeon will add images in order to carefully examine the anterior inferior glenoid to assess for the possibility of bone loss. If the West Point view radiograph did not delineate the issue, often MRI or CT scan will be used. Importantly, throwers can damage the Inferior capsule (Inferior Glenohumeral Ligament) both at the humeral head (Humeral Avulsion of the Gleno-Humeral Ligament – HAGHL lesion) and more typically from the glenoid. These are seen best via MRI (Figures 12 & 13).[5,6]

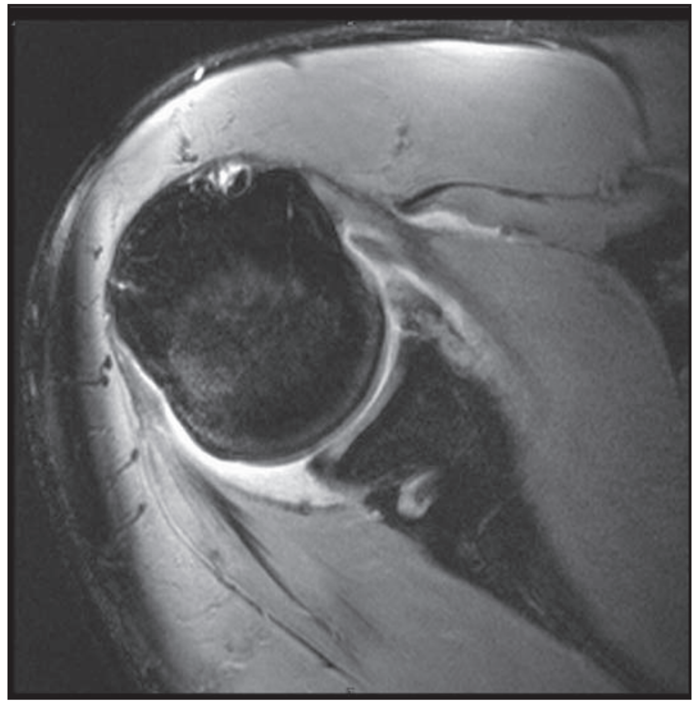

Figure 11. *An axial slice MRI of an acute capsulolabral lesion immediately following a dislocation event. Note the disruption of continuity of the anterior capsule and labrum. This image also reveals a small Hill-Sachs lesion with the indentation of the posterior humeral head and underlying marrow edema. In this case, the acute effusion of the joint acts similar to contrast in highlighting particular structural injuries.*

Figure 10. *Dislocation of the glenohumeral joint is demonstrated in this axillary view. This perspective clearly reveals the disordered anatomical relationship of the humeral head and glenoid fossa*

Throwers can have both classic impingement (soft tissue "pinching" of subacromial tissues anteriorly during throwing) as well as posterior or internal impingement that is associated with cocking--maximal external rotation--enabling the supraspinatus and infraspinatus to be "pinched" against the posterior superior glenoid. Frequently, these pathologies are apparent via manual examination but may be further defined with MRA in an abducted and externally rotated position (Figures 14 & 15). The scapula is positioned by soft tissues to permit appropriate function of the arm through orientation of the glenoid in relation to the humeral head. This finely tuned process is described as scapulohumeral rhythm and provides the harmonious functions of the upper extremity while enabling it to be anchored to the trunk. The scapulothoracic joint provides an upward rotation and sliding movement that requires a well-orchestrated sequence of proximal muscular actions in concert with humeral

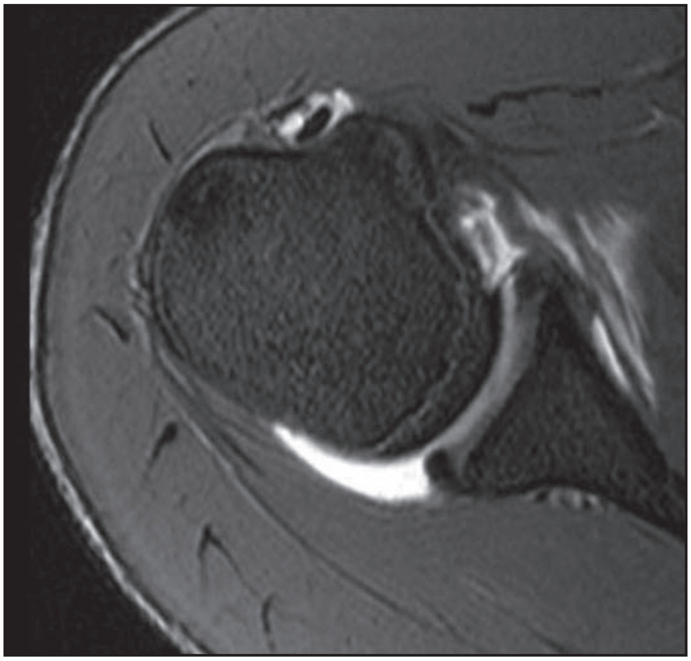

Figure 12. *An axial view MRI revealing disruption of the humeral attachment of the glenohumeral ligament.*

Figure 13. *In this coronal-oblique slice MRA, the so-called "J Sign" is evident against the high signal contrast with avulsion of the glenohumeral ligament.*

rotators (actually centering/compressing the humeral head onto the glenoid) and humeral movers culminating in upper extremity functional actions. The superior projection of the scapula includes the acromion,

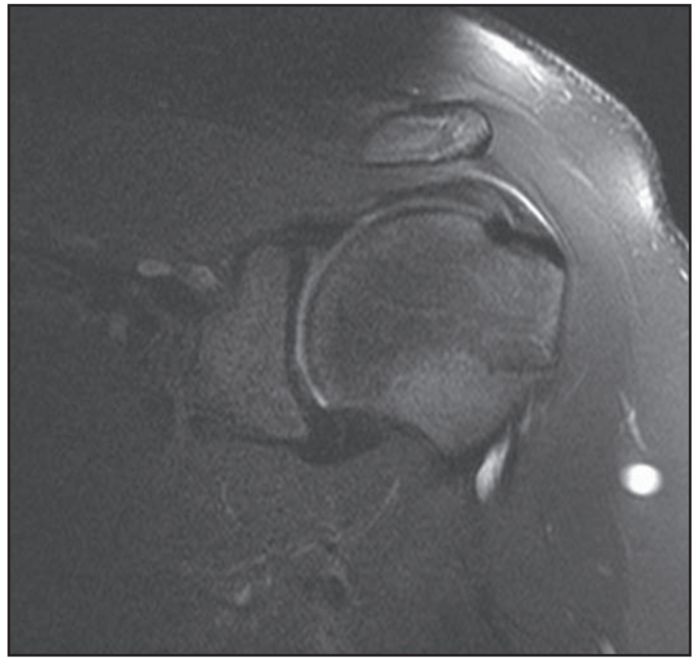

Figure 14. *In this coronal-oblique slice MRI of a 14 year-old athlete, note the proximity of the humeral head and acromion with the signal changes in the interposed supraspinatus tendon.*

Figure 15. *Posterior or internal impingement of the glenohumeral joint is present in this MRA as the shoulder is positioned in abduction and external rotation. Note the soft tissue disruption posteriorly and the accompanying indentation of the humeral head because of repeated abutment against the posterior glenoid rim.*

which provides the "roof" of the glenohumeral joint proper while the inferior projection is the coracoid process serving as an anchor for muscle and ligament insertions (Figure 16).

The humerus provides the proximal rounded head which articulates with the rather flat glenoid fossa of the scapula. This round head onto a flat "saucer" provides an inherently unstable glenohumeral joint with the disproportionally small size of the glenoid contributing as well. Because there is significant loading to soft tissues – especially during deceleration after the ball has been released – the previously mentioned which might be described as minimal or mild "instability issues" may at times be inherent to enable the pitcher to have greater velocity and ball movement. MRI is again the modality of choice for instability.[5] The tissue which frequently gets abused most by throwing is the glenoid labrum. The glenoid labrum is a fibrocartilagenous rim which helps increase the contact between the humeral head and the flat glenoid. It can be viewed as functioning much like the peripheral surface thickness works as the meniscus of the knee. Although very dense, only special image modalities will define this wedge shaped fibrous

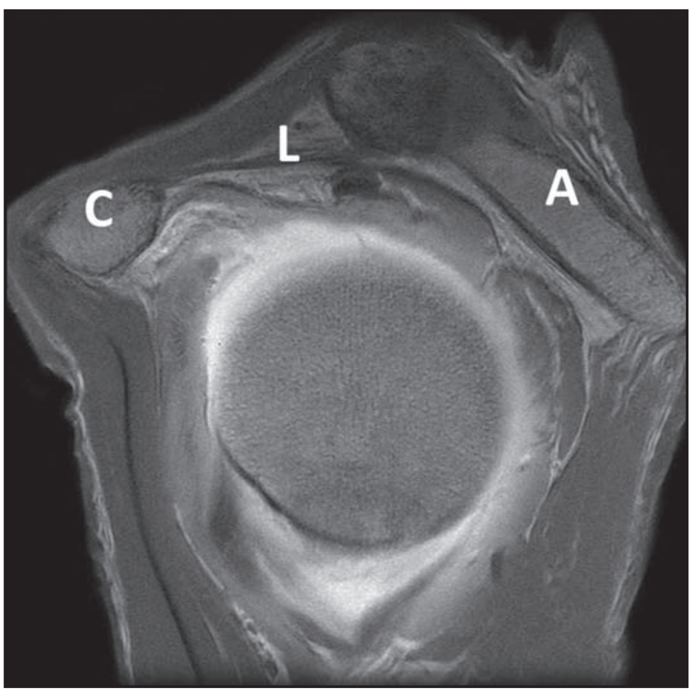

Figure 16. *This sagittal-oblique slice MRI demonstrates the proximity of the acromion as part of the coracoacromial arch to the humeral head. The interposed tissues are at significant risk for impingement with overhead throwing activities. C = Coracoid, L = Coracoacromial Ligament, A = Acromion.*

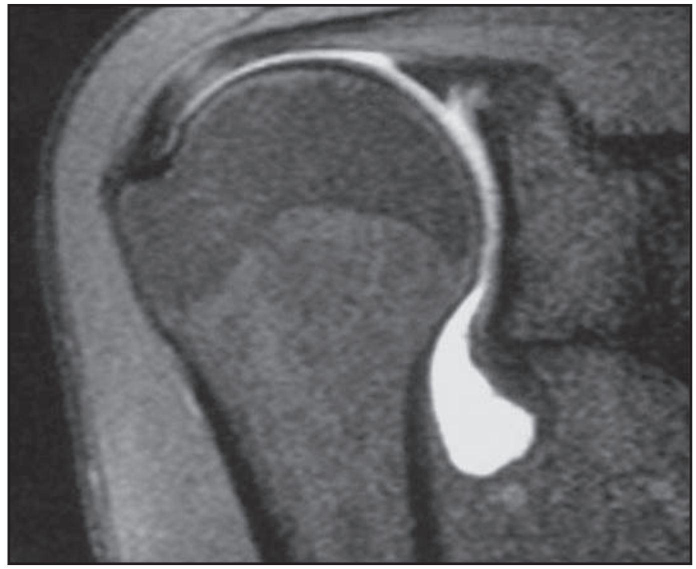

Figure 17. *In this coronal-oblique slice MRA, note how the intra-articular contrast fills the defect in the superior aspect of the labrum consistent with a SLAP (superior labrum anterior to posterior) lesion.*

structure well, with MRI being most the typically utilized (Figure 17). Unfortunately, some specific injuries to the labrum are actually just normal variants and nearly all professional pitchers have asymptomatic labral tears.[8] Thus, care in the selection of imaging modality is advised with MRA being most frequently chosen. When damage occurs in the superior region, it described as a SLAP lesion (Superior Labrum Anterior to Posterior) and is most commonly seen in the 20-40 year old male with a history of overhand throwing.

The space between the humeral head and the acromion is often referred to as the supra-humeral space. This includes several soft tissues that can be "pinched" if inadequate muscular action, decreased space, or enlargement of soft tissues occurs. This again is described as classic impingement syndrome and should be defined as specifically as possible to enable definitive care. There are some individuals who may have a higher susceptibility to this condition related to bony encroachment[9] (Figure 18).

Sometimes the rotator cuff does sustain injury and can present as fairly minimal symptoms (slight loss of velocity, arm feels tired, I'm not as strong ...). Sometimes this occurs as the season progresses and radiography is not useful. The use of US may be assistive, but often MRI is required to allow full

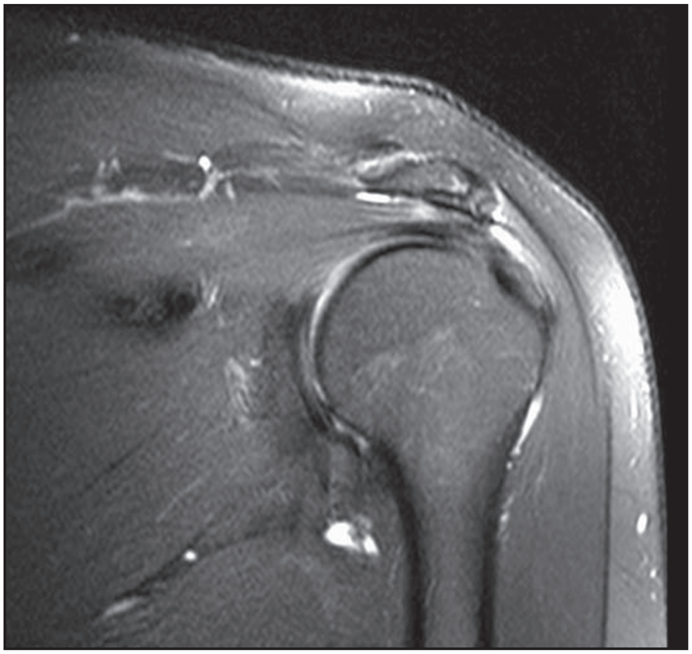

Figure 18. *In this coronal-oblique slice MRI, note the osteophyte at the tip of the acromion sloping downwardly and lessening the acromiohumeral distance. Also, observe the signal changes in the supraspinatus tendon immediately inferior to the osteophyte.*

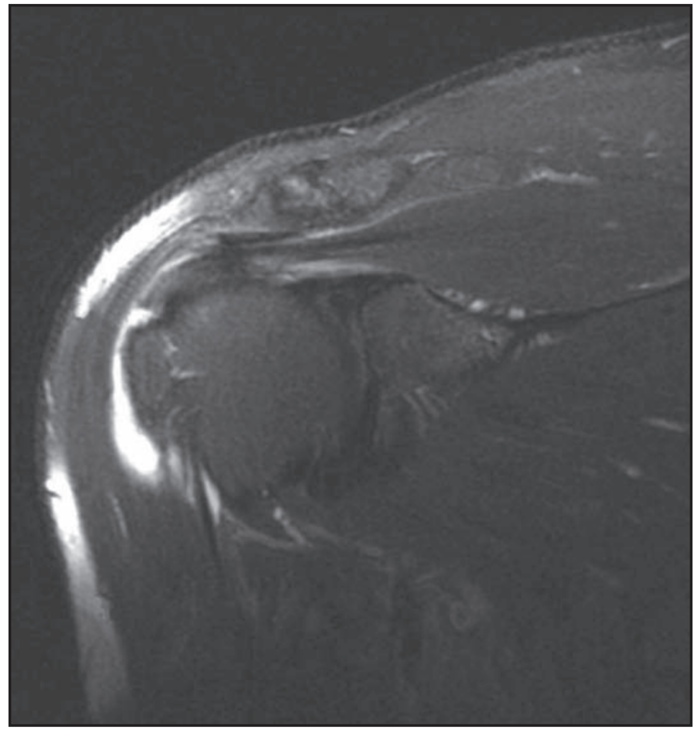

Figure 19. *In this MRI, a partial tear of the rotator cuff is evident originating from the bursal side of the tendon. These types of lesions are less frequently encountered than articular sided lesions.*

appreciation of the tissue injury. MRI can show partial tears of the supraspinatus on either the bursal superior side of the tendon or the articular inferior side of the tendon (Figures 19 & 20). When this is the presentation, a balanced approach in rehabilitation is tried before surgical considerations, often with success.[6,7]

Just as the rotator cuff is highly activated during throwing, the biceps can have involvement related to decelerating the elbow again after ball release. Biceps palpation requires significant external rotation and gentle digital pressure. When irritated, tendon healing fails – enabling the tendon to become thicker and thus more easily entrapped during overhead actions. When surgical intervention is considered, a MRI is typically the modality of choice (Figure 21). Other muscle-tendon units can be injured and are typically treated initially via rehabilitation and then more substantial diagnostics only if they have not responded. Again, MRI is the modality of choice often using different patterns of density to better define specific soft tissues.[5,6]

Additional special studies are used when vascular or neural injury is considered. Typically, when

Figure 20. *A coronal-oblique slice MRI with significant signal intensity changes and indications of discontinuity of the supraspinatus tendon immediately proximal to its humeral attachment on the articular side.*

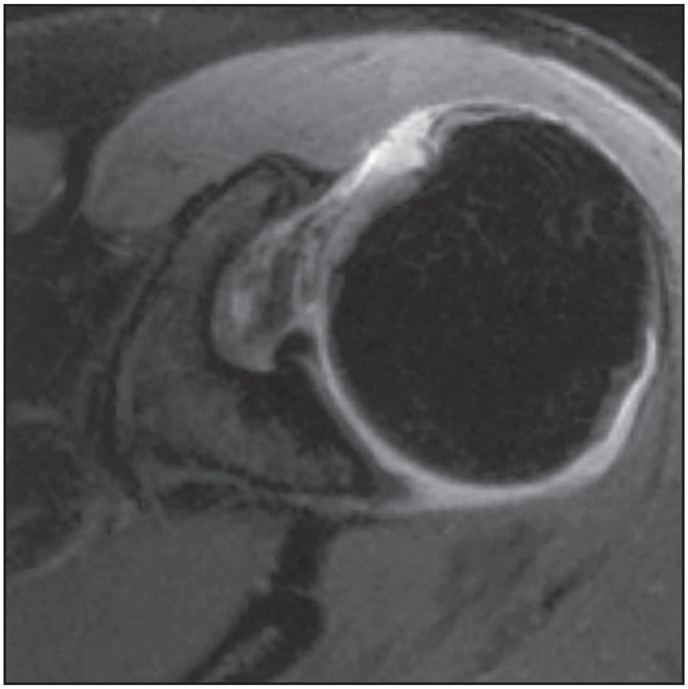

Figure 21. *In this axial slice MRI, note the enlargement of the biceps tendon as it courses over the humeral head to its proximal attachment. Increased signal intensity surrounding the tendon, consistent with inflammation of the synovial sheath is also present.*

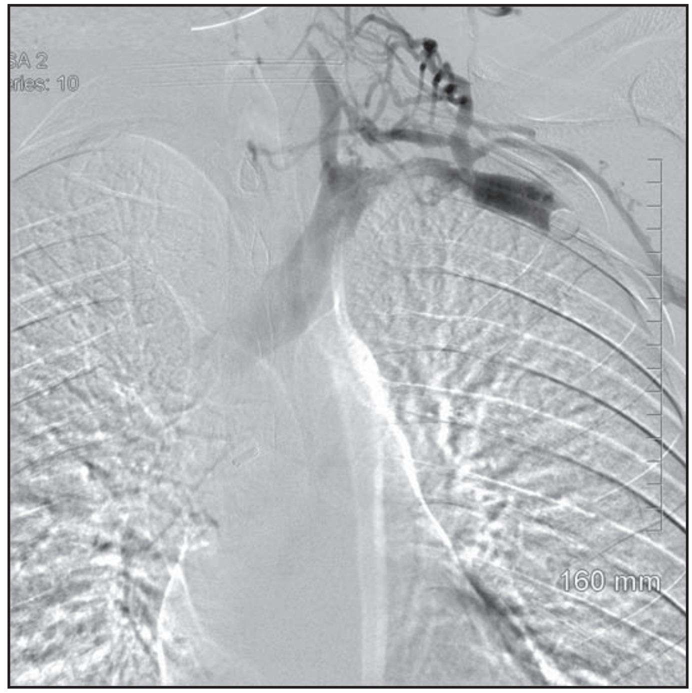

Figure 22. *Contrast venogram indicating occlusion of the left subclavian vein. Note the intensity of the injected contrast distally compared to the proximal portion of the vessel.*

an effort thrombosis is suspected to be present, a venogram usually identifies the occluded area and intervention is tissue plasminogen activator (TPA) followed by a slow return to function (Figure 22).[10] The classic thoracic outlet syndrome may occur, but it is not common. Neural injuries may range from long thoracic nerve stretch to other compressive or elongating forces. Generally, rehabilitation can be useful but surgical releases may be required when MRI demonstrates stretch or compression.

CONCLUSION

The evolution of imaging technology is now allowing new insights to the changes to the shoulder complex of throwing athletes, principally the glenohumeral joint and its periarticular tissues, both of an adaptive and a pathological nature not previously appreciated. Clinicians caring for throwing athletes will prudently understand that imaging of the shoulder complex is sometimes required for diagnosis, but more frequently serves as supplemental information to a carefully completed clinical examination. Similarly, the selection of the most indicated imaging modality for each individual is based upon the athlete's history and the clinical examination results. Subsequent decisions based on the resultant interpretation of imaging must be made with an understanding of the context of the entirety of the clinical presentation and the knowledge of findings common among throwing athletes, including those which are sometimes asymptomatic.

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