Impingement syndromes of the shoulder can be caused by external or internal causes. External causes are due to primary abnormalities in the coracoacromial arch causing extrinsic compression of the subacromial bursa and the rotator cuff, leading to rotator cuff tear and retraction, as first described by Neer in 1972, and including subacromial and subcoracoid impingement. It occurs most commonly in middle-aged nonathletic individuals. Internal causes of impingement are secondary to rotator cuff and capsular dysfunction and are categorized by the location of the impingement and the underlying pathophysiological or mechanical cause of the impingement. These include posterosuperior impingement, anterosuperior impingement, anterior impingement, and entrapment of the long head of the biceps tendon (LHBT). Although the diagnosis of internal impingement is primarily clinical, magnetic resonance imaging (MRI) can play an important role in confirming clinical suspicion or suggesting the diagnosis. In this article, the authors discuss the MRI evaluation and pathophysiological mechanisms of internal impingement syndromes of the shoulder.

**POSTEROSUPERIOR IMPINGEMENT**

Posterosuperior impingement, which was first described by Walch and colleagues, refers to contact of the undersurface of the posterosuperior rotator cuff with the posterosuperior labrum when the arm is abducted and externally rotated (ABER), where the cuff can become pinched between the labrum and the greater tuberosity. It occurs most frequently in professional throwing athletes and is attributed to repetitive overhead motion, most commonly in baseball pitchers, tennis players, javelin throwers, and swimmers. Typical symptoms include posterior superior shoulder pain that commences during the late cocking phase of overhead movement and intensifies during the early acceleration phase.

Jobe presented an expanded spectrum of injury occurring in overhead throwing athletes in the setting of posterosuperior impingement, which includes injuries to the superior labrum, the rotator cuff tendon, the greater tuberosity, the inferior glenohumeral ligament, and the superior glenoid bone. He also suggested that internal impingement in throwing athletes may progressively worsen because of gradual stretching of the anterior capsuloligamentous structures, leading to anterior displacement of the humeral head and impingement of the rotator cuff and the posterosuperior labrum between the greater tuberosity of the humerus and the glenoid margin. This theory led to the initial treatment approach for anterior glenohumeral instability using anterior capsulolabral reconstruction; however, results of this treatment were unpredictable. Halbrecht and colleagues disagreed with Jobe’s premise of anterior instability worsening internal impingement and showed that glenohumeral instability, where the humeral head is subluxed anteriorly, resulting in decreased contact with the posterosuperior glenoid compared with the reduced position. Therefore, they proposed that anterior instability does not worsen internal impingement but rather lessens it. The role...
of anterior capsular laxity as a causative factor in posterosuperior impingement is still controversial.

Burkhart and colleagues\(^7\) proposed that posterosuperior impingement is a normal phenomenon in all shoulders and is not usually pathologic in the disabled throwing shoulder. Rather they proposed that scarring of the posterior joint capsule leads to loss of internal rotation of the humeral head in the throwing athlete, starting a pathologic cascade that results in posterosuperior shift of the gleno-humeral rotation point during abduction and external rotation that is maximal in the late cocking phase of throwing. The posterosuperior displacement of the rotation point may be also caused by the thickened posterior capsule moving inferior to the humeral head on abduction and external rotation, according to Burkhart and colleagues.\(^7\) At this point the shift results in maximal shear stress on the posterosuperior labrum and the biceps anchor, resulting in a peel back mechanism that produces a posterior type IIB superior labrum anterior and posterior (SLAP) lesion with posterior extension.\(^8\) This is also referred to as glenohumeral internal rotation deficit (GIRD), because it is believed that the primary initiating event of this cascade of events is scarring of the posterior joint capsule leading to restriction of internal rotation or excessive external rotation. Throwing athletes with

---

**Fig. 1.** Schematic drawings of the different types of internal impingement. The red mark indicates the location of the pathology along the bicipital labroligament complex. (A) Posterosuperior impingement. (B) Anterosuperior impingement (ASI). (C) Anterior Impingement. (D) Entrapment of the long head of the biceps tendon. (Courtesy of Salvador Beltran, MD.)
GIRD require an increase of the external rotation during the late cocking phase to achieve sufficient throwing power (Fig. 2).

The magnetic resonance (MR) and MR arthrographic findings of posterosuperior impingement have been described by several authors, and they include (Figs. 3 and 4): (1) tearing of the posterior undersurface fibers of the supraspinatus tendon and anterior undersurface of the infraspinatus tendon, (2) tearing of the posterosuperior glenoid labrum or type IIB SLAP lesion, (3) humeral head impaction or subcortical humeral head cysts, (4) laxity of the anterior capsule, and (5) thickening of the posterior capsule (Fig. 5). It is important to note that when evaluating MR images obtained in the ABER position, nonpathologic entrapment of the articular surface fibers of the supraspinatus tendon occurs in all normal individuals and when isolated this finding does not suggest pathologic impingement. However, if there are additional findings associated with posterosuperior impingement as previously described, then the diagnosis can be suggested on the ABER view.

ANTEROSUPERIOR IMPINGEMENT

Anterosuperior impingement was first described in 2000 by Gerber and Sebesta, who observed internal impingement between the humeral head and the anterior superior glenoid rim on arthroscopy while the patient’s arm was horizontally adducted, maximally externally rotated, and anteriorly elevated. This patient had symptoms of anterior superior shoulder pain attributed to repetitive overhead movement that was either occupational (masonry) or sports related (pole vaulting). During arthroscopy, partial tears of the deep fibers of the subscapularis tendon along the lesser tuberosity attachment were described, in addition to tearing of the humeral attachments of the coracohumeral and superior glenohumeral ligaments (biceps pulley lesion).

Habermeyer later described anterosuperior impingement as impingement of the long head of...
the biceps tendon with the anterosuperior glenoid rim and noted that an important factor for this to develop is the additional partial articular-sided tear of the subscapularis tendon and a lesion of the biceps pulley.\textsuperscript{17} Tears of the undersurface of the anterior supraspinatus tendon were also identified. The etiology of the biceps pulley lesion can be traumatic or degenerative. Traumatic causes include a fall on an outstretched arm while the arm is in full internal or external rotation, or while falling backward on the hand or elbow.\textsuperscript{18} Degenerative or chronic injury can occur in patients with repetitive overhand activity.\textsuperscript{16}

Lesions of the biceps pulley have been classified by Bennett\textsuperscript{19} and Habermeyer and colleagues\textsuperscript{17} based on lesions involving the subscapularis tendon, superior glenohumeral/medial coracohumeral (SGHL-MCHL) complex, and the lateral coracohumeral ligament (LCHL).

Biceps subluxation and instability was first classified by Bennett in 2001.\textsuperscript{19} Bennett has since modified his classification based on subsequent arthroscopic findings.\textsuperscript{20} He classifies biceps pulley injuries as involving the intra-articular subscapularis tendon (type 1) (Fig. 6), the medial sheath (comprised of the SGHL-MCHL ligament complex) (type 2) (Fig. 7), both the medial sheath and subscapularis tendon (type 3) (Fig. 8), the supraspinatus and lateral coracohumeral ligament (type 4) (Fig. 9), or all structures—intra-articular subscapularis tendon, medial sheath, supraspinatus tendon, and LCHL (type 5) (Fig. 10).
Type 1 lesions are isolated lesions of the subscapularis tendon, and although the medial sheath remains intact, tearing of the subscapularis tendon, which lends structural support to the medial sheath, is sufficient to result in some degree of deformation of the medial sheath allowing the biceps tendon to lie medially within the bicipital groove. Tearing of the medial sheath alone (type 2) results in subluxation of the biceps tendon between the subscapularis tendon and the coracohumeral ligament, which often has the appearance of an intratendinous subluxation. However, if axial and sagittal images are reviewed carefully, an intact subscapularis tendon is seen at its lesser tuberosity insertion. Intra-articular dislocation of the biceps tendon can only occur after both the intra-articular subscapularis tendon and medial sheath are disrupted (type 3).

Articular-sided tears of the anterior supraspinatus tendon that propagate into the rotator interval can result in tearing of the lateral coracohumeral ligament. Although the rotator cuff is not considered to be part of the biceps reflection pulley, the rotator cuff provides important superolateral tension on the medial coracohumeral ligament, as it contributes to the rotator interval capsule by contiguity with the medial coracohumeral ligament. Disruption of the normal tension results in anterior dislocation of the biceps tendon in relation to the subscapularis tendon and coracohumeral ligament (type 4). Tears of the anterior supraspinatus and cranial fibers of the subscapularis tendons (ie, the anterior rotator cuff) are highly associated with biceps tendon pathology, ranging from tendon subluxation or dislocation to partial or complete tendon tears. When there is injury to both the lateral and medial stabilizing structures of the biceps pulley, the biceps tendon is free to dislocate anteriorly or into the joint (type 5).

Habermeyer classified biceps pulley lesions into 4 types (Fig. 11). Type 1 lesions are isolated tears of
the medial sheath or SGHL-MCHL complex along
the anterior aspect of the pulley. The supraspinatus
and subscapularis tendons are intact, and there is
no biceps tendon subluxation. Type 2 lesions
involve a pulley lesion in association with
partial-thickness articular surface tear of the ante-
rior fibers of the supraspinatus tendon and mild
medial subluxation of the biceps tendon. Type 3
lesions involve a pulley lesion in association with
partial deep tearing of the superior fibers of the sub-
scapularis tendon and subluxation of the biceps
tendon, partially extending beyond the contain-
ment of the SGHL-MCHL sling. Type 4 lesions
involve a pulley lesion in association with partial

Fig. 7. Bennet type 2 lesion. (A) Schematic a Type 2 Bennet lesion with tearing of the medial sheath and medial
subluxation of the biceps tendon. (B) Axial fat saturated T2W images demonstrating a torn medial sheath (short
arrow) and medial subluxation of the biceps tendon (long arrow). (A) From Petchprapa CN, Beltran LS, Recht MP,
et al. The rotator interval: a review of anatomy, function, and normal and abnormal MRI appearance. Am J
Roentgenol 2010;195(3):570; with permission.)

Fig. 8. Bennet type 3 lesion. (A) Schematic type 3 Bennet lesion with disruption of the medial sheath, which
consists of the medial coracohumeral ligament (MCHL) and superior glenohumeral ligament (SGHL) complex,
and a tear of the subscapularis tendon. There is intra-articular dislocation of the biceps tendon. (B) Axial pro-
ton density image demonstrating resultant intra-articular dislocation of the biceps tendon (arrow). (A) From
Petchprapa CN, Beltran LS, Recht MP, et al. The rotator interval: a review of anatomy, function, and normal
and abnormal MRI appearance. Am J Roentgenol 2010;195(3):570; with permission.)
articular surface tears of the supraspinatus and subscapularis tendons and medial dislocation of the biceps tendon, which is located anterior to the lesser tuberosity.

ANTERIOR IMPINGEMENT

Anterior impingement occurs when there is contact between the rotator cuff, which has a partial undersurface tear, and the superior labrum just anterior to the biceps anchor. It is important to note that contact between the rotator cuff and the superior labrum is normal when the shoulder is in forward flexion. This has been demonstrated in cadaveric studies that simulated the Neer\(^2\) and Hawkins\(^2\) tests to demonstrate contact between the articular surface of the rotator cuff and the anterosuperior glenoid rim.\(^2\) However, Struhol demonstrated that when there is a tear of the rotator cuff in this area, the contact becomes abnormal, as there is fragmented tissue that is sheared and compressed between the superior humeral head and the glenoid.\(^2\) \(^5\) Anterior impingement occurs in the general nonathletic population, in contrast to posterosuperior impingement, which occurs in elite athletes. The clinical presentation mimics that of subacromial impingement, which includes pain with forward elevation of the arm and overhead use of the arm as well as tenderness over the anterior rotator cuff area. The patients have no signs of instability.

Struhol described arthroscopic findings of partial-thickness tears of the rotator cuff in all 10 patients with anterior internal impingement.\(^2\) This was demonstrated intraoperatively while performing the Hawkins test, which resulted in contact between an abnormal and fragmented rotator cuff with the anterior superior labrum. On preoperative MRI, only 20% of patients showed a partial-thickness rotator cuff tear. Additional findings at arthroscopy included fraying and detachment of the anterosuperior labrum (SLAP IIA) in 60% of patients, and partial subscapularis tears in 20% of patients.

Since anterior impingement can mimic classic subacromial impingement, and since treatment strategies are significantly different, MRI can play an important role in the correct diagnosis and management of these patients by identifying rotator cuff and associated labral pathology in the characteristic location, and ruling out changes associated with classical subacromial impingement.

ENTRAPMENT OF THE LONG HEAD OF THE BICEPS TENDON

Entrapment of the long head of the biceps tendon (LHBT) within the joint and subsequent pain and locking of the shoulder on elevation of the arm were first described by Boileau and colleagues.\(^2\)\(^6\) They evaluated 21 patients who on physical examination had tenderness elicited in the region

---

Fig. 9. Bennet type 4. (A): Schematic type 4 Bennet lesion with tearing of the lateral coracohumeral ligament (LCHL) and anterior extra-articular dislocation of the biceps tendon. (B) Axial gradient echo image with a tear of the LCHL (arrow), which normally should be visualized attaching to the greater tuberosity, and extra-articular dislocation of the biceps tendon (short arrow), which is located anterior to the subscapularis tendon (white dotted arrow). ([A] From Petchprapa CN, Beltran LS, Recht MP, et al. The rotator interval: a review of anatomy, function, and normal and abnormal MRI appearance. Am J Roentgenol 2010;195(3):570; with permission.)
overlying the bicipital groove and loss of the final 10° to 20° of passive elevation. On arthrography, they demonstrated the hourglass biceps, which has a characteristic morphology related to hypertrophy of the intra-articular biceps tendon. During surgery, entrapment of the hypertrophic intra-articular portion of the long head of the biceps tendon was demonstrated in each case with a dynamic intraoperative test (hourglass test) that involved forward elevation of the arm with the elbow extended. They described a characteristic buckling of the tendon, which was squeezed between the humeral head and the glenoid, resembling an hourglass, as it was squeezed at its middle portion between the humeral head and the glenoid. They attributed the entrapment of the tendon to the hypertrophy of the intra-articular portion, which leads to a disproportion between the tendon and the cross-sectional size of the bicipital groove, preventing the tendon from sliding into the groove, leading to its entrapment or mechanical block. In all cases, complete elevation of the arm, which was symmetric to the other
arm, was restored following resection of the intra-articular portion of the biceps tendon with either biceps tenodesis or tenotomy.

The definitive diagnosis of the hourglass biceps is made primarily by the combination of the appropriate clinical history and surgical findings described. MRI and MR arthrography may suggest the diagnosis with the characteristic hypertrophic morphologic changes of the intra-articular biceps tendon (Fig. 12).
SUMMARY

Internal impingement syndromes are relatively frequent in the professional throwing athletic population. Their diagnosis is typically based on combined clinical and arthroscopic evaluation; however MRI and MR arthrography can contribute to the preoperative assessment of these patients by demonstrating a constellation of findings specific for each 1 of the 4 types of impingement syndromes.

REFERENCES


