Shoulder Instability

The pathologic increase in glenohumeral motion is a common disorder in physically active patients. Diagnosis and treatment of patients with shoulder instability continues to evolve with a better understanding of pathology and treatment outcomes.

Anatomy

Shoulder stability is the end result of the shoulder stabilizing structures working properly together. The constraints on shoulder motion can be divided into static stabilizers and dynamic stabilizers (Table 1).

Static stability is chiefly maintained by joint congruency, the labrum, and the shoulder ligaments. The glenohumeral joint is a ball and shallow socket joint with a constant mismatch between the radii of curvatures. The unconstrained bony relationship allows the shoulder to obtain a large excursion and range of motion. The glenoid socket is deepened by the glenoid labrum, which is made of fibrocartilage. The labrum serves as the attachment site for the glenohumeral capsule and biceps tendon, and decreases the glenoid radius of curvature to more closely match the humeral curvature. Discrete thickening of the capsule in consistent locations form the glenohumeral ligaments (Figure 1). The glenohumeral capsule connects to the humerus at the rotator cuff insertion and inferiorly onto the humeral neck.

The main dynamic stabilizers are the rotator cuff, scapulothoracic rhythm, and the long head of the biceps. The neurologic feedback that connects the dynamic stabilizers to each other and to the static stabilizers is called proprioception. A dysfunction of any of the stabilizers can lead to instability, dysfunction, and pain in the shoulder. The rotator cuff consists of four muscles (subscapularis, supraspinatus, infraspinatus, and teres minor) whose tendons coalesce to dynamically stabilize the humeral head in the center of the glenoid cavity throughout the full range of shoulder motion by generating force couples in the coronal and transverse planes of the glenohumeral joint. Loss of the coronal plane force couple results in superior head migration, but not necessarily loss of function. Disruption of the transverse force couple can result in pain and loss of function.

Biomechanics

The ligaments of the shoulder limit the extremes of motion. The labrum acts as a wedge to limit sliding and increases the wall height to prevent dislocation. When the arm is abducted and externally rotated, the anteroinferior glenohumeral ligament is stretched. An anterior dislocation can occur with a failure of the anterior stabilizing structures, from the anterior glenoid rim, labrum, capsule (ligaments), or humeral insertion.

With the arm in the adducted, forward flexed position, a force applied to the arm stresses the posterior glenoid, posterior labrum, and posterior capsule. Posterior dislocation or subluxation of the joint results in an injury to one or more of these structures. Repetitive submaximal stress to the ligaments can produce a pathologic increase in joint range of motion. The subsequent atraumatic instability pattern often is associated with generalized laxity, instability in multiple planes, abnormal proprioception, and scapulohumeral rhythm dysfunction.

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The role of glenoid bone loss in patients with recurrent anterior instability has received considerable recent attention. Anterior glenoid bone loss of up to 25% was classically treated with open soft-tissue repair.5 Reports of higher rates of recurrent instability after arthroscopic repairs in patients with substantial bone loss has heightened interest in this problem.6 A biomechanical study has shown a significant decrease in anterior shoulder stability with bone loss of at least 21% of the glenoid.7 The type of anterior glenoid bone loss may also play a role in treatment. Patients with recent onset of recurrent dislocations will likely have identifiable bone at the time of repair. Patients with long-standing instability will likely have resorption of the bone and blunting of the glenoid margin.8 Humeral bone loss from a Hill-Sachs lesion or reverse Hill-Sachs lesion can contribute to instability because the glenoid can fall into the humeral head defect. The location and size of these engaging lesions and the importance of the lesions in regard to anterior bone loss continues to be explored.

As previously stated, the rotator cuff provides dynamic shoulder stability by generating force couples in the coronal and transverse planes of the glenohumeral joint (Figure 2). A force couple is composed of two equal but oppositely directed forces that act simultaneously on opposite sides of an axis of rotation. Translational forces are cancelled out, linear motion is eliminated, and torque is produced. Loss of the coronal plane force couple results in superior head migration, but not necessarily loss of function. The transverse force couple is composed of the subscapularis anteriorly and the infraspinatus/teres minor posteriorly, and provides anterior-posterior glenohumeral stability throughout active elevation. Disruption of the transverse force couple results in loss of concavity compression, a pathologic increase in translation or subluxation of the humeral head toward the cuff deficiency, and decreased active abduction.

The functions of the long head of the biceps tendon, described as the fifth tendon of the rotator cuff,9 are proposed to involve shoulder flexion, abduction, and glenohumeral joint stabilization during rotation. One study provided radiographic evidence of the superior stabilizing effect of the biceps tendon,10 and another study evaluated biceps activity electromyographically during 10 basic shoulder motions and reported very little biceps activity.11 Although its functional contributions are debated, painful lesions of the biceps tendon can coexist with rotator cuff tears.12

**Classification**

Instability can be classified into categories based on timing, etiology, and the direction of instability. Instability can be acute or insidious in onset, can occur after

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**Table 1**

<table>
<thead>
<tr>
<th>Type</th>
<th>Subtypes</th>
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<tbody>
<tr>
<td>Static</td>
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<tr>
<td>Osteochondral</td>
<td>Proximal humerus: articular surface (Hill-Sachs lesion, posttraumatic defect, osteonecrosis), abnormal humeral version</td>
</tr>
<tr>
<td></td>
<td>Glenoid: articular surface; bony defect, fracture, or erosion; abnormal morphology (dysplasia); abnormal glenoid version</td>
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<tr>
<td>Capsulolabral complex</td>
<td>Glenoid labrum</td>
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<tr>
<td></td>
<td>Glenohumeral ligaments</td>
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<tr>
<td></td>
<td>Coracohumeral ligament</td>
</tr>
<tr>
<td>Coracoacromial ligament</td>
<td>Negative intra-articular pressure</td>
</tr>
<tr>
<td>Synovial fluid</td>
<td>adhesion-cohesion</td>
</tr>
<tr>
<td>Rotator cuff</td>
<td></td>
</tr>
<tr>
<td>Dynamic</td>
<td></td>
</tr>
<tr>
<td>Rotator cuff</td>
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<tr>
<td>Long head of biceps</td>
<td>Kept out of the way</td>
</tr>
<tr>
<td>Scapulothoracic rhythm</td>
<td>Kept out of the way</td>
</tr>
<tr>
<td>Concavity-compression</td>
<td>Kept out of the way</td>
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<tr>
<td>Proprioception</td>
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</table>

a single traumatic event, or can be the result of repetitive microtraumas. Instability can occur in a single plane or in multiple directions. An understanding of the spectrum of disorders that result from shoulder instability can help in diagnosing and treating patients.

Anterior Instability
The most common direction of dislocation is anterior, that is, the humeral head comes to lie anterior to the glenoid. A subluxation event can occur that may not produce a dislocation but can result in continued instability.\(^{13}\)

When an anterior dislocation occurs, a lesion to the anterior stabilizing structures has occurred. The injury can take the form of a labral detachment from the glenoid (Bankart lesion), bone and labral detachment (bony Bankart lesion), ligament stretching or tearing, or detachment of the capsule/ligament from the humerus. When the Bankart lesion heals along the medial glenoid neck, it is often referred to as an anterior periosteal sleeve avulsion.\(^{14}\) The anterior periosteal sleeve avulsion lesion highlights the fact that healing of a Bankart lesion does not stabilize the shoulder; the labrum must be in the proper location on the glenoid edge to stabilize the shoulder.

MRI may be helpful in determining the presence of anterior glenoid rim fractures, labral tears, the size of humeral defects, and rotator cuff tears. CT provides better detail of the bony defects compared with MRI, but does not allow visualization of the soft tissues.

Treatment
When a shoulder dislocation is diagnosed, closed reduction of the joint is attempted. The patient typically is given pain medication and muscle relaxants for closed reduction in the emergency department. The patient should be evaluated for rotator cuff tears and neurologic injury after the shoulder is reduced. Inability to reduce the shoulder dislocation can result from chronic dislocation, interposed soft tissue, and buttonholing of the humerus under the conjoined tendon. If the shoulder remains dislocated, the patient should be treated with closed reduction while under general anesthesia. Open reduction is also a possibility. Consideration should be given to advanced imaging before surgical reduction (if it can be obtained expeditiously) because the studies may show an interposed rotator cuff, large losses of humeral bone, or associated fractures; these findings may alter surgical treatment.

Natural History
The role of nonsurgical treatment in young, active patients with anterior instability continues to be defined. Physical therapy does not decrease dislocation recurrence rates except in a very tightly controlled population. Immobilization in external rotation can reduce the labrum back to a more anatomic position compared with traditional immobilization in internal rotation.\(^{15}\) There appears to be a clinically significant reduction in recurrent dislocation if the shoulder is immobilized for 3 weeks in external rotation. In contrast, one study reported no difference in instability when comparing traditional to external rotation immobilization after an anterior dislocation in a young active population.\(^{16}\)

Several large cohorts of first-time dislocators were evaluated with variable incidences of recurrent instability ranging from 8% to 75%.\(^{17-19}\) These studies reported lower rates of recurrent instability compared with smaller studies with patient-based outcomes.\(^{17,20,21}\)

A 2007 study reported on a cohort of patients with dislocations and associated large (> 5 mm) and displaced (> 2 mm) fractures of the anteroinferior glenoid rim. Patients were followed for an average of 5.6 years.\(^{22}\) Nonsurgical treatment was used only in patients with a concentrically reduced joint. No patient in the cohort had a dislocation, and the average outcome score was excellent.

Fifty percent to 80% of patients younger than 20 years at the time of the initial dislocation have a recurrent dislocation. The rate of recurrent instability declines with age.\(^{18,23}\) Patients older than 40 years appear to be at increased risk for rotator cuff tears and neuro-

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**Figure 2** Illustration showing force couples of the shoulder. O = center of rotation, S = subscapularis, D = deltoid, I = infraspinatus, and RC = rotator cuff.
logic injury.\textsuperscript{24}

For young and active patients, the recurrence of instability is an indication for either open or arthroscopic stabilization. With the high recurrence rates reported after nonsurgical treatment in young, active patients, some authors recommend surgical repair for these patients at the time of the first shoulder dislocation.\textsuperscript{25}

**Arthroscopic Versus Open Repair**

 Patients with recurrent anterior shoulder instability can be treated using open or arthroscopic repair. Multiple studies have reported excellent results for open repair, with an approximate 5% rate of recurrent instability after surgery. With older arthroscopic repair techniques, results are less reliable, with recurrent instability rates of 15% to 33%.\textsuperscript{2,3,26} With improvement in arthroscopic repair techniques, results have approached those of open repair, with successful outcomes in 90% to 96% of patients.\textsuperscript{27-29}

In a randomized controlled trial comparing open and arthroscopic repair for recurrent anterior shoulder instability, the two groups had similar outcome scores and rates of recurrence.\textsuperscript{30} In two studies that systematically reviewed the literature,\textsuperscript{31,32} the authors reported that when modern suture anchor techniques were used, outcome scores were similar or appeared to favor arthroscopic repair over open repair.

**Recurrent Instability After Repair**

When instability occurs after shoulder repair, multiple potential sources can be considered, including excessive bone loss from the anterior glenoid or humerus, capsular laxity, failure of labrum healing, medialization of the labrum, and unrepaird humeral avulsion of the inferior glenohumeral ligament. An 89% instability recurrence rate was reported for contact athletes when the anterior bony deficiency of 20% to 30% of the joint surface was treated with soft-tissue repair only.\textsuperscript{9} Significant bone lesions can be treated arthroscopically by incorporating the lesions into the repair. A 93% success rate was reported in patients with an average defect measuring 24% of the joint surface.\textsuperscript{33} However, the quality of the bony fragments may be an important consideration because a significantly higher instability recurrence rate was identified in patients with attritional fragments.\textsuperscript{11} An association of recurrent instability with attritional bone loss on the glenoid has been reported.\textsuperscript{26}

For defects of the anterior glenoid covering more than 25% to 30% of the joint surface, an open or arthroscopic coracoid transfer procedure (Figure 3) or structural iliac crest graft can be used. This technique can also be considered in the primary setting. A 4.4% instability recurrence rate was reported in patients with significant anterior glenoid bone loss who were treated with the Latarjet procedure.\textsuperscript{34} The use of structural iliac crest has been supported by reports of high rates of patient satisfaction;\textsuperscript{35,36} however, concerns regarding humeral head articulation on the graft, which leads to degenerative changes, have been raised.\textsuperscript{37}

Large Hill-Sachs lesions (> 25% of the joint surface) can be considered for osteochondral allograft,\textsuperscript{38} remplissage,\textsuperscript{39} or infraspinatus transfer into the defect. There appears to be a biomechanical correlation between the size and location of a Hill-Sachs lesion and the ability of the humeral head to track on the glenoid.\textsuperscript{40} Bone grafting of defects larger than 37.5% of the joint surface has been recommended based on biomechanical testing.\textsuperscript{41}

**Posterior Instability**

Although posterior shoulder dislocations are less common than anterior dislocations, posterior dislocations are commonly missed. Mechanisms involved in posterior dislocations include trauma to the anterior aspect of the shoulder, an indirect force applied through an adducted or flexed arm, seizure, and electrocution.

**Acute Posterior Dislocation**

Unlike anterior instability, posterior instability does not lead to frequent recurrent dislocations. Once the dislocation is reduced, a short period of immobilization in
external rotation is recommended, followed by physical therapy and range-of-motion exercises. The diagnosis of a posterior dislocation can be difficult. Diagnostic modalities such as CT can be a valuable adjunct in establishing the diagnosis.

Surgical Treatment
Patients with recurrent posterior shoulder instability or those with continued pain with loading of the arm in the forward flexed position (bench press or football pass blocking) are candidates for surgical posterior shoulder stabilization. Stabilization can be performed through an open posterior approach or arthroscopically. The goal of any repair is to address the posterior labral detachment, repair any capsular tears, and/or reduce the volume of the posterior capsule. Success has been reported with both open and arthroscopic approaches. Results for open surgery have been successful in 80% to 85% of patients at 5- to 7-year follow-ups. With shorter follow-ups, arthroscopic repairs have been reported to have similar results.

Chronic Posterior Dislocation
After several weeks of posterior dislocation, the bone of the humeral head and the glenoid begins to erode. If left untreated, destruction of the humerus and glenoid can occur. After 2 to 3 weeks, a closed reduction is unlikely to achieve a reduction of a posterior dislocation; an open repair will be required.

Prior to proceeding with open reduction, CT can help determine the extent and location of bone loss. After reduction, the shoulder can be assessed for stability. Options to improve stability include subscapularis or lesser tuberosity transfer into the reverse Hill-Sachs lesion, osteochondral bone grafting, segmental humeral head replacement, and humeral head replacement. For glenoid bone loss, iliac crest bone graft can be used to restore bone stock.

As the dislocation becomes more chronic, the bone of the humeral head becomes osteoporotic and arthritic. If humeral head arthritis is extensive, if the head collapses during reduction, or if bone loss is more than 50% of the articular surface, humeral head replacement is needed to restore stability and treat the arthritis. Total shoulder replacement can be considered when significant glenoid arthritis is present.

Multidirectional Instability
When instability occurs in more than one plane, the term multidirectional instability (MDI) is used. Patients with MDI often have generalized shoulder laxity, have had no acute trauma, and do not have a true dislocation of the joint. MDI can result from poor technique during athletic activities, genetics (Ehlers-Danlos syndrome), poor scapulohumeral mechanics, and rotator cuff dysfunction.

Comparison with the unaffected side will help to identify instability and increased motion in multiple planes. Provocative testing for anterior or posterior instability as described previously can be positive, and inferior instability may be present. Inferior instability is characterized by a positive sulcus test and a sulcus that does not reduce with external rotation; both are signs of rotator interval injury. MRI with intra-articular administration of gadolinium can be helpful to determine the presence of labral tears. In most patients with MDI, no labral pathology is present and the capsular volume is increased.

Nonsurgical Treatment
Treatment for MDI is nonsurgical and includes prolonged abstinence from the sporting activity that provoked the symptoms. Results of nonsurgical treatment have been variable, with success rates reported as high as 80%. One report outlined significant dysfunction after nonsurgical treatment, with one third of patients with poor outcomes at 8-year follow-up.

Surgical Treatment
Moderate success in treating MDI has been achieved with open capsular shift, with the goal of reducing the capsular volume of the shoulder. Open techniques can be performed from an anterior or posterior approach, with some surgeons choosing the approach based on the direction of primary instability. An 88% success rate was reported following inferior capsular shift surgery. Similarly, techniques have been developed to accomplish volume reduction during arthroscopy. Early results for arthroscopic plication have been promising, with success rate reported from 85% to 88%.

Rotator Cuff Disorders
The understanding, evaluation, and treatment of rotator cuff tears have evolved since the 1934 publication of Codman’s landmark text, *The Shoulder*. Codman proposed that cuff tears have a traumatic origin, described the fundamental pathology and pathophysiology of the rotator cuff, and detailed the associated clinical findings and treatment options. In 1937, the theory of outlet impingement was introduced and it was proposed that rotator cuff tears occur secondary to chronic, repetitive contact between the greater tuberosity and the acromion. A later study introduced the three stages of outlet impingement (*Table 2*), which represent the spectrum of disease severity, and described the technique of anterior acromioplasty designed to remove the offending structures that contribute to symptomatic outlet impingement of the rotator cuff tendon. It is likely that all of these theories of rotator cuff tear etiology are correct, and that one simplified mechanism does not apply to all situations.

An age-dependent increase in the incidence of full-thickness rotator cuff tears has been reported in patients older than 50 years. A 22% to 23% rate of asymptomatic tears was reported in two studies with a combined total of 999 patients; the incidence of asymptomatic full-thickness tears increased dramatically for each decade after 50 years of age.
The spectrum of rotator cuff disease occurs in a wide range of patients, from the young, elite, overhead athlete who presents with a partial-thickness rotator cuff tear to the elderly patient with a massive, irreparable tear.

History and Physical Examination
A thorough history and physical examination is the first step in evaluating a patient with shoulder pain. Patient factors associated with poor healing after rotator cuff repair, when considered individually, may not preclude an attempt at repair (Table 3). The examination of a patient with a suspected rotator cuff tear begins with the cervical spine, which must be ruled out as the source of the patient’s symptoms. The shoulder girdle is then inspected in both shoulders. The deltoid is evaluated for atrophy, detachment, swelling, and/or evidence of anterosuperior escape. The supraspinatus and infraspinatus fossae are inspected for evidence of muscular atrophy. Tenderness to palpation over the acromio-clavicular (AC) joint and the insertion of the supraspinatus on the greater tuberosity (the Codman point) should also be evaluated. Active and passive ranges of motion are compared, and rotator cuff strength is measured and compared with the normal contralateral side, if asymptomatic.

Table 2

<table>
<thead>
<tr>
<th>Neer Stages of Impingement*</th>
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<tr>
<td>Stage</td>
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<tr>
<td>I</td>
</tr>
<tr>
<td>II</td>
</tr>
<tr>
<td>III</td>
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*The Neer stages of impingement progress from reversible changes to irreversible tendinosis, and finally to full-thickness rotator cuff tears. As the severity of staging increases, the likelihood of successful conservative therapy decreases. (Reproduced with permission from Neer CS: Impingement lesions. Clin Orthop Relat Res 1983;173:70-77.)

Table 3

<table>
<thead>
<tr>
<th>Patient Factors Associated With Poor Healing After Rotator Cuff Repair*</th>
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<tbody>
<tr>
<td>Age older than 65 years</td>
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<tr>
<td>Female sex</td>
</tr>
<tr>
<td>Smoking</td>
</tr>
<tr>
<td>Duration of symptoms</td>
</tr>
<tr>
<td>Medical comorbidities</td>
</tr>
<tr>
<td>Inability to elevate &gt; 100°</td>
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<tr>
<td>Weak elevation and external rotation</td>
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</tbody>
</table>

*Patient factors that have been associated with diminished tendon healing after cuff repair must be considered in conjunction with tear characteristics (fatty infiltration, retraction, atrophy) when determining treatment options.

The supraspinatus is tested at 30° abduction and internal rotation, and the infraspinatus is tested in adduction with the elbows flexed to 90° and in maximal external rotation. Subscapularis strength is tested with the belly press test (upper subscapularis) and the lift-off test (lower subscapularis). The teres minor muscle is an external rotator that is tested with the shoulders in 90° of abduction. At this point, a diagnostic subacromial injection of local anesthetic is used to determine if existing motion and/or strength deficits are caused by a rotator cuff tear or pain. Any differences in strength and/or motion are retested and the patient is evaluated for the presence of lag signs, which are indicative of full-thickness tears of the respective rotator cuff muscles shown in Table 4.

Associated Lesions
The biceps tendon, glenohumeral and AC joints, os acromiale, and the suprascapular nerve may be involved in the symptom complex of rotator cuff disease; each lesion should be identified during the workup phase and treated appropriately for the best outcome.

AC joint arthritis is fairly common in patients with rotator cuff disease. Specific findings include radiographic degenerative changes, tenderness to palpation directly over the AC joint, and pain in the AC joint with cross-arm adduction and/or the active compression test. An os acromiale is found in approximately 8% of the population and should be recognized preoperatively. The potential for poorer outcomes after rotator cuff repair in patients with stable or unstable meso-os acromiale has been reported. Suprascapular nerve compression can cause shoulder pain and weakness that can mimic full-thickness supraspinatus and/or infraspinatus tears, or may be seen in conjunction with tears that include supraspinatus retraction of 2 cm or more.

It is important to evaluate the patient for associated symptomatic lesions so that the lesions may be appropriately treated. The use of diagnostic injections with 1% plain lidocaine requires a small investment of time in the clinic, but provides a wealth of information for treatment planning.
Plain radiographs are obtained in the plane of the scapula and include AP views in internal and external rotation, a scapular Y view (10° to 15° of caudal tilt in the lateral scapular plane), and an axillary lateral view. Greater tuberosity sclerosis and excrescences, subacromial spurs and/or sclerosis (sourcil sign), and narrowing of the acromiohumeral distance are indications of rotator cuff tears. Radiographs should also be evaluated for glenohumeral arthritis, which may preclude cuff repair.

CT is useful in evaluating rotator cuff tears and is ideal for grading the severity of bone loss in severe cuff tear arthropathy. The Goutallier grading system (Table 5) of rotator cuff muscle fatty infiltration is based on CT imaging and remains an important method for determining whether a tear is reparable. A higher degree of preoperative fatty infiltration on CT (≥ grade 3) is associated with recurrent tears and lower Constant scores.

MRI is an excellent method to confirm the diagnosis of a rotator cuff tear because it shows the number of tendons involved, the degree of retraction, fatty infiltration, and muscle atrophy. This information is crucial for determining the potential for healing after repair. The addition of intra-articular contrast is particularly beneficial for detecting small, full-thickness tears and for improved prediction of the extent of partial articular-sided tears.

Ultrasound is an accurate, noninvasive method of detecting rotator cuff tears, is less expensive than MRI or CT arthrography, but requires an experienced technician and may not provide the same degree of information for evaluating concomitant pathology. Some evidence indicates that ultrasound is comparable to MRI for assessing rotator cuff tears.

Tear Classification

Rotator cuff tears have been classified according to the depth (full- versus partial-thickness), etiology, age of the tear, size, shape, number of tendons involved, and topography/trophicity of the tear. As such, there is no standard classification for rotator cuff tears. The Patte classification is the most elaborate system and includes anatomic and pathologic considerations that are important for defining an individual treatment plan for each patient (Table 6 and Figure 4).

Treatment

There are three arms of treatment for disorders of the rotator cuff: (1) preventive, (2) conservative, and (3) surgical. Prevention focuses on body mechanics, proper use and strengthening of core body and shoulder girdle musculature, and avoiding aggravating activities. When cuff symptoms develop in the absence of a full-thickness tear, conservative therapy, including rest, activity modification, gentle passive and active motion exercises, anti-inflammatory medication, and periodic subacromial corticosteroid injections, can provide relief. Therapeutic corticosteroid injections should be used with knowledge of the potential detrimental effects on the tendon and bone and decreased potential

<table>
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<th>Table 4</th>
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<tr>
<td><strong>Lag Signs for Rotator Cuff Tear</strong></td>
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<tr>
<td><strong>Muscle</strong></td>
</tr>
<tr>
<td>Supraspinatus</td>
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<tr>
<td>Infraspinatus</td>
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<tr>
<td>Teres minor</td>
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<tr>
<td>Upper subscapularis</td>
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<td>Lower subscapularis</td>
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*The various lag signs are useful in determining the integrity of each muscle of the rotator cuff. Diagnostic injections help determine if weakness is caused by pain, full-thickness tearing, or both.

<table>
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<th>Table 5</th>
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<tr>
<td><strong>Goutallier Classification of Fatty Infiltration</strong></td>
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<tr>
<td><strong>Grade</strong></td>
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<td>2</td>
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*Fatty infiltration of the rotator cuff muscles was first based on CT, but is now more commonly evaluated on MRI studies. Fatty infiltration greater than grade 2 is associated with a higher rate of failure.

Upper Extremity

For patients whose symptoms are not relieved by conservative measures, or for those who have a full-thickness rotator cuff tear, surgical treatment is recommended.

Surgical Treatment

Surgical treatment of rotator cuff tears can be performed through open, arthroscopically assisted mini-open, or all-arthroscopic techniques. Acromioplasty and subacromial decompression have therapeutic and technical roles in rotator cuff surgery; the goal is to smooth the undersurface of the arch to relieve pressure on the cuff without disrupting the deltoid origin or destabilizing the coracoacromial arch.

Open Rotator Cuff Repair: Basic Principles

Diagnostic arthroscopy results enable the surgeon to visualize and address concomitant pathology before proceeding with a rotator cuff repair. In large and massive tears, the degree of glenohumeral arthritis may be more severe than suggested by preoperative imaging; therefore, the treatment plan may be altered to exclude repair and proceed with arthroscopic débridement, subacromial decompression, and biceps tenotomy or tenodesis as dictated by the pathology (Table 7).

With open repair, portals should be closed and the shoulder reprepped and draped to prevent infection. Skin incisions should be made with consideration for the current surgery and any potential revision surgery, particularly with open repair of large and massive tears. An oblique incision from the posterior edge of the AC joint to the anterolateral corner of the acromion that extends 2 to 3 cm distally over the raphe between the anterior and middle deltoid provides excellent visualization for cuff repair and allows anterosuperior access for revision surgery (reverse shoulder arthroplasty) through the same incision.

Distal clavicle excision and two-step acromioplasty improve access to the subacromial space without the need to extend the deltoid split (Figure 5). Subacromial bursectomy improves visualization and is facilitated by rotating the arm. The coracoacromial ligament is palpated in external rotation, adduction, and released if it is tight. This exposes the rotator cuff for evaluation, mobilization, and repair. Advances in arthroscopic surgery have made repair techniques (single-row, double-row, transosseous, and transosseous equivalent) similar in arthroscopic and open surgery. Following repair, the deltoid is meticulously repaired.

Arthroscopic Repair

Arthroscopic rotator cuff surgery, which requires a methodic, stepwise approach for successful and timely completion of a sturdy repair, is becoming increasingly popular. Patient positioning depends on the surgeon’s preference. The beach chair position with an articulated arm holder can be used. This positioning allows for easy conversion to an open procedure if necessary, and the arm holder allows flexibility of arm positioning throughout the surgery. Two-step acromioplasty, as previously described, is performed. The coracoacromial ligament may be preserved in large and massive repairs.

Partial-Thickness Tears

Surgical treatment of partial-thickness tears includes débridement, transtendinous in situ repair, or tear completion and repair. Tears that are at least 50% (6 mm) of the tendon thickness should be considered for repair because, over time, these tears may progress to full-thickness tears. Patient factors must be considered when evaluating treatment options. No prospective study compares in situ repair with tear completion and repair despite reported good and excellent results with both techniques. Tear completion allows for débridement of the degenerative tendon, thorough tuber-

### Table 6

**Patte Classification of Rotator Cuff Tears**

<table>
<thead>
<tr>
<th>Extent of Tear</th>
<th>Group I: Partial tears or full-substance tears &lt; 1 cm in sagittal diameter at bony detachment</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>a. Deep, partial tears</td>
</tr>
<tr>
<td></td>
<td>b. Superficial tears</td>
</tr>
<tr>
<td></td>
<td>c. Small, full-substance tears</td>
</tr>
<tr>
<td>Group II:</td>
<td>Full-substance tears of entire supraspinatus</td>
</tr>
<tr>
<td>Group III:</td>
<td>Full-substance tears involving more than one tendon</td>
</tr>
<tr>
<td>Group IV:</td>
<td>Massive tears with secondary osteoarthritis</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Topography of Tear in Sagittal Plane</th>
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<tbody>
<tr>
<td>Segment 1: Subscapularis tear</td>
</tr>
<tr>
<td>Segment 2: Coracohumeral ligament tear</td>
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<tr>
<td>Segment 3: Isolated supraspinatus tear</td>
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<tr>
<td>Segment 4: Tear of entire supraspinatus and one half of infraspinatus</td>
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<tr>
<td>Segment 5: Tear of supraspinatus and infraspinatus</td>
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<tr>
<td>Segment 6: Tear of subscapularis, supraspinatus, and infraspinatus</td>
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</tbody>
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<table>
<thead>
<tr>
<th>Topography of Tear in Frontal Plane</th>
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<tbody>
<tr>
<td>Stage 1: Proximal stump close to bony insertion</td>
</tr>
<tr>
<td>Stage 2: Proximal stump at level of humeral head</td>
</tr>
<tr>
<td>Stage 3: Proximal stump at level of glenoid</td>
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<thead>
<tr>
<th>Quality of Muscle</th>
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<tbody>
<tr>
<td>1. Minimal fatty streaking</td>
</tr>
<tr>
<td>2. Less fat than muscle</td>
</tr>
<tr>
<td>3. Equal fat and muscle</td>
</tr>
<tr>
<td>4. More fat than muscle</td>
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</tbody>
</table>

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<thead>
<tr>
<th>State of the Biceps Tendon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Intact</td>
</tr>
<tr>
<td>2. Subluxated</td>
</tr>
<tr>
<td>3. Dislocated</td>
</tr>
</tbody>
</table>

For patients whose symptoms are not relieved by conservative measures, or for those who have a full-thickness rotator cuff tear, surgical treatment is recommended.
osity preparation, and repair of healthy tendon to bone. The proposed benefit of transtendinous repair is avoiding the creation of a full-thickness tear.

Single-Row Versus Double-Row Repair

There is no clear consensus on whether single- or double-row repair of rotator cuff tears is better.33,76 Double-row fixation is more costly, time-consuming, and technically more difficult when performed arthroscopically. Biomechanical studies comparing the two techniques have reported higher initial fixation strength and stiffness, improved footprint restoration, and decreased gap formation and strain with double-row fixation.77-79 Recent prospective randomized studies have failed to demonstrate a convincing difference in effectiveness between the two techniques, but tear size may prove to be a determining factor.80-82 At 2-year follow-up, higher American Shoulder and Elbow Surgeon and Constant scores were reported with double-row fixation in tears larger than 3 cm; however, cuff integrity was not evaluated with MRI at follow-up.83 In a nonrandomized retrospective comparison, a clinical difference was not found between repair techniques at 2 years, but improved healing for double-row compared with single-row fixation was shown with CT arthrography.84 These data suggest that double-row fixation may prove better for larger tears, whereas single-row fixation is probably adequate for smaller (< 3 cm) tears.

Transosseous and Transosseous Equivalent Repairs

Transosseous and transosseous equivalent rotator cuff repair techniques produce low bone-tendon interface motion, excellent footprint restoration, a high number of cycles to failure, and favorable distribution of stress over the repair in biomechanical and clinical evaluations.85-88

Table 7

<table>
<thead>
<tr>
<th>Biceps Pathology Indicating the Need for Tenodesis or Tenotomy*</th>
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<tbody>
<tr>
<td>Subluxation</td>
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<tr>
<td>Fraying</td>
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<tr>
<td>Tenosynovitis</td>
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<tr>
<td>Insertional detachment</td>
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<tr>
<td>Hypertrophy</td>
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</table>

*The functional contributions of the long head of the biceps tendon are debated, but biceps pathology is well-recognized as a pain generator. Sometimes, only subtle changes are found at diagnostic arthroscopy and, if left untreated (with tenotomy or tenodesis), the biceps can be a source of postoperative pain.

Repair Augmentation: Grafts and Patches

Recurrent tears of the repaired rotator cuff occur more frequently with large and massive tears,89 with up to 94% of these repairs failing by 1-year follow-up.90 Augmentation of large and massive rotator cuff repairs with allograft or xenograft tissues is proposed to improve repair strength and provide a bioreplaceable collagen network in an effort to decrease failure rates. Commonly used materials for grafts include human dermal allograft, porcine dermis, and porcine smooth intestine submucosa. Based on a randomized trial of large and massive cuff repairs, the authors recommended against porcine smooth intestine submucosa augmentation for cuff repair because of adverse graft reactions and failure to demonstrate improved outcomes.91 There are no similar randomized trials evaluating if augmented repair with human dermal allograft is beneficial, but there are no reports of adverse graft reactions, and the potential benefit of mechanical and biologic augmentation are worthy of consideration in young patients with large or massive cuff tears.
Tendon Transfers
Irreparable large and massive tears are challenging to treat, especially in younger patients (60 years or younger) with higher functional demands. Tendon transfers are a viable option to reduce pain and restore function when the rotator cuff cannot be mobilized for repair. Latissimus dorsi tendon transfer is suited for irreparable posterosuperior cuff tears, and pectoralis major tendon transfer is designed for treating anterosuperior tears with an irreparable subscapularis tendon.

Study results support the recommendation of latissimus dorsi tendon transfer for patients with an intact subscapularis, an irreparable posterosuperior cuff tear with external rotation deficit, and grade 2 or less fatty infiltration of the teres minor on preoperative imaging. In contrast, other authors have reported improved results in patients with posterosuperior tears associated with preoperative teres minor dysfunction. Each of these studies report improvements in external rotation and forward elevation, as well as subjective improvements that support latissimus dorsi tendon transfer as a viable option for patients who have painful, irreparable posterosuperior cuff tears and an external rotation deficit.

The results of pectoralis major tendon transfer in 30 shoulders were reviewed. The authors reported Constant scores improved from 47 to 70 points at an average follow-up of 32 months. The pectoralis major was transferred superficial to the conjoined tendon. Worse outcomes were observed in patients with concomitant irreparable supraspinatus tears, whereas a reparable supraspinatus tear did not affect the postoperative outcome. Pectoralis major tendon transfer under the conjoined tendon has been described in a group of 12 older patients (average age 65 years); the Constant score improved from 26.9 points preoperatively to 67.1 points at a mean of 28 months postoperatively. Dramatic improvement in pain scores was noted in addition to the reported functional gains.

Postoperative Rehabilitation
Postoperatively, patients are maintained in a shoulder sling and pillow that positions the arm in approximately 20° to 30° of abduction to take tension off the cuff.
repair. Traditionally, passive-assisted forward elevation and external rotation are started immediately. Internal rotation of the arm up the back is delayed 3 weeks (for small or medium tears) to 6 weeks (for large or massive tears). Active motion combined with terminal stretching commences at approximately 6 weeks, depending on the extent of the tear. Resistive motion is added according to each patient’s individual progress, usually at 10 weeks. Despite advances in repair techniques, recurrent cuff defects remain a treatment challenge for the orthopaedic surgeon. As such, there is a trend toward decelerated postoperative rehabilitation that delays passive elevation and external rotation in an effort to improve tendon healing.

Annotated References


9. In patients with postoperative instability with moderate anterior bone loss treated with arthroscopic repair, a 14.2% rate of recurrent instability was found in those patients with attritional bone loss. No instability was reported when significant bone was incorporated into the repair.


14. Military cadets were followed prospectively for 9 months and all instability episodes were recorded. Most instability events (85%) were subluxations without true dislocation. Level of evidence: L.


16. A total of 198 patients with anterior dislocation of the shoulder were randomized to treatment with immobilization in internal rotation or external rotation for 3 weeks. Immobilization in external rotation reduced the risk of recurrence and was beneficial in patients age 30 years or younger.


The authors found that bracing in external rotation may not be as effective as previously believed in the prevention of anterior dislocation of the shoulder because further dislocation occurred a mean 33.4 months after treatment.

18. Jakobsen BW, Johanssen HV, Suder P, Sojbjerg JO: Primary repair versus conservative treatment of first-time traumatic anterior dislocation of the shoulder: A ran-

The authors studied the results of nonsurgical treatment of primary shoulder dislocation and found that half of the dislocations had not recurred or had stabilized over time.


One hundred thirty-one patients were followed prospectively after an initial dislocation. Approximately one third of the patients experienced recurrent instability of the shoulder. Level of evidence: I.


Patients with large displaced Bankart lesions, a single dislocation, and a postreduction concentric humeral head were followed after nonsurgical treatment. No patients experienced recurrent instability.


Patients with large displaced Bankart lesions, a single dislocation, and a postreduction concentric humeral head were followed after nonsurgical treatment. No patients experienced recurrent instability.


Patients with first-time anterior shoulder dislocations were randomized to arthroscopic stabilization versus joint lavage alone. Patients treated with stabilization had a risk reduction for instability of 82% and dislocation rate of 76%. Level of evidence: I.


The authors report on a systematic review with meta-analysis of articles from 1985 to 2006 dealing with open compared with arthroscopic Bankart repair. When older techniques were eliminated, no significant difference in outcomes was found.


A systematic literature review and meta-analysis found higher outcomes score for patients treated with modern arthroscopic technique compared with open repair. Higher instability scores were reported in patients treated with arthroscopic repairs. Level of evidence: II.


In a therapeutic case series, the authors demonstrate the
effectiveness of the modified Latarjet procedure in the treatment of patients with dramatic bone loss in whom open or arthroscopic soft-tissue reconstruction is not an option. Level of evidence: IV.


The authors used arthroscopic capsulotenodesis of the posterior capsule and infraspinatus tendon to treat traumatic shoulder instability in patients with glenoid bone loss and a large Hill-Sachs lesion.


41. Sekiya JK, Wickwire AC, Stehle JH, Debski RE: Hill-Sachs defects and repair using osteoarticular allograft transplantation: Biomechanical analysis using a joint compression model. Am J Sports Med 2009;37(12):2459-2466. The authors concluded that the size and orientation of humeral head defects greatly contributes to glenohumeral joint function. An increase in the size of the defect required less anterior translation before dislocation and decreased the stability ratio. As a result, the risk of recurrent instability was increased.


58. Abboud JA, Silverberg D, Pepe M, et al: Surgical treatment of os acromiale with and without associated rota-


This review synthesizes a new “gold standard” rehabilitation program for rotator cuff impingement syndrome based on level I and II studies evaluating nonsurgical treatment of this disorder in an effort to standardize therapy for improved outcome comparisons. Level of evidence: I.


A single dose of corticosteroids significantly weakened intact and injured rotator cuff tendons at 1 week. Decreased maximum load, stress, and stiffness returned to baseline after 3 weeks.


Single-tendon tears were nine times more likely to heal after arthroscopic repair than tears involving more than one tendon. Early repair of full-thickness rotator cuff tears will prevent tear progression and will likely improve patient outcomes. Level of evidence: IV.


A randomized controlled trial comparing open acromioplasty and rotator cuff repair to arthroscopic acromioplasty and mini-open rotator cuff repair demonstrated significantly better quality of life and shoulder-specific outcome scores at 3 months in the mini-open group. However, at 1 and 2 years postoperatively there was no difference in outcome between the groups. Level of evidence: I.


Long-term follow-up of open cuff repairs showed durable clinical results, despite a retear rate of 57%. A wide lateral extension of the acromion was identified as a previously unknown risk factor for retearing. Level of evidence: IV.


A meta-analysis of case series comparing arthroscopic to mini-open repair reported no difference in functional outcomes or complication rates. A variety of repair methods were reviewed in the selected series. Level of evidence: III.


Forty-six patients with grade I or II (Ellman) partial-thickness, articular-sided, cuff tears were treated with arthroscopic subacromial decompression and débridement (grade II only). At 50.6 months, only three patients progressed to a full-thickness tear. Good or excellent results were reported in 87% of patients. Level of evidence: IV.


74. Kamath G, Galatz LM, Keener JD, Teefey S, Middleton W, Yamaguchi K: Tendon integrity and functional out-

Arthroscopic completion and repair of partial-thickness cuff tears resulted in 88% healing rate. Advanced age was associated with repair failure. Level of evidence: IV.


Transtendinous repair techniques resulted in residual shoulder discomfort at the extremes of motion in 41% of patients. Large tendon retraction and/or a relatively small exposure footprint area in an older patient without a traumatic etiology were predictive of residual symptoms. Level of evidence: IV.


In a prospective study comparing single- versus double-row arthroscopic cuff repair, the authors found no difference in clinical or functional outcome at 2 years. Age, sex, and baseline strength significantly and independently influenced outcome. Level of evidence: I.


The authors compared arthroscopic single- and double-row repairs and found no substantial difference was found between repair types at a minimum of 12 months. The average tear size was 1.8 cm, and most tears (82.5%) were small or medium size (1 to 3 cm).


The authors compared arthroscopic single- and double-row rotator cuff repairs. No substantial difference was found between repair types at a minimum of 12 months. The average tear size was 1.8 cm, and most tears (82.5%) were small or medium size (1 to 3 cm).


Sixty patients prospectively randomized to single- or double-row arthroscopic rotator cuff repair showed no difference in outcome clinically or on MRI arthrography at 2 years. Level of evidence: I.


On postoperative MRI, the retear rate was 5% for small to medium size tears and 40% for large and massive tears. The average clinical outcome improved significantly, but large postoperative defects were associated with lower functional scores. Level of evidence: IV.


A cohort study of 78 patients retrospectively compared arthroscopic single- and double-row cuff repairs. There was no difference in clinical or functional outcome for tears smaller than 3 cm. Patients with tears larger than 3 cm had better clinical results with double-row repairs. No postoperative imaging was used. Level of evidence: II.


The authors compared arthroscopic single- and double-row cuff repairs and found no significant clinical difference between the repair types. Postoperative CT arthrography showed significantly better healing with double-row repairs at 6-month follow-up. Level of evidence: II.


An arthroscopic transosseous equivalent rotator cuff repair technique showed improved pressurized contact area and overall pressure between tendon and footprint when compared with a double-row technique.


A biomechanical study comparing double-row fixation with corkscrew anchors, knotless anchors, and transosseous tunnels showed a higher individual failure rate with corkscrew anchors compared to knotless and transosseous techniques. Level of evidence: controlled laboratory study.
Retrospective analysis of arthroscopic transosseous equivalent cuff repair showed that 88% of small and medium, and 86% of large and massive tears were healed on 12-month postoperative MRIs. Persistent tears were not correlated with patient age or the initial tear size. Level of evidence: IV.


The authors recommend latissimus dorsi tendon transfer for irreparable posterosuperior rotator cuff tears with loss of active external rotation associated with a deficient teres minor muscle. They caution against latissimus dorsi tendon transfer in the absence of active motion deficiency. Level of evidence: IV.

A retrospective review of 22 patients who underwent latissimus dorsi tendon transfer for massive irreparable posterior-superior rotator cuff tears demonstrated significant improvement in mean absolute Constant scores, age-adjusted Constant scores, and subjective shoulder values. Patients with preoperative teres minor fatty infiltration less than or equal to grade 2 demonstrated significantly better postoperative Constant scores, active elevation, and external rotation. Level of evidence: IV.

