Partial-Thickness Rotator Cuff Tears

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Partial-thickness tears of the rotator cuff have been diagnosed with increased frequency because of a heightened awareness of the condition by clinicians and improved diagnostic methods. Research into the causes, natural history, and optimal treatment of this condition lags behind that of full-thickness tears. However, despite the limitations in the existing literature, there has emerged a consensus among shoulder experts that partial-thickness rotator cuff tears should be aggressively treated in the active athlete because of the unfavorable natural history of these lesions and success of accepted surgical algorithms. This review will provide an overview of the theories regarding the origins of partial-thickness rotator cuff tears, discuss the relative accuracy of accepted diagnostic techniques, and summarize the indications and methods of operative repair with an emphasis on the results of various treatment approaches.

Keywords: partial-thickness; rotator cuff; review

Increased knowledge of the rotator cuff has led to an appreciation of the seminal contributions provided by Codman's[14] and Neer's original descriptions[69,70] of the spectrum of rotator cuff disease. At one end of this spectrum is edema of the rotator cuff tendons that progresses to an inflammatory tendinopathy secondary to either tendon strain or direct impingement from the undersurface of the acromion—the so-called impingement syndrome. Fibrosis of the cuff tendons and, with time, partial-thickness or full-thickness tears of the rotator cuff may ensue. Cadaveric and natural history studies focusing on the prevalence of rotator cuff disease have shown an increasing incidence with age.[19,40,54,55,90,94] These data become particularly relevant given the widespread increase in athletic activity by people of all ages. A greater understanding of the pathogenesis of rotator cuff disease, combined with improved diagnostic techniques, has translated into advances in the treatment of rotator cuff abnormalities.

Thus far, the majority of research, both basic and clinical, dealing with the rotator cuff has focused primarily on the 2 ends of the spectrum: cuff inflammation and full-thickness tears of 1 or more of the cuff tendons. Accordingly, these 2 pathologic conditions are responsible for the majority of rotator cuff–related diagnoses. However, the improvement in both noninvasive imaging modalities and arthroscopic surgical techniques has been accompanied by an increase in the recognition of partial-thickness rotator cuff tears. The purpose of this article is to review the available literature dealing with partial-thickness rotator cuff tears, with particular emphasis on the optimal method(s) of diagnosis, tear classification, indications for and techniques of operative repair, and treatment results. Limitations in the existing literature will be discussed, as will areas for future research.

ANATOMICAL CONSIDERATIONS

Gross Anatomy

An understanding of normal rotator cuff anatomy is essential for the surgeon treating rotator cuff abnormalities. Knowledge of the histologic and gross appearances of the cuff provides relevant insight into the abnormal state as well as a foundation for reconstructing the anatomy of the diseased rotator cuff. Clark and Harryman[13] have nicely detailed the gross and histologic anatomy of the tendons, ligaments, and capsules of normal cadaveric shoulders with particular emphasis on the rotator cuff. The tendinous insertions of the rotator cuff muscles, the articular capsule, the coracohumeral ligament, and the glenohumeral ligament complex blend into a confluent sheet before insertion into the humeral tuberosities. The tendons of the spinati muscles join 15 mm proximal to their insertion and are not readily separable by blunt dissection. The infraspinatus and teres minor fuse near their musculotendinous junctions. The supraspinatus and subscapularis tendons join as a sheath that surrounds the biceps tendon at the entrance of the bicipital groove.[23] The roof of this sheath consists of a portion of the supraspinatus tendon, whereas a sheet of the subscapularis tendon serves as the floor. This relationship is relevant to the frequent coexistence of subscapularis tendon tears with lesions of the long head of the biceps, a relationship that is not only statistically significant[86] but also clinically relevant.

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The coracohumeral ligament complex plays an important role in rotator cuff anatomy as well. The coracohumeral ligament is a thick band of fibrous tissue extending from the coracoid process along the surface of the capsule to the tuberosities between the supraspinatus and subscapularis tendons. The ligament is deep to the tendinous insertion of the cuff and blends with the capsule and supraspinatus tendon to form part of the roof of the biceps sheath. A 1-cm-wide thickening of fibrous tissue extends posteriorly from the coracohumeral ligament's origin on the coracoid to the posterior margin of the infraspinatus. This band is an extension of the coracohumeral ligament and travels between the capsule and the cuff tendons.[11] A sheet of fibrous tissue from the coracohumeral ligament's origin also extends posterolaterally to form a sheet over the superficial supraspinatus and infraspinatus tendon insertions.[13]

Rotator Cuff Histology

Previous histologic studies have determined that the rotator cuff is made up of multiple, confluent tissue layers functioning in concert.[13] An understanding of the layered architecture is relevant when discussing the possible causes, pathoanatomy, and reconstruction of partial-thickness rotator cuff lesions.

Histologic sections through the supraspinatus and infraspinatus reveal 5 distinct layers (Figure 1). The most superficial layer (layer 1) contains large arterioles and comprises fibers from the coracohumeral ligament. This layer is 1 mm thick and contains fibers that are oriented obliquely to the long axis of the muscle bellies. Layer 2 is 3 to 5 mm thick and represents the direct tendinous insertion into the tuberosities. Large bundles (1-2 mm in diameter) of densely packed parallel tendon fibers compose layer 2. The subscapularis tendinous insertion exhibits a similar structure with collagen fiber bundles that parallel the long axis of the muscle and splay before insertion. A group of bundles from the subscapularis joins with fibers of the supraspinatus to serve as the floor of the biceps sheath, whereas the roof of the biceps sheath is formed by fibers from layer 2 of the supraspinatus. Recognition of the anatomy of the biceps sheath is important for understanding the spectrum of pathologic disruption seen with supraspinatus, subscapularis, and biceps tendon lesions. Layer 3 is approximately 3 mm thick and comprises smaller bundles of collagen with a less uniform orientation than in layer 2. Fibers within this layer travel at 45° angles to one another to form an interdigitating meshwork that contributes to the fusion of the cuff tendon insertion. Layer 4 comprises loose connective tissue and thick collagen bands that merge with the coracohumeral ligament at the most anterior border of the supraspinatus. Layer 5 (2 mm thick) represents the shoulder capsule and comprises a sheet of interwoven collagen extending from the glenoid labrum to the humerus.

The layered anatomy of the rotator cuff lends insight into the various types of partial-thickness tears, particularly the intratendinous type. Clark and Harryman's work[13] has shown the rotator cuff, the coracohumeral ligament complex, and the bicipital sheath to be intimately interconnected. Anatomical considerations allow the treating physician to recognize that rotator cuff injury is a spectrum of disease spanning from the partial-thickness tear to the massive cuff tear.

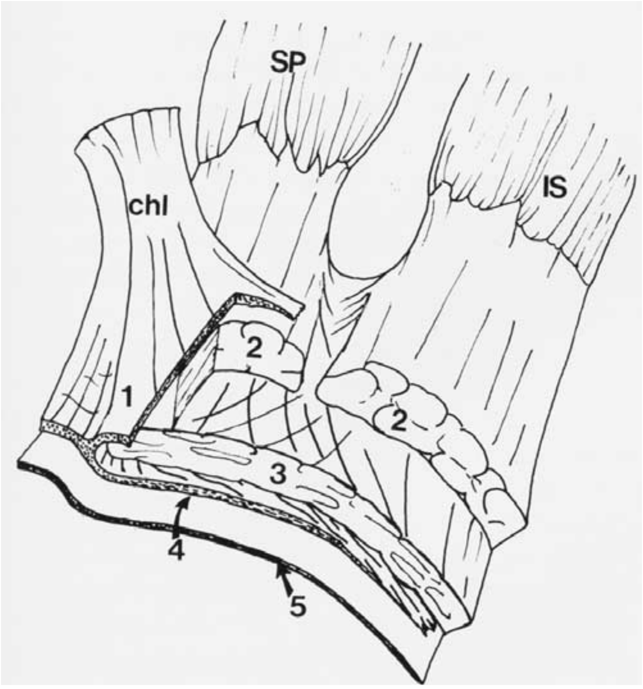

Figure 1. Schematic diagram of a rotator cuff dissection sectioned transversely to demonstrate the 5-layer histologic configuration of the cuff. SP, supraspinatus; IS, infraspinatus; chl, coracohumeral ligament. Reprinted with permission from Clark et al.[13]

Footprint Anatomy

The insertion site of the rotator cuff tendon at the greater tuberosity is often referred to as the footprint. Dugas et al[20] examined 20 normal cadaveric rotator cuff specimens and mapped the footprint using a 3-space digitizer. The mean medial-to-lateral insertion widths of the supraspinatus, infraspinatus, teres minor, and subscapularis tendons were 12.7, 13.4, 11.4, and 17.9 mm, respectively. The mean minimum medial-to-lateral insertion width of the entire rotator cuff insertion occurred at the midportion of the supraspinatus and was 14.7 mm. The articular surface-to-tendon insertion distance was less than 1 mm along the anterior 2.1 cm of the supraspinatus-infraspinatus insertion. This distance progressively increased to a mean distance of 13.9 mm at the most inferior aspect of the teres minor insertion. The mean anteroposterior distances of the supraspinatus, infraspinatus, teres minor, and subscapularis insertions were noted to be 1.63, 1.64, 2.07, and 2.43 cm, respectively. Ruotolo et al[84] examined 17 normal cadaveric rotator cuffs. The supraspinatus tendon insertion was a mean of 1.7 mm from the articular margin.

Knowledge of the insertion distances from the articular margin is important when assessing the extent of articular-sided partial-thickness tears. For example, an articular-sided partial-thickness tear of the supraspinatus with a medial cuff insertion-to-articular margin distance greater than 7 mm is consistent with a partial-thickness tear of greater than 50% of the tendon thickness.

Vascular Supply

The vascular supply to the rotator cuff consists of an anastomotic network formed by the suprascapular and subscapular arteries, as well as osseous flow from the circumflex arteries.[65] The size of the blood vessels decreases from proximal to distal and from medial to lateral along the musculotendinous units as they travel between layers 2 and 3. The arterioles are larger and the vessels more prevalent on the bursal surface of the cuff and branch between layers 2 and 3,[13,65,80,83] which may play a role in the healing potential of bursal-sided tears. The articular side of the rotator cuff is relatively hypovascular when compared with the rich blood flow of the bursal side of the cuff.[54] The relative frequency of bursal-sided versus articular-sided partial-thickness tears may or may not be a reflection of this difference in vascularity.

INCIDENCE AND PREVALENCE OF PARTIAL-THICKNESS ROTATOR CUFF TEARS

The true incidence of partial-thickness rotator cuff tears remains unknown. As early as the 1930s, Codman noted that the incidence of partial-thickness tears was probably double that of full-thickness tears.[14] The majority of current data pertaining to this topic has been gleaned from cadaveric studies that reflect an older segment of the population. However, the true incidence of partial-thickness tears in young overhead-throwing athletes is unknown. Imaging studies of asymptomatic shoulders have revealed the presence of partial-thickness tears.[12,15,64,90]

The vast majority of these tears seem to occur in the supraspinatus tendon. In a study of 306 cadaveric shoulders, Lohr and Uhthoff[65] noted a 32% incidence of partial-thickness tears and a 19% incidence of full-thickness tears within the supraspinatus tendon. Cadaveric studies have noted intratendinous tears to actually be more common than bursal-sided or articular-sided tears. Yamanaka and Fukuda[106] reported an incidence of supraspinatus partial-thickness and full-thickness tears of 13% and 7%, respectively, in a group of 249 cadaveric specimens. Partial-thickness tears were further grouped as bursal-sided (2.4%), intratendinous (7.2%), and articular-sided (3.6%). However, several authors have noted that, clinically, articular-sided tears are 2 to 3 times more common than bursal-sided tears. In fact, among a population of young athletes, Payne et al[77] found that articular-sided tears comprised 91% of all partial-thickness tears. This discrepancy between cadaveric and clinical studies may be because the intratendinous tear is more difficult to diagnose via arthroscopy, MRI, or ultrasound than is the bursal-sided or articular-sided tear. Therefore, the true prevalence of partial-thickness supraspinatus tears is likely to be greater than that currently documented in the literature.

Partial-thickness tears of the subscapularis have also merited attention.[46,86] A cadaveric study of 46 shoulders found 17 articular-sided partial-thickness tears at the superior portion of the subscapularis.[86] Concomitant lesions of the long head of the biceps were also seen in 30.4% of these tears, which was statistically significant. Therefore, lesions within the biceps tendon mandate close evaluation for related injury within the subscapularis tendon.

CAUSES OF PARTIAL-THICKNESS ROTATOR CUFF TEARS

As basic science and clinical research continue to enhance our understanding of the pathophysiology of rotator cuff disease, partial-thickness rotator cuff tears appear to be the end result of a common pathway from multiple contributing factors.[26,33,57,58,99] These factors can be broadly categorized as either intrinsic or extrinsic to the rotator cuff tendons.[26] Intrinsic causes may be subclassified into age-related metabolic and vascular changes that lead to degenerative tearing[55] or intratendinous lesions developing from shear stress.[68] Extrinsic causes may be because of either subacromial impingement,[70] shoulder instability (typically anterior),[66] internal impingement,[18,43,44,60,75,101] a single acute traumatic injury, or repetitive microtrauma.[1,24] Often, more than 1 of these factors (either intrinsic or extrinsic) is responsible for the development of a partial-thickness tear.[26]

Consideration of tear origin in the context of the subtype of partial-thickness cuff tears is critical for optimal diagnosis and may allow insight into the healing potential of the tear after different treatment approaches.[25-30] Age-related degenerative changes including decreased cellularity, fascicular thinning and disruption, accumulation of granulation tissue, and dystrophic calcification have all been noted and are unlikely to be reversible. A zone of relative hypovascularity is also seen on the articular surface of the rotator cuff lateral to the so-called rotator cable,[11,13,37,54,83] which is also accentuated with aging.[5,36,47,87,107] In addition, the articular surface of the rotator cuff has an ultimate stress to failure that is approximately half that of the bursal surface,[68] with thinner and less uniformly arranged collagen bundles. Intrinsic changes in the vascularity of the rotator cuff and age-related degenerative changes may be responsible for articular-surface tears in patients older than 40 years without other clear mechanisms. This theory is supported by both cadaveric and clinical studies that have shown an increasing prevalence of partial-thickness rotator cuff tears with age, as well the histologic correlation noted between areas of relative hypovascularity and recognized patterns of degenerative changes.[19,40,49,54,55,80,90]

Another potential cause of partial-thickness rotator cuff tears and their propagation may be differential shear stress within the tendons. The 5-layer histologic structure of the rotator cuff predisposes it to the development of internal shear forces.[13] An increasing focus on intratendinous strain[3,81] and the recognition of intratendinous tear extension,[26-28] particularly through the work of Fukuda[29-31], have enhanced our understanding of the causes and optimal treatment of partial-thickness tears. A cadaveric biomechanical study by Bey et al[3] found that partial articular surface tears developed increased intratendinous strain at greater than 15° of shoulder abduction. Another cadaveric study by Reilly et al[81] demonstrated that intratendinous defects result in elevated strain patterns within the tendon, which are increased on the articular surface with shoulder abduction to 120°. These same authors noted tear propagation from the articular to the bursal surface and concluded that load sharing through the supraspinatus tendon was altered by an intratendinous tear. A corresponding increase in articular surface strain to levels previously reported to result in tendon failure was also found at and above 90° of abduction.[68] Intratendinous strain as a causative factor in the development and propagation of partial-thickness tears is especially relevant in overhead-throwing athletes, whose rotator cuff tendons are placed under repetitive strains with powerful eccentric forces acting on the tendon during deceleration (discussed below).

The extrinsic theory of rotator cuff pathophysiology was popularized by Neer in 1972.[69] This impingement theory proposes that the progressive spectrum of rotator cuff tendinopathy results from rotator cuff impingement predominantly against subacromial osteophytes or the coracoacromial ligament or both. Evidence supportive of an extrinsic cause in the development of partial-thickness rotator cuff tears is somewhat limited.[56,74] A cadaveric study of subacromial histologic changes observed in conjunction with bursal-sided tears has been used only to draw a connection between this group of partial tears and extrinsic, subacromial impingement.[74] Although this concept has biologic plausibility, a finite-element analysis of the supraspinatus tendon has demonstrated that subacromial impingement generates extrinsic compression and stress concentrations sufficient to cause tearing on not only the bursal side but also on the articular surface as well as within the tendon.[56] Although these data suggest that subacromial impingement may cause any type of partial-thickness tear, bursal-sided tears are more commonly associated clinically with subacromial impingement.

Extrinsic mechanisms of partial-thickness rotator cuff tears extend beyond subacromial impingement to a spectrum of microinstability, repetitive microtrauma, acute traumatic events, and internal impingement. The concept of internal impingement has been described as contact between the posterosuperior aspect of the glenoid and the undersurface of the rotator cuff (Figure 2) and is supported by cadaveric, radiographic, and arthroscopic studies.[†] Most commonly occurring in the overhead-throwing athlete, this contact may be physiologic or pathologic and is influenced by many factors, including subtle anterior instability through attenuation of the anterior band of the inferior glenohumeral ligament,[44,75] posterior capsular tightness, decreased humeral retroversion,[82,101] tension overload,[1] poor throwing mechanics,[44] and scapular muscle imbalance.[16,18,24,34] Repetitive microtrauma from intratendinous strain occurring during eccentric contraction of the rotator cuff in the deceleration phase of throwing in combination with subtle capsular laxity and internal impingement are likely prominent factors in the pathogenesis of articular surface partial-thickness tears commonly seen in overhead-throwing athletes.[1,60,93] The critical distinction in assessing these issues is determining which components of the athlete's clinical picture are adaptive for repetitive throwing at a high level and which factors are pathologic developments that lead to clinical symptoms and deterioration of function.

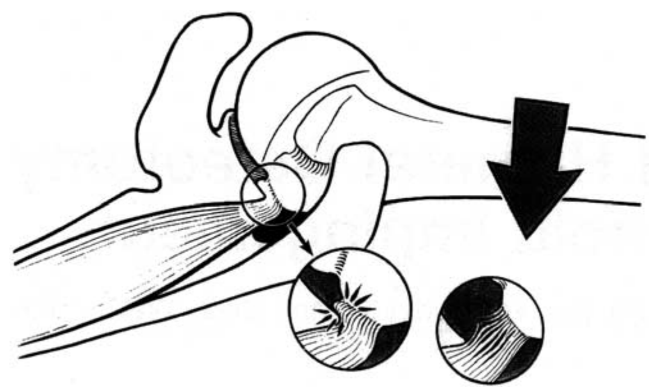

Figure 2. Schematic representation of posterosuperior glenoid impingement. Reprinted with permission from Riand et al.[82]

CLASSIFICATION OF PARTIAL-THICKNESS ROTATOR CUFF TEARS

Although Codman described partial-thickness articular surface tears as "rim rents" in 1934,[14] consideration of the contemporary classification of rotator cuff tendinopathy begins with Neer's[70] influential description of the stages of impingement. This system improved our understanding of rotator cuff abnormalities as a spectrum extending from stage I (inflammation, hemorrhage, edema, and pain) through stage II (tendon fibrosis) to stage III (progressive tearing).[70] We now know that a multitude of factors other than impingement are at play in the development of partial-thickness tears, and unfortunately, Neer's[70] system fails to allow for a consistent and reliable description of these tears. More useful systems have a greater influence on treatment options and outcomes assessment by addressing both tear location and extent to allow for greater interobserver reliability.

Ellman[21] presented a classification of partial-thickness rotator cuff tears with descriptions of location (articular, bursal, interstitial), grade (grade 1, <3 mm deep; grade 2, 3-6 mm deep; grade 3, >6 mm deep), and tear area (in mm^2). Snyder defined a partial articular supraspinatus tendon avulsion as the PASTA lesion and helped to recognize this injury as a separate clinical entity.[63,91,92] In addition, Snyder proposed a classification system for partial-thickness tears based on tear location (articular, bursal, or

[†]References 18, 43, 44, 45, 50, 59, 75, 101.

complete) and tear severity (0-4 scale, ranging from normal to greater than 3 cm severe cuff injury).[92] Yamanaka and Fukuda[106] and Conway[16] expanded on this development by drawing further attention to the intratendinous extension of these lesions, first described by Codman,[14] particularly in overhead-throwing athletes. Conway proposed the PAINT lesion to describe partial articular tears with intratendinous extension.[16] Previous studies had focused less attention on intratendinous tearing. However, over time, the presence of this entity has clearly been recognized as a critical component of the optimal diagnosis and treatment of partial-thickness tears.[26]

DIAGNOSIS

Clinical Examination

Diagnosis of partial-thickness rotator cuff tears can be challenging, as the clinician must correlate the often nonspecific physical examination findings with available imaging modalities. The details of a comprehensive shoulder examination are beyond the scope of this article; however, such an evaluation is indicated in the examination of these patients.

A thorough examination begins with an assessment of the cervical spine for range of motion, palpable tenderness or muscle spasm, and for provocative tests, such as the Sperling maneuver, to rule out a compressive neuropathy that may lead to radicular symptoms referred to the shoulder region. The shoulder girdle should be inspected for signs of muscle atrophy or scapulothoracic asymmetry with active shoulder motion. Range of shoulder motion (both active and passive) and grading of muscle strength in the planes of elevation, extension, abduction, adduction, internal rotation, and external rotation with contralateral comparisons are also performed.

The results of impingement tests, such as the Neer and Hawkins tests, with or without subacromial local anesthetic injection, are often positive in the presence of partial-thickness rotator cuff tears, although occasionally these test results are negative, especially in the high-level, well-conditioned athlete. Loss of supraspinatus muscle strength with complete or near-complete resolution of pain after a subacromial injection suggests the presence of a full-thickness rotator cuff tear, whereas maintenance of strength in the absence of pain on supraspinatus testing suggests either rotator cuff inflammation or an articular surface or intratendinous partial-thickness tear.

Tests to evaluate unidirectional or multidirectional shoulder instability, such as the Jobe test, the sulcus sign, the relocation test, and the degree of anterior and posterior humeral translations are mandatory in the young throwing athlete who may possess both rotator cuff injury and shoulder instability because of internal impingement described earlier. The O'Brien test may help distinguish lesions of the long head of the biceps tendon from conditions involving the acromioclavicular joint, which often coexist with conditions involving the rotator cuff. A thorough neurovascular assessment of the upper extremity with an emphasis on distal muscle strength, sensation, and pulses completes the examination.

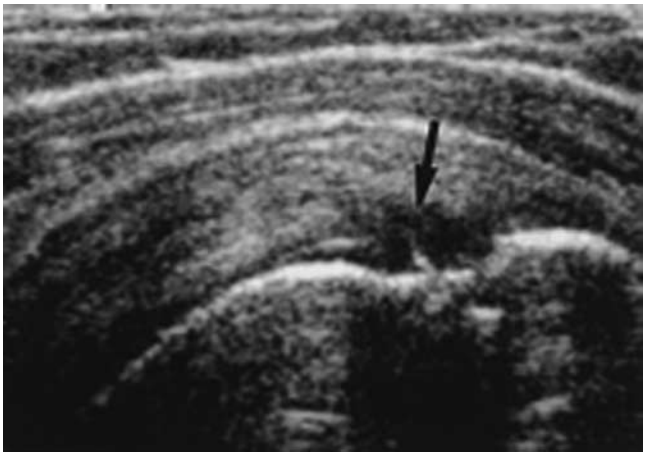

Figure 3. Ultrasonographic image showing a small hypoechoic tendon tear, located on the deep articular side of the rotator cuff (arrow). The image is oriented in a plane parallel to the longitudinal axis of the tendon. Reprinted with permission from Teefey et al.[94]

Diagnostic Imaging

Although plain radiographs are rarely helpful in making the diagnosis of a partial-thickness rotator cuff tear, they are an important component of evaluating the patient with shoulder pain. The identification of a greater tuberosity notch,[67] though nonspecific, has been described as an indicator of partial-thickness articular surface tears in throwing athletes. The presence of a subchondral cyst in the greater tuberosity may also be seen in the presence of rotator cuff pathologic abnormalities.

Conventional and positional radiographic arthrography[33,42,71] and subacromial bursography[32,88,108] historically have been used as the primary imaging modalities in the evaluation of the rotator cuff. However, the accuracy of arthrography and bursography has been a topic of debate in the literature. Although proponents touted accuracy rates of up to 83%[42] and 67%,[32] respectively, other studies have shown less favorable results, with reported accuracy rates as low as 15%[33] and 25%,[42] respectively.

As a result of these disparate data, arthrography and bursography have been replaced largely by ultrasonography and MRI. Increased use and improved techniques of ultrasonography have led to its emergence as a useful tool in the diagnosis of rotator cuff abnormality[100,109] (Figure 3). Specifically, Wiener and Seitz[104] reported a sensitivity of 94% and a specificity of 93% for the diagnosis of partial-thickness rotator cuff tears. Although valuable as a cost-effective and often well-tolerated procedure, ultrasound continues to be operator dependent. As a result, its utility is predicated on the availability of personnel with experience in its performance and interpretation, as evidenced by only a 41% detection rate of partial-thickness rotator cuff tears.[6]

The development of various techniques of MRI, including sequence alteration, contrast arthrography, and differential arm positioning (abduction external-rotation),[48,61,98] has improved the accuracy with which rotator cuff injuries are identified. Ultrasonography and MRI provide relatively similar accuracy rates for the diagnosis of partial-thickness tears.[95] However, a significant advantage of MRI is its ability to diagnose the concomitant pathologic lesions often seen with partial-thickness tears (eg, labral tears, biceps tendon lesions).

The diagnosis of partial-thickness rotator cuff tears is based on the presence of increased signal in the rotator cuff without discontinuity on T1-weighted images. This finding corresponds to increased signal noted on T2-weighted sequences with the identification of a focal defect on either the bursal or articular surfaces or within the tendon substance[26,58,79] (Figure 4). Defining the shape of the rotator cuff with MRI remains a diagnostic challenge in differentiating between small focal tears, partial-thickness tears, and an inflammatory process.[48,78]

The identification of partial-thickness rotator cuff tears by standard MRI historically has shown only moderate success. Previous reports have described sensitivity rates between 56% and 72% and specificity rates of 85% for arthroscopically proven tears.[97] Gartsman and Milne[33] reported a false-negative rate of 83% in a study of 12 arthroscopically verified articular-sided tears. As a result of these rather disappointing results, fat-suppression,[78] positional variation,[48] and contrast magnetic resonance arthrography[61] have been employed to improve the diagnostic accuracy and reliability of MRI. Gadopentate contrast–magnetic resonance arthrography with coronal oblique fat-suppressed images has been recently shown to have a sensitivity of 84%, a specificity of 96%, a positive-predictive value of 93%, and an overall reported accuracy of 91%.[61] A significant advantage of MRI, and more specifically magnetic resonance arthrography, is the ability to diagnose concomitant abnormalities, which is critical to providing optimal treatment.[67] Placement of the arm in a position of abduction and external rotation (ABER view) has also been a useful adjunct to routine imaging to identify not only articular-surface tears but also labral lesions, especially in throwers who often demonstrate this combined injury pattern.

Diagnostic Arthroscopy

Arthroscopy has proven invaluable in the diagnosis and treatment of partial-thickness rotator cuff tears. Direct inspection and probing of the tendon from its articular and bursal surfaces, a thorough examination of the cuff's footprint, and a systematic, comprehensive diagnostic shoulder examination have enhanced the identification and treatment of these lesions. Several techniques have been proposed to facilitate arthroscopic diagnosis of partial-thickness tears, including the Fukuda color test using methylene blue[27] and the Snyder suture marking technique[92] for the evaluation of articular surface tears (Figure 5). The Lo and Burkhart "bubble sign"[53] has also been described to enhance the accuracy of arthroscopic diagnosis of intratendinous tears. This test is performed by placing an 18-gauge spinal needle directly into the area of a suspected intratendinous tear from the bursal surface and injecting 0.5 mL of sterile normal saline. If the saline is injected easily and dilatation

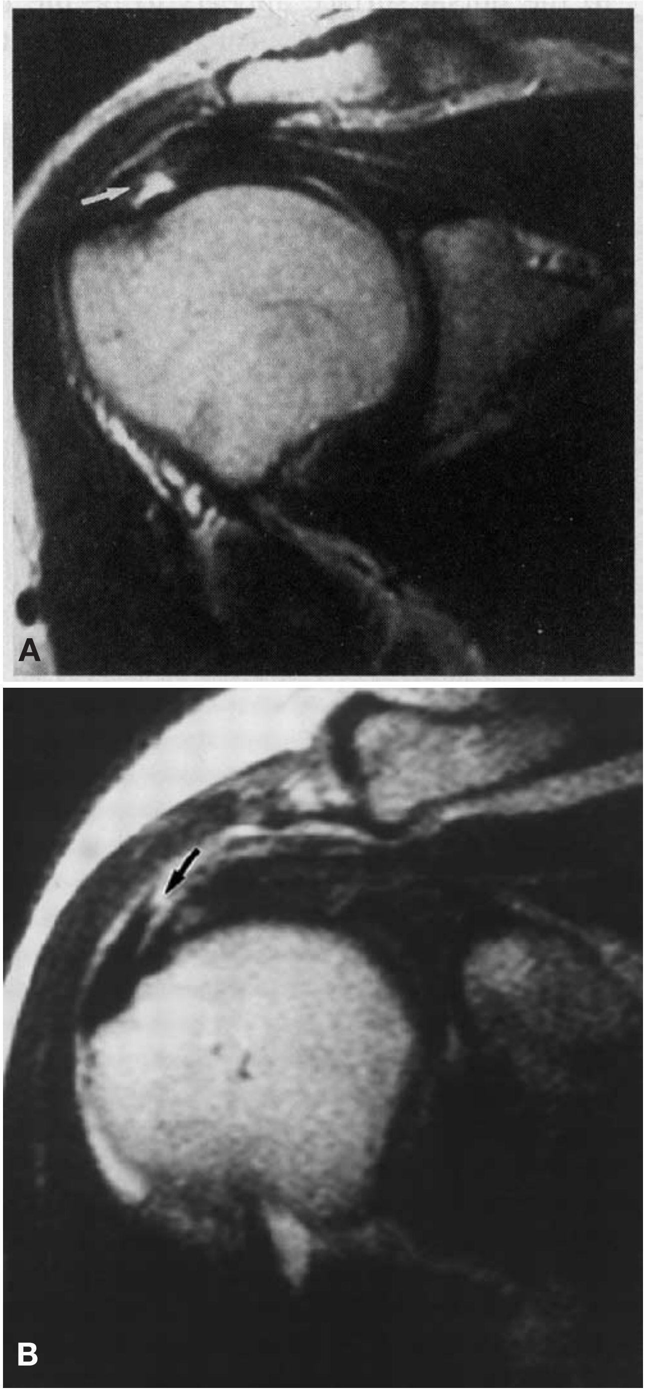

Figure 4. A, T2-weighted oblique coronal image showing a deep partial-thickness tear (arrow) involving the articular surface of the cuff. B, T2-weighted oblique coronal image showing an irregular oblique tear (arrow) involving the bursal side of the cuff. Reprinted with permission from Herzog et al.[39]

appears in this area, then an intratendinous tear is strongly suspected.

TREATMENT OPTIONS AND INDICATIONS

No simple treatment algorithm for partial-thickness rotator cuff tears exists. This condition is often only 1 of several pathologic conditions present in the painful shoulder, any one of which may be responsible for the patient's symptoms. As mentioned previously, partial-thickness tears are quite common, especially in the active, aging population.[12,15,64] Therefore, the presence of a documented tear on an MRI or an ultrasound may be merely a diagnostic red herring that is not contributing to the patient's symptoms. As a result, the published treatment options for partial-thickness rotator cuff tears vary because there is limited literature on which to base any one treatment decision. However, as with most conditions in sports medicine, these options basically involve either nonoperative or surgical treatment.

Nonoperative Treatment

Patients with partial-thickness tears due to suspected external acromial impingement are treated similarly to those with rotator cuff tendinopathy and subacromial bursitis. Activity modification with avoidance of overhead or pain-provoking activities is recommended, along with a short course of a nonsteroidal anti-inflammatory medication to reduce the associated pain[36] and inflammation of the condition. A dedicated physical therapy program is recommended, with specific attention directed toward reestablishing and/or maintaining normal shoulder kinematics with stretching of contracted capsular structures. Anterior capsular tightness is addressed by stretching in external rotation with the arm at the side to avoid placing the shoulder in a zone of impingement (60° to 120° of abduction). Posterior capsular contractures are eliminated by stretching with the arm in adduction and internal rotation and horizontal, cross-body adduction. Thermal modalities (eg, moist heat, ultrasound) can be used to facilitate the reduction of pain and improve motion, although data to support their use are limited. Subacromial or intra-articular corticosteroid injections can also be used judiciously, depending on the location of the tear for those patients with persistent symptoms unresponsive to other means of pain reduction. No more than 2 to 3 injections are recommended because of the potentially deleterious effect on the rotator cuff tissue, especially in younger athletes.

As pain decreases and shoulder motion improves, attention is focused on strengthening the rotator cuff and periscapular musculature. Focused rotator cuff strengthening may be accomplished through the use of elastic tubing or free weights. Strengthening of the shoulder girdle musculature is recommended to restore normal scapulothoracic mechanics to stabilize the platform on which the glenohumeral joint functions. Left unaddressed, scapulothoracic dyskinesia increases the likelihood of extrinsic acromial impingement on the rotator cuff.

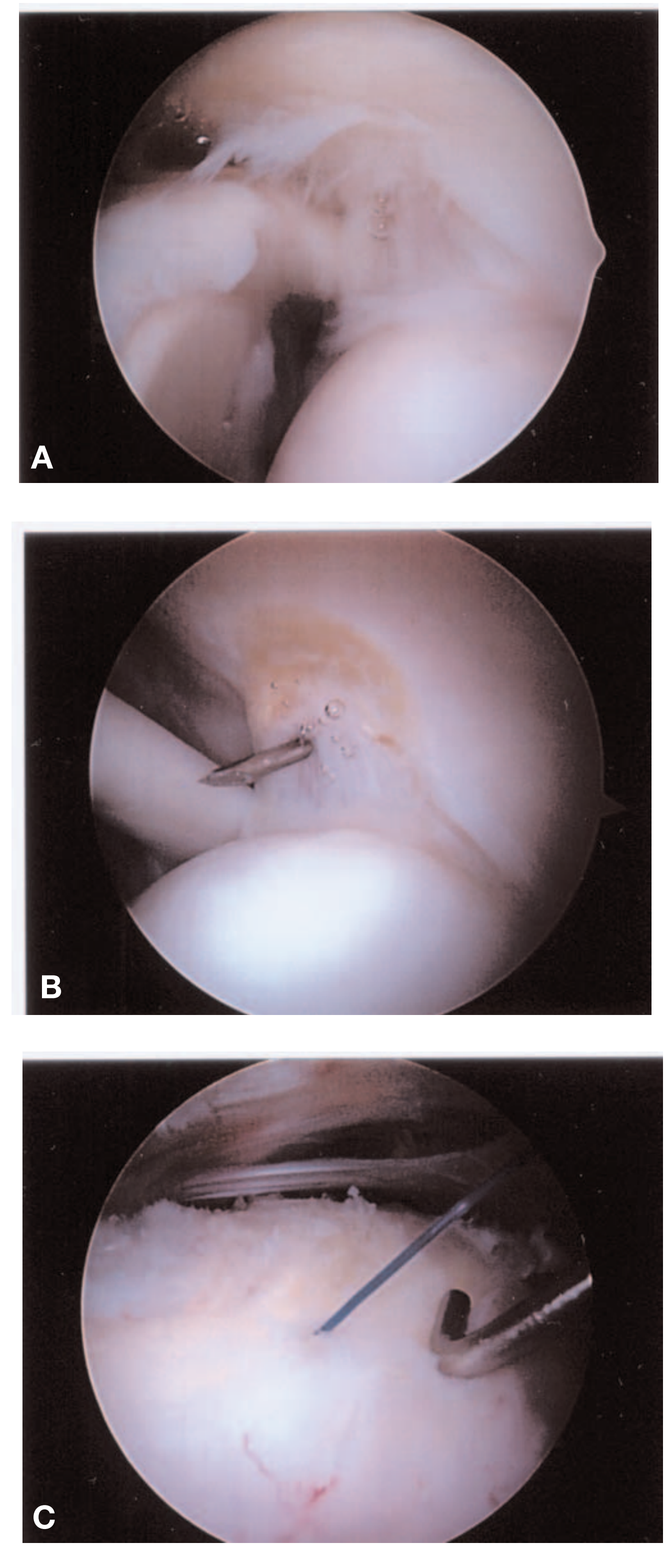

Figure 5. A, arthroscopic view of an articular-surface tear of the supraspinatus tendon. B, 18-gauge spinal needle traversing the tear for later passage of a monofilament marking suture. C, arthroscopic view of the bursal surface of the rotator cuff with the marking suture identifying the site of the previously identified articular-surface tear.

Throwing athletes with coexistent anterior shoulder instability or internal impingement, or both, are treated similarly with pain reduction through the use of anti-inflammatory medications and strengthening of the muscles of the rotator cuff and shoulder girdle complex. Particular emphasis should be placed on the stretching of contracted posterior capsular tissues, which have been shown to result in the loss of internal rotation.[16,24,26] However, loss of internal rotation may also be seen in the presence of increased humeral or glenoid retroversion and should be taken into consideration. Eccentric and plyometric strengthening of the rotator cuff should be included in the rehabilitation program to mimic the deceleration and follow-through phase of the throwing motion. Trunk and lower extremity strengthening should also be emphasized during this time, as significant throwing strength is generated from these areas. Attention to core strengthening reduces the degree of effort that the shoulder and arm must exert to produce power during throwing. Restoration of proper throwing mechanics is followed by a progressive throwing program particular to the demands of the patient's sport.

Operative Treatment

The timing of surgical intervention has not been firmly established. Failure of 3 to 6 months of nonoperative treatment has been recommended as a threshold for surgery in those patients with symptomatic partial-thickness rotator cuff tears. However, other patient factors, such as activity level, the coexistence of other lesions, and timing issues specific to the patient's sport, may dictate earlier intervention. The surgical management of partial-thickness tears basically involves 1 of 3 options: arthroscopic debridement of the tear, debridement with acromioplasty, or rotator cuff repair with or without acromioplasty. Surgery may be performed open, arthroscopically assisted, or entirely arthroscopic. To date, there are not sufficient data to support one technique over another in the management of partial-thickness tears. However, arthroscopy allows a thorough evaluation of the entire intra-articular surface of the shoulder joint as well as the subacromial space, which represents a distinct advantage over a purely open surgical procedure. The presence of such associated lesions as labral tears, bicipital lesions, Hill-Sachs deformity, loose bodies, and glenohumeral chondrosis should also be treated concurrent with management of the rotator cuff tear irrespective of the surgical method.

Arthroscopic Assessment. Arthroscopic evaluation of the shoulder begins with the patient in either the beach-chair or lateral decubitus position. Placement of the arm in a position of 30° of abduction, forward flexion, and external rotation with longitudinal traction provides an excellent view of the articular cuff surface using a standard 30° arthroscope. The use of a 70° arthroscope from a posterior portal allows an assessment of the infraspinatus and teres minor tendons and may be helpful in the evaluation of the subscapularis. As an alternative, the arthroscope may be placed in an anterior portal viewing posteriorly to assess the most posterior aspect of the cuff and posterior labrum. Placement of the arm in 90° of external rotation and abduction can be done to assess the presence of impingement of the undersurface of the infraspinatus against the posterior-superior labrum.

Visualized defects of the articular surface of the rotator cuff tear are probed from an anterior portal and gently debrided with a rotary shaver of all frayed, nonviable tissue to determine the depth and area of injury. Placement of an 18-gauge spinal needle from the anterolateral aspect of the shoulder through the cuff defect with passage of a 2-0 monofilament suture may be used to mark the location of the tear for later viewing of the bursal surface (Figure 5).

A thorough evaluation of the bursal surface of the rotator cuff from the subacromial space is often hindered by the presence of a thickened, inflamed, hypertrophic bursa often present with rotator cuff injury. Debridement of this tissue through mechanical or electrothermal means via a lateral working portal facilitates visualization of the entire bursal surface of the cuff, as does moving the shoulder through a range of motion. Viewing from a lateral or anterior portal allows for a thorough inspection of the cuff, including the area previously marked by the tagging suture.

Identification of a bursal-sided defect is followed by debridement of the frayed cuff tissue with an assessment of tear depth. Fraying of the bursal surface often corresponds to the area previously marked with the tagging suture. This area should be probed to assess the depth and dimensions of the cuff defect. Full-thickness tears are often found by palpating these areas identified on preoperative imaging studies as only partial-thickness injuries. In those situations in which imaging studies suggest the presence of rotator cuff tendinopathy or an intratendinous tear, both the articular and bursal surfaces will appear normal. Palpation of the cuff tissue to assess tissue integrity and the injection of saline into the area in question can be used to diagnose intratendinous tears (Figure 6).

Release of the coracoacromial ligament and debridement of the undersurface of the acromion with a high-speed bur to remove any acromial or acromioclavicular spurs (coplaning) have been recommended by some authors for the older patient with either articular-sided or bursal-sided tears due to external cuff impingement.[89] The creation of a flat (type 1) acromion[4] has historically been the goal of a subacromial decompression. However, an aggressive acromioplasty may not be necessary in a younger throwing athlete with a normal subacromial outlet. Care must be taken during release of the coracoacromial ligament and acromial debridement to not release the anterior deltoid.[85] Data suggest that removal of 4 mm of the acromion results in a loss of 46% of the anterior deltoid attachment, whereas 6 mm of excised acromion results in a loss of 74% of the anterior deltoid.[96]

Repair of Articular-Sided and Bursal-Sided Tears. A critical factor to consider in the surgical management of a partial-thickness tear is the depth of the lesion. There is no consensus regarding the influence of tear area as a determinant of treatment, despite the fact that the surface extent of the tear may be as important as tear depth in regard to clinical outcome.[8] There has been a generalized consensus on the degree of tear depth that warrants an

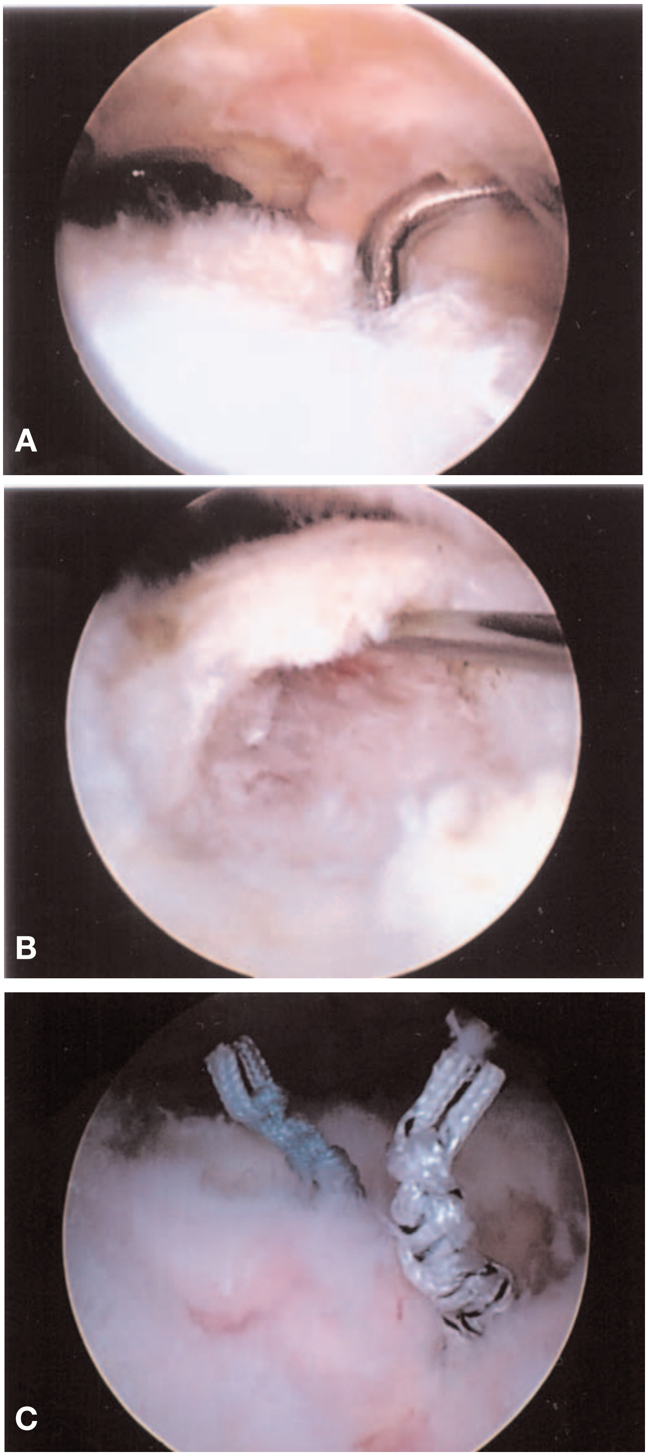

Figure 6. A, probing of the bursal surface of an area suspected of containing an intratendinous partial-thickness tear. B, intratendinous tear confirmed after opening the bursal surface. C, subacromial view of the rotator cuff after arthroscopic repair of an intratendinous tear.

attempt at repair. In general, most authors have recommended repair of a tear that involves 50% or more of the tendon's thickness, irrespective of the surface of involvement (articular or bursal).[102,103] However, at present, there are insufficient data to support this number as a standard, and assessment of tear depth can be difficult, despite the use of calibrated probes. Recent work by Nicholson[72] used 30% tear depth as a threshold for repair. Sedentary patients may do well with decompression alone, even in the setting of a tear 50% of the depth of the rotator cuff, whereas active patients will likely benefit from a more aggressive approach with an attempted repair for a tear that is between 30% and 50% of cuff depth. An aggressive attempt at repair is also indicated in those patients with an acute, traumatic tear and in those whose tear is on the bursal surface because of the favorable blood supply of this region and the generally poor outcome associated with debridement of bursal-sided tears.[17]

Arthroscopic repair of articular-sided or bursal-sided partial-thickness tears may involve completion of the tear or transtendinous repair of the tendon down to the bone with suture anchors. Advocates of the latter technique favor the ability to preserve the intact portion of the rotator cuff.[52] For repair of complete tears, single or double-row suture anchor fixation may be used, although there are currently insufficient data to support one technique over another. Anchors may be metallic or bioabsorbable, depending on surgeon preference, although we favor bioabsorbable anchors. Our preference is the 5.0-mm BioCorkscrew anchor (Arthrex, Naples, Fla) loaded with No. 2 FiberWire (Arthrex). Optimally, the anchors are placed at a 45° angle (dead man's angle)[9] to the direction of contractile force of the rotator cuff muscles. Two anchors are typically used for a double-row repair of tears 1.5 cm or less in length from anterior to posterior, and 3 to 4 anchors are typically used for tears greater than 1.5 cm. Lo and Burkhart[52] have described a transtendinous repair technique for partial-thickness articular surface tears that restores the medial footprint of the cuff while preventing a length-tension mismatch that may result from removing normal cuff tissue that is then advanced too far laterally.[10] Articular-sided partial-thickness tears may be repaired by making a small perforation in the rotator cuff to place medial anchors. The sutures from these anchors may then be used to repair the articular side of the tear and thus restore the footprint while leaving the lateral aspect of the footprint intact. Bursal-sided partial-thickness tears may be repaired by placing a lateral row of anchors and thus preserving the medial footprint. Restoration of the native footprint anatomy and length-tension relationships may be more technically difficult with this latter technique.

For a double-row repair, medial anchors are placed at the medial margin of the rotator cuff footprint just lateral to the articular surface, and the lateral anchors are placed at the lateral margin of the footprint. Attention to anchor positioning is imperative to reestablish the normal footprint. A larger area of footprint repair may potentially improve the rate of tendon healing and strength of the repair. In one study, transosseous tunnels were shown to restore 85% of the rotator cuff footprint compared with only 67% with suture anchor repair.[2] This finding would represent a theoretical benefit from either the mini-open or standard open approach to repair these tears or the implementation of double-row fixation through an arthroscopic technique.[51]

Intratendinous Tears. Intratendinous tears that are either identified by the methods discussed earlier or that represent an extension of a surface tear can be repaired with multiple mattress sutures. This method is favored for those intratendinous tears oriented in a predominantly medial-to-lateral direction. The intratendinous tear is identified and opened on the bursal surface using either basket forceps or arthroscopic scissors while viewing from the subacromial space. All nonviable tissue is debrided, with care taken not to disrupt the intact articular surface attachment of the cuff. A recent study using immunohistochemical analysis on surgical and cadaveric specimens has suggested that based on morphologic architecture, only limited debridement of the tissue medial to a rotator cuff tear is required to optimize healing at the time of repair.[35] This situation represents an issue of balance in determining the amount required to remove nonviable tissue for optimal healing while preserving rotator cuff tendon to maximize healing and optimize length-tension relationships in an anatomical restoration of the footprint. The use of an accessory anterior working portal is useful to pass multiple vertical mattress No. 2 nonabsorbable sutures through either a suture relay system or penetrating suture grasper. Multiple sutures are placed from anterior to posterior along the entire length of the intratendinous tear.

RESULTS OF TREATMENT

Nonoperative Treatment

As previously mentioned, the treatment options for partial-thickness rotator cuff tears range from nonoperative management to surgical repair. Unfortunately, the current literature available to guide practitioners lacks randomized, prospective studies assessing the results of treatment as a function of such factors as tear size, tear location, mechanism, and patient activity level.[‡] In addition, most studies lack adequate statistical power, which makes any treatment recommendations subject to question.

The results of nonsurgical management of partial-thickness tears are largely unknown as no long-term follow-up studies using a standardized treatment protocol exist in the literature. The natural history of partial-thickness tears is not fully known, but current data are suggestive. Fukuda[28-30,38] found no evidence of healing occurring in histologic sections obtained from partial-thickness tears, and in some specimens, the tear was nearly full thickness. Although imaging[90] and clinical[41] studies have suggested that partial-thickness tears do, in fact, progress, the statistical significance of these data is unclear. Yamanaka and Matsumoto[108] arthrographically followed 40 articular-sided tears treated nonoperatively during a 2-year period and found tear progression in 80% of patients. A decrease in tear size occurred in only 10%, and complete disappearance of the tear occurred in another 10%. Therefore, tear progression is certainly of utmost concern during nonoperative management.

Arthroscopic Debridement Alone

Budoff et al[7] evaluated 79 shoulders with partial-thickness cuff tears treated with arthroscopic debridement alone after a follow-up period ranging from 25 to 93 months. Acromial (25%), acromial and clavicular (15%), and clavicular (<1%) osteophytes were resected in some patients, although no formal acromioplasty or release of the coracoacromial ligament was performed. Of note, a large percentage of these patients (77%) had associated labral abnormalities. Using the University of California at Los Angeles (UCLA) Shoulder Rating Scale, the results of debridement alone were good to excellent in 89% of those with less than 5 years of follow-up. In those with follow-up greater than 5 years, the results decreased to 81%.

Andrews et al[1] reported 85% good and excellent results with arthroscopic debridement of partial-thickness tears in 34 young athletes with a mean follow-up of 13 months. All patients in that study had associated labral lesions, and 25% had abnormalities of the long head of the biceps tendon.

Arthroscopic Debridement Combined With Subacromial Decompression

The literature has reported favorable results with combined debridement of partial-thickness tears and concomitant subacromial decompression. A large number of studies reporting the results of subacromial decompression for a host of shoulder injuries exist. However, few studies have examined a uniform population with similar pathologic changes, such as partial-thickness rotator cuff tears. Snyder et al[92] retrospectively reviewed 31 patients with partial-thickness tears treated in this fashion and reported 84% good to excellent results. However, 13 of the 31 patients did not undergo subacromial decompression. Interestingly, no significant difference was found in the outcome, regardless of whether decompression was performed.

Esch et al[22] evaluated the results of arthroscopic subacromial decompression according to the degree of the tear. Seventy-six percent of the patients with a partial-thickness tear demonstrated satisfactory scores on the UCLA Shoulder Rating Scale, with an improvement in pain, function, active forward flexion, and strength. Patient satisfaction was demonstrated in 82% of these patients. Interestingly, there was no significant difference in outcome between those with full-thickness versus partial-thickness tears.

Cordasco et al[17] evaluated the clinical outcome of arthroscopic acromioplasty and debridement in 162 patients with normal or partial-thickness tears of the rotator cuff. There was no difference in outcome between those with partial-thickness tears less than 50% of tendon thickness compared with those without any tears. However, they noted an increased failure rate in patients with grade 2B (bursal-sided tears affecting less than 50% of tendon thick-

[‡]References 29, 33, 42, 46, 52, 57, 62, 63, 73, 76, 77, 105.

ness). As a result, they recommended repair in combination with acromioplasty for these particular tears, although an objective evaluation of this recommendation was not performed.

Payne et al[77] evaluated 43 athletes younger than 40 years with partial-thickness tears treated with arthroscopic debridement and subacromial decompression. Those with acute, traumatic injuries had a satisfactory outcome 86% of the time, with a return to preinjury sports in 64%. Those with insidious onset of pain due to a partial-thickness tear were not as successful, with only a 66% satisfactory rate and a 45% return to preinjury sports. As might be predicted, success with arthroscopic debridement in this latter group was predicated on the absence of glenohumeral instability and the presence of subacromial inflammation.

Repair of Partial-Thickness Tears

The repair of partial-thickness rotator cuff tears has received a great deal of attention. Itoi and Tabata[42] reviewed results from open repair of partial-thickness rotator cuff tears with and without anterior acromioplasty or coracoacromial ligament resection. Good to excellent results were obtained in 82% of shoulders. No statistical difference was noted between groups with regard to the performance of an additional acromioplasty or coracoacromial ligament resection.

Weber[103] retrospectively reviewed 2 similar groups of patients with partial-thickness rotator cuff tears (greater than 6 mm cuff thickness avulsed from the humerus) who were observed for 2 to 7 years. One group was treated with arthroscopic debridement and acromioplasty with 14 good and no excellent results. The second group underwent arthroscopic acromioplasty and mini-open repair with 28 good and 3 excellent results. As a result of this study, Weber recommended repair of partial-thickness tears greater than 50% of the tendon thickness. However, an accurate method to assess cuff thickness, the effect of varying individual tendon dimensions, and prospective confirmation of this recommendation remain to be determined.

Conway[16] reported an 89% return to the same or higher level of play in a group of 14 baseball players who underwent repair of intratendinous rotator cuff tears. However, this group had additional injuries, including superior labrum anterior posterior tears, anterior instability, and hypertrophic subacromial bursae, that were also treated and that likely affected the final results.

Park et al[76] compared the results of arthroscopic repair of patients who had partial-thickness rotator cuff tears with those of patients who had full-thickness tears. After a mean follow-up of 34 months, both groups demonstrated similar improvements in pain, motion, and function by the American Shoulder and Elbow Society Score. Evaluation at final follow-up showed that 93% of all patients had good or excellent results, and 95% demonstrated satisfactory outcome with regard to pain reduction and functional outcome. Caution was given regarding the careful preoperative assessment of the acromioclavicular joint as a potential source of pain, as the only 2 fair results were seen in patients with arthritis of this joint.

FUTURE DIRECTIONS

As a result of the paucity of randomized, prospective studies specifically addressing the optimal management of partial-thickness rotator cuff tears, there exists the opportunity for advances in both basic as well as clinical research dealing with this condition. Application of current animal models of full-thickness tears may be used for the simulation of partial-thickness tears. Biomechanical studies comparing current fixation techniques to novel methods, such as double-row repair, may also lead to new treatment strategies. The use of growth factors to stimulate healing, as has been applied to other areas of sports medicine, may also have clinical application in the treatment of partial-thickness cuff tears. Finally, clinical outcomes research dealing with such issues as an injury mechanism-based tear classification system, the natural history and risk of tear progression, the indications for operative intervention, and the results of prospective, randomized clinical trials are all areas in need of further research to optimize the treatment of this condition.

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