THE ROTATOR CUFF

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KEY POINTS

- The majority of symptomatic rotator cuff disease patients respond to a nonoperative program emphasizing the restoration of normal biomechanics, unrestricted motion, and functional force couples.
- Early surgical management should be considered for acute rotator cuff tears in physiologically young and very active individuals.
- The ability to recognize the complex layered anatomy in addition to the tear configuration is critical if an anatomic repair is to be achieved.
- The rotator cuff muscles centralize the humeral head and permit a single center of rotation while providing stability and strength. During active shoulder elevation, the rotator cuff muscles depress the humeral head, allowing efficient elevation of the extremity.
- When surgery is necessary, the goal should be to properly and anatomically restore the balanced forces of the supraspinatus and deltoid muscles so that their counteraction is maintained.
- Tearing of the rotator cuff as a function of age is a common occurrence. Many of these tears may be clinically silent.
- Mechanical impingement is the most common recognizable source of recurring rotator cuff pain and disability in the active population. When impingement-type symptoms present in a younger patient, great care must be taken to avoid overtreating because the impingement may be internal or may be secondary to instability which effectively moves the cuff closer to the arch.
- The unaffected shoulder can serve as a "normal" template for comparison during physical examination. One should survey for atrophy or asymmetry, especially in the supra- and infraspinatus fossae. Long-standing rotator cuff tears are often accompanied by significant, visible atrophy.
- The initial evaluation of the painful shoulder should include quality plain radiographs. The standard radiographs should include a true anterior-posterior view with the shoulder in the internal and neutral position, an axillary view and the outlet (supraspinatus) view described by Neer and Poppen which is used to evaluate and classify acromial morphology and arch anatomy.
- Magnetic resonance imaging (MRI) is the test of choice when evaluating the soft tissues of the shoulder. T1 weighted images revealing increased signal in the rotator cuff, combined with a focal defect or loss of continuity of the cuff on the T2 weighted image, is a common finding when a full or partial-thickness tear is encountered.
- MRI scans for those anticipating shoulder surgery can be helpful in evaluating tears, assessing possible atrophy, and establishing the presence of co-morbidities.

Injuries to the rotator cuff occur commonly. Treatment for these common disorders is most effective when a management algorithm can be developed based on a keen understanding of pertinent anatomy, pathology, and outcomes studies supporting specific treatment. Suffice to say that the majority of patients with symptomatic rotator cuff disease respond to a well-planned, nonoperative program emphasizing the restoration of normal biomechanics, unrestricted motion, and functional force couples. Clearly there will be those patients in whom the pathology has progressed to a point where surgical intervention may be appropriate.

This chapter is organized into three sections: The first details the anatomy, biology, function, and pathoanatomy; the second section focuses on the physical exam and diagnostic testing; the final section considers treatment alternatives and selected techniques.

BASIC SCIENCE

Anatomy and Biology

The rotator cuff consists of the supraspinatus, infraspinatus, teres minor, and subscapularis muscles, all of which arise from the scapula and insert into the proximal humerus. The subscapularis muscle is innervated by the upper and lower scapular nerves, and arises from the anterior surface of the scapula, inserting into the lesser tuberosity. The nerve supply to the supraspinatus is provided by the suprascapular nerve, and the muscle originates from the supraspinatus fossa, inserting into the greater tuberosity. The infraspinatus muscle is also innervated by the suprascapular nerve after it passes around the spinoglenoid notch. The muscle arises from the infraspinatus fossa and inserts into the posterolateral aspect of the greater tuberosity. The axillary nerve innervates the teres minor, which originates from the inferior and lateral aspect of the scapula, inserting into the inferior portion of the greater tuberosity.

Another important and under appreciated feature of the rotator cuff is its distinct layered makeup (1–3). The first layer is a superficial one extending from the coracoid process to the greater tuberosity following the course of the coracohumeral ligament. The second layer consists of the supraspinatus and infraspinatus tendinous fibers. Layer three is composed of the same muscle groups, but the fibers are oriented obliquely and interconnect with the adjacent rotator cuff fibers including the subscapularis. The deep fibers of the coracohumeral ligament make up the fourth layer extending into the supraspinatus and infraspinatus junction laterally. Layer five represents the actual capsular layer of the joint. The ability to recognize the complex layered anatomy in addition to the tear configuration is critical if an anatomic repair is to be achieved. Furthermore, collagen organization is more robust on the bursal aspect of the rotator cuff as compared to articular-sided fibers (4,5), a pertinent fact when evaluating partial thickness tears. It is also worth noting that a significant contribution to the vascular environment of the rotator cuff, when considering healing potential, may arise from adjacent subacromial structures including the bursa (6,7).

Investigators have further refined the insertional anatomy of the rotator cuff components (8,9). Each segment of the rotator cuff has a specific "footprint" that can be quantified. This is particularly important when assessing partial thickness cuff tears (**Fig 13-1**). The depth of the tear, as judged by the amount of exposed "footprint," allows the clinician to not only estimate the severity of the tear, but to also choose the most effective treatment (10–12).

The vascular anatomy of the rotator cuff has been well described. The anterior humeral circumflex, the subscapular, and the suprascapular arteries provide the primary blood

A B

Fig 13-1. A: The insertional anatomy of the rotator cuff depicted on model. Green represents supraspinatus footprint; infraspinatus footprint shown in red. **B:** Cadaveric representation of distinct insertional anatomy for the rotator cuff.

Fig 13-2. Arrow points to zone of diminished vascularity on coronal photomicrograph.

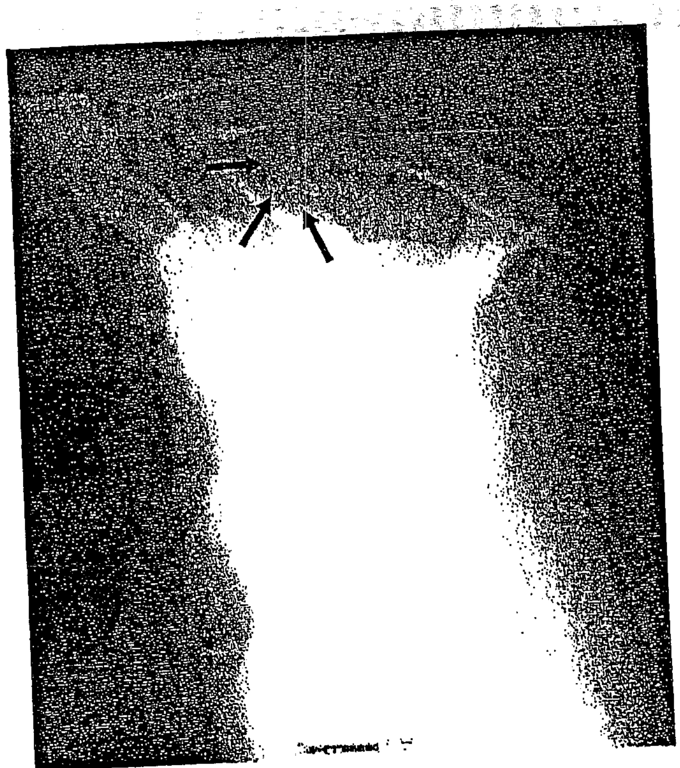
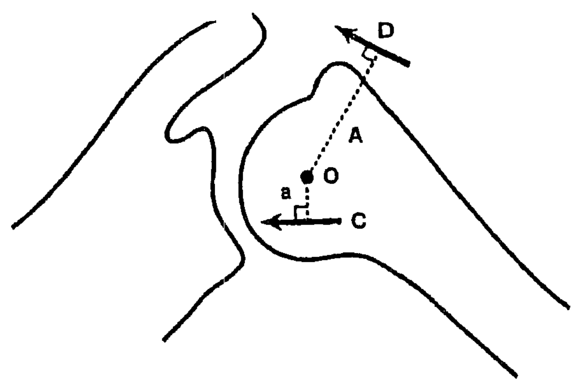


Fig 13-3. Radiograph of subacromial outlet reveals sharp, bony excresence (*arrows*) originating from coracoacromial ligament attachment site.

supply to the rotator cuff (13–15). Lindblom has described an area of avascularity in the supraspinatus tendon proximal to its insertion into the greater tuberosity (16,17) **(Fig 13-2)**. Other authors have reported a dynamic reason for the decreased vascularity within the supraspinatus tendon, citing a "wringing out" effect with supraspinatus tension (18). Benjamin (19) described the histological transition that takes place from tendon to calcified fibrocartilage to bone, accounting for the vascular differences at the insertion site. The zone of uncalcified fibrocartilage is more avascular with respect to the other zones and may be vulnerable to delayed or incomplete healing when traumatized.

The subacromial arch is defined as the space between the distal clavicle and acromion superiorly and the humeral head inferiorly. This space between the acromion and humeral head averages 8 to 12 millimeters on plain x-ray, and can be further divided into the coracoacromial arch which is formed by the acromion, coracoacromial ligament and the coracoid process. As the rotator cuff passes beneath this arch, contact between the tendons and the arch can occur, leading to tendon pathology as well as secondary changes to the arch in the form of traction-based ossification within the coracoacromial ligament at the acromial attachment site (20–26) **(Fig 13-3)**.



$$\Sigma M_o = O = C \times a - D \times A$$
$$D \times A = C \times a$$

Fig 13-4. Coronal plane force couple. The inferior portion of the rotator cuff (below the center of rotation) creates a moment that must balance the deltoid moment. *(C)*, resultant rotator cuff forces; *(D)*, deltoid muscle force; *(O)*, center of rotation; *(a)*, moment arm of the inferior portion of the rotator cuff; *(A)*, moment arm of the deltoid. (From Lo IK, Burkhart SS. Current concept in arthroscopic rotator cuff repair. *Am J Sports Med*. 2003;31:308-324; reprinted with permission.)

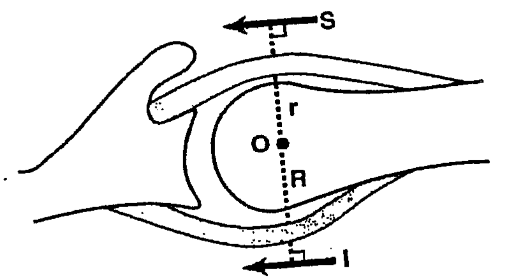
Function

The rotator cuff muscles centralize the humeral head and permit a single center of rotation while providing stability and strength. During active shoulder elevation, the rotator cuff muscles depress the humeral head, allowing efficient elevation of the extremity while the head remains reduced in the glenoid (27–30). Studies have been performed evaluating the individual rotator cuff muscles and their respective contribution to shoulder strength. The supraspinatus and infraspinatus provide approximately 45% of abduction strength and the infraspinatus contributes nearly 90% of external rotation power (31,32). The supraspinatus and deltoid muscles provide balancing forces in the coronal plane of motion (33) **(Fig 13-4)**.

The importance of balanced force couples cannot be overemphasized, and the goal of surgery, when necessary, should be to properly and anatomically restore these forces such that their counteraction is maintained. Furthermore, the importance of the transverse force couple and the need for balanced function in this plane was further emphasized by Burkhart (34–38) **(Fig 13-5)**. Loss of greater than half of the infraspinatus or loss of subscapularis function leads to superior humeral head migration, a phenomenon often detected on plain films as the acromial-humeral head distance diminishes to less than 7 millimeters **(Fig 13-6)**.

If the coronal and transverse force couples remain functional and balanced, the end result is a properly centered humeral head and surprisingly good function even if a significant, possibly irreparable tear is present. Burkhart remains a pioneer in helping us recognize that torn rotator cuffs can be very functional and that attempting to "cover the humeral head" utilizing nonanatomic tissue re-approximation is an approach that must be avoided (35). Burkhart's concept of partial repairs in an effort to restore force couples has been successfully applied in lieu of tendon transfers that may serve only to weaken the balanced force couple (36–40).

Although there has been speculation that the biceps serves as a humeral head depressor and maintains an active role in shoulder function, comparative anatomic studies (41) as well as electromyographic data indicate that the biceps probably does not function as a humeral head depressor (42), and that the hypertrophy often encountered in the massive rotator cuff tear may be inflammatory in origin (43) as opposed to a reflection of intrinsic strengthening (44). There is some evidence from EMG studies that the biceps may serve as an additional shoulder stabilizer in those with anterior shoulder instability (45,46).



$$\Sigma M_O = O = IxR - Sxr$$
$$\therefore IxR = Sxr$$

Fig 13-5. Transverse plane force couple *(axillary view)*. The subscapularis tendon anteriorly is balanced against the infraspinatus and teres minor tendons posteriorly. *(I)*, infraspinatus; *(S)*, subscapularis; *(o)*, center of rotation; *(r)*, moment arm of the subscapularis tendon; *(R)*, moment arm of the infraspinatus and teres minor tendons. (From Lo IK, Burkhart SS. Current concept in arthroscopic rotator cuff repair. *Am J Sports Med*. 2003;31;308-324; reprinted with permission.)

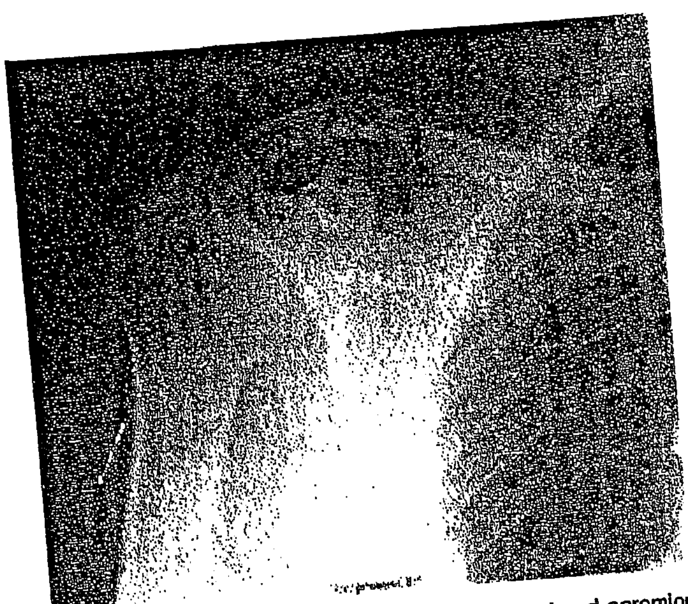


Fig 13-6. Loss of interval between humeral head and acromion indicates massive rotator cuff tear and compromised humeral head containment.

Pathoanatomy

Before describing the mechanics of rotator cuff pathology, post-mortem studies provide an interesting backdrop to the issue of etiology. There is little doubt that rotator cuff tearing is a function of age among other factors. Post-mortem studies have indicated an incidence of full or partial thickness tears ranging from 5% to nearly 40% (47–51). Fukuda et al. (52) reported a 13% incidence of partial rotator cuff tears in a cadaveric study of 249 anatomic specimens. The prevalence of these partial thickness tears appears to increase with age. DePalma (53) studied 96 shoulders of patients aged 18 to 74 years without a history of shoulder dysfunction and found an incidence of partial ruptures of the supraspinatus tendon in 37%. Petersson (54) reported on 27 asymptomatic patients ranging from 55 to 85 years of age with a nearly 50% incidence of full or partial thickness tears based on arthrographic studies. Suffice to say that tearing of the rotator cuff as a function of age is clearly a common occurrence. Furthermore, many of these tears, both full thickness and partial, may be clinically silent (10,49,55). As clinicians, we must be cautious in attributing causation to findings detected during diagnostic testing as these results may simply reflect the senescence process without significant clinical sequelae.

After a tear is noted, its natural history deserves attention. Several authors have reported on the progression of partial to full thickness tears (49,56,57). There is also evidence that full thickness tears are unable to heal spontaneously although an ineffective healing response may occur (58,59). Codman (60) believed that spontaneous healing of partial tears might occur, yet histological studies of partial thickness rotator cuff tears has yielded no evidence of active repair (61). Yamanaka (56) studied 40 patients with symptomatic articular-sided partial rotator cuff tears treated nonoperatively with serial arthrography. Repeat arthrography revealed that 10% of the tears had presumably healed, 10% had decreased in size while enlargement of tear size occurred in 51%, and 28% progressed to a full thickness tear. A study comparing operative and nonoperative treatment for full-thickness rotator cuff tears concluded that larger rotator cuff tears in older individuals most likely progress in size although they can remain clinically quiescent (48). The study also concluded that the results of rotator cuff repair are clearly superior to that achieved with nonoperative measures only.

In a compelling longitudinal study of the natural course of rotator cuff tears, Yamaguchi et al. (49) reported on the risk of progression of asymptomatic rotator cuff tears detected by ultrasound in 58 patients with unilateral symptoms and bilateral rotator cuff tears. Fifty-one percent of asymptomatic tears became symptomatic over a three-year follow-up period. Nine of 23 patients restudied with ultrasound clearly demonstrated an increase in tear size, and no patient showed evidence of healing.

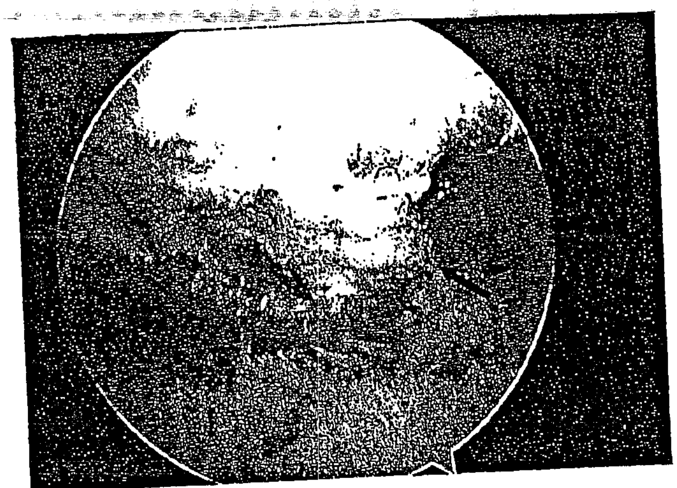


Fig 13-7. Arthroscopic view of a symptomatic acromial spur (*arrows*) after coracoacromial ligament release in subacromial space of a left shoulder.

Etiology

When considering the possible causes of rotator cuff disease, mechanical impingement of the rotator cuff is considered the most common recognizable source of recurring pain and disability in the active population. Neer's classic work (20,62) served to organize the clinician's approach to rotator cuff disease and, most importantly, to define rotator cuff pathology as a spectrum of disease ranging from reversible edema to cuff fiber failure.

Primary impingement occurs at the anterior one third of the acromion and coracoacromial arch (24,63–68). The mechanical stresses endured by the rotator cuff, as well as its poor vascular design, both dynamic and static, have been well documented (13–17). Additional factors influencing rotator cuff pathology include acromial shape (20,22,24, 69–71), slope (21,72–75), coracoacromial ligament size (76,77), postfracture deformity, os acromiale (78–82) and acromioclavicular joint spurring (24,83). Snyder (72) has recently reported on the "keeled" acromion, a particularly pernicious acromial variant associated with rotator cuff injury.

Functional abnormalities, such as asynchronous shoulder motion, posterior capsular contractures, scapular dyskinesia, glenohumeral instability, and distant neurological injury leading to weakness can also adversely affect the rotator cuff on a secondary basis with increased impingement forces concentrated in the subacromial space (84,85,86,87).

Impingement may occur from a direct mechanical insult, usually the result of an acromial excrescence excoriating the bursal aspect of the rotator cuff (**Fig 13-7**). However, another plausible injury cascade begins with intrinsic cuff failure, leading to insufficient humeral head depression and subsequent superior migration with creation of a traction spur within the coracoacromial ligament as a secondary phenomenon (24,26,68,71). The cause for intrinsic cuff failure can range from fatigue on an overuse basis to underlying shoulder instability or superior labral pathology, injuries that have been associated with internal impingement and articular sided cuff failure (88–93). Regardless of etiology, a narrowed or stenotic supraspinatus outlet poses continued risk to the rotator cuff.

CLINICAL EVALUATION

History

Rotator cuff disease, especially that related to the impingement phenomenon, is usually evident from the history alone. A painful range of motion beginning at 70 degrees of forward flexion through 120 degrees is commonplace with pain localizing to the anterior-superior shoulder, often radiating down the lateral upper arm into the deltoid insertion. Overhead activities are the most provocative, and in instances where the rotator cuff has actually torn, night pain and difficulty sleeping are common complaints. Motion is usually not restricted, other than that due to pain; however, for longer standing injuries, a secondary adhesive capsulitis pattern can be encountered, especially in the older population. Most often the onset of pain is insidious and takes place over a longer period of time, but for those with an acute injury, a tearing sensation associated with profound early weakness may be the presenting history.

Because rotator cuff disease reflects a spectrum of pathology, the history and physical findings may overlap. There may be little difference in the presentation and findings of patients with isolated impingement, partial and even small full thickness rotator cuff tears.

Physical Examination

After completing a detailed history, a focused examination can be undertaken. It is critical to compare extremities as the unaffected shoulder can serve as a "normal" template to

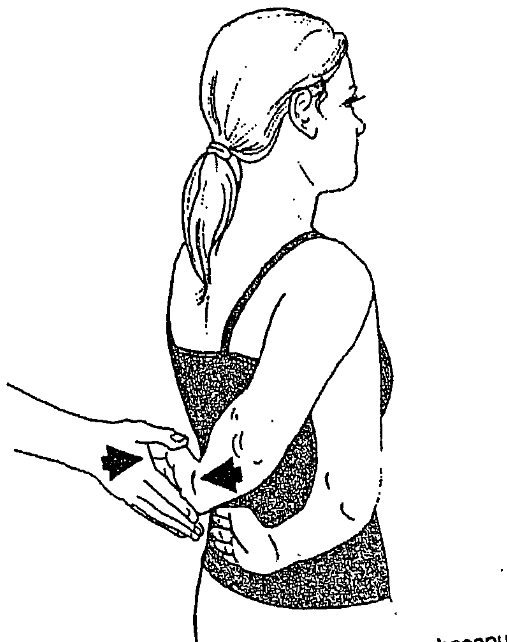


Fig 13-8. Lift-off test evaluating integrity of the subscapularis. May be difficult position to achieve in patients limited by pain and motion restrictions.

which one can compare. One should survey for atrophy or asymmetry, especially in the supra and infraspinatus fossae. Long-standing rotator cuff tears are often accompanied by significant, visible atrophy. Examination should include assessment of range of motion, both active and passive, observing forward flexion, abduction in the scapular plane, internal rotation, and external rotation both in abduction and with the elbow at the side. Careful evaluation of scapular tracking should be included as poor scapulo-thoracic mechanics can lead to secondary subacromial pathology. In some instances of suspected impingement, simply treating scapular dyskinesia can alleviate secondary subacromial space symptoms (84,86,87). Strength testing should be performed in an attempt to isolate the different components of the rotator cuff to assess weakness. The "lift-off" test can help to assess subscapularis integrity (94) (Fig 13-8).

Although clinically useful, placing the arm in the testing position can be provocative and difficult to achieve, especially in the older population. The "belly-press" test (or Napolean sign) can also help determine integrity of the subscapularis, is less provocative than the "lift-off" test and can actually be quantified to assess partial tears as well (95,96) (Fig 13-9).

Resisted external rotation with the elbow by the side is useful in detecting tears extending into the infraspinatus

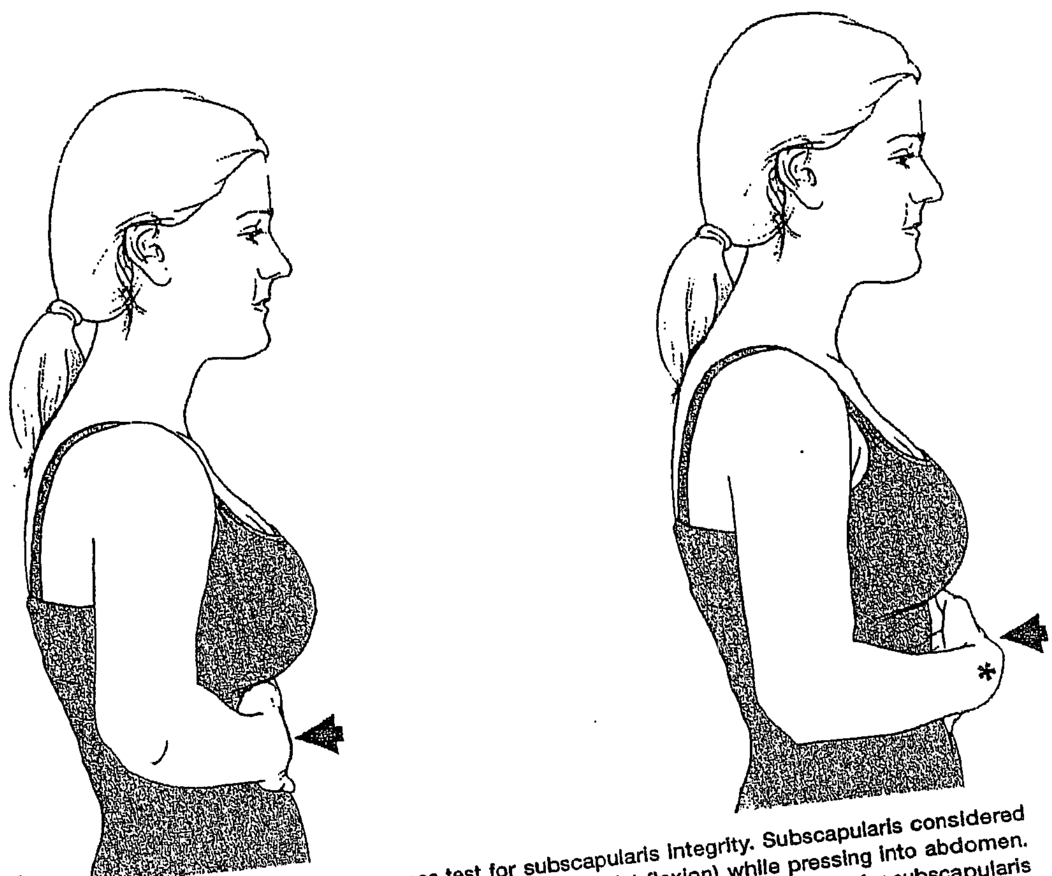


Fig 13-9. A: Alternative belly-press test for subscapularis integrity. Subscapularis considered intact if wrist and elbow remain in straight line (no wrist flexion) while pressing into abdomen. B: Positive belly-press test for injured subscapularis as wrist flexion substitutes for subscapularis while pressing against abdomen.

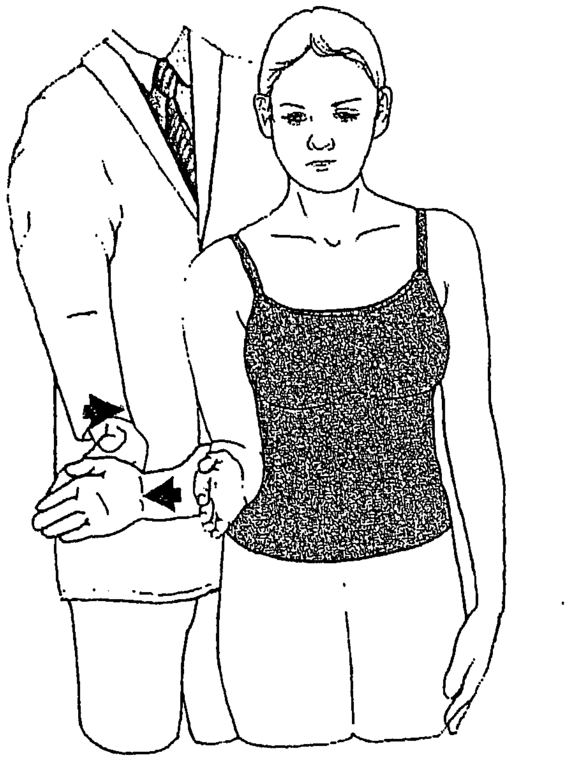


Fig 13-10. External rotation testing evaluates infraspinatus and teres minor integrity. Weakness indicates loss of posterior transverse force couple.

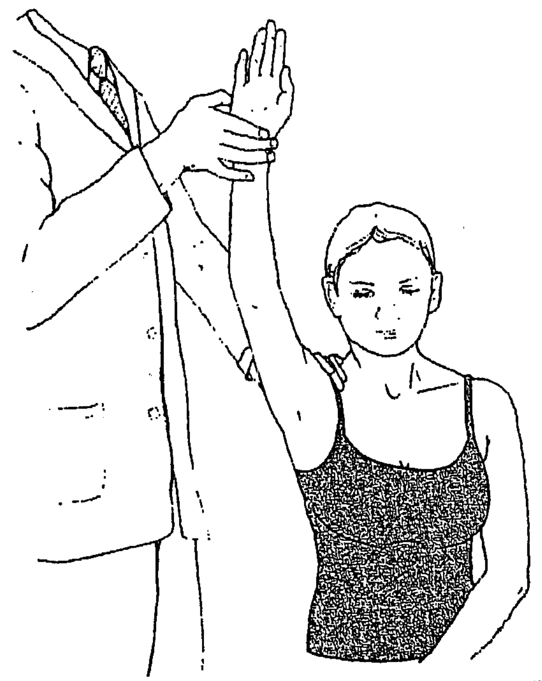


Fig 13-12. Neer sign for impingement. Neer test utilizes the same maneuver following a subacromial injection of anesthetic. Amelioration of pain confirms diagnosis of impingement.

(Fig 13-10). This manual test is critical for assessing the posterior transverse force couple while the "belly-press" test determines subscapularis function. If significant weakness is noted in either or both muscle groups, loss of humeral head containment is imminent if not already present. Loss of the normal distance between the humeral head and acromion should be evident, and one must proceed with great caution if a decompression is undertaken. Violation of the arch in conjunction with inadequate transverse force couples may ultimately lead to erosion of the acromion by the humeral head and subsequent anterior-superior humeral head migration (97–99) (Fig 13-11).

Fig 13-11. Loss of humeral head containment and anterior-superior subluxation can result from acromioplasty if transverse force couples are compromised. Humeral head can erode through the thinned acromion.

The impingement sign (Fig 13-12) as originally described by Neer involves stabilizing the scapula while elevating the shoulder in the scapular plane. Pain elicited in the arc from 70 to 120 degrees is indicative of the impingement phenomenon. Confirmation of this finding in the form of the impingement test consists of complete resolution of pain during the painful arc of motion after an anesthetic has been injected into the subacromial space.

A variation of the impingement sign is the Hawkin's test (Fig 13-13) in which the shoulder is placed in 90 degrees of forward flexion, the elbow is flexed 90 degrees and the shoulder is then internally rotated. Rotation of the greater tuberosity under the arch in this position decreases space for the rotator cuff leading to impingement pain.

Diagnostic Imaging

It is essential that the initial evaluation of the painful shoulder include quality plain radiographs. The standard radiographs should include a true anterior-posterior view with the shoulder in the internal and neutral position, an axillary view, and the outlet (supraspinatus) view described by Neer and Poppen (100), which is used to evaluate and classify acromial morphology and arch anatomy. Bigliani et al. (69)

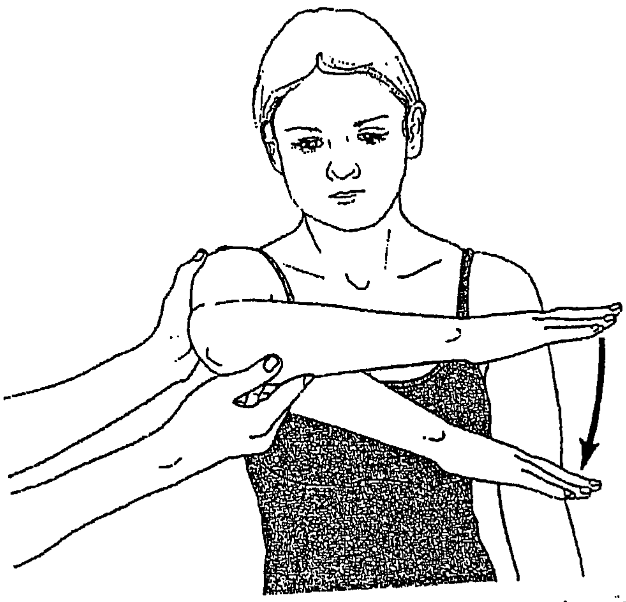


Fig 13-13. Positive Hawkins sign, indicative of subacomial impingement, is elicited when pain occurs as the shoulder is internally rotated with the shoulder forward flexed 90 degrees.

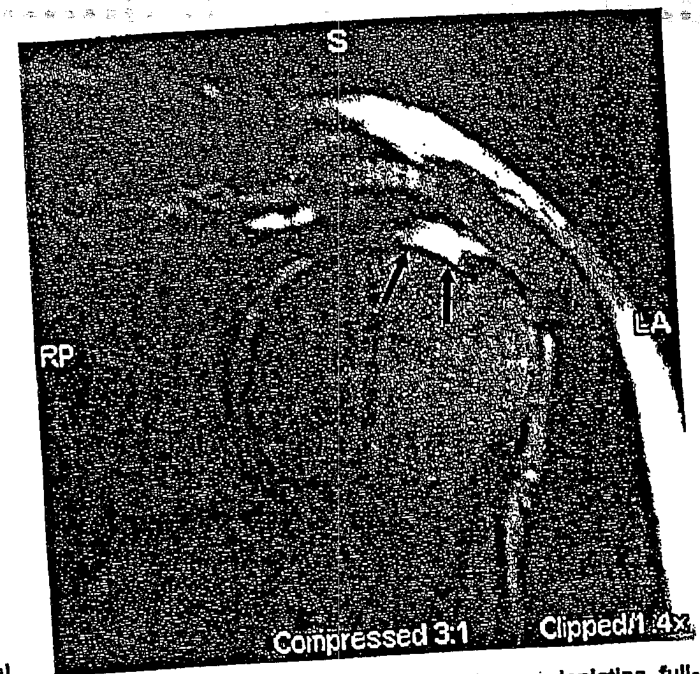


Fig 13-15. Coronal MR T-2 weighted image depicting full-thickness rotator cuff tear (*arrows*); fluid filling the gap is enhanced on T-2 imaging.

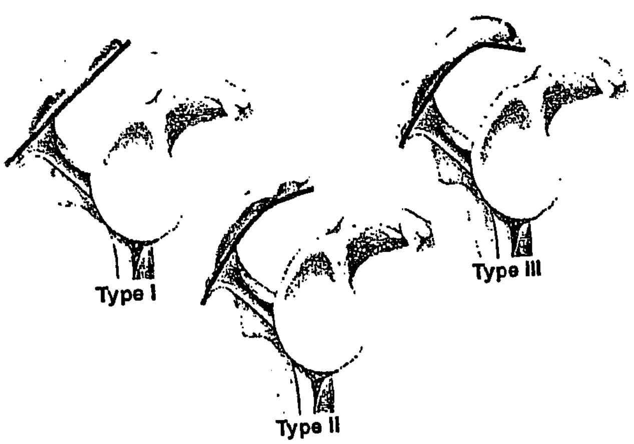


Fig 13-14. Acromial shape can be categorized into Type I: flat, Type II: curved, and Type III: hooked. Type III associated with impingement anatomy.

have classified the types into I flat, II curved, and III hooked (Fig 13-14). In addition to establishing morphology, the thickness of the acromion should also be assessed and if surgery is recommended, a pre-operative decision can be made regarding the amount of bone to be resected so as to prevent excessive thinning or inadequate bone resection.

The standard anterior-posterior views may show superior migration of the humeral head consistent with a cuff tear and potential subscapularis involvement. Cystic and/or sclerotic change in the greater tuberosity may also signal tendon pathology. The axillary view is most helpful in assessing concomitant glenohumeral degenerative changes, but is most helpful in establishing the presence of an os acromiale (78,79).

Magnetic resonance imaging is the current test of choice when evaluating the soft tissues of the shoulder (101,102). T1 weighted images revealing increased signal in the rotator cuff combined with a focal defect or loss of continuity of the cuff on the T2 weighted image is a common finding when a full or partial- thickness tear is encountered (Fig 13-15). The addition of a contrast agent such as gadolinium significantly enhances the positive predictive value for diagnosing a full thickness tear, and can also aid in detecting and quantifying partial tears of the cuff as well (103,104). Several studies have demonstrated a poor correlation between arthroscopic findings and MRI abnormalities (105,106). The combination of fat suppressed images combined with contrast has been reported to significantly improve the sensitivity and specificity for detecting full and partial thickness cuff tears (107).

One must exercise caution when interpreting MR findings because asymptomatic individuals may have significant rotator cuff findings on MRI, but may remain completely asymptomatic (55). Magnetic resonance imaging continues to demonstrate its greatest utility and potential when combined with a thorough and reliable history and physical examination.

Although an MRI scan is not essential for every patient with shoulder pain, for those anticipating a surgical procedure, a pre-operative MRI scan can be helpful for the following reasons: evaluating whether a cuff tear accompanies a suspected impingement syndrome, the presence of which would alter the post-operative regimen, allowing the patient to properly plan for post-operative care; determining the size and potential tear configuration, including retraction, delamination, and thinning, factors that need to be considered in the surgical planning; assessing the presence or absence of atrophy (Fig 13-16) or fatty infiltration (Fig 13-17), both important prognostic factors (108–110); and establishing the presence of co-morbidities such as partial biceps or labral tears.

Fig 13-16. Oblique sagittal view through supraspinatus fossa demonstrates atrophic changes (*arrows*) within the supraspinatus muscle belly which should completely fill the fossa.

Fig 13-17. Oblique sagittal view through the supraspinatus fossa demonstrating fatty infiltration within the substance of the muscle belly. Fatty streaks within the subscapularis and infraspinatus are also visible.

DECISION-MAKING AND TREATMENT

Because rotator cuff pathology can represent as a wide spectrum of disease, there is some utility to compartmentalizing the most common entities in an effort to develop algorithms which guide treatment. The management of impingement with or without associated cuff tearing, partial thickness-tears and full-thickness rotator cuff injuries will be the primary topics of this section.

Impingement: Primary

Impingement of the tendinous portion of the rotator cuff as it passes under the coracoacromial arch is a classic cause of rotator cuff injury. The impingement syndrome, as originally described by Neer (20), encompasses a spectrum of pathologic changes involving the rotator cuff and associated bony changes within the coracoacromial arch, affecting primarily those 40 years of age and older. When impingement-type symptoms present in a younger population, great care must be taken to avoid over-diagnosing and over-treating as the impingement may be internal or secondary to instability, which effectively moves the cuff closer to the arch (87,90,93). Middle-aged to older patients presenting with impingement symptoms are generally recreational overhand athletes or individuals whose occupation requires repetitive, forceful overhead work. These patients present with chronic, low-level shoulder pain that is exacerbated with overhead activity or motions that necessitate internal rotation of the humerus in the abducted position, such as reaching behind a car seat. The pain usually localizes to the anterosuperior shoulder with radiation into the deltoid insertion region, following the course of the underlying bursa and capsule. Frequently, the primary reason for presenting to the orthopaedic surgeon is sleep disturbance.

Treatment of impingement syndrome is patient specific. After the diagnosis has been made, the varying degrees of pathology and patient expectations must be considered. To assist in developing a treatment plan, Neer (20) described the three stages of rotator cuff involvement: Stage 1: reversible edema and inflammation; Stage 2: tendon fibrosis and chronic inflammation, a stage that has been further subcategorized (74) into Type 1 without a cuff tear and Type 2 associated with a partial thickness tear; and Stage 3 complete fiber failure with a full thickness tear. Knowing the status of the rotator cuff is critical in making therapeutic decisions.

If impingement is diagnosed, the initial treatment should be conservative. Great care should be taken to evaluate the scapula and to diagnose any associated dyskinesia. In addition

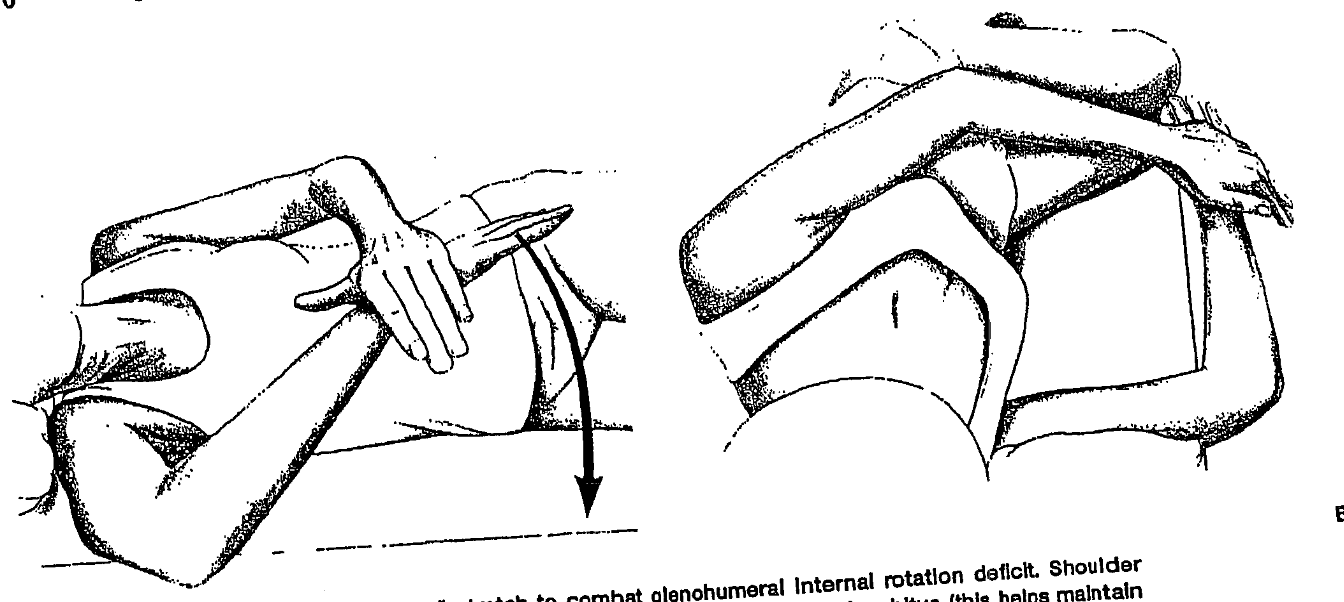


Fig 13-18. A: "Sleeper" stretch to combat glenohumeral internal rotation deficit. Shoulder abducted 90 degrees with patient in 60 to 70 degrees of lateral decubitus (this helps maintain scapular stability to prevent substitution). Elbow maintained in 90 degrees of flexion while internal rotation generated with opposite extremity. B: "Sleeper" stretch from superior view.

to proper activity modification, physical therapy exercises can be of great benefit, focusing not only on rehabilitating the rotator cuff musculature, but also on re-establishing a full, pain-free range of motion and normal scapulo-thoracic rhythm and strength. The net effect of a proper rehabilitation program should result in decreased inflammation and thickening in the subacromial space as well as an increase in the interval between the humeral head and acromion.

The younger overhand athlete with impingement-type pain should be carefully examined for a functional loss of internal rotation. A tight posterior capsule tends to shift the humeral head in a posterior-superior direction leading to rotator cuff symptoms. By simply stretching the posterior capsule using the "sleeper" stretch (Fig 13-18), resolution of symptoms can often be achieved in this population of patients. Nonsteroidal anti-inflammatory medication is appropriate to assist in decreasing associated soft tissue swelling while, on occasion, the judicious use of a steroid can be very helpful when introduced into the subacromial space (110).

For those who fail conservative care, surgery may be appropriate. Most patients who respond to a nonoperative program will do so within a six-month period (10,48). If surgery is indicated, an MRI may prove useful to determine whether or not there is concomitant significant cuff pathology. If the cuff is intact, a simple subacromial decompression should be performed (Fig 13-19). If the impingement has resulted in associated cuff tearing, the tear may need to be repaired in addition to the decompression.

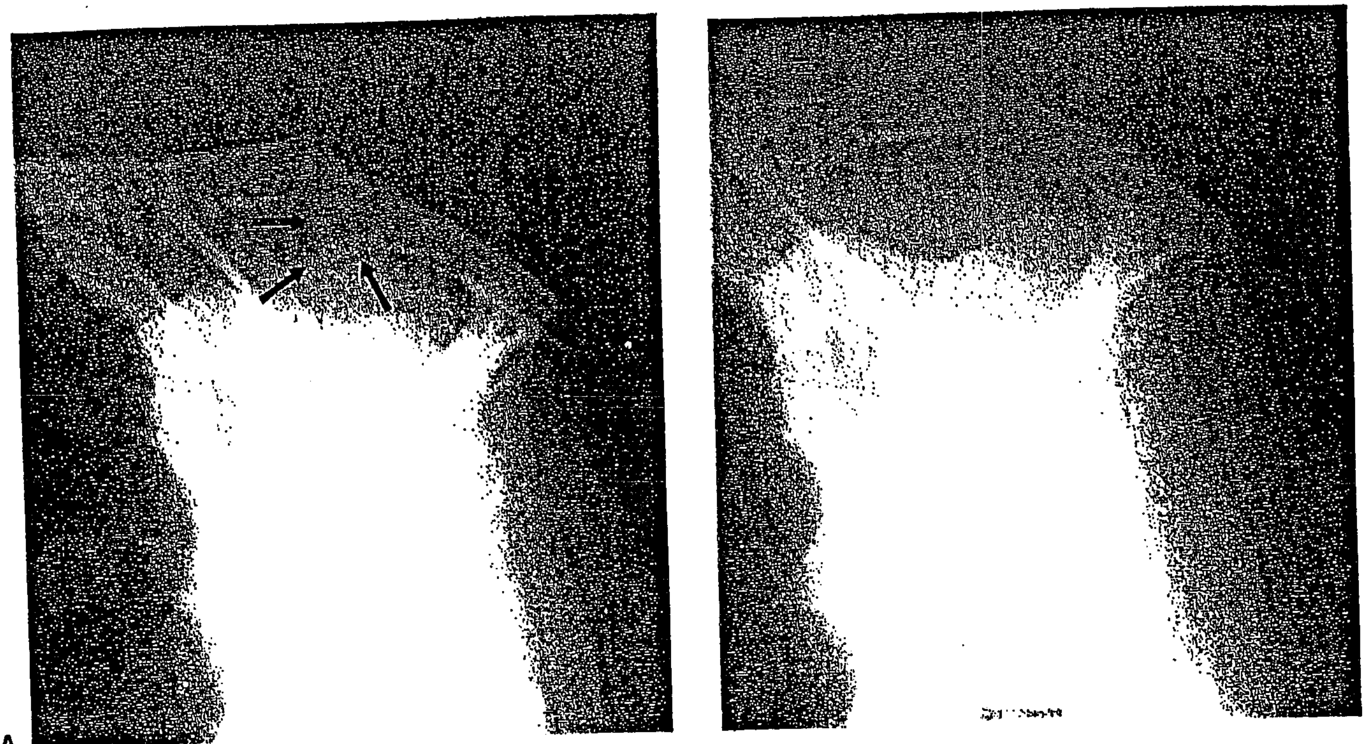
In the properly selected patient, the results of subacromial decompression have been reliable and durable (66,67, 111–114). Although there are several described surgical techniques for subcromial decompression (115), the "cutting block" approach may be the most reliable with regard to referencing the final result against known anatomic guidelines (116) (Fig 13-20). Furthermore, pre-operative planning should include the shape and width of the acromion such that over or under-resection is avoided (117).

Subacromial decompression has become one of the most common procedures performed by the orthopaedist, and although a success rate of nearly 90% has been reported for isolated decompressions, a word of caution is warranted. Failures can and do occur. Authors have reported failure rates ranging from 5% to 40% (118–120). Despite appropriate treatment, complications and unsatisfactory results can occur (118,121–123). When a failed acromioplasty is encountered, it is incumbent upon the treating surgeon to invoke a systematic, thorough analysis of the failed acromioplasty. The work-up should attempt to answer the follow questions: Was the initial diagnosis correct? Was the appropriate operation chosen? Was the procedure performed technically correctly? Was associated pathology recognized? Was the postoperative rehabilitation timely and appropriate?

As these questions are answered during the re-evaluation, the cause for failure can be established and categorized as initial diagnostic error, treatment failure, or a complication of treatment, and then appropriately treated.

Impingement: Secondary

Individuals with shoulder instability or other underlying pathology can develop significant abnormal mechanics that can lead to rotator cuff functional disability, eventual fatigue and loss of humeral head containment. When this occurs, rather than the coracoacromial arch moving toward the cuff, the cuff migrates cephalad as containment is compromised. In addition to articular-sided internal impingement-type



A B

Fig 13-19. A: Type III acromion (*arrows*) contributing to classic external impingement phenomenon. B: Appearance of acromial outlet after acromioplasty.

rotator cuff tearing, secondary changes, including traction spurring of the CA ligament and abrasive changes of the bursal aspect of the cuff can be encountered.

Several investigators have described partial articular-sided rotator cuff tears resulting from internal impingement (68,88,90–93). This entity represents contact between the undersurface of the cuff and the posterior-superior glenoid and labrum. There exist a plethora of potential causes for

Fig 13-20. Cutting-block technique for precision acromioplasty.

internal impingement including physiologic to pathologic change from repetitive intra-articular contact, torsional forces created by loss of humeral head retroversion, ligamentous insufficiency and abnormal mechanics, especially with regard to scapular dyskinesia. These patients are younger, and often complain of pain localizing to the posterior shoulder. They also complain of early fatigue and loss of control in the throwing motion. Fatigue of the dynamic stabilizers and excessive external rotation secondary to overstretching of the anterior capsule may predispose individuals to development of internal impingement. A subset of patients, usually baseball pitchers, develop a glenohumeral internal rotation deficit (GIRD syndrome) with a significant loss of internal rotation on the affected side (93) (Fig 13-21). This contracture initiates a cascade of kinematic abnormalities that can result in increased torsional strain within the cuff, labral abnormalities and tertiary capsular insufficiency, all implicated in the secondary articular-sided partial cuff tears. In later stages, the ability to discriminate between primary and secondary impingement may be challenging. Even if a primary instability is present and treatment is directed toward correcting the primary pathology, consideration of subacromial debridement up to and including bony resection must be considered as part of the overall treatment regimen if changes such as bursal-sided cuff tearing and fraying of the coaracoacromial ligament are witnessed. The real challenge for the clinician is to carefully evaluate these patients to assign the correct diagnosis before proceeding with surgical treatment. Performing a subacromial decompression without treating

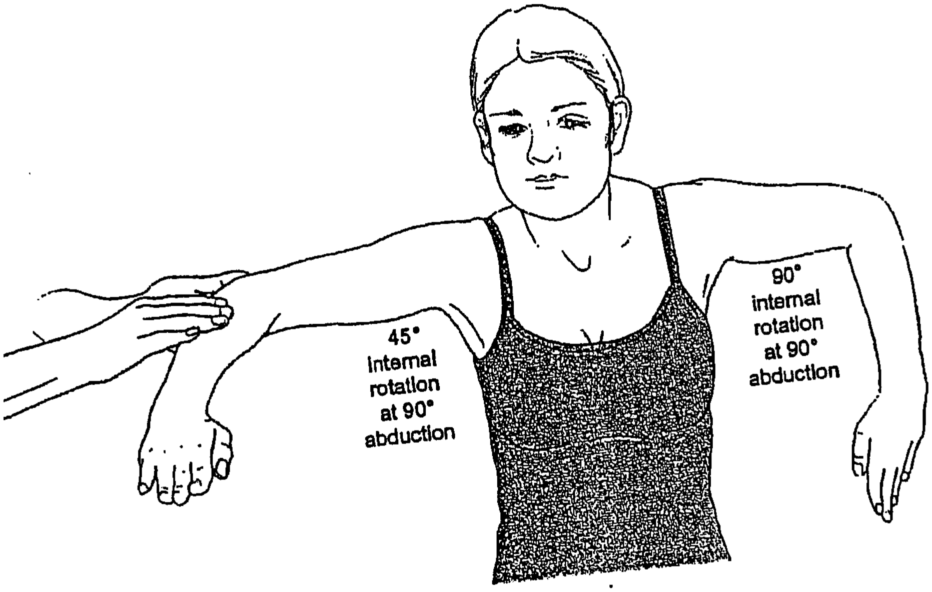


Fig 13-21. Typical physical findings in patient with glenohumeral internal rotation deficit. Scapula must be stabilized while testing range of motion.

instability in those with underlying symptomatic shoulder laxity can serve to worsen the degree of instability (124).

Partial Thickness Rotator Cuff Tears: Treatment

Partial thickness rotator cuff tears can result from intrinsic cuff degeneration and tendinopathy absent an injury or impingement. The lack of uniformity of collagen bundles and the paucity of vascular supply contributes to weakness, especially along the articular aspect of the rotator cuff (4,5, 9–13,125). These degenerative tears often exit the articular surface and can be well visualized at surgery, but sometimes can be entirely contained within the cuff (intrasubstance), and therefore easily missed.

As noted earlier, extrinsic impingement due to narrowing of the supraspinatus outlet can result in chronic cuff abrasion leading to a partial cuff tear. Histological changes consistent with trauma have been found on the undersurface of cadaveric acromion specimens with bursal surface tears but not in those with articular surface tears (126). This suggests that bursal-surface tears may be more likely to be related to abrasion of the cuff by the acromion. Furthermore, extrinsic impingement due to coracoacromial arch narrowing has been postulated to cause partial tears on the articular side as well as the bursal surface of the cuff based on transmural shear stress (127) leading to fiber failure of the laminated cuff.

Trauma, absent impingement, can cause a partial thickness tear, usually leading to a partial avulsion of the articular surface of the cuff. This can be the result of repetitive microtrauma or simply a single high-energy episode. This type of avulsion injury has been named the "PASTA" lesion (partial articular sided tendon avulsion) (128).

The symptoms of partial thickness rotator cuff tears are nonspecific and may overlap with impingement, rotator cuff tendonitis, and small, full thickness rotator cuff tears. Similar to the impingement population, most patients have a painful arc of motion between 60 and 120 degrees of elevation. They may also have loss of motion with posterior capsular tightness and resultant restriction of internal rotation.

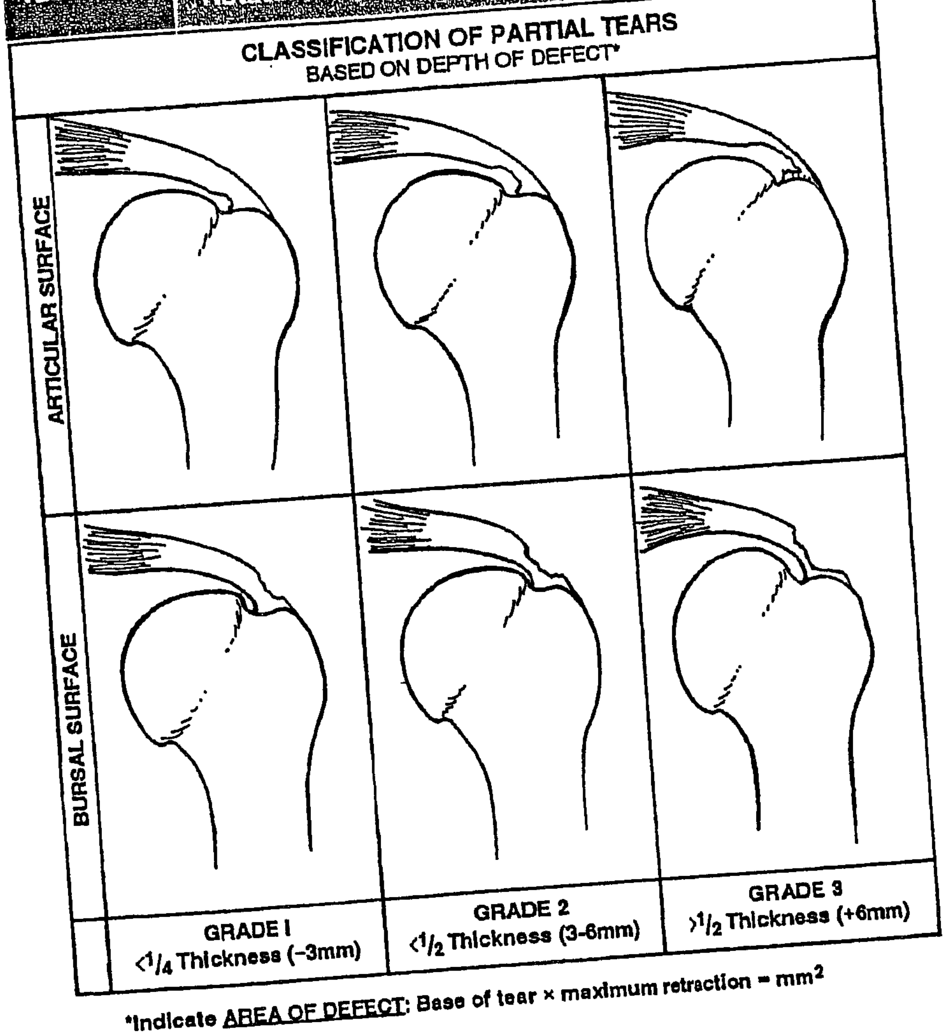
The impingement signs described by Neer (pain with forced passive forward elevation) and Hawkins (pain with passive internal rotation of the arm placed in 90 degrees of forward flexion) are positive in nearly all patients with symptomatic partial thickness rotator cuff tears. Strength is usually preserved on clinical examination; however, pain inhibition may result in an apparent loss of strength and in a decrease in active range of motion in these patients with a partially torn rotator cuff.

The clinical course of patients with partial thickness rotator cuff tears is often indistinguishable from that of patients with impingement syndrome, tendonitis, or small, full thickness rotator cuff tears. Symptoms may also be difficult to differentiate from bicipital tendonitis, labral or SLAP lesions, and mild cases of adhesive capsulitis.

There is currently no universally accepted classification system for partial thickness rotator cuff tears. Evaluating the results of treatment has been challenging due to this lack of conformity. Although the classification of partial tears continues to be refined, the system most commonly used is that proposed by Ellman (129) in which the depth of the tear is estimated: Grade I: 1-3 mm, Grade II: 3-6mm, and Grade III: 6mm or greater (**Table 13-1**).

Anatomic knowledge of the "footprint" makes this assessment more uniform and reproducible. If the average supraspinatus "footprint" is approximately 12 mm in size, it is possible to grade the percentage of tearing. Using the "footprint" as a guide, if more than 6 mm of the footprint is exposed, a greater than 50% tear of the supraspinatus insertion has

Table 13-1 Ellman Classification for Partial-thickness Rotator Cuff Tears



occurred (8). Snyder (10) has proposed a grading system in which the articular and bursal sides of the cuff are evaluated separately in an effort to be more precise in judging severity (**Table 13-2**).

Individuals with a suspected partial tear due to extrinsic impingement or intrinsic tendinopathy are treated in a similar fashion as those with impingement syndrome. Subacromial bursal inflammation is controlled with activity modification, nonsteroidal anti-inflammatory medication, and the judicious use of injectable corticosteroids. The role of rehabilitation to restore normal joint mechanics and strengthen the rotator cuff and parascapular musculature has been proposed to reduce the progression of rotator cuff disease in those with both external and internal impingement. The role of the external rotators which act as humeral head depressors may play a role in reducing external impingement thus reducing further mechanical impingement of the cuff from the coracoacromial arch.

Partial thickness tears that fail to respond to conservative measures usually require surgical intervention, including debridement alone, debridement in conjunction with a subacromial decompression, and decompression combined with a rotator cuff repair, either mini-open or arthroscopic.

Arthroscopic debridement alone of partial tears has led to mixed results (113,130,131). One study evaluating the results for decompression alone recorded failure rates exceeding 50% (132). Furthermore treating a partial tear without addressing potential underlying causes such as instability has also been associated with a high failure rate (88).

Arthroscopic subacromial decompression combined with arthroscopic debridement of partial tears has also led to mixed results. Several investigators have described failure rates ranging from 20 to 30% in this treatment group (133–135). Ryu (66) reported on 35 patients treated with an arthroscopic subacromial decompression and debridement with a follow-up of 23 months and had 86% good results with

Table 13-2 Snyder Classification System for Grading Partial-thickness Rotator Cuff Tears

Location of Tears	
A	Articular surface
B	Bursal surface
Severity of Tear	
0	Normal cuff, with smooth coverings of synovium and bursa
I	Minimal, superficial bursal or synovial irritation or slight capsular fraying in a small, localized area; usually <1 cm
II	Actually fraying and failure of some rotator cuff fibers in addition to synovial, bursal, or capsular injury; usually <2 cm
III	More severe rotator cuff injury, including fraying and fragmentation of tendon fibers, often involving the whole surface of a cuff tendon (most often the supraspinatus); usually <3 cm
IV	Very severe partial rotator tear that usually contains, in addition to fraying and fragmentation of tendon tissue, a sizable flap tear and often encompasses more than a single tendon

bursal sided tears exhibiting a more favorable result as compared to articular-sided lesions.

Because of concerns about cuff integrity and tear progression, repair of extensive partial rotator cuff tears has been recommended (52,57,134,135). Ellman (134) was one of the first to recommend arthroscopic subacromial decompression along with open repair of significant, partial tears of the rotator cuff. Fukuda (61), reporting on 66 patients with partial tears treated with an open acromioplasty and repair, achieved satisfactory results in 94% of his patients.

Weber (136) has documented the clear advantage of repairing separate partial thickness tears in conjunction with subacromial decompression. His re-operation rate was significantly lower for those treated with a concomitant repair versus those who simply underwent a debridement. In another study, Weber (137) determined that by completing the articular-sided tear, excising unhealthy tissue and advancing healthy tendon back to its attachment site, an all-arthroscopic approach led to results equal to those reported with the mini-open technique.

Bursal-sided partial tears of the rotator cuff are usually a direct result of mechanical impingement occurring at the arch. These injuries are readily visualized at surgery and the depth of the tear can be accurately estimated in most cases. For those with a Grade I or II partial tear in conjunction with impingement, a simple debridement in association with a subacromial decompression may be the most appropriate treatment. For those individuals who have a significant partial tear, Grade III, and higher post-operative expectations of their shoulder, a more aggressive approach including repair of the partial tear in addition to the decompression may be more suitable.

The articular-sided tears occur two to three times more commonly than bursal-sided tears, and may not necessarily be associated with the impingement phenomenon. Repetitive traction forces or underlying primary pathology such as a superior labral injury or symptomatic capsular redundancy can result in articular-sided cuff tears. Additionally in some instances, internal impingement may be the source of the tearing. The GIRD syndrome (glenohumeral internal rotation deficit) has been established as a common pathway for articular-sided partial rotator cuff injuries. Loss of internal rotation leads to abnormal joint mechanics with subsequent loss of the normal cam effect on the glenohumeral joint. This permits pathologic hyper-external rotation, superior labral pathology and cuff tearing on a tensile failure basis (93). Others have postulated a direct contact lesion occurring between the articular surface of the cuff and the posterior-superior glenoid and labrum (88,90).

Grade I and II articular-sided partial thickness tears should be debrided. Careful consideration to an underlying primary pathology, especially instability, must be given, and if discovered, treated concomitantly. A Grade III articular-sided partial tear deserves a repair, either trans-tendon or by completing the tear and converting to a full thickness lesion. Whether a decompression is warranted or not should be determined by the presence or absence of subacromial changes. Those lacking pathologic changes in the subacromial space such as coracoacromial ligament fraying should not be treated with a decompression as further instability is potentially incurred.

If a repair of a partial tear is performed, the arthroscopic trans-tendon technique for treating significant partial articular sided rotator cuff tears ('PASTA' lesion: partial articular-sided tendon avulsion) has been described (138) (Fig 13-22).

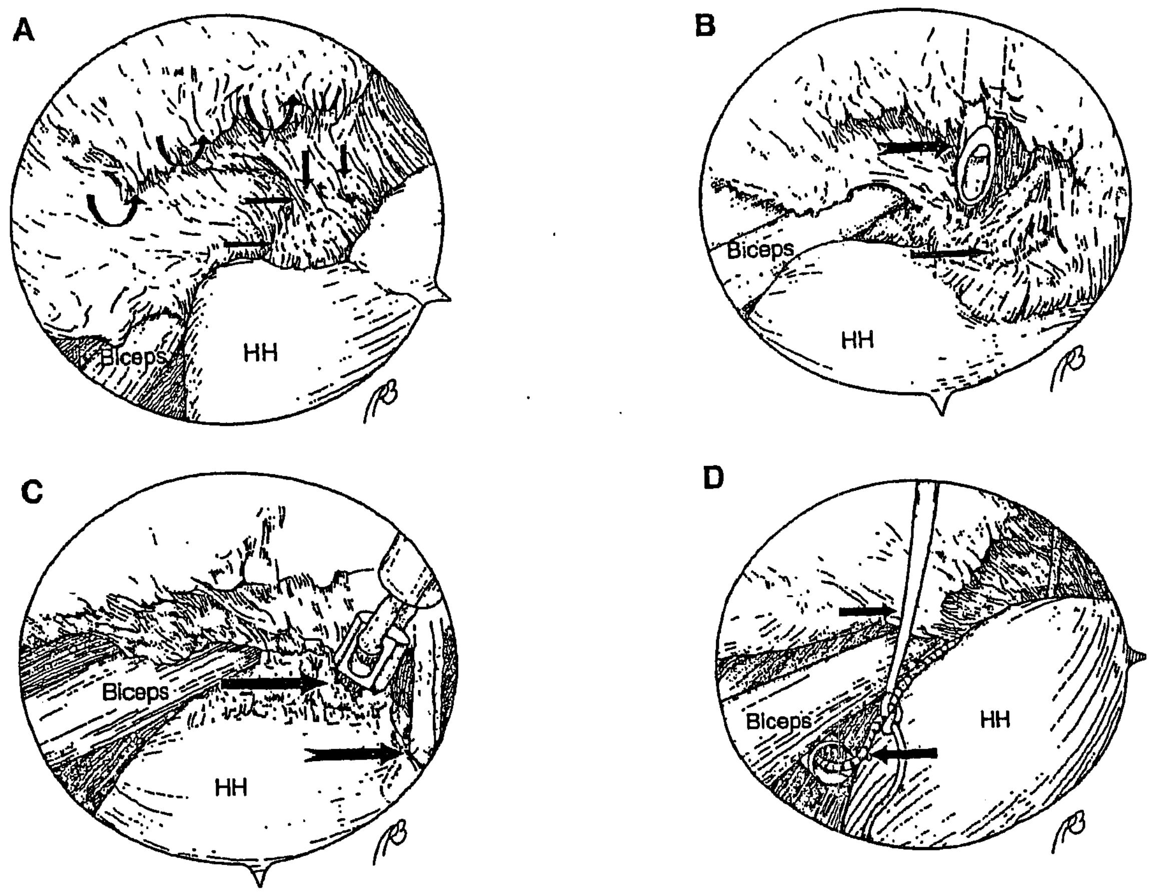
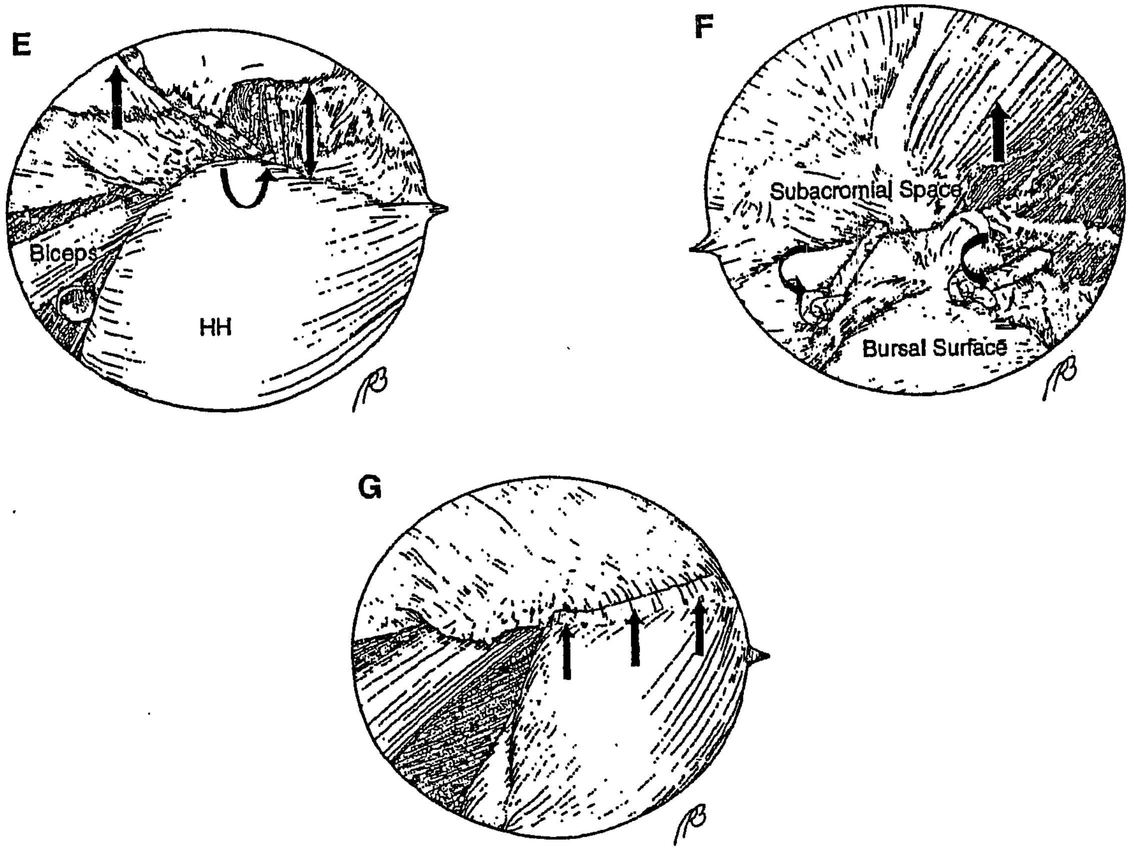


Fig 13-22. A: Identify and quantitate the tear (*curved arrows*) using the anatomic "footprint" (*straight arrows*) as the reference point. Prepare the exposed footprint with a motorized shaver using a standard anterior portal. Debride the partial articular-sided tear. B: Pass a percutaneous spinal needle lateral to the edge of the acromion (*large arrow*). This needle will traverse through the substance of the remaining attached rotator cuff into the exposed footprint (*small arrow*). This will serve as a guide for anchor insertion. Rotation of the shoulder may facilitate accurate needle placement. C: A narrow diameter sleeve or instrument specific cannula is passed percutaneously through the rotator cuff (transtendon) and the appropriate instrumentation is used to place 1 or 2 anchors (*arrows*), each double-loaded, depending on the size of the tear. D: For each anchor in sequence, a suture limb of the anchor is grasped through the anterior portal. A loaded spinal needle (No.1 absorbable suture) is then passed through the bursal side of the cuff, aiming for the edge of the partial tear. The suture is introduced into the joint and grasped through the anterior portal and will serve as a suture shuttle. A simple loop is tied in the absorbable suture and one of the limbs from the anchor, which has been brought through the anterior portal, is loaded on the shuttle outside the joint by tightening the loop. The shuttle (*arrow pointing right*) and accompanying anchor suture (*arrow pointing left*) are then pulled retrograde, in order, through the cannula, the tear edge, and into the subacromial space. E: After the shuttle is brought through the cuff (*left arrow*), the remaining sutures are passed in a similar fashion and eventually tied in the subacromial space to reproduce the anatomic footprint (*double arrow*) to the humeral head (*HH*). F: The arthroscope is introduced into the subacromial space. Color-coded sutures facilitate identification of matched sutures. The appropriate suture pairs (*curved arrows*) are separated and then tied through the lateral or anterior cannula. G: The arthroscope is reintroduced into the glenohumeral joint and the edge of the partial tear should be contiguous with the articular margin, completely effacing the previously exposed footprint (*arrows*). (From Stetson WB, Ryu RKN, Bittar ES. Arthroscopic treatment of partial rotator cuff tears. *Oper Tech Sports Med.* 2004; 12:135-148; reprinted with permission.)

Fig 13-22. *(continued)*



This method seeks to replace the partially torn tendon to its native "footprint" on the tuberosity, preserving the remaining fiber attachment. It is an alternative technique to the arthroscopic approach championed by Weber (137) in which the tear is first converted to a full-thickness injury and then repaired arthroscopically.

Full-thickness Rotator Cuff Tears: Treatment

It is important to understand that not all full thickness rotator cuff tears are alike, and that some complete tears are compatible with excellent function and minimal discomfort. Armed with biomechanical models, basic engineering principles, and kinematic studies of patients with known rotator cuff tears, Burkhart (35,40) defined the "functional rotator cuff tear." His reasoning was based on intact force couples in the transverse and coronal planes despite tearing. With the humeral head well-centered, the anatomically deficient rotator cuff tear can still provide functional integrity. A biomechanically functioning torn rotator cuff must spare a portion of the infraspinatus as well as the subscapularis. Alterations in this relationship can cause the centroid to move superiorly, thereby allowing the humeral head to translate superiorly and limiting shoulder elevation and normal kinematics.

Because not all tears are symptomatic, are there indications for the nonsurgical management of full-thickness tears? Yamaguchi has proposed three categories of risk: Group 1: those not at risk for irreversible changes to the rotator cuff in the near future; Group II: those at risk for irreversible changes with prolonged nonsurgical management; and Group III: those already with irreversible changes (139).

Irreversible changes include fatty infiltration, muscle atrophy, degenerative joint disease, and morphologic changes to the cuff including retraction and thinning. These irreversible changes in turn reflect the pre-operative risk factors portending a poorer outcome including larger tears, delay in treatment, and advanced age (141-143).

The size of the tear, degree of retraction, the presence or absence of fatty infiltration or atrophy, patient age, and activity level help the clinician determine the appropriate category, and then decisions can be made regarding the duration of nonsurgical management versus early surgical intervention. If a small tear can progress during the course of nonsurgical management but the results of treatment are not jeopardized, a prolonged conservative course may be worthwhile without posing a significant risk to the final outcome.

As noted earlier, the clinical presentation of a full-thickness rotator cuff tear can mimic findings consistent with simple impingement or with a partial thickness tear. The most common physical finding that distinguishes those with full thickness tears from impingement is weakness upon stress testing. Although weakness may be an indication of inhibitory pain, the Neer test can help document actual tendon weakness. After pain is relieved with the subacromial injection, significant weakness on stress testing is indicative of a full thickness injury. Often in those with large, chronic tears, visible atrophy within the supraspinatus and infraspinatus fossa may be present.

Small Tears Less Than 1 Centimeter

Smaller tears are easily missed as patients present with findings and symptoms consistent with impingement. Occasionally weakness is present, but even following the Neer test, significant weakness may not be detected. These tears usually involve the supraspinatus tendon insertion, and pain is the primary presenting complaint. Examination usually reveals normal motion and strength.

After the diagnosis has been confirmed, usually by MR testing, definitive treatment can be individualized. Several authors have shown that small tears treated with decompression alone can achieve significant pain relief while maintaining good function (66,113,135,143,144). In an older patient unable or unwilling to undergo the more arduous rehabilitation associated with a full thickness repair, the simple decompression alternative is a realistic one. In the younger, more active population, obvious concern regarding propagation of the tear is a legitimate one. The study by Yamaguchi et al. (49), revealing a 51% incidence of asymptomatic to symptomatic tearing over a five-year period raises doubts about a simple decompression resulting in a lasting and durable outcome for those who lead a vigorous lifestyle. For those individuals, a decompression in conjunction with a repair is the treatment of choice.

Although the open acromioplasty and rotator cuff repair technique has been associated with a high success rate, the technique has been supplanted by the arthroscopically assisted mini-open and the all-arthroscopic techniques (145–157). Several studies have validated these two newer approaches with success rates equal to those achieved through an incision alone (146,152). Furthermore, the mini-open and all-arthroscopic techniques have demonstrated little or no difference when compared in clinical studies (152).

The all-arthroscopic approach relies on meticulous technique and a well-patterned step-wise approach to a successful outcome. Arthroscopy is particularly helpful in allowing a panoramic view of the torn rotator cuff. After the tear pattern is recognized, an anatomic repair can be achieved. The goal of rotator cuff surgery is to achieve an anatomic repair in which the tendon is stressed appropriately and can function as originally intended.

Using standard anterior, posterior, and lateral portals, the tear is identified and the tear pattern recognized (**Fig 13-23**). Small tears are generally crescentic in nature with minimal retraction due to their small size. Associated pathology is identified such as biceps fraying or tearing, and treated. A subacromial decompression is accomplished if there are findings of impingement such as coracoacromial ligament fraying.

The actual rotator cuff repair begins with mobilization of the cuff, if necessary, and using a grasper to reapproximate the torn edge of the cuff back to the greater tuberosity. Simply mobilizing the cuff tendon in larger, retracted tears from a medial to lateral position and re-attaching to bone is usually an oversimplified approach and one that usually leads to structural failure. Chronic tears often have a specific pattern of retraction, and diagonal reduction maneuvers recreate the original anatomic attachment. The bony bed of the greater tuberosity can be prepared with the shaver blade or a curette in an attempt to minimize bone loss and to maximize the pullout strength of the implants. The suture anchors are placed 5 to 7 mm from the articular margin and are separated by at least 1 cm (**Fig 13-24**). The insertion angle

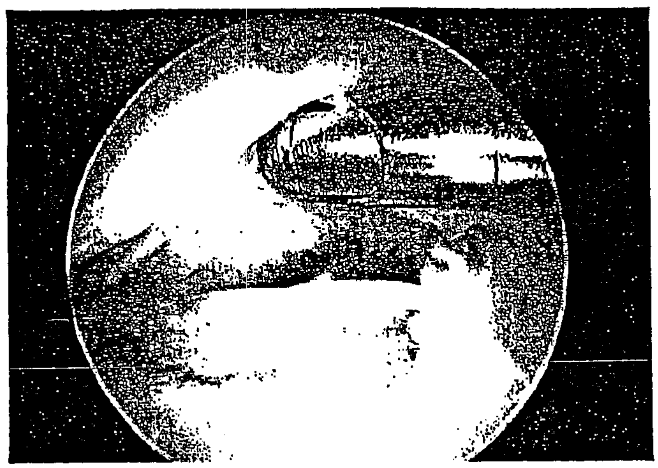


Fig 13-23. Small full-thickness rotator cuff tear with crescent pattern and minimal retraction visualized from the lateral portal of a right shoulder.

Fig 13-24. Double-loaded anchors inserted into the greater tuberosity approximately one centimeter apart and 1 to 2 cm from the articular margin. An insertion angle of 45 degrees or less improves pull-out characteristics of the implants.

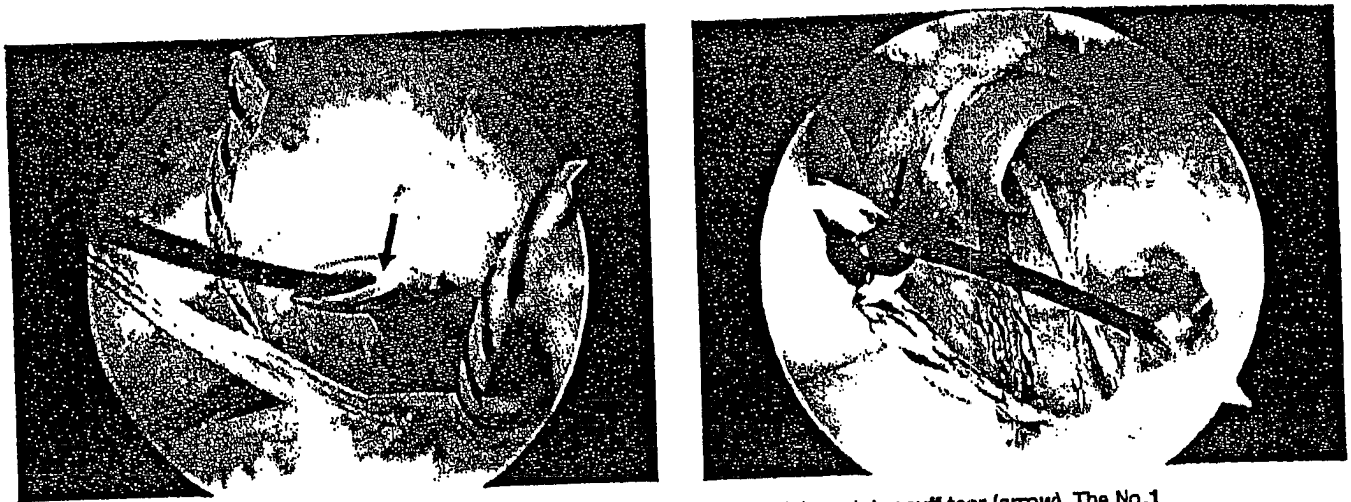


Fig 13-25. A: Suture hook passed through the free edge of the rotator cuff tear (*arrow*). The No.1 absorbable suture functions as a suture shuttle. B: No. 1 absorbable suture is retrograded through the free edge of the rotator cuff tear after loading with a suture limb (*arrow*) from one of the anchors.

approximates 45 degrees from the long axis of the humerus to maximize pull-out characteristics (54).

There exists a multitude of implant devices intended for rotator cuff repair, and for all, satisfactory bone purchase is essential. After the anchors are inserted, the sutures must be either ante- or retrograded through the free edge of the torn tendon (Fig 13-25). Numerous ingenious instruments and devices are available to assist the surgeon in accomplishing this portion of the procedure. Several accessory portals are also available which can facilitate retrograde suturing of the rotator cuff.

After the sutures have been passed, careful, meticulous knot-tying is required during which both knot and loop security must be maintained, loop security referring to the tension with the suture itself as it passes through tissue. The final result should consist of an anatomic repair with excellent coaptation of tissue to the bony bed (Fig 13-26). As the shoulder is ranged, no undue tension on the repair site should be present. Satisfactory clearance in the subacromial space should be verified as well.

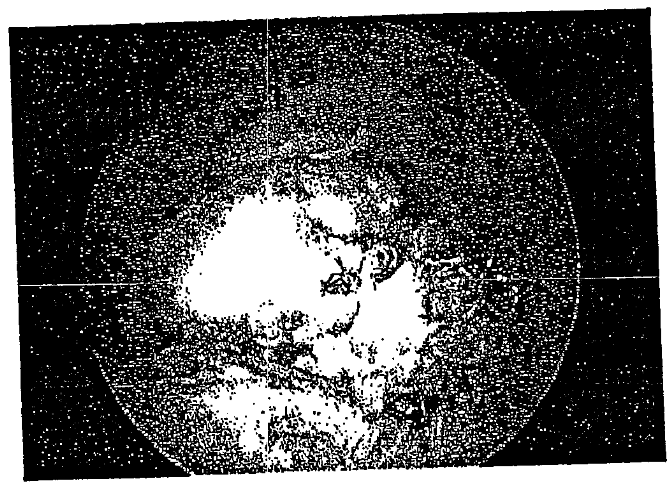


Fig 13-26. After completion of arthroscopic repair, knot and loop security must be maintained. Shoulder is ranged to assess undue tension, as anatomic repair should obviate premature fixation failure.

Medium to Large Size Tears 1 to 4 Centimeters

When larger tears are encountered, the option of a simple decompression becomes less compelling. Some authors have described satisfactory early results with this approach only to discover progressive deterioration, especially in the larger tears (113,135,143). Although the possibility of an isolated decompression in a low demand individual with limited goals remains an option, patients with sizeable tears are more likely to benefit from a formal repair of the torn tendon.

The goals and steps outlined for smaller tears is applicable for tears of all sizes. There are, however, several technical "pearls" that can improve the ease of the procedure as well the final result in the larger and more challenging tears. Again, initial accurate identification of the tear configuration is the key step in achieving an anatomic repair. In those with a chronic, retracted U-shaped tear, the principle of margin convergence can be used with great effect on the final construct. Converging the free margin of the retracted tear to the greater tuberosity by placing side to side sutures not only facilitates the tendon to bone repair, but also relieves the forces at the repair site as well (98,158) (Fig 13-27).

For those chronically retracted L-shaped tears with an anterior extension, an interval release (147,159) that divides the coracohumeral ligament can be very effective in gaining length and satisfactory mobilization such that an anatomic repair can be performed consisting of a side to side repair followed by tendon to bone (Fig 13-28). This same approach

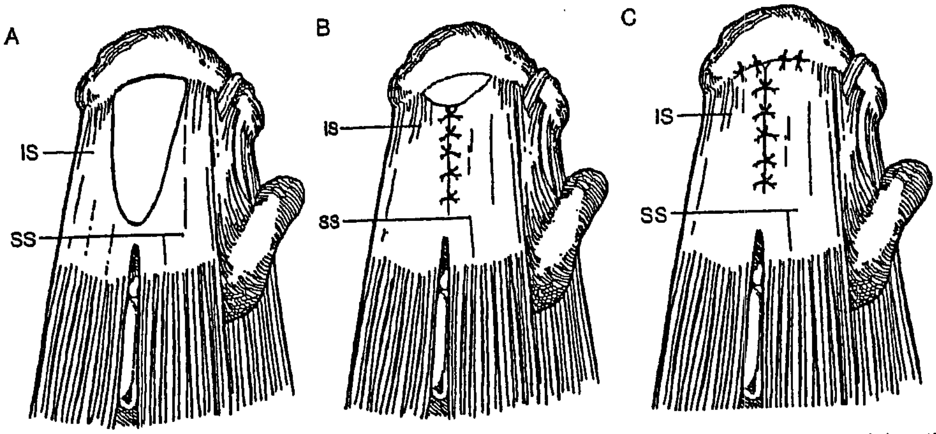


Fig 13-27. U-shaped cuff tear. A: Superior view of a U-shaped rotator cuff tear involving the supraspinatus *(SS)* and infraspinatus *(IS)* tendons; (B), U-shaped tears demonstrate excellent mobility from an anterior-to-posterior direction and are initially repaired with side-to-side sutures using the principle of margin convergence; (C), the repaired margin is then repaired to bone in a tension-free manner. (From Lo IK, Burkhart SS. Current concept in arthroscopic rotator cuff repair. *Am J Sports Med.* 2003;31:308-324; reprinted with permission.)

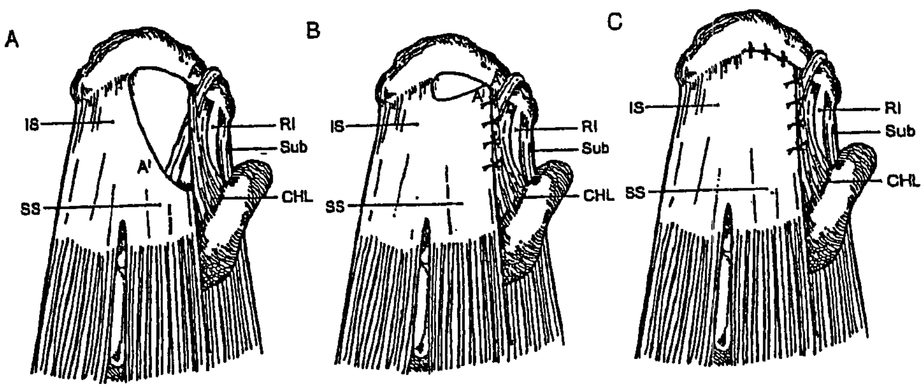


Fig 13-28. Chronic L-shaped tear. A: superior view of a chronic L-shaped tear, which has assumed a U-shaped configuration. B: L-shaped tears demonstrate excellent mobility from an anterior-to-posterior direction; however, one of the tear margins (usually the posterior leaf) is more mobile. These tears should be initially repaired using side-to-side sutures A' → A) by using the principle of margin convergence. C: The converged margin is then repaired to bone in a tension-free manner. *IS*, infraspinatus tendon; *SS*, supraspinatus tendon; *RI*, rotator interval; *Sub*, subscapularis tendon; *CHL*, coracohumeral ligament. (From Lo IK, Burkhart SS. Current concept in arthroscopic rotator cuff repair. *Am J Sports Med.* 2003;31:308-324; reprinted with permission.)

can be utilized for those L-shaped tears that exhibit a posterior extension with a diagonal retraction pattern.

Massive Rotator Cuff Tears

These tears usually exceed 4 to 5 cm in dimension, but can be deceiving. Clearly a tear retracted in a lateral to medial direction of 5 cm presents as a very challenging repair whereas a tear extending 5 cm in an anterior to posterior direction without significant retraction is a much easier surgical problem to solve. In general, massive tears refer to those chronic, retracted tears that are usually accompanied by fatty infiltration, muscle belly atrophy as well as thinning and scarring of the torn end of the rotator cuff. The approach to these massive, retracted tears can be difficult, and requires that the clinician gather as much information as possible before embarking on a therapeutic course.

These patients often present with pain as their overwhelming symptom, and on examination can exhibit significant motion restriction. Not uncommonly, if motion is restored with a well-supervised physical therapy program, the pain can be significantly reduced. If functioning force couples are in effect, restoration of motion may be all that is required to attain a satisfactory result without surgery.

For those with significant strength deficits, the prospect of a repair has to be considered. Certainly concomitant fatty infiltration and muscle atrophy are poor prognostic factors, and patients must be counseled accordingly. Achieving reattachment of the rotator cuff may not result in significant functional improvement if the rotator cuff is significantly diseased in advance of surgery.

Simple debridement and acromial "contouring" have been described as salvage-type procedures that may palliate some of the pain (66,144); however, the risk of violating the coracoacromial arch and of losing anterior-superior head containment must be carefully considered before embarking on a debridement-only approach. Clearly, if such an approach is selected, minimizing bone resection is of utmost importance. If the rotator cuff cannot keep the humeral head centered, the coracoacromial arch becomes a fulcrum for shoulder elevation. If the arch is violated and an aggressive bone resection is performed, the humeral head can erode through what remains of the acromion (Fig 13-11).

The technical principles guiding the repair of massive rotator cuff tears remain consistent with the techniques previously described. As the tear patterns become more complex, additional surgical maneuvers become applicable such as the double-interval slide described by Burkhart and Lo (159). When a complete repair of a massive tear is not technically feasible, consideration of a partial repair must be entertained. Restoring balanced force couples in a massive tear may provide enough stability for a functional outcome.

A discussion of post-operative rotator cuff integrity and its effect on the final outcome is relevant (160). Utilizing ultrasound, Harryman et al. (161) reported on a 65% incidence of intact rotator cuffs post-operatively. In his study, the results were directly correlated with the integrity of the final repair, namely pain relief and strength were better in those with an intact cuff. Galatz et al. (162) reported on the outcome of large and massive rotator cuffs repaired arthroscopically. Seventeen of 18 tears recurred as documented by post-operative ultrasound. Although at 12 months following surgery, the results were impressive from a pain relief and functional perspective, at 2 years and greater follow-up, two-thirds of the patients exhibited deterioration in both categories. Klepps et al. (163) described an experience with post-operative MR evaluation of open cuff repairs and noted that 74% had an intact cuff post-operatively if the initial tear was smaller while those with larger tears had an intact cuff in 62% of the cases. In this study, the end result was not affected by the integrity of the repair, and furthermore, improved strength, as well as pain relief, was noted in those who exhibited a recurrent tear based on post-operative imaging. Jost (164) reported similar findings with their patient population in which an intact cuff did not correlate with better results.

Perhaps the partial repair concept may be the best explanation. Burkhart et al. (89,90) has proposed a unified rationale for the treatment of rotator cuff tears, including partial repairs based on maintaining functional force couples. An arthroscopic approach to partial repairs in large and massive tears has also been reported as an alternative to tissue transfer (91,92). A proponent of partial repair of otherwise massive, irreparable tears of the rotator cuff, Burkhart has argued that maintaining force couples is of greater concern than closing the defect. Although the repair is not water tight, and although a defect may be present post-operatively as judged by MR or ultrasound, the restoration of balanced force couples keeps the humeral head well-centered thereby allowing the extrinsic musculature to function efficiently.

CONCLUSIONS

Understanding the anatomy, biology, and pathoanatomy of the rotator cuff is of utmost importance if skilled treatment of rotator cuff injuries is the objective. Recognizing the spectrum of disease and the various etiologies takes effort and experience. After the injury is understood, the pathoanatomy well-visualized, and the patient's specific needs acknowledged, treatment of the rotator cuff injury can be well-formulated with every expectation of a satisfactory outcome for both patient and surgeon.

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