Shoulder Instability: Management and Rehabilitation

Kimberley Hayes, PT[1]
Mary Callanan, MD[2]
Judie Walton, PhD[3]
Anastasios Paxinos, MD[4]
George A. C. Murrell, MD, PhD[5]

Shoulder dislocation and subluxation occurs frequently in athletes with peaks in the second and sixth decades. The majority (98%) of traumatic dislocations are in the anterior direction. The most frequent complication of shoulder dislocation is recurrence, a complication that occurs much more frequently in the adolescent population. The static (predominantly capsuloligamentous and labral) and dynamic (neuromuscular) restraints to shoulder instability are now well defined. Rehabilitation aims to enhance the dynamic muscular and proprioceptive restraints to shoulder instability. This paper reviews the nonoperative treatment and the postoperative management of patients with various classifications of shoulder instability. *J Orthop Sports Phys Ther. 2002;32:xxx-xxx.*

Key Words: *dislocation, muscle control, pathogenesis, recurrence, surgery*

Shoulder stability is the result of a complex interaction between static and dynamic shoulder restraints. Disruption to these restraints manifests itself in a spectrum of clinical pathologies ranging from subtle subluxation to shoulder dislocation. This article describes the anatomical variants associated with both traumatic and atraumatic shoulder instability and evaluates existing literature pertaining to nonoperative and surgical management with the ultimate aim of providing guidelines for the rehabilitation of various classifications of shoulder instability.

Epidemiology

Primary Dislocations The shoulder is a joint evolved for mobility, and to some extent, stability has been sacrificed to achieve a wide range of motion.[66] Instability is usually defined as a clinical syndrome that occurs when shoulder laxity produces symptoms. Dislocation and subluxation of the glenohumeral joint occurs relatively frequently in athletes. Rowe[82] identified a bimodal distribution of primary shoulder dislocation with peaks in the second and sixth decade (Figure 1A). In up to 98% of cases, the shoulder displaces in an anterior direction[17,59,82] and in about 2% of cases it displaces in the posterior direction.[82]

The major cause of primary shoulder dislocation is traumatic injury. Almost 95% of first-time shoulder dislocations result from either a forceful collision, falling on an outstretched arm, or a sudden wrenching movement. In these individuals the stabilizing structures are forcefully stretched in a sudden manner. About 5% of dislocations have an atraumatic origin (eg, minor incidents such as raising the arm or moving during sleep).[6,17,66,82] These individuals may have capsular laxity or altered muscle control of the shoulder complex or both.[55]

Recurrent Dislocations An important complication of primary dislocation is subsequent recurrent dislocations. Based on a study by Rowe,[82] about 70% of those who

[1]*Physiotherapist, Sports Medicine and Shoulder Service and Orthopaedic Research Institute, St George Hospital Campus, University of New South Wales, Sydney, Australia.*
[2]*Sports medicine registrar, Sports Medicine and Shoulder Service and Orthopaedic Research Institute, St George Hospital Campus, University of New South Wales, Sydney, Australia.*
[3]*Director of Outcomes Research, Sports Medicine and Shoulder Service and Orthopaedic Research Institute, St George Hospital Campus, University of New South Wales, Sydney, Australia.*
[4]*Surgical fellow, Sports Medicine and Shoulder Service and Orthopaedic Research Institute, St George Hospital Campus, University of New South Wales, Sydney, Australia.*
[5]*Chief, Sports Medicine and Shoulder Service, Director, Orthopaedic Research Institute, St George Hospital Campus, University of New South Wales, Sydney, Australia.*
Send correspondence to George Murrell, Department of Orthopaedic Surgery, St. George Hospital, Kogarah NSW 2217, Sydney Australia. E-mail: murrell.g@ori.org.au

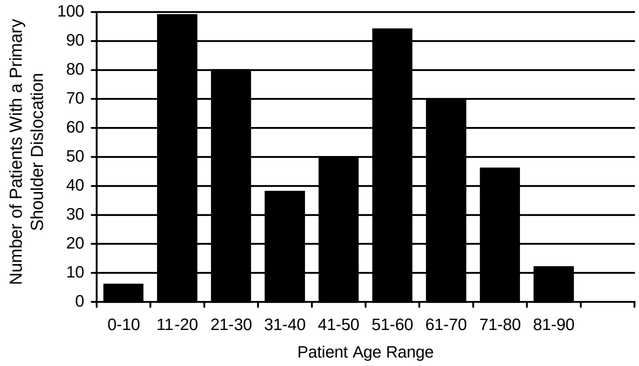

FIGURE 1A. Age distribution (in years) of subjects presenting with primary shoulder dislocation (n = 500). Data from Rowe.[84]

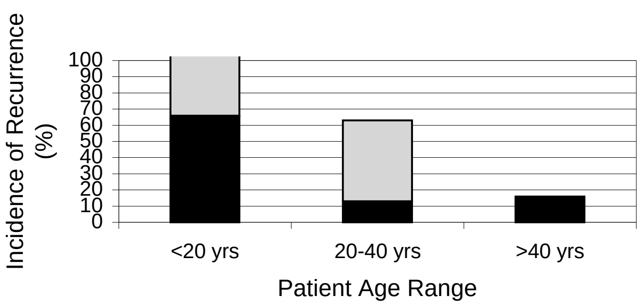

FIGURE 1B. Recurrence rate for the nonoperative management of primary shoulder dislocation. Dislocation recurs in 66% to 100% of people aged 20 years or under, 13% to 63% of people aged between 20 and 40 years, and 0% to 16% of people aged 40 years or older. Data from Hovelius et al,[42] Marans et al,[61] McLaughlin et al,[65] Rowe,[84] and Simonet and Cofield.[87]

have already dislocated can expect to dislocate again within 2 years of the initial injury.

Younger and older subjects have a comparable incidence of primary shoulder dislocation (Figure 1A). However, the incidence of recurrent dislocation is highly age-dependent and occurs much more frequently in the adolescent population than in the older population (Figure 1B). Dislocation has been reported to recur in 66% to 100% of people aged 20 years or under, 13% to 63% of people aged between 20 and 40 years, and in 0% to 16% of people aged 40 years or older.[42,61,65,82,87]

Functional Anatomy and Biomechanics

Static shoulder restraints refer to the bony ball and socket configuration of the shoulder and the major soft tissues holding these bones together. The soft tissues include the capsule, the glenohumeral ligaments and the glenoid labrum. Dynamic shoulder restraints refer to the neuromuscular system, including proprioceptive mechanisms and the scapular and humeral muscles.

Static Stabilizers While the shoulder joint surfaces are highly congruent,[89] there is minimal bony con

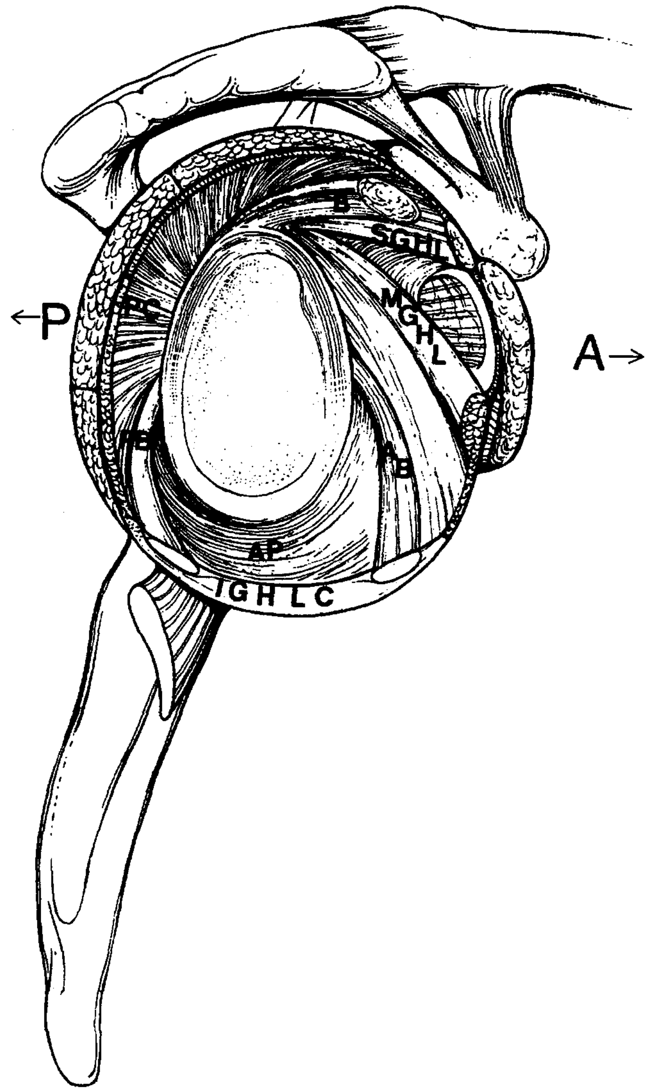

FIGURE 2. Anatomical section of the shoulder joint with the humeral head removed. Abbreviations: B, biceps tendon; SGHL, superior glenohumeral ligament; MGHL, middle glenohumeral ligament; IGHLC, inferior glenohumeral ligament complex, comprising the anterior band (AB), posterior band (PB), and the axillary pouch (AP); PC, posterior capsule; A, anterior; P, posterior. Adapted with permission from O'Brien et al.[72]

tainment of the humeral head in the glenoid cavity. At most, only 25% of the humeral head is in contact with the glenoid fossa in any given shoulder position.[13] Under normal circumstances the shoulder capsule is relatively large and loose.[19] The discrete thickenings or capsular ligaments of the capsule have been named the superior glenohumeral ligament (SGHL), the middle glenohumeral ligament (MGHL), and the inferior glenohumeral ligament complex (IGHLC) (Figure 2).[72] The relative contributions of the capsuloligamentous restraints to stability of the glenohumeral joint are variable. The SGHL primarily limits anterior and inferior translation of the adducted humerus.[15,72] The MGHL primarily limits anterior translation in the lower and middle ranges of abduction.[15,72] The IGHLC is the longest and strongest of the glenohumeral ligaments[85] and has been identified as the primary static restraint against anterior, posterior, and inferior translations when the humerus is abducted beyond 45°.[72]

The labrum constitutes the fibrocartilagenous rim of the glenoid. Inferiorly it is firmly attached to the glenoid, although it may be loose and mobile anterosuperiorly. Although variable in size, the labrum contributes to shoulder stability by increasing the depth of the glenoid cavity from an average of 4.5 to 9.0 mm in the superior-inferior direction and from an average of 2.5 to 5.0 mm in the anterior-posterior direction.[43] The labrum may also act as a chock block, having been shown to increase resistance to glenohumeral translation by up to 20%.[58,63] The labrum provides attachment of the glenohumeral ligaments anteriorly, and the biceps tendon superiorly.

Dynamic Stabilizers A number of dynamic EMG studies have shown that the rotator cuff works in a combined synergistic action to create a compressive force at the glenohumeral joint during shoulder movement.[16,45,55] Radiographic evaluation of glenohumeral kinematics in the normal shoulder has shown that the center of the humeral head deviates from the center of the glenoid fossa by no more than an average of 0.3 mm throughout abduction in the plane of the scapula.[22,79] With fatigue of the rotator cuff and deltoid muscles, there was an average 2.5 mm superior migration of the humeral head.[22]

The biceps assist the rotator cuff in creating glenohumeral joint compression. In an abducted and externally rotated cadaveric shoulder model,[46] static loading of the rotator cuff and biceps brachii muscle (long and short heads) significantly reduced the magnitude of simulated anterior humeral head translation. For conditions of increasing shoulder instability (vented capsule, simulated Bankart lesion) the biceps brachii made a greater contribution to shoulder stability than the individual muscles of the rotator cuff.[46]

The individual tendons of the rotator cuff splay and interdigitate to form a wide, continuous insertion on the humeral tuberosities.[23] Near their insertions, the deep surface of these tendons are tightly adherent to the underlying joint capsule.[23,24] It has been hypothesized that contraction of the rotator cuff muscles may tighten the underlying capsule, creating a soft tissue barrier to excessive humeral head translation.[104,105]

EMG studies of shoulder kinematics have shown that the scapulothoracic muscles operate as functional units to create upward scapular rotation.[9,45] Synchronous scapular rotation and humeral elevation is prerequisite for maintaining optimal alignment of the glenoid fossa and humeral head.[45] Because there are no scapulothoracic ligamentous restraints, the scapulothoracic muscles also serve to stabilize the scapula on the thorax. Stability of the scapula in relation to the moving upper extremity provides a secure platform for the glenohumeral articulation and the action of attaching humeral muscles.

It has been suggested that proprioceptive mechanisms involving reflexive muscular action may protect against excessive translations and rotations of the glenohumeral joint.[100] A recent histological investigation[97] has demonstrated the presence of mechanoreceptors (ruffinian corpuscles and pacinian corpuscles) within the capsuloligamentous restraints of the shoulder. These specialized nerve endings relay afferent information relating to joint position and joint motion awareness (proprioception) to the central nervous system. The perceived sensation of shoulder joint position and movement is likely to play an important role in coordinating muscular tone and control. It has been suggested that joint instability secondary to trauma may be associated with a decrease in proprioceptive reflexes and thus a predisposition to subsequent reinjury.[97]

Traumatic Anterior Dislocation

Mechanism of Injury The most common mechanism of anterior shoulder dislocation has been described as forced external rotation and abduction of the humerus as seen in a basketball player who attempts to block an overhead pass.[5,59] Other mechanisms of injury have included a fall onto an elevated outstretched arm and direct force application to the posterior aspect of the humeral head.[5,59]

Sequelae of Anterior Dislocation There are several morphological changes associated with anterior dislocation of the glenohumeral joint. The most significant in terms of recurrent instability are those associated with the inferior glenohumeral ligament complex and its attachments to the labrum and humerus. In 1923 Bankart[8] described anterior labral detachment as the essential lesion in traumatic anterior instability (Figure 3). Rowe and Zarins[84] noted the lesion in 85% of traumatic instability cases requiring surgery. An osseous Bankart defect on the antero-inferior glenoid rim is best appreciated radiographically with a West Point view.[73] Detachment of the anterior labrum and plastic deformation of the capsule and inferior glenohumeral ligament complex[10] contribute to increased anterior humeral translation.[44,90]

The most common bony lesion associated with traumatic glenohumeral instability is a compression fracture at the posterolateral margin of the humeral head. This occurs as the humeral head impacts into the glenoid edge during dislocation and has been termed the Hill Sach's lesion.[39] This lesion has been reported to occur in over 80% of traumatic instability cases[21,73,99] and is best appreciated radiographically with a Stryker Notch view and an anteroposterior view with the shoulder in internal

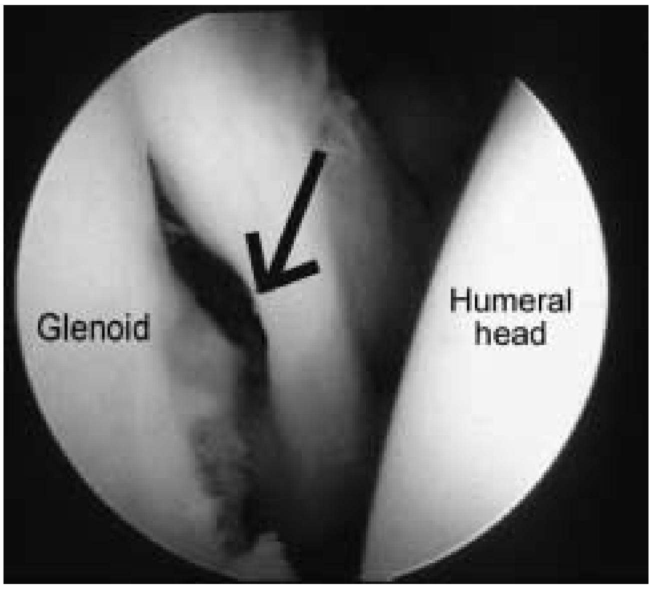

FIGURE 3. Detachment of the labrum and capsule from the anterior glenoid (Bankart lesion), left shoulder.

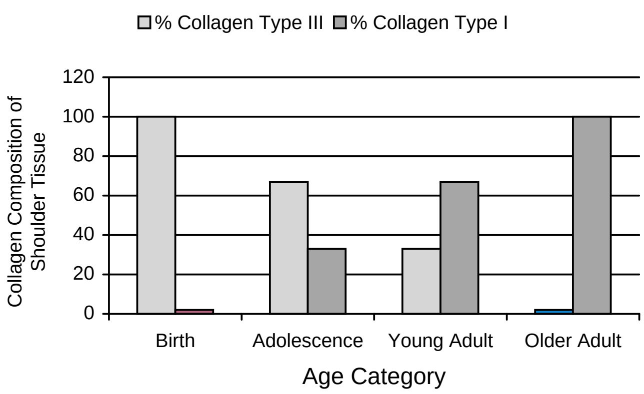

FIGURE 4. Schematic illustration of the changing ratios of collagen types III:I in soft tissues over time. Data from Bakerman.[7]

rotation.[73] The lesion must involve more than 30% of the proximal humeral articular surface to play a significant role in recurrent instability.[90] The lesion is smaller than this in the majority of cases of traumatic shoulder instability.[83,99]

Scapulothoracic motion asymmetry, as determined by Moire topographic evaluation, has been found in 64% of patients with antero-inferior shoulder instability compared to 18% of subjects with normal shoulders.[101] In 36% of patients with antero-inferior instability, this asymmetry presented as scapular winging, hence an increased anterior orientation of the glenoid with repeated shoulder elevation. Simulated glenoid anteversion in the abducted and externally rotated shoulder has been shown to significantly increase in situ strain of the anterior band of the inferior glenohumeral ligament.[102] Regardless of whether scapulothoracic motion asymmetry represents a cause or an effect of shoulder instability, suboptimal glenohumeral joint alignment implies an increased loading of surrounding capsuloligamentous restraints.

Proprioceptive deficits have been shown for patients with traumatic anterior shoulder instability.[88,10] Warner et al[100] reported a significantly greater threshold to detection of passive shoulder motion for patients with shoulder instability compared to subjects with normal shoulders (2.8° angular displacement versus 1.9° angular displacement before detection of passive shoulder motion). Reproduction of a joint reference position was also significantly less accurate for subjects with shoulder instability.[100] Interestingly, in this same study, a third group of test subjects who had undergone arthroscopic or open Bankart repair demonstrated normal proprioceptive function for both of the variables examined. Capsulolabral integrity may thus be important for normal proprioceptive function.

Age-Related Changes

The high incidence of recurrent shoulder dislocation in the adolescent population as opposed to recurrence in those over 40 years of age may be explained, in part, by the collagen profile of encapsulating shoulder tissues. Collagen is the major protein of ligaments and tendons. In newborns, soluble collagen (type III) is synthesized and the fibers formed from collagen type III are supple and elastic. With each passing decade, collagen-producing cells make less soluble collagen and progressively convert to synthesizing an insoluble, more stable type I collagen (Figure 4). This form of collagen has sulfur groups that have a high tendency to cross-link and form bridges between the collagen filaments, causing the fibers they comprise to be relatively tough and nonelastic. This changing ratio of collagen types I and III throughout the body is so reliable that chronological age of an individual can be determined by analyzing the collagen type III content of a skin sample according to the following equation:[7] collagen type III (mg)/wet dermis (gm) = $1.3e^{-Age/23.5}$. Thus, the higher content of stretchy collagen in tendons and ligaments can help to account for the observation that younger people who have already had a dislocated shoulder are much more prone to recurrent dislocation than older people. Once excessively stretched, their capsule and ligaments may be too loose to provide the secure and stable shoulder support required for maximum athletic performance.

Atraumatic Dislocation

A small group of patients dislocate or sublux their shoulders with minimal force application or by putting their arms into certain positions. Neer and Foster[70] thought the pathological entity was a loose redundant inferior capsule and introduced the term multidirectional instability. Multidirectional instability is less often associated with a labral detachment or Bankart lesion. The condition is associated with generalized ligamentous laxity.[3,70]

The definitive etiology of atraumatic instability is still not clear and it may be multifactorial. Current etiological theories include suboptimal muscle control for shoulder function, a deficiency in the rotator cuff interval, and connective tissue abnormalities.

EMG analyses of shoulder motion have demonstrated altered patterns of shoulder muscle activity for patients with atraumatic anterior instability when compared to normal subjects.[56] Radiographic analyses of glenohumeral kinematics in patients with atraumatic multidirectional instability have demonstrated an increase in humeral translation and a decrease in upward rotation of the glenoid fossa for scapular plane abduction when compared to normal subjects.[75] While these studies have shown a correlation between abnormal shoulder muscle activity, glenohumeral incongruence and scapulohumeral motion asymmetry, it remains to be determined whether these findings represent a cause or an effect of atraumatic shoulder instability.

Clinical studies have documented an association between the size of the rotator cuff interval (a defect in the anterosuperior capsule between the superior border of the subscapularis tendon and the anterior margin of the supraspinatus tendon) and the amount of anterior[84] and inferior glenohumeral translation.[71] A biomechanical study using a cadaveric shoulder model has confirmed the importance of the anterosuperior capsule in preventing inferior subluxation of the adducted shoulder.[36] A large rotator cuff interval has been viewed by some authors as a possible causal mechanism in some cases of atraumatic shoulder instability.

Rodeo et al[81] analyzed the collagen and elastic fibers in the shoulder capsule in patients with unidirectional anterior instability, multidirectional instability at primary surgery, multidirectional instability at revision surgery, as compared to patients with no history of instability. Skin analysis between these groups demonstrated a significantly smaller mean collagen fibril diameter in skin samples in the primary multidirectional instability group compared with the unidirectional anterior instability group. This suggests the possibility of an underlying connective tissue abnormality.

Acquired Shoulder Instability

Chronic stress associated with repetitive overhead sports has been cited as a predisposing factor to anterior shoulder instability.[1,2,31,57] These athletes usually perform activities such as throwing, volleyball, and tennis, all of which require extreme external rotation with the humerus abducted and extended in the horizontal plane. A current hypothesis is that repetitive glenohumeral capsular overload in this position of extreme range of motion leads to gradual attenuation of the antero-inferior static restraints,[38,57] increased glenohumeral translation and a continuum of shoulder pathology.[57] On the basis of arthroscopic observations, Kvitne and Jobe[57] described a pattern of injury in this athletic population that involved primary instability and secondary subacromial impingement or posterosuperior glenoid impingement of the undersurface of the rotator cuff with the posterosuperior glenoid rim. In a separate retrospective review of arthroscopic findings for 61 throwing athletes, Nakagawa et al[69] reported anterior joint laxity in 33% of patients, detachment of the superior glenoid labrum in 51% of patients, posterior labral injury in 80% of patients, and rotator cuff tears in 66% of patients. While this study confirmed the presence of several different shoulder pathologies in this athletic population, there was no correlation among anterior joint laxity, superior or posterior labral injury, and a rotator cuff tear.

Nonoperative Management of Dislocation

Traumatic Instability Various treatments, including shoulder immobilization, activity restriction, and exercise rehabilitation have been advocated in the management of primary traumatic anterior shoulder dislocation. While low recurrence rates have been reported for this condition for conservatively managed older patients, the prognosis for patients aged 20 years and younger is generally considered to be poor.

In a prospective study of 257 patients (age range 12 to 40 years) with a primary traumatic anterior shoulder dislocation, Hovelius et al[42] found no difference in redislocation rates between treatment with early mobilization and treatment with 3 to 4 weeks of immobilization. Regardless of the immobilization period, redislocation occurred in 47% of patients aged from 12 to 22 years, 34% of patients from 23 to 29 years, and 13% of patients aged from 30 to 40 years for the 2-year duration of the study.

Other studies of primary traumatic anterior shoulder dislocation performed retrospectively have found no beneficial effect of immobilization of up to 6 weeks duration.[61,87] In one study of 21 patients (age range 4 to 16 years), 100% recurrence rates were reported for immobilization periods that included 0, 4, and 6 weeks in duration.[61] Another study of 116 patients (age range 14 to 96 years) reported an overall redislocation rate of 33% with no difference in recurrence for periods of immobilization between 0 and 6 weeks duration.[87] In the same study, 82% of athletes aged 30 years or younger sustained a redislocation (all due to athletic injury) compared to 30% of nonathletes of similar ages. While the type or length of shoulder immobilization had no influence on the rate of recurrence, significantly better results were reported for patients aged 30 years or younger with 6 to 8 weeks of activity restriction compared to activity restriction of less than 6 weeks in duration (resolution of symptomatic shoulder instability in 56% and 15% of patients, respectively).

Therefore, the literature does not support shoulder immobilization with a traditional sling in the nonoperative management of primary traumatic anterior shoulder dislocation. In a recent study[47] of 18 patients who underwent magnetic resonance imaging between 1 and 60 days after traumatic anterior dislocation (6 patients with a primary dislocation, 12 patients with recurrent dislocation), better approximation between the Bankart lesion and the glenoid neck occurred with the humerus positioned in adduction and external rotation as compared to that which occurred with conventional immobilization in a position of humeral adduction and internal rotation. In support of this finding, a cadaveric shoulder experiment[37] involving similar humeral positions (adduction and external rotation versus adduction and internal rotation) and a simulated Bankart lesion, demonstrated significantly greater contact force between the detached glenoid labrum and the glenoid neck with the arm in the externally rotated position. Lack of capsulolabral and glenoid contact after glenohumeral joint dislocation helps to explain the observation in previous studies that the rate of recurrence is not influenced by the method or duration of shoulder immobilization.[47]

There have been few studies investigating outcomes for exercise rehabilitation in the nonoperative management of primary traumatic anterior shoulder dislocation. In one prospective study[6] of 20 male patients (age range 18 to 22 years), Aronen and Regan reported a return to unrestricted duty and sports participation without redislocation for 75% of cases with a rehabilitation program that emphasized strengthening for the muscles of shoulder internal rotation and adduction (mean follow-up of 35.8 months). Another study[107] of 104 patients (mean age ± SD = 21.5 ± 8.5 years) reported a success rate of 83% with a 6-week graduated exercise regime of limited abduction (mean follow-up of 156 months). These studies support a role for activity restriction and exercise rehabilitation in the nonoperative management of primary traumatic anterior shoulder dislocation.

In a prospective randomized study[54] involving 40 patients, aged 30 years or younger, with a primary traumatic anterior shoulder dislocation, Kirkley et al[54] reported a 47% redislocation rate for a treatment group that received 3 weeks of immobilization followed by a supervised shoulder range of motion and muscle strengthening regime (activity restriction enforced for 4 months). In the same study, a redislocation rate of 16% was reported for a treatment group that received immediate arthroscopic surgery followed by an identical immobilization and rehabilitation regime (mean follow-up of 32 months). Another prospective study[17] involving 29 shoulders with recurrent anterior shoulder instability secondary to a previous dislocation demonstrated good or excellent results (as determined by the Rowe and Zarins grading system[84]) in only 7% of cases with a rehabilitation program that emphasized progressive strengthening of the rotator cuff, deltoid, and scapular stabilizer muscles (mean follow-up of 46 months). Further research is warranted to clarify the efficacy of exercise rehabilitation in the nonoperative management of primary traumatic anterior shoulder dislocation.

Atraumatic Instability As for traumatic instability, there have been few investigations pertaining to exercise rehabilitation in the nonoperative management of atraumatic shoulder instability. In a prospective study[17] of 47 patients (age range 12 to 54 years) with anterior, posterior, and multidirectional instability of atraumatic origin, good or excellent results as determined by the Rowe and Zarins grading system[84] were reported in 80% of cases with a rehabilitation program that emphasized progressive strengthening of the rotator cuff, deltoid, and scapular stabilizer muscles (mean follow-up of 46 months). Shoulder strengthening and coordination exercises combined with lifestyle modification is the most commonly recommended treatment for atraumatic instability.[17,60,70,103]

There is much to learn about the best methods to enhance compression of the humeral head on the glenoid and to restore scapulothoracic motion symmetry and proprioception to the unstable shoulder. Most authors have acknowledged the importance of strengthening exercises for all components of the rotator cuff and deltoid as a means of controlling glenohumeral translation. Infraspinatus and teres minor strengthening exercises performed in higher degrees of abduction have been advocated as a means for reducing anterior glenohumeral ligamentous strain during the throwing motion.[18] Strengthening exercises have also been advocated for the biceps brachii as well as the latissimus dorsi, pectoralis major, and teres major to enhance the stabilizing action of the rotator cuff muscles at the glenohumeral joint.[27,46,78,104]

Functional exercises that require coordination among multiple muscle groups (eg, hitting a tennis ball backhanded) have been recommended for retraining normal patterns of muscle activity in the patient with shoulder instability.[27] In a pilot project[80] involving nonoperative treatment of atraumatic anterior shoulder instability, significant improvements in work and sport function and pain intensity were reported for a functional retraining program designed to improve rotator cuff muscle control through the use of electromyographic biofeedback. Changes in work and sport function and pain intensity were not significant for a second rehabilitation program that consisted of isokinetic resistance exercises designed to improve shoulder muscle strength and endurance.

Various forms of scapular muscle retraining have been advocated in the rehabilitation of shoulder instability.[27,53,105] These have included exercises designed to stabilize the scapulothoracic articulation (isometric exercises, manual stabilization techniques), to restore normal patterns of scapular muscle activity (upper extremity weight-bearing activities), and to maximize scapulothoracic muscle strength and endurance in preparation for a return to normal functional use (resistance exercises, plyometric exercises, sport-specific drills). It remains to be determined whether scapular motion asymmetry can be corrected with exercise rehabilitation in the patient with shoulder instability.

The interplay between neural and muscular mechanisms for dynamic glenohumeral joint stability is incompletely understood. Inman[45] theorized that proprioceptive mechanisms were elicited as a result of specific movement patterns rather than isolated muscle actions. This theory would imply a role for functional exercises that include positions of instability to evoke reflexive muscular activity that may protect against potential joint instability. Other forms of neuromuscular re-education,[27,104,105,106] including joint repositioning tasks, proprioceptive neuromuscular facilitation techniques, upper extremity weight-bearing exercises, and plyometric exercises have been used to retrain proprioceptive mechanisms. Further research is needed to determine the efficacy of these exercises in the rehabilitation of shoulder instability.

Surgical Management

Traumatic Unidirectional Instability The most recent and most successful surgical procedures for unidirectional shoulder instability reattach the detached labrum and associated glenohumeral ligaments with little disruption to the length or attachment of other structures around the shoulder (Bankart repair). An open Bankart repair consists of detachment and later reattachment of the humeral insertion of subscapularis (or a split of the subscapularis) and a reattachment of the labrum to the anterior glenoid with sutures through bone or with suture anchors. Most surgeons also reduce any capsular redundancy by tightening the anterior capsule with sutures. Open anterior stabilization is associated with a 12° loss of external rotation of the shoulder, probably secondary to shortening of the subscapularis tendon after detachment-reattachment.[34]

Arthroscopic techniques for unidirectional glenohumeral instability have been developed to reattach the labrum without an open incision and without subscapularis detachment. The reported redislocation rates for arthroscopic anterior shoulder stabilization are higher than those reported for open procedures (2–18% versus 11%) (Table 1). However, arthroscopic procedures are associated with less loss in external rotation than open procedures. Arthroscopic techniques for reattaching the labrum can be divided into three categories: (1) a transglenoid suture technique,[14,26,35,51,62,74,76] (2) arthroscopically delivered and tied suture anchors,[33,40,93] and (3) arthroscopically delivered biodegradable tacs.[4,12,25,26,28,51,52,86,92] A comparison of the reported rates of recurrent dislocation for each technique is made in the Table.

Multidirectional Instability The most commonly performed and most successfully reported surgical procedure for multidirectional instability of the shoulder is an anterior capsular shift, an open procedure that involves the overlaying and thus shortening of the anterior and inferior capsule.[3,60,77] Closure of the capsular interval between the subscapularis and supraspinatus has been reported to be successful in a small series of patients with subluxation.[30,36]

More recently, capsular shrinkage has been advocated as a treatment for more subtle cases of shoulder instability. Thermal denaturation of collagen results in uncoupling of the triple helices and shortening of the collagen. A recent study noted a 15% to 40% reduction in length of a cadaveric shoulder capsule subjected to 65°C to 72°C heat (Figure 5).[98] Also noted was an associated 15% loss in load to failure properties. Arthroscopic devices have been designed to deliver heat to the shoulder capsule with the potential to ''shrink'' redundant capsule arthroscopically. A short-term study has reported excellent results using this technique.[86] Further long-term evaluations are necessary to identify the technique, indications, and results of this novel method of reducing capsular volume.

Postoperative Rehabilitation

The basic principles of nonoperative rehabilitation for shoulder instability (restoration of glenohumeral compression stability, scapulohumeral motion synchrony, and proprioceptive mechanisms) apply equally to postoperative patients. The specific content of postoperative rehabilitation varies according to the stabilization procedure performed, individual pathology, and the activity level of the individual.

Anterior Stabilization

Cryotherapy Cryotherapy in the postoperative shoulder (applied for 15-minute durations every 1 to 2

TABLE. Comparison of dislocation rates for treatment methods for anterior shoulder instability.

Technique	Year*	Number of Patients	Follow Up (Years)	Recurrence	Reference
No surgery					
Rehabilitation	1996	245	10.0	48%	41
Rehabilitation	1996	55	8.0	85%	26
				Mean: 55%	
Open surgery					
Open Bankart	1996	12	2.5	8%	35
Open Bankart	1997	60	12.0	5%	34
Open Bankart	1998	26	3.0	4%	12
Open Bankart	2000	22	4.5	9%	25
Open Bankart	2000	66	4.0	23%	96
Open Bankart	2001	48	3.0	10%	52
Open Bankart	2001	26	1.1	12%	92
				Mean: 11%	
Arthroscopic surgery					
Transglenoid suture	1996	37	5.6	19%	76
Transglenoid suture	1996	21	2.7	14%	26
Transglenoid suture	1996	29	4.9	27%	62
Transglenoid suture	1996	15	2.5	33%	35
Transglenoid suture modified	1996	42	3.2	5%	62
Transglenoid suture	2000	41	4.3	2%	74
Transglenoid suture	2000	72	N/A	7%	14
Transglenoid suture	2000	108	4.5	32%	51
				Mean: 18%	
Suture anchor	1995	30	2.0	7%	40
Suture anchor + shrink	2000	53	2.8	8%	33
Suture anchor + shift	2000	29	2.0	7%	93
				Mean: 7%	
Bankart tack	1995	19	1.6	0%	4
Suretac	1998	20	3.0	20%	12
Suretac	2000	20	3.4	30%	28
Suretac	2000	37	4.5	11%	25
Fastak	2000	55	3.2	16%	51
Suretac	2001	48	3.1	13%	26
Suretac	2001	60	2.3	15%	52
Suretac	2001	30	1.1	23%	92
				Mean: 17%	
Suretac + shrink	1999	43	3.0	2%	86
				Mean: 2%	

*Year of publication.

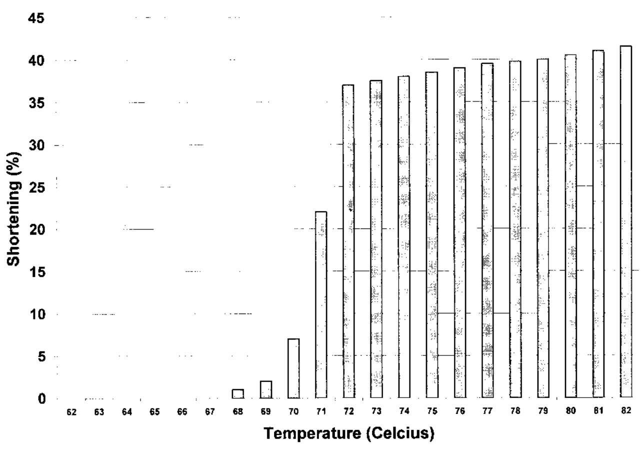

FIGURE 5. The effects of heat on glenohumeral capsular length. Data from Vangsness et al.[97]

waking hours for the first 24 hours, and 4 to 6 times daily for the ensuing 9 days) has been shown to significantly decrease the frequency and intensity of shoulder pain both at rest and during rehabilitation as compared to no-cryotherapy conditions.[91] We recommend 15 minutes of cryotherapy every second hour for the first week after a stabilization procedure and after every exercise session for the duration of rehabilitation.

Activity Restriction The postoperative management of anterior instability has typically involved a minimum of 6 weeks of activity restriction to minimize stress to healing structures. During this period of limited upper extremity use, we recommend active exercise of noninvolved joints (elbow, wrist, and hand). In the case of the injured athlete, rehabilitation also aims to maintain cardiovascular fitness and lower limb and trunk muscle condition.

Isometric Exercise Isometric shoulder muscle exercises, initially performed with the arm adducted by the side of the body, provide a means for preventing muscular inhibition during the period of activity restriction. Isometric exercises for the scapulothoracic muscles are commenced during the first postoperative week. Isometric exercises for the humeral muscles are commenced during the second postoperative week. Care is taken when performing isometric internal rotation for the first 6 weeks following an open Bankart repair, in which the subscapularis muscle is detached and reattached, to prevent rupture from its humeral insertion. We recommend pain-free contractions of 3 to 5 seconds duration and a minimum of 30 daily repetitions[20,32,64] for all isometric exercises.

Range of Motion Exercises Assisted shoulder exercises initially performed within a limited range of motion are designed to protect the surgical repair and prevent adhesion formation in the early postoperative period. These exercises are commenced during the second postoperative week. External rotation range of motion is limited to 30° (0° abduction) for the first 4 postoperative weeks. Combined external rotation and abduction range of motion is avoided for the first 6 postoperative weeks. Assisted elevation is initially performed in the plane of the scapula to maximize humeral and glenoid congruency.[50] The absence of pain, apprehension, and abnormal movement patterns with assisted exercise are prerequisite for the progression to active range of motion exercise. Rehabilitation aims to restore full active range of motion by 12 weeks after arthroscopic[29] and open anterior stabilization.[103]

Scapulothoracic Muscle Retraining In addition to isometric scapulothoracic muscle exercises, the first postoperative week involves treatment for any strength or flexibility deficits within the lumbar or thoracic areas.[53] Upper extremity weight-bearing exercises that incorporate specific scapular movements at glenohumeral angles of less than 60° elevation are introduced during the third postoperative week.[53] Light resistance exercises are commenced during the fourth postoperative week. We emphasize retraining for scapular protraction and retraction and advocate multiple sets of up to 30 repetitions for exercises that involve both concentric and eccentric modes of contraction.

Dynamic scapulothoracic stability, scapulohumeral motion synchrony, and an absence of pain and apprehension for movements performed between 0° and 90° elevation are prerequisite for further rehabilitation progression. Once these goals have been achieved, upper extremity weight-bearing exercises are advanced to higher angles of elevation and weight-bearing loads are increased (eg, press-ups, push-ups, and quadruped exercises).[53] The scapulothoracic muscles are comprehensively conditioned through the use of free weights,[27,67] various resistance machines[27,53] (eg, rowing, upright rows, and pull-downs, anterior to the frontal plane) and training activities[27,105,106] (eg, throwing movement exercises, blocking and ball defense exercises, and water-based exercises) designed to replicate stresses that will be imposed upon the shoulder during functional upper extremity use.

Rotator Cuff and Humeral Muscle Strengthening Exercises Rotator cuff strengthening is commenced with isometric exercises, as detailed above. Light resistance exercises for the rotator cuff and biceps brachii muscles are introduced during the fourth postoperative week. (For open stabilization procedures involving detachment or reattachment of the subscapularis, resistance exercises for the subscapularis muscle are introduced during the sixth postoperative week). We advocate exercises that involve both concentric and eccentric modes of contraction initially performed at glenohumeral angles of less than 45° elevation. We use the same range of motion to commence strengthening of the latissimus dorsi, pectoralis major, and teres major.

Dynamic control of the scapulothoracic and glenohumeral joints and an absence of pain and apprehension for movements performed between 0° and 45° elevation are prerequisite for exercise progression to higher angles of elevation. Rotator cuff strengthening for higher angles of elevation includes the use of Theraband[27,105] (eg, internal and external rotation), free weights[11,49,94] (eg, prone horizontal abduction with arm externally rotated and scapular plane elevation), and training activities[27,106] (eg, underarm, side-arm, and overhead throwing or catching exercises using balls of various weights and sizes). Humeral muscle strengthening includes Theraband exercises[27] (eg, extension and adduction initiated from 90° flexion and abduction, respectively), free weights[94] (scapular plane elevation with arm internally rotated and horizontal abduction with arm internally and externally rotated), press-ups,[27,94] push-ups,[48] and various weight machines.[27]

Proprioception In the latter stage of rehabilitation, emphasis is given to functional exercises that prepare the neuromuscular and cardiovascular systems for the return to sports participation. We include activities that require the coordination of multiple muscles (eg, catching and throwing activities, racquet and other batting activities, and goal defense activities) to achieve the desired magnitude, duration, and sequence of motor output for a given functional task. These exercises initially use glenohumeral positions that are least likely to provoke an instability episode. An absence of symptoms and quality of movement are fundamental prerequisites for exercise progression to positions that maximally challenge the dynamic shoulder restraints.

Stabilization for Multidirectional Instability: Special Considerations

Postoperative rehabilitation for multidirectional instability is characterized by activity restriction and strict range of motion control. Care is taken to prevent overstretching of tightened capsular tissues, particularly after thermal shrinkage procedures that induce an initial decrease in collagen tensile strength.[95,98] We restrict axial loading of the upper extremity for 6 weeks. For cases with an anterior component of instability, we restrict external rotation range of motion to 30° (0° abduction) for the first 4 postoperative weeks and avoid combined external rotation and abduction range of motion for the first 6 postoperative weeks. For cases with a posterior component of instability, we avoid combined flexion, internal rotation, and horizontal adduction for the first 6 postoperative weeks.

Glenohumeral and scapulothoracic muscle retraining guidelines used in the postoperative management of anterior instability are also appropriate for the postoperative rehabilitation of multidirectional instability. We advocate a more conservative approach to the rate of rehabilitation progression after stabilization procedure for multidirectional instability, as the success of this condition may be more dependent upon the restoration of normal shoulder muscle function.

CONCLUSION

In summary, there have been significant advances in methods to restore function in both unidirectional and multidirectional shoulder instability.[68] Biomechanical and anatomical studies have enhanced our understanding of the mechanics of the shoulder joint with implications for the management and rehabilitation of shoulder instability. Further investigation of the mechanisms responsible for dynamic glenohumeral control will help to delineate the optimal treatment for shoulder instability.

ACKNOWLEDGEMENTS

All authors were employed by or received financial support from the St. George Hospital and South East Health Service.

REFERENCES

1. Abrams JS. Special shoulder problems in the throwing athlete: pathology, diagnosis, and nonoperative management. *Clin Sports Med.* 1991;10:839–861.
2. Allen AA, Warner JJ. Shoulder instability in the athlete. *Orthop Clin North Am.* 1995;26:487–504.
3. Altchek DW, Warren RF, Skyhar MJ, Ortiz G. T-plasty modification of the Bankart procedure for multidirectional instability of the anterior and inferior types. *J Bone Joint Surg Am.* 1991;73:105–112.
4. Arciero RA, Taylor DC, Snyder RJ, Uhorchak JM. Arthroscopic bioabsorbable tack stabilization of initial anterior shoulder dislocations: a preliminary report. *Arthroscopy.* 1995;11:410–417.
5. Aronen JG. Anterior shoulder dislocations in sports. *Sports Med.* 1986;3:224–234.
6. Aronen JG, Regan K. Decreasing the incidence of recurrence of first time anterior shoulder dislocations with rehabilitation. *Am J Sports Med.* 1984;12:283–291.
7. Bakerman S. Quantitative extraction of acid-soluble human skin collagen with age. *Nature.* 1962;196(4852):375–376.
8. Bankart ASB. The pathology and treatment of recurrent dislocation of the shoulder joint. *Br J Surg.* 1923;2:23–29.
9. Basmajian JV, DeLuca C. *Muscles Alive: Their Functions Revealed by Electromyography.* 5th ed. Baltimore, MD: Williams and Wilkins; 1985.
10. Bigliani LU, Pollock RG, Soslowsky LJ, Flatow EL, Pawluk RJ, Mow VC. Tensile properties of the inferior glenohumeral ligament. *J Orthop Res.* 1992;10:187–197.
11. Blackburn TA, McLeod WD, White B, Wofford L. EMG analysis of posterior rotator cuff exercises. *Athletic Training.* 1990;25:40–45
12. Boileau P, Clement T, Walch G, Argenson C. Results of anterior stabilization of the shoulder using open and arthroscopic Bankart suture repair. *Proceedings of the 8th Congress of the European Society of Sports Traumatology, Knee Surgery and Arthroscopy.* Nice, France; 1998.
13. Bost FC, Inman VT. The pathological changes in recurrent dislocation of the shoulder. A report of Bankart's operative procedures. *J Bone Joint Surg.* 1942;24A:595–613.
14. Boszotta H, Helperstorfer W. Arthroscopic transglenoid suture repair for initial anterior shoulder dislocation. *Arthroscopy.* 2000;16:462–470.
15. Bowen MK, Warren RF. Ligamentous control of shoulder stability based on selective cutting and static translation experiments. *Clin Sports Med.* 1991;10:757–782.
16. Bradley JP, Tibone JE. Electromyographic analysis of muscle action about the shoulder. *Clin Sports Med.* 1991;10:789–805.
17. Burkhead WZ, Jr., Rockwood CA, Jr. Treatment of instability of the shoulder with an exercise program. *J Bone Joint Surg Am.* 1992;74:890–896.
18. Cain PR, Mutschler TA, Fu FH, Lee SK. Anterior stability of the glenohumeral joint. A dynamic model. *Am J Sports Med.* 1987;15:144–148.
19. Carmichael SW, Hart DL. Anatomy of the shoulder joint. *J Orthop Sports Phys Ther.* 1985;6:225–228.
20. Carolan B, Cafarelli E. Adaptations in coactivation after isometric resistance training. *J Appl Physiol.* 1992;73:911–917.
21. Caspari RB, Geissler WB. Arthroscopic manifestations of shoulder subluxation and dislocation. *Clin Orthop.* 1993;54–66.
22. Chen SK, Simonian PT, Wickiewicz TL, Otis JC, Warren RF. Radiographic evaluation of glenohumeral kinematics: A muscle fatigue model. *J Shoulder Elbow Surg.* 1999;8:49–52.
23. Clark JM, Harryman DT. Tendons, ligaments, and capsule of the rotator cuff. Gross and microscopic anatomy. *J Bone Joint Surg Am.* 1992;74:713–725.
24. Clark J, Sidles JA, Matsen FA. The relationship of the glenohumeral joint capsule to the rotator cuff. *Clin Orthop.* 1990;29–34.
25. Cole BJ, L'Insalata J, Irrgang J, Warner JJ. Comparison of arthroscopic and open anterior shoulder stabilization. A two to six-year follow-up study. *J Bone Joint Surg Am.* 2000;82A:1108–1114.

26. DeBerardino TM, Arciero RA, Taylor DC. Arthroscopic stabilization of acute initial anterior shoulder dislocation: the west point experience. *J South Orthop Assoc.* 1996;5:263–271.
27. Dines DM, Levinson M. The conservative management of the unstable shoulder including rehabilitation. *Clin Sports Med.* 1995;14:797–816.
28. Dora C, Gerber C. Shoulder function after arthroscopic anterior stabilization of the glenohumeral joint using an absorbable tac. *J Shoulder Elbow Surg.* 2000;9:294–298.
29. Ellenbecker TS, Mattalino AJ. Glenohumeral joint range of motion and rotator cuff strength following arthroscopic anterior stabilization with thermal capsulorrhaphy. *J Orthop Sports Phys Ther.* 1999;29:160–167.
30. Field LD, Warren RF, O'Brien SJ, Altchek DW, Wickiewicz TL. Isolated closure of rotator interval defects for shoulder instability. *Am J Sports Med.* 1995;23:557–563.
31. Galinat BJ, Warren RF, Buss DD. Pathophysiology of shoulder instability. In: McGinty JB, ed. *Operative Arthroscopy.* New York, NY: Raven Press; 1991.
32. Garfinkel S, Cafarelli E. Relative changes in maximal force, EMG, and muscle cross-sectional area after isometric training. *Med Sci Sports Exerc.* 1992;24:1220–1227.
33. Gartsman GM, Roddey TS, Hammerman SM. Arthroscopic treatment of anterior-inferior glenohumeral instability. Two- to five-year follow-up. *J Bone Joint Surg Am.* 2000;82A:991–1003.
34. Gill TJ, Micheli LJ, Gebhard F, Binder C. Bankart repair for anterior instability of the shoulder. Long-term outcome. *J Bone Joint Surg Am.* 1997;79:850–857.
35. Guanche CA, Quick DC, Sodergren KM, Buss DD. Arthroscopic versus open reconstruction of the shoulder in patients with isolated Bankart lesions. *Am J Sports Med.* 1996;24:144–148.
36. Harryman DT, Sidles JA, Harris SL, Matsen FA. The role of the rotator interval capsule in passive motion and stability of the shoulder. *J Bone Joint Surg Am.* 1992;74:53–66.
37. Hatrick C, O'Leary S, Miller B, Goldberg J, Sonnabend D, Walsh W. Should acute anterior dislocation of the shoulder be treated in external rotation. *Orthopaedic Research Society 48th Annual Meeting.* Dallas, TX; 2002.
38. Herrington L. Glenohumeral joint: Internal and external rotation range of motion in javelin throwers. *Br J Sports Med.* 1998;32:226–228.
39. Hill HA, Sachs MD. The grooved defect of the humeral head. A frequently unrecognised complication of dislocations of the shoulder joint. *Radiology.* 1940;35:690–700.
40. Hoffmann F, Reif G. Arthroscopic shoulder stabilization using mitek anchors. *Knee Surg Sports Traumatol Arthrosc.* 1995;3:50–54.
41. Hovelius L, Augustini BG, Fredin H, Johansson O, Norlin R, Thorling J. Primary anterior dislocation of the shoulder in young patients. A ten-year prospective study. *J Bone Joint Surg Am.* 1996;78:1677–1684.
42. Hovelius L, Eriksson K, Fredin H, et al. Recurrences after initial dislocation of the shoulder. Results of a prospective study of treatment. *J Bone Joint Surg Am.* 1983;65:343–349.
43. Howell SM, Galinat BJ. The glenoid-labral socket. A constrained articular surface. Clin Orthop. 1989;122–125.
44. Howell SM, Galinat BJ, Renzi AJ, Marone PJ. Normal and abnormal mechanics of the glenohumeral joint in the horizontal plane. *J Bone Joint Surg Am.* 1988;70:227–232.
45. Inman VT, Saunders DM, Abbott LC. Observations on the function of the shoulder. *J Bone Joint Surg.* 1944;26:1–30.
46. Itoi E, Newman SR, Kuechle DK, Morrey BF, An KN. Dynamic anterior stabilisers of the shoulder with the arm in abduction. *J Bone Joint Surg Br.* 1994;76:834–836.
47. Itoi E, Sashi R, Minagawa H, Shimizu T, Wakabayashi I, Sato K. Position of immobilization after dislocation of the glenohumeral joint. A study with use of magnetic resonance imaging. *J Bone Joint Surg Am.* 2001;83A:661–667.
48. Jobe FW, Moynes DR, Brewster CE. Rehabilitation of shoulder joint instabilities. *Orthop Clin North Am.* 1987;18:473–482.
49. Jobe FW, Moynes DR. Delineation of diagnostic criteria and a rehabilitation program for rotator cuff injuries. *Am J Sports Med.* 1982;10:336–339.
50. Johnston TB. Movements of the shoulder joint. A plea for the use of the "plane of the scapula" as the plane of reference for movements occurring at the humero-scapular joint. *Br J Surg.* 1937;25:252–260.
51. Kandziora F, Jager A, Bischof F, Herresthal J, Starker M, Mittlmeier T. Arthroscopic labrum refixation for post-traumatic anterior shoulder instability: Suture anchor versus transglenoid fixation technique. *Arthroscopy.* 2000;16:359–366.
52. Karlsson J, Magnusson L, Ejerhed L, Hultenheim I, Lundin O, Kartus J. Comparison of open and arthroscopic stabilization for recurrent shoulder dislocation in patients with a Bankart lesion. *Am J Sports Med.* 2001;29:538–542.
53. Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med.* 1998;26:325–337.
54. Kirkley A, Griffin S, Richards C, Miniaci A, Mohtadi N. Prospective randomized clinical trial comparing the effectiveness of immediate arthroscopic stabilization versus immobilization and rehabilitation in first traumatic anterior dislocations of the shoulder. *Arthroscopy.* 1999;15:507–514.
55. Kronberg M, Brostrom LA. Electromyographic recordings in shoulder muscles during eccentric movements. *Clin Orthop.* 1995;143–151.
56. Kronberg M, Brostrom LA, Nemeth G. Differences in shoulder muscle activity between patients with generalized joint laxity and normal controls. *Clin Orthop.* 1991;181–192.
57. Kvitne RS, Jobe FW. The diagnosis and treatment of anterior instability in the throwing athlete. *Clin Orthop.* 1993;107–123.
58. Lippitt S, Matsen F. Mechanisms of glenohumeral joint stability. *Clin Orthop.* 1993;20–28.
59. Liu SH, Henry MH. Anterior shoulder instability. Current review. *Clin Orthop.* 1996;327–337.
60. Mallon WJ, Speer KP. Multidirectional instability: current concepts. *J Shoulder Elbow Surg.* 1995;4:54–64.
61. Marans HJ, Angel KR, Schemitsch EH, Wedge JH. The fate of traumatic anterior dislocation of the shoulder in children. *J Bone Joint Surg Am.* 1992;74:1242–1244.
62. Marcacci M, Zaffagnini S, Petitto A, Neri MP, Iacono F, Visani A. Arthroscopic management of recurrent anterior dislocation of the shoulder: analysis of technical modifications on the caspari procedure. *Arthroscopy.* 1996;12:144–149.

63. Matsen FA, Harryman DT, Sidles JA. Mechanics of glenohumeral instability. *Clin Sports Med.* 1991;10:783–788.
64. McDonagh MJ, Hayward CM, Davies CT. Isometric training in human elbow flexor muscles. The effects on voluntary and electrically evoked forces. *J Bone Joint Surg Br.* 1983;65:355–358.
65. McLaughlin HL, Cavallaro WU. Primary anterior dislocation of the shoulder. *Am J Surg.* 1950;80:615–621.
66. Moseley HF. *Recurrent Dislocation of the Shoulder.* London, England: E and S Livingstone Ltd.; 1961.
67. Moseley JB, Jr., Jobe FW, Pink M, Perry J, Tibone J. EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med.* 1992;20:128–134.
68. Murrell GAC, Bhargav D. Medical and surgical manipulation of the shoulder capsule and labrum. *APLAR J Rheum.* 1999;2:247–252.
69. Nakagawa S, Yoneda M, Hayashida K, Wakitani S, Okamura K. Greater tuberosity notch: an important indicator of articular-side partial rotator cuff tears in the shoulders of throwing athletes. *Am J Sports Med.* 2001;29:762–770.
70. Neer CS, Foster CR. Inferior capsular shift for involuntary inferior and multidirectional instability of the shoulder. A preliminary report. *J Bone Joint Surg Am.* 1980;62:897–908.
71. Nobuhara K, Ikeda H. Rotator interval lesion. *Clin Orthop.* 1987;223:44–50.
72. O'Brien SJ, Neves MC, Arnoczky SP, et al. The anatomy and histology of the inferior glenohumeral ligament complex of the shoulder. *Am J Sports Med.* 1990;18:449–456.
73. O'Brien SJ, Warren RF, Schwartz E. Anterior shoulder instability. *Orthop Clin North Am.* 1987;18:395–408.
74. O'Neill DB. Arthroscopic Bankart repair of anterior detachments of the glenoid labrum. A prospective study. *J Bone Joint Surg.* 1999;81:1357–1366.
75. Ozaki J. Glenohumeral movements of the involuntary inferior and multidirectional instability. *Clin Orthop.* 1989;107–111.
76. Pagnani MJ, Warren RF, Altchek DW, Wickiewicz TL, Anderson AF. Arthroscopic shoulder stabilization using transglenoid sutures. A four-year minimum follow-up. *Am J Sports Med.* 1996;24:459–467.
77. Pagnani MJ, Warren RF. Multidirectional instability: medial T-plasty and selective capsular repairs. *Sports Med Arthrosc Rev.* 1993;1:249–258.
78. Pagnani MJ, Warren RF. Stabilizers of the glenohumeral joint. *J Shoulder Elbow Surg.* 1994;3:173–190.
79. Poppen NK, Walker PS. Normal and abnormal motion of the shoulder. *J Bone Joint Surg Am.* 1976;58:195–201.
80. Reid DC, Saboe LA, Chepena JC. Anterior shoulder instability in athletes: comparison of isokinetic resistance exercises and an electromyographic biofeedback re-education program-a pilot program. *Physiotherapy Canada.* 1996;48:251–256.
81. Rodeo SA, Suzuki K, Yamauchi M, Bhargava M, Warren RF. Analysis of collagen and elastic fibers in shoulder capsule in patients with shoulder instability. *Am J Sports Med.* 1998;26:634–643.
82. Rowe CR. Prognosis in dislocations of the shoulder. *J Bone Joint Surg.* 1956;38A:957–977.
83. Rowe CR, Zarins B, Ciullo JV. Recurrent anterior dislocation of the shoulder after surgical repair. Apparent causes of failure and treatment. *J Bone Joint Surg Am.* 1984;66:159–168.
84. Rowe CR, Zarins B. Recurrent transient subluxation of the shoulder. *J Bone Joint Surg Am.* 1981;63:863–872.
85. Sarrafian SK. Gross and functional anatomy of the shoulder. *Clin Orthop.* 1983;173:11–19.
86. Siebert W, Sommerfeld F, Pape HG. Laser assisted capsular shrinkage-results of shoulder instability. *Proceedings of the SICOT 21st Triennial World Congress.* Sydney, Australia; 1999.
87. Simonet WT, Cofield RH. Prognosis in anterior shoulder dislocation. *Am J Sports Med.* 1984;12:19–24.
88. Smith RL, Brunolli J. Shoulder kinesthesia after anterior glenohumeral joint dislocation. *Phys Ther.* 1989;69:106–12.
89. Soslowsky LJ, Flatow EL, Bigliani LU, Mow VC. Articular geometry of the glenohumeral joint. *Clin Orthop.* 1992;181–1
90. 90. Speer KP, Deng X, Borrero S, Torzilli PA, Altchek DA, Warren RF. Biomechanical evaluation of a simulated Bankart lesion. *J Bone Joint Surg Am.* 1994;76:1819–1826.
91. Speer KP, Warren RF, Horowitz L. The efficacy of cryotherapy in the postoperative shoulder. *J Shoulder Elbow Surg.* 1996;5:62–68.
92. Sperber A, Hamberg P, Karlsson J, Sward L, Wredmark T. Comparison of an arthroscopic and an open procedure for posttraumatic instability of the shoulder: a prospective, randomized multicenter study. *J Shoulder Elbow Surg.* 2001;10:105–108.
93. Tauro JC. Arthroscopic inferior capsular split and advancement for anterior and inferior shoulder instability: technique and results at 2- to 5-year follow-up. *Arthroscopy.* 2000;16:451–456.
94. Townsend H, Jobe FW, Pink M, Perry J. Electromyographic analysis of the glenohumeral muscles during a baseball rehabilitation program. *Am J Sports Med.* 1991;19:264–272.
95. Tyler TF, Calabrese GJ, Parker RD, Nicholas SJ. Electrothermally-assisted capsulorrhaphy (ETAC): a new surgical method for glenohumeral instability and its rehabilitation considerations. *J Orthop Sports Phys Ther.* 2000;30:390–400.
96. Uhorchak JM, Arciero RA, Huggard D, Taylor DC. Recurrent shoulder instability after open reconstruction in athletes involved in collision and contact sports. *Am J Sports Med.* 2000;28:794–799.
97. Vangsness CT, Jr., Ennis M, Taylor JG, Atkinson R. Neural anatomy of the glenohumeral ligaments, labrum, and subacromial bursa. *Arthroscopy.* 1995;11:180–184.
98. Vangsness CT, Jr., Mitchell W, Nimni M, Erlich M, Saadat V, Schmotzer H. Collagen shortening. An experimental approach with heat. *Clin Orthop.* 1997;267–271.
99. Warner JJ, Flatow EL. Anatomy and biomechanics. In: Bigliani LU, ed. *The Unstable Shoulder.* Rosemont, IL: American Academy of Orthopaedic Surgeons; 1996.
100. Warner JJ, Lephart S, Fu FH. Role of proprioception in pathoetiology of shoulder instability. *Clin Orthop.* 1996;35–39.
101. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using moire topographic analysis. *Clin Orthop.* 1992;191–199.
102. Weiser WM, Lee TQ, McMaster WC, McMahon PJ. Effects of simulated scapular protraction on anterior glenohumeral stability. *Am J Sports Med.* 1999;27:801–805.

103. Wickiewicz TL, Pagnani MJ, Kennedy K. Rehabilitation of the unstable shoulder. *Sports Med Arthrosc Rev.* 1993;1:227–235.
104. Wilk KE, Arrigo CA, Andrews JR. Current concepts: the stabilizing structures of the glenohumeral joint. *J Orthop Sports Phys Ther.* 1997;25:364–379.
105. Wilk KE, Arrigo C. Current concepts in the rehabilitation of the athletic shoulder. *J Orthop Sports Phys Ther.* 1993;18:365–378.
106. Wilk KE, Voight ML, Keirns MA, Gambetta V, Andrews JR, Dillman CJ. Stretch-shortening drills for the upper extremities: theory and clinical application. *J Orthop Sports Phys Ther.* 1993;17:225–239.
107. Yoneda B, Welsh RP, MacIntosh DL. Conservative treatment of shoulder dislocation in young males. *J Bone Joint Surg.* 1982;64B:254–255.