Upper Extremity Injuries in Tennis Players
Diagnosis, Treatment, and Management

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KEYWORDS

• Upper extremity • Tennis • Shoulder • Wrist • Elbow • Treatment

KEY POINTS

- Common upper extremity tennis injuries involve soft tissue and are usually a result of overuse.
- Tennis injuries have a complex association with biomechanical properties of tennis strokes and serves.
- Injury profile of tennis injuries varies by injury site, mechanism of injury, athlete experience level, and presence of known risk factors.
- Diagnosis can be a challenge and depends on a thorough understanding of current research topics.

INTRODUCTION

Tennis is one of the most popular sports in the world, owing to the unique combination of aerobic and anaerobic activity that is enjoyable for all ages and skill levels. At the competitive level, tennis is showcased through the dynamic exchange of intricate strokes and serves by some of the world's most versatile athletes. However, the physical demands of this sport are known to put athletes at risk for a variety of musculoskeletal injuries.[1] A recent study of professional tennis competitions found that more than 50% of men's and women's departures from competition could be attributed to injury.[2] Although specific injury incidence varies by age, sex, and experience level, studies of the general tennis population report that incidence can range from 0.05 to 2.9 injuries per player per year.[1] This observed high prevalence of injury has led many researchers to study how tennis mechanics contribute to the profiles of various musculoskeletal injuries.

Descriptive epidemiologic studies of tennis injuries have found that injuries occur most frequently in the lower extremity, followed by the upper extremity, then trunk.[1–3] Although the upper extremities are not the most prevalent injury site, a recent study investigating the epidemiology of the National Collegiate Athletic Association (NCAA) men's and women's tennis injuries suggested that tennis has a higher proportion of upper extremity injuries than other NCAA sports.[3] Additionally, distinct patterns of injury are observed among sites of occurrence. Lower extremity tennis injuries are mostly acute and result from traumatic events, whereas upper extremity injuries are mostly chronic and result from repetitive overuse. To better understand these findings, risk factors for upper extremity overuse injuries have been widely

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presented in the literature for the overhead-throwing and striking athlete population. These studies proposed that the excessive loading of upper extremity contributes significantly to soft tissue problems,[4] revealing the important role that technique modification of joint biomechanics can have in both injury prevention and treatment.

Physicians are confronted with a variety of challenges in the management of injuries sustained in the upper extremity joints of the wrist, elbow, and shoulder. These challenges are intensified in the overhead athlete, as the complex anatomic interactions of these joints often produce a spectrum of pathology.[5] This article aims to review concepts related to the biomechanical origin, diagnosis, treatment, and prevention of common upper extremity tennis injuries in an effort to guide clinical decision-making. With knowledge of tennis biomechanics and their relation to injury, physicians can provide patients with informed opinions and make treatment recommendations that fit the individual needs and expectations of each athlete.

BIOMECHANICS

Similar to other racket sports, tennis is composed of diverse strokes and serves, each consisting of different biomechanical factors that could contribute to the spectrum of upper extremity injury. The tennis serve is the most energy-demanding tennis motion, and has been shown to comprise nearly 45% to 60% of all strokes performed in a tennis match.[6] The serve is characterized by 5 different phases of motion:

1. Wind-up
2. Early cocking
3. Late cocking
4. Acceleration
5. Follow through

Other stroke types include the forehand or backhand groundstroke, which each have 3 different phases of motion:

1. Racket preparation
2. Acceleration
3. Follow through

Specific and dynamic upper extremity positioning can account for large amounts of the speed at impact and varies by stroke type.

When investigating the production of high-energy tennis strokes and their contribution to tennis injury etiology, the kinetic chain concept of motion cannot be ignored. The kinetic chain describes the route and direction of energy flow in tennis strokes and serves. In this process, musculoskeletal joints, such as the knee, shoulder, and elbow, serve as links in the kinetic chain by absorbing, generating, and transmitting energy to the next link, completing a cycle of energy from the ground to the tennis ball at impact with the racket. In a single tennis match, this cycle is repeated numerous times and relies heavily on an athlete's strength, endurance, flexibility, and technique.[6,7] If energy transfer in one joint is not efficiently coordinated, subsequent joints can easily become overloaded. For example, a biomechanical study of the tennis serve found that the mechanical loads transmitted to the shoulder and elbow increased by 17% and 23% in the absence of proper knee flexion when attempting to produce a velocity similar to that of a serve performed with correct knee flexion.[8,9] Additionally, a tennis player's ability to use the kinetic chain is often dependent on experience level. Several studies have found that advanced players are more efficient at manipulating the kinetic chain to reduce the impact forces transmitted to upper extremity joints. In turn, novice or recreational tennis players often use excessive and uncoordinated strength in the absence of efficient technique, which does not translate into increased ball velocity and rather overload the joint and increases risk of injury.[10,11] These results imply that optimal technique can contribute immensely to maximizing injury prevention and minimizing loads placed on each joint.

WRIST INJURIES

In tennis, wrist injuries are most commonly experienced as ulnar pathology related to the extensor carpi ulnaris (ECU) tendon and occur during forehand groundstrokes. The forehand stroke is the most frequently used groundstroke in tennis and is performed with the dominant forearm in full supination and the wrist flexed in ulnar deviation.[6] Wrist flexion and extension are important components of ball velocity after ball-racket impact. For example, a study by Seeley and colleagues[12] determined that increasing tennis ball velocity from medium to fast during the forehand stroke required 31% greater angular velocity of the wrist joint at impact. Therefore, dynamic repetition of this stroke depends largely on the integrity of the ECU and its ability to contribute to wrist flexion and extension.

Injury risk to both the ECU tendon and its fibro-osseous sheath increases when the tendon is overloaded by strong forces transmitted to the wrist at impact. A major component of the forehand stroke that is associated with wrist extensor and flexor overload is the generation of top-spin, which can be accomplished through using specific racket grip techniques. The contribution of grip techniques to wrist injury was studied by Tagliafico and colleagues[13] in 370 nonprofessional tennis players. These investigators found that utilization of Western and semi-Western grip types, which are most effective in generating top-spin rotation in the forehand stroke, were associated with ulnar-sided wrist injuries that almost exclusively pertained to ECU tendinopathy. Additionally, the nondominant wrist in the 2-handed backhand stroke can be subjected to the same harmful forces as that of the forehand stroke. This observation is most likely attributed to the extensive ulnar deviation experienced by the nondominant wrist at stroke impact.[14] These studies indicate that athletes using the Western or semi-Western grip types of the forehand stroke, as well as those using the 2-handed backhand stroke, are at higher risk of experiencing ulnar wrist symptoms and can benefit from prevention exercises aimed at strengthening the wrist extensor and flexor units of both arms.

Although less prevalent than ECU tendinitis, tennis players can also experience acute ECU injury as a result of traumatic subsheath rupture or attenuation. Disruption of the ECU subsheath leads to a loss of tendon stabilization and can result in painful subluxation or snapping of the ECU tendon over the ulnar groove.[15] Specifically, acute ECU subluxation is connected with performance of the low forehand stroke. In this stroke, sudden hypersupination of the forearm occurs with the wrist in flexion and ulnar deviation, generating a traumatic force capable of disrupting subsheath integrity. Physicians treating tennis players with ECU pathology should distinguish between these chronic and acute injuries to make informed treatment decisions.

Diagnosis

In many cases of ECU subluxation, patients may report painful snapping over the ulnar styloid of the wrist that limits athletic participation. A detailed physical examination starts with discussion of both mechanism of injury and symptom history. Next, physicians should carefully palpate the dorsoulnar wrist, specifically assessing the scapholunate, triquetrolunate, distal radio-ulna, and ulnocarpal joints. Additionally, the hook of the hamate, flexor, and extensor tendons are examined and the Finkelstein test for DeQuervain tenosynovitis is performed. Plain radiographs in 3 views should be ordered to rule out osseous pathologies, such as fractures or distal radio-ulna joint arthritis.

Although various physical tests for ECU pathology exist, the intricate structures of the wrist are often difficult to isolate. For this reason, results of clinical maneuvers often can be elusive and contradictory, further complicating the diagnostic process. Recently, in an effort to better distinguish ECU tendinitis from ECU subluxation, Ruland and Hogan[16] developed the ECU synergy test. This key provocative maneuver relies on synergistic muscle activity to achieve isometric contraction of the ECU tendon and discern between intra-articular and extra-articular ECU pathology (**Table 1**). This test has proven useful in clinical settings and should be used before imaging studies. In the case of an ambiguous diagnosis or recurrent symptoms, MRI and dynamic ultrasound studies can supplement physical examination. MRI can be useful for visualization of ECU tendinitis or confirmation of other soft tissue abnormalities, such as scapholunate ligament or triangular fibrocartilage complex tears.[17] Dynamic ultrasound is an effective method for identification of ECU subluxation.[18–20] These differing findings highlight the clinical importance of performing the ECU synergy test before selecting an imaging modality, in an effort to gain information about injury type and minimize the unnecessary use of imaging studies.

Treatment

ECU tendinitis is treated with nonoperative methods such as rest, nonsteroidal anti-inflammatory drugs (NSAIDs), splinting, and technique modification. If symptoms are persistent, corticosteroid injections into the ECU sheath may be useful. For the treatment of ECU subluxation, cast immobilization with the wrist pronated and extended for 6 weeks can be considered before operative treatment.[15] If symptoms persist after conservative treatment, surgical reconstruction of the fibro-osseous tunnel of the sixth extensor compartment is recommended. Typically, this reconstruction can be performed by wrapping a strip of the extensor retinaculum around the ECU and suturing the tendon in place. A recent study by MacLennan and colleagues[18] investigating outcomes of ECU tendon sheath reconstruction in 21 patients diagnosed with ECU subluxation observed a significant improvement in postoperative grip strength, flexion-extension, pronation-supination, and Disabilities of the Arm, Shoulder, and Hand (DASH) scores at long-term follow-up. Another study that evaluated surgical outcome in a sample consisting of 10 professional athletes (7 tennis players) found that the athletes were able to return to previous levels of play after an average of 8 months (range 3–21).[21] These study results indicated that excellent surgical outcomes

Table 1
A summary of physical tests useful for the diagnosis of common upper extremity tennis conditions

Condition	Physical Test	Description	Positive Result
Extensor carpi ulnaris (ECU) tendinitis/subluxation	ECU synergy test	• Patient rests arm on table with elbow flexed at 90° • With forearm in full supination, examiner palpates the ECU tendon • Ensuring that wrist is neutral, use other hand to grasp patient's long finger and resist patient's radial abduction of the thumb	Pain experienced along the dorsal ulnar wrist
Lateral epicondylitis	Cozen test	• Patient elbow is stabilized by palpation of examiner's thumb over lateral epicondyle • Patient is asked to make a fist and pronate forearm with radial deviation and extension • Examiner resists patient movement	Pain experienced at the lateral epicondyle
	Mill test	• Patient arm in passive pronation with wrist flexed and elbow extended • Examiner palpates the lateral epicondyle with thumb	Pain experienced at lateral epicondyle
	Maudsley test	• Resisted middle digit extension • Specifically target resistance of the middle extensor digitorum communis (EDC) tendon	Pain experienced in elbow region above lateral epicondyle
Labral pathology	Modified dynamic labral shear test	• Patient stands • Examiner flexes elbow 90°, then abducts into scapular plane above 120° and externally rotated to maximum ability • Guide arm into maximal horizontal abduction, and shear load to joint maintaining this position	Pain experienced along posterior joint line with or without clicking
	O'Brien test	• Patient stands • Examiner places arm at 90° forward flexion, 10° horizontal adduction with internal rotation • Place hand over elbow and ask patient to resist downward pressure • Ask patient to externally rotate palms up, place hand over palm and ask patient to resist downward pressure	Pain experienced at joint line during internal rotation, yet pain improves with external rotation
Rotator cuff pathology	Neer test	• Patient stands with arm passive at side of body with elbow extended • Examiner internally rotates arm through full forward flexion	Pain experienced at anterior-lateral area of shoulder
	Hawkin test	• Patient stands • Examiner places shoulder in 90° of shoulder and elbow flexion, then rotates internally	Pain experienced with internal rotation

facilitating a return to previous level of play are achievable in both operative and nonoperative treatments for ECU wrist pathology.

ELBOW INJURIES

Elbow pathology in tennis players frequently differs by level of play. Less-experienced or recreational tennis players typically experience elbow injury as a result of incorrect technique or equipment, whereas professional tennis players may injure the elbow as a result of more subtle incorrect technique. With this, physicians can tailor medical treatment and recommendations to fit the tennis player's experience level for both the treatment and prevention of elbow injury.

Lateral Epicondylitis

One of the most prevalent tennis injuries presenting to general and specialty clinicians is lateral epicondylosis, commonly termed "tennis elbow." Epidemiologic studies estimated that up to 50% of tennis players will develop lateral elbow symptoms throughout their tennis career, with a primary population consisting of recreational tennis players.[22,23] Consensus on cause of lateral epicondylitis does not exist; however, many different etiologies have been proposed. In addition to anatomic predisposition of the extensor carpi radialis brevis (ECRB) tendon to irritation, overloading of wrist extensors during the backhand tennis stroke is thought to be a key contributor to the prevalence of the condition.[24–26] Despite lower utilization compared with forehand strokes and serves, the backhand stroke is an important skill for tennis players. It can be performed using a 1-handed or 2-handed approach; however, the 1-handed approach is more commonly associated with elbow pathology. This stroke is accomplished with the elbow extended and the wrist supinated, applying stress to the forearm extensor unit and transmitting particularly large forces to the ECRB at the lateral epicondyle. Numerous studies have identified both intrinsic technical skill factors and extrinsic equipment variations that contribute to the high prevalence of this condition in the recreational tennis player.

Differences in the backhand technique of experienced and recreational tennis players can be observed in kinematic studies of forearm muscle coordination during backhand stroke production. Grip tightness is a key feature of a powerful backhand stroke; however, it must be coordinated appropriately with phases of the backhand serve to prevent injury to the elbow. For example, a kinematic study of the backstroke performed by Wei and colleagues[10] found that experienced tennis players use a tight grip at ball-racket impact, then immediately decrease their grip tightness in the follow-through phase. This study found that use of this quick-release grip reduced 89.2% of the impact force transmitted to the lateral epicondyle region of the elbow. However, when grip force was quantified in recreational players, these researchers found that the tight grip was incorrectly retained throughout both ball impact and follow-through phase, resulting in reduction of only 61.8% of impact force transmitted to the elbow. Electromyography studies of the same test groups revealed similar results when forearm muscle activity was quantified, finding that the wrist extensors of recreational players exceeded maximal contraction levels at both ball impact and follow-through phase, whereas those of experienced players reached maximal activity at ball impact and were submaximal in the follow-through phase. From this, physicians and rehabilitation specialists should communicate the importance of decreasing grip strength and relaxing forearm muscles in the follow-through phase of the backhand stroke. These modifications have serious implications for lateral epicondylitis prevention in recreational tennis players.

Overloading of the elbow joint also can occur as a result of equipment-dependent factors, such as racket size or quality. Incorrect grip size of the racket handle has recently been associated with increased force transmission to the elbow. A study by Rossi and colleagues[27] quantified the forces acting on the dominant tennis arm with varying racket handle grip sizes, finding that grip size significantly influenced the impact forces transmitted to the forearm extensor muscles, particularly when the grip was too small or large. These researchers observed that when racket handles were not the appropriate size for a tennis player's hand, the players increased grip force on the racket, which in turn increased harmful force transmission to the elbow. This study highlights the benefits of properly fitting equipment, of which less-experienced tennis players may not be familiar with.

Diagnosis

Patients with lateral epicondylitis typically present with pain and tenderness over the lateral epicondyle, which may radiate distal to the forearm throughout the extensor muscle area. Patients usually experience discomfort with passive flexion and resisted wrist extension, as well as pain with grasping objects firmly. A variety of physical tests can be performed to aid diagnosis, including the Cozen test, Mill test, and Maudsley test (see **Table 1**). The differential diagnosis includes radial tunnel syndrome and posterior interosseous nerve entrapment. In cases in which the diagnosis is unclear, MRI can be used to confirm and plan treatment; however, clinical tests and physical examination are typically sufficient for diagnosis.[28]

Treatment

There is no standard protocol for treatment of lateral epicondylitis. Nonoperative therapy is recommended before operative intervention. In most cases, symptoms will resolve without treatment within 6 to 12 months. In the tennis athlete, the wait-and-see approach is not always a realistic option, as athletes often need to return to play quickly. When conservative treatment is selected by the patient and physician, NSAIDs are typically the first approach and are often recommended with splinting, stretching, and strengthening exercises. Additionally, physiotherapy that combines elbow manipulation and strengthening exercises targeting the extensor muscles of the forearm have proven to provide short-term symptom relief.[29] If symptoms do not improve with NSAIDs or therapy, corticosteroid or platelet-rich plasma injections may be considered, although there is a lack of evidence supporting the use of injections over other nonoperative treatments. A recent randomized control trial conducted by Coombes and colleagues[30] compared 1-year postoperative outcome measures of 3 groups of lateral epicondylitis patients: those receiving physiotherapy with corticosteroid injection, those receiving physiotherapy only, and those receiving injection only. These researchers did not observe a clear benefit when comparing these groups with control patients with lateral epicondylitis, and in turn found that corticosteroid treatment resulted in less improvement and greater 1-year recurrence. Similar studies of conservative treatments have failed to find long-term benefits.[29,31–35]

In the case of nonoperative treatment failure, surgical release of the ECRB at the lateral epicondyle can be performed with an arthroscopic or open approach, and provides safe and effective relief of symptoms with minimal complications.[36–38] Recent literature has focused on exploring outcomes of arthroscopic release and has contributed to the growing support of arthroscopy as a viable method of ECRB release for recalcitrant cases.[39–42] Studies of functional recovery after surgical ECRB release indicated that patients can typically return to play within 3 to 6 months after surgery.[43]

Medial Epicondylitis

Medial epicondylitis involves tendinopathy of the pronator teres and flexor carpi radialis muscles in the attachment of the flexor-pronator tendon to the medial epicondyle. This condition is found in 10% to 20% of epicondylitis cases and is believed to be a result of repetitive eccentric loading of the flexor and pronator muscles of the forearm.[44] Contrary to the incidence of lateral epicondylitis, medial epicondylitis is most common among higher-level tennis players, and can result from advanced technical deficits, such as open-stance hitting, short-arming strokes, and excessive wrist snapping during serves and forehand strokes.[9]

Diagnosis

Patients with medial epicondylitis present with persistent pain and tenderness over the medial epicondyle, which may radiate distal to the forearm throughout the flexor-pronator muscle area. Specifically, patients experience pain during the early acceleration phase of serves and forehand strokes, in which the forearm is pronated with wrist flexion. In this position, the elbow joint is in valgus stress and the flexor-pronator muscles are maximally contributing to elbow stabilization.

Physical examination reveals tenderness with resisted wrist flexion and forearm protonation. Possible differential diagnoses include medial collateral ligament tear, ulnar neuropathy, and medial elbow instability. Similar to lateral epicondylitis, a medial epicondylitis diagnosis is usually achieved clinically through physical examination and MRI is useful in diagnosis confirmation in cases of ambiguity.[45] A recent retrospective review of surgical patients with medial epicondylitis conducted by Vinod and Ross[46] emphasized the utility of clinically evaluating pronator strength to quantify weakness of the forearm and clinically track pathologic changes in flexor-pronator tendon injury. This aspect is useful in monitoring the clinical course and making treatment decisions for recalcitrant medial epicondylitis in the tennis player.

Treatment

Nonoperative approaches to treatment, such as NSAIDs, strength and flexibility programs, and rest, are used before operative treatment. Steroid injections may provide short-term symptom relief, yet fail to display significant long-term benefits when compared with control patients.[47] Conservative treatment is typically effective in symptom alleviation in 88% to 96% of cases.[48] If symptoms persist after 3 to 6 months of conservative treatment, operative intervention is considered. Surgical methods can be implemented earlier in athletes with MRI indicating tendon disruption. Open methods of surgical debridement of the common flexor tendon have continually demonstrated successful in symptom alleviation.[49] Additionally, recent investigations have suggested that suture anchor fixation of the flexor-pronator mass can also be a method of symptom relief.[50] Contrary to lateral epicondylitis, an arthroscopic approach is typically not recommended in surgical management of medial epicondylitis, owing to the close proximity of both the ulnar collateral ligament and the ulnar nerve to the medial epicondyle. Postoperative rehabilitation is centered on the strengthening and stretching of the flexor-pronator muscles and athletes can return to play in 3 to 6 months as tolerated.[50]

SHOULDER INJURIES

The shoulder joint is the most mobile joint in the body and balances both stabilization and rotational range of motion. In tennis players, this delicate equilibrium is manipulated to create powerful serves and groundstrokes through external rotation and abduction of the shoulder. Overuse injuries to the shoulder are prevalent among tennis players of all skill levels and have been shown to contribute to nearly 4% to 17% of all tennis injuries.[3,51] In a recent study investigating the causes of professional tennis player departures from competition, Okholm Kryger and colleagues[2] found that shoulder injuries were the second most frequent cause of departure for both sexes. For these reasons, it is not only important that clinicians are familiar with the intricate pathology, diagnosis, and treatment of athletic shoulder injuries, but also aware of the mechanical origin of these injuries and how they relate to tennis-specific movements.

Risk Factors

The scapula plays a key role in stabilizing glenohumeral joint mobility during arm motion by frequently changing positions to promote shoulder movements. In the tennis serve, the scapula follows distinct patterns of motion, characterized by retraction/protraction as the serve progresses from early to late cocking stage and upward rotation during the acceleration phase.[52] These fine movements are orchestrated by surrounding rotator cuff muscles that attach to the scapula and other surrounding capsular structures. If shoulder structures become weak or dysfunctional as a result of chronic overload, tennis players may develop scapular dyskinesis. This condition is characterized by an imbalance of the scapula, leading to alterations in scapular movement, which produces pain and functional deficiency during overhead serving motions. In some cases, the affected scapula may demonstrate a drooping appearance or inferior medial border prominence at rest when compared with the unaffected shoulder, a condition commonly referred to as SICK (Scapular malposition, Inferior medial border prominence, Coracoid pain, and dysKinesis of scapular movement) scapula.[53] In most tennis athletes, the presence of scapular dyskinesis or SICK scapula has been found to be associated with shoulder injuries,[53–57] although the exact interactions of these conditions with shoulder injuries are largely undefined.[58] The scapula's role in optimal shoulder performance indicates that an assessment of scapular function is crucial in both preparticipation athletic evaluations and evaluation of tennis athletes presenting with shoulder pain or dysfunction. Once identified, scapular abnormalities can be corrected with rehabilitative stretching programs that successfully target the restoration of muscular and capsular strength and flexibility in the shoulder.[59,60]

In tennis, internal rotation of the shoulder is considered one of the most important positive contributors to ball velocity, especially during the serve.[8] However, repetition of the abduction-extension motion of tennis serves and other overhead strokes can alter the rotational arc of the shoulder, producing an increased degree of external rotation at the expense of posterior capsule tightening. Although increased external rotation produces a more powerful serve, posterior tightening decreases the degree to which the athlete's shoulder can internally rotate and can eventually lead to the development of glenohumeral internal-rotation deficit (GIRD). GIRD is quantitatively characterized by a $>18^\circ$loss of internal rotation in the athlete's dominant shoulder compared with the nondominant shoulder, as measured during clinical evaluation.[61] The presence of this deficit changes the glenohumeral kinematics of the tennis serve and has also been found to be associated with higher risks of shoulder injury.[62,63] Athletes with GIRD typically present with deep posterior shoulder pain that is accompanied with a decrease in degrees of internal rotation and increase in external rotation, as compared to the nondominant arm and measured by a goniometer. The progression of GIRD can be reversed by stretching programs that target the posteroinferior capsule, which have proven to successfully increase internal and total rotation and reduce GIRD in high-level tennis players.[5,64]

Internal impingement is another condition that is related to shoulder injury development. It is defined as the abnormal mechanical impingement of rotator cuff tendons against the superior glenoid rim and labrum. Internal impingement occurs in healthy shoulders of athletes[65]; however, it can be injured from increased posterior capsule compression. Continual compressive forces in the posterior shoulder capsule can cause a shift of the glenohumeral joint axis.[5] Similar to GIRD and scapular dyskinesis, these compressive loads are experienced during exaggerated external rotation in the late cocking stage of the tennis serve and patients will present with posterosuperior pain and dysfunction. Posterior internal impingement has been shown to occur alongside both GIRD and scapular dyskinesis, and may become increasingly pathologic when associated with these risk factors.[55,66]

Labral Injury

The labrum is a common site of injury for overhead athletes, as it is a key contributor to optimizing capsular tension in the shoulder. Labral pathology in athletes has been studied extensively in literature and is often associated with both GIRD and scapular dyskinesis conditions.[55,57,62,67] Superior labral anterior-to-posterior (SLAP) lesions are the most common labral injuries experienced by athletes. They are characterized by fraying or tearing of the superior labrum at the site of biceps tendon attachment, disrupting the underlying interaction with the glenoid. Although different classifications of severity exist, the most common SLAP lesion involves the detachment of both the superior labrum and the biceps tendon from the glenoid.[68] Biomechanical studies investigating athletic labral injuries have indicated that the mechanics of the late cocking stage of overhead throws and serves play the largest role in the etiology of SLAP lesions.[69,70]

Diagnosis

The diagnosis of the SLAP lesion is notoriously difficult for physicians and requires detailed knowledge of shoulder pathology and careful clinical examination. Athletes with SLAP lesions will present with deep pain that is accompanied by shoulder weakness or dysfunction experienced during the external rotation of the cocking stage of the overhead motion. Some athletes may also report the experience of a popping sensation.[67] There are many clinical tests to aid in the diagnosis of an SLAP lesion; however, a single test with optimal specificity does not exist.[61] Despite these diagnostic limitations, recent explorations have indicated that a combination of the modified dynamic labral shear test and O'Brien active compression test yields the most accurate diagnosis (see **Table 1**).[71] MRI has also proven to be a useful modality to rule out the diagnosis of an SLAP lesion, but is not an accurate clinical diagnostic tool when used alone.[72]

Treatment

Similar to other chronic soft tissue injuries, nonoperative treatment is used before consideration of surgical[46] repair for SLAP lesions. Conservative treatment typically encompasses the use of NSAIDs with the same specialized physical therapy programs that strengthen, stabilize, and increase flexibility of scapular and posterior capsule structures. Surgical treatment of SLAP lesions is usually deployed if symptoms are not relieved after 4 to 6 months. Depending on the severity of the SLAP lesion, patients may benefit from either arthroscopic debridement or repair. However, arthroscopic repair is the standard treatment for SLAP lesions, especially those that involve the detachment of both the posterior labrum and the biceps tendon from the glenoid. The arthroscopic approach typically involves placing multiple suture anchors on the glenoid to secure the attachment of the labrum. A recent prospective study evaluating this technique found that 87% of patients reported a good or excellent outcome at a 2 year follow-up.[73] Similar studies on pain and functional outcome improvement in overhead athlete populations have also supported these findings.[74,75] Alternatively, recent literature has described the utility of biceps tenodesis in the surgical treatment of SLAP lesions, but outcomes studies have indicated that this procedure is most effective for an older, nonathletic population.[76] The results of these evaluations indicate that the athletic status of a patient may have a large role in guiding the treatment decisions being made for SLAP lesions.

It is undisputed that athletic activity contributes heavily to the etiology of labral injury in tennis players. It is also a significant factor in evaluating postoperative outcome, as an athlete's perception of treatment success is largely based on the ability to return to play. Functional outcomes and return to play period of both nonoperative and operative SLAP lesion treatments continue to be a source of controversy in athletic literature. Studies of overhead athletes have reported inconsistent results regarding return to previous level of play, reporting successful return in anywhere from 20% to 94%[61,77,78] of overhead athlete patients. Additionally, literature suggested that the likelihood of overhead athletes returning to previous levels of play is significantly lower than that of nonthrowing athletes.[79] These studies have strong implications for clinicians, in that they suggest postoperative return to play cannot be guaranteed in the overhead athlete. This observation highlights the necessity for sufficient physician communication with tennis players about realistic treatment outcomes that may not satisfy the patient's athletic expectations.

Rotator Cuff Injury

Rotator cuff injury is frequent in the general population, with a degenerative etiology seen mostly in older patients. However, these injuries are also prevalent in younger populations of overhead-throwing athletes, occurring as a result of repetitive, high-energy loading of the shoulder joint. In energetic overhead motions, the muscles and tendons comprising the rotator cuff are the most important components of dynamic shoulder stabilization. In athletes, rotator cuff tendinopathy is most often associated with posterior internal impingement, which can cause fraying or tearing of the rotator cuff tendons with repetition. Additionally, scapular dyskinesis has been shown to contribute to rotator cuff pathology, as the rotator cuff muscles synchronicity is disrupted by abnormal scapular range of motion.

Diagnosis

Patients with rotator cuff injury typically present with pain experienced during throwing and dysfunction that inhibits peak performance of tennis serves and other overhead motions, similar to other soft tissue shoulder pathology. If the injury is the result of posterior internal impingement, the supraspinatus and infraspinatus tendons will be most affected, and pain will be experienced in the late cocking phase of the tennis serve. Diagnosis can be achieved during a careful clinical examination that assesses rotator cuff muscle strength, range of motion, and posterior instability supplemented with imaging studies. In many cases, tests that evaluate impingement, such as the Neer or Hawkin test, can be useful for diagnosis (see **Table 1**). MRI has proven to be a successful supplement to clinical examination and can aid in rotator cuff tear identification, although ultrasound has also proven to be an effective diagnostic tool when used correctly.

Treatment

As a mainstay of chronic soft tissue injury, conservative treatment of rest, NSAIDs, and physical therapy programs focusing on strengthening and stretching of the rotator cuff muscles are used before the consideration of surgery. Minor injuries to the rotator cuff usually respond well to treatment, and often permit return to athletic overhead activity within approximately 3 months.[80] If nonsurgical treatment fails after 3 to 6 months, operative treatment is considered via arthroscopy or open methods. Surgical treatment methods depend on the thickness and location of the muscle tear, as surgical approach is typically altered to fit individual patient needs. Surgery can be accomplished through open or arthroscopic methods, offering either debridement or repair to improve symptoms. For partial thickness tears, repair is recommended if the tear comprises greater than 50% of the tendon, whereas debridement is recommended in cases below 50%. For full-thickness tears, a suture anchor approach has increasingly emerged as viable option for firm restoration of rotator cuff tendons to the proper anatomic position. These strengths were demonstrated in a cadaver study conducted by Burkhart and colleagues[81] that tested the cyclic loading capabilities of suture anchor fixation compared with transosseous bone tunnel fixation. The long-term outcomes of rotator cuff debridement and repair in the overhead athlete are not well defined in the literature. However, the few studies that have investigated outcomes in this population reported that satisfactory result of debridement is achieved in anywhere from 66% to 76% of athletes, with roughly 45% to 85% being able to return to play.[82–84] Whereas debridement results are somewhat promising, outcomes of surgical partial- and full-thickness repair are increasingly dismal, with some studies observing an inability to return to play in more than half of patients.[84,85] These suboptimal results suggest that physicians should approach surgical repair of rotator cuff tears with caution when considering overhead athletes. Similar to outcomes of SLAP repair, it is imperative that physicians discuss the realities of surgical intervention in shoulder pathology and prepare athletes for potential inability to return to previous levels of play.

SUMMARY

Tennis is a complex and physically demanding sport that can produce a wide range of similarly complex injuries. Upper extremity injuries occur from repetitive overloading of joints, and diagnosis is frequently challenging for physicians, owing to the complex interaction between soft tissue anatomy and biomechanics of the kinetic chain. Diagnosis and treatment of common tennis injuries vary by the location of the injury and can depend on the mechanism of injury, experience level of the athlete, and the presence of physical risk factors that are affected by muscular strength, flexibility, and coordination. Operative management is considered after trying conservative treatment, yet should be approached with caution, in that favorable outcomes may not be realistic and a return to previous level of play may not be achievable.

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