Tennis elbow (lateral epicondylitis) is a common soft tissue condition treated by many physical therapists in a variety of clinical settings. The purpose of this paper is to review the relevant anatomy, clinical examination, differential diagnosis, conservative care, and surgical treatment for patients with tennis elbow. The incidence of lateral epicondylitis has been found to vary with different population groups. Allander (1) reported an incidence of 1-3% in a population study of 15,000 subjects. In two separate studies at industrial health clinics, lateral epicondylitis was found to be most commonly associated with work-related activities, ranging from 35 to 64% of all diagnosed cases (1,2,25). In fact, people who played tennis constituted a rather small proportion of the total, only 8% (1). However, as a group, tennis players do run a higher risk of developing lateral epicondylitis. Maylack (32) reviewed the epidemiological data available concerning injuries among tennis players and reported that 50% of competitive tennis players will suffer from at least one episode of lateral epicondylitis.

ANATOMY

The elbow is a complex ginglymus or hinge joint that allows motion of flexion and extension (54). The proximal and distal radio-ulnar joints allow the motion of pronation and supination. The distal humerus consists of two condyles forming the articular surfaces of the trochlea and capitellum (capitulum). Above the condyles are the medial and lateral epicondyles. The medial epicondyde serves as the attachment of the ulnar collateral ligament and the origin of the forearm flexor-pronator group of muscles. The lateral epicondyle, located just above the capitellum, is the origin of the extensor-supinator group. This lateral area is involved with tennis elbow. This review of anatomy will concentrate on structures found on the lateral side of the joint: osseous, bursae, capsuloligamentous, nerve, and musculotendinous.

Osseous Structures

The lateral epicondyle is less prominent than the medial epicondyle. Just proximal to the lateral epicondyle is the supracondylar ridge or column. The ridge is easily palpable and separates the lateral head of the triceps on the posterior surface of the humerus from the brachioradialis, extensor carpi radialis longus anteriorly, and the extensor carpi radialis brevis. The distal end of the humerus is flattened anteroposteriorly and is the widest part of the bone. At the junction of the shaft and the distal end, the humerus is anteriorly rotated 30-45° (33,34). The articular surface of the humerus is formed by the trochlea and capitellum. The trochlea is a hyperboidal, pulley-like surface that articulates with the semilunar notch of the ulna. The capitellum, on the other hand, is almost spheroidal in shape. Hyaline cartilage is generally more thick on the capitellum than on the trochlea (2 mm compared with 1 mm) (35). The trochleocapitellar groove separates the capitellum from the radial head. The lateral epicondyle is less prominent than the medial epicondyle.
lum from the trochlea, distinguishing the articulation with the head of the radius. Hyaline cartilage covers the radial head as well as the outside circumference that articulates with the ulna. The ulnar portion of the humeroulnar joint is made up by the sigmoid notch. Unlike the other joint surfaces, the notch does not have a continuous hyaline cartilage surface.

Capsuloligamentous Structures

The stability of the elbow joint is provided by the bony anatomy and the ligaments, which are actually specialized thickenings of the joint capsule (33). The radial (lateral) collateral ligament is commonly described as originating from the lateral epicondyle and terminating diffusely in the annular ligament (22). McVay (33) and Wadsworth (53) have described the lateral ligamentous structures as a single complex. Morrey (34) described four separate ligaments that comprise the lateral ligament complex. The radial collateral ligament originates at the lateral epicondyle and attaches distally by blending into the annular ligament. The lateral ulnar collateral ligament arises posterior to the radial collateral ligament and passes superficial to the annular ligament to attach to a discrete bony tubercle on the proximal ulna. The accessory lateral collateral ligament fibers are intimately associated with the annular ligament and function to augment it during varus stress of the elbow. Finally, the annular ligament is a stout structure that attaches on the sigmoid notch of the ulna, encircles the radial head, and again attaches to the sigmoid notch.

The anterior joint capsule inserts proximally above the coronoid and radial fossae. Distally, the capsule attaches to the anterior margin of the coronoid (medially) as well as to the annular ligament (laterally). The anterior portion is taut in extension and becomes lax with flexion. The posterior portion of the capsule is attached proximally just above the olecranon fossa and along the medial and lateral margins of the trochlea. Distally, attachment is along the medial and lateral articular margin of the sigmoid notch, and laterally along the lateral aspect of the sigmoid notch to form a confluence with the annular ligament (34).

A synovial membrane lines the capsule but is separated from the capsule by fat pads opposite the olecranon, coronoid, and radial fossae. A fold of synovial tissue has been described as projecting between the capitellum and radial head, forming the "meniscus" of the radiohumeral joint. A synovitis of the fold has been recognized and implicated by several authors (8,41) in the etiology of lateral epicondylitis. McVay (33) indicated that radioulnar bursitis may occur from the irritation of repeated or violent extension of the wrist with the forearm pronated. Goldie (18), however, found no involvement of the bursae in 176 elbows examined. Rather, his investigation identified the presence of a subtendinous space near the extensor carpi radialis brevis attachment to the lateral epicondyle that was filled with granulation tissue, hypervascularized, and edematous in patients with tennis elbow (18). Goldie (18) concluded that this constituted the pathogenesis of lateral epicondylitis and his contention was strengthened by the observation that excision of the granulation tissue resulted in complete recovery from symptoms of the condition for the vast majority of the patients.

Neurologic Structures

The principal neurologic structure found on the lateral aspect of the elbow is the radial nerve. As a continuation of the posterior cord, the nerve originates from branches of the C6, C7, and C8 nerve roots. After winding around the posterior surface of the shaft of the humerus from medial to lateral, the nerve pierces the lateral intermuscular septum to enter the anterior compartment of the arm (Figure 1). Once the nerve reaches the anterior compartment of the arm, it lies deep in a furrow bound on the medial side by the brachialis muscle with the extensor carpi radialis longus muscle overlying it anterolaterally and the capitellum lying posteriorly. In this area, referred to as the radial tunnel, nerve branches are sent to the brachialis, brachioradialis, and extensor carpi radialis longus muscles, to the periosteum of the lateral epicondyle, and to anterior structures of the radiohumeral joint and annular ligament (23). In the antecubital space,

At industrial health clinics, lateral epicondylitis was found to be most commonly associated with work-related activities.
the nerve divides near the arcade of Frohse into the superficial and deep branches (Figure 2). At about the level of the radial head, the extensor carpi radialis brevis muscle receives its innervation from the superficial radial nerve. The deep branch passes through the arcade of Frohse between the two heads of the supinator muscle which it innervates (47). It emerges from the muscle as the posterior interosseous nerve, innervating the extensor digitorum communis, extensor carpi ulnaris, and extensor digiti quinti. The posterior interosseous artery accompanies the nerve, which sends motor branches distally to supply the abductor pollicis longus, extensor pollicis longus, extensor pollicis brevis, and extensor indicis on the dorsum of the forearm (43).

Musculotendinous Structures

The extensor carpi radialis longus originates from the supracondylar ridge below the origin of the brachioradialis. This attachment is between the brachialis medially and the extensor carpi radialis brevis inferolaterally. The extensor carpi radialis longus crosses the elbow and carpal joints to insert onto the dorsal base of the second metacarpal and is covered by the brachioradialis over most of the forearm. Its function is that of wrist extension, radial deviation, and possibly elbow flexion.

Originating from the lateral inferior aspect of the lateral epicondyle, the extensor carpi radialis brevis origin is the most lateral of the extensor group. The extensor carpi radialis brevis is covered by the extensor carpi radialis longus and its fibers are almost indistinguishable from those of the extensor carpi radialis longus and extensor digitorum communis in most cases. The extensor carpi radialis brevis muscle also has additional attachments to the radial collateral ligament and the intermuscular septa between it and the common extensor muscles (48). The extensor carpi radialis brevis muscle tendon inserts to the dorsal surface of the base of the third metacarpal bone. Pure wrist extension with some assistance in radial deviation are the main functions of the extensor carpi radialis brevis. Electromyographic studies by Kashiwagi (24) showed the extensor carpi radialis brevis contracted strenuously at all times during daily functional activities. During the back-
stroke in tennis, the extensor carpi radialis brevis contracted more powerfully than any other forearm muscle.

The extensor digitorum communis originates from the anterior distal aspect of the lateral epicondyle and accounts for most of the contour of the extensor surface. Parts of the extensor digitorum communis are also attached to the septum and tendon from which the extensor carpi radialis brevis arises (18). The extensor digitorum communis insertion contributes to the extensor mechanism for the index, long, ring, and little fingers. In addition to extension of the wrist and digits, Wright (57) suggests that the extensor digitorum communis may assist with elbow flexion when the arm is pronated.

The extensor carpi ulnaris muscle has two heads of origin. The humeral origin is the most medial of the common extensor group while the ulnar attachment is along the superior border and aponeurosis of the anconeus muscle. By inserting into the dorsal base of the fifth metacarpal, the extensor carpi ulnaris acts as a wrist extensor and an ulnar deviator.

The supinator is a flat muscle taking its origin from the anterolateral aspect of the lateral epicondyle, lateral collateral ligament, and the proximal anterior crest of the ulna. The supinator runs distally and radially to insert broadly onto the proximal anterior crest of the ulna. The supinator runs distally and radially to insert broadly onto the proximal radius. The muscle is a forearm supinator whose effectiveness is not altered by degree of elbow flexion (34). An important feature of the supinator is that a branch of the radial nerve pierces the muscle to gain access to the extensor surface of the forearm. Therefore, the supinator muscle can be a site of nerve entrapment (43).

Goldie (18) described the development of a space distal to the lateral epicondyle as the bone attains adult shape. He termed this gap, deep to the aponeurosis, as the subtendinous space. The space contains thin areolar tissue as well as fat tissue acting as a shock-absorbing pad when the extensor muscles contract. Goldie (18) documented that patients suffering from tennis elbow replace this areolar and fat tissue in the subtendinous space with fibrotic, granular-type tissue.

**PATHOLOGY AND DIFFERENTIAL DIAGNOSIS**

Lateral epicondylitis is a syndrome characterized by pain over the outer aspect of the elbow and is usually aggravated by radial extension of the wrist (3,11,12,15,25,29,37). This syndrome most commonly occurs in the 35–50 year age group, is found in men more than women, and tends to involve the subject's dominant arm. Tenderness is typically localized to the tendinous origin of the extensor carpi radialis brevis. The pain can be aggravated by gripping, heavy lifting, or simple tasks of daily living. Chronic symptoms are commonly associated with inadequately large muscle power and endurance. Most investigators contend that repetitive and cumulative injury produces this condition. The consequent force overload may be due to factors localized at the elbow (intrinsic) or the result of factors acting at a distance from the elbow (extrinsic).

**Intrinsic Factors**

Intrinsic factors appear to be the most causal factors (3,11,12,15,26,38,53) and occur when there is excessive loading of normal musculo-skeletal tissue. Overexertion of the extensor muscles of the wrist as a result of repeated gripping and twisting (i.e., supination/pronation) movements may occur prior to the onset of symptoms. Cyriax (11) and Lafrentiere (26) report that these forceful contractions lead to irritation and partial tears of the involved musculature. These repetitive high moments of force are beyond the adaptive capacity of the tissue with subsequent deterioration occurring (29). The site of tissue degeneration continues to be somewhat controversial, although the extensive work by Goldie (18), noted previously in this review, has done much to clarify the nature of the lesion. Cyriax (11) theorized that a muscle tears most easily at its attachment to the bone rather than at the musculotendinous junction or the muscle belly. He stated that the site of maximal tenderness is the site of the injury. However, Garrett et al. (16) state that muscle damage always occurs at the musculotendinous junction. Kivi (25) proposed that the connective tissue plays an important role. While muscle fibers are well supplied with blood and have good healing potential, the tendon fibers attached to the periosteum are relatively avascular and tend to heal more slowly. Lesions are characterized by macroscopic and microscopic tears, which may be superficial or deep. Microscopically, avulsion fractures and round cell infiltration may be present. Scattered foci of fine calcification and scar tissue with marginal areas of cystic degeneration and fibrinoid degeneration may be evident in some cases (53). Repair is often by immature granulation tissue, but rupture of the extensor carpi radialis brevis tendon is rare.

**Signs and Symptoms**

Swelling or ecchymosis is rare, except in cases of external trauma. The arm is painless at rest and during passive range of motion. With repeated microtrauma, an inflamma-
tory condition of the periosteum may develop, which can lead to formation of granulation tissue and adhesions. Granulation tissue contains a large number of free nerve endings which may be responsible for increased tenderness to palpation (11,38,53). The tenderness is most notable at the anterior aspect of the lateral epicondyle and the lateral forearm. Palpation of the radial collateral ligament may elicit exquisite tenderness and is usually increased with varus (adduction) stress to the elbow. Grip strength may be decreased, but the articular and neurological signs are normal. In severe cases, pain at rest occurs along with varying decreases of motion at the extremes of flexion and extension.

According to Bosworth (3), it is difficult to determine whether the extensor muscle origin or the annular ligament is responsible for the symptoms, as they are firmly attached to each other. He contends that rotation of the radial head beneath these structures during pronation and supination causes trauma. This movement produces a pulsating effect, which can cause a stenosis and fibrosis of the annular ligament and the extensor origin. Cyriax (11) and Leach and Miller (28) both concur with this explanation.

In most cases, the lesion involves the junctional tissue at the common extensor muscle origin of the lateral epicondyle, specifically, the extensor carpi radialis brevis (3,11,15,25,26,28,38,40,45,53). If the extensor carpi radialis brevis is involved, extension of the wrist will be more painful if resistance is given at the heads of the metacarpals rather than at the fingertips (11). Radial extension will more specifically indicate the extensor carpi radialis brevis or extensor carpi radialis longus. Pain with resisted extension of the middle finger is present when the extensor carpi radialis brevis is involved (53). Tenderness above the epicondyle will indicate that the extensor carpi radialis longus is involved, while anterolateral tenderness would arise from extensor carpi radialis brevis tissue inflammation. Ulnar extension will provoke the extensor carpi ulnaris. Radial and ulnar extension involve the extensor digitorum communis, but most authors agree that involvement of the extensor digitorum communis or the extensor carpi ulnaris is rare (3,11).

The onset of pain is usually gradual. The force generated by muscle contraction may not produce pain until healing has begun and there is some adhesion between the tendon and the inflamed periosteum (11). Tendons may heal in a somewhat lengthened position, forcing intact muscles to absorb a greater amount of the strain. Other simple diagnostic tests can include the forced elbow extension test, which is usually positive. The forearm is held fully pronated and the wrist palmarly flexed; passive elbow extension then produces lateral elbow pain, which may limit full extension of the joint. Grip limited by pain, as measured by dynamometry, has been shown to be yet another reliable and sensitive index of irritability among patients with lateral epicondylitis (51).

Elbow radiographs are usually normal. Ectopic calcification of the lateral epicondyle appears in 25–50% (25,28) of the cases, but its presence does not appear to alter the prognosis. Radiographs can be obtained to eliminate the possibility of arthritic changes at the radiohumeral articulation or tumor within the substance of the supinator muscle. Although not advocated as part of the diagnostic work-up, arthroscopic exam may prove valuable in cases resistant to conservative measures and caused by intra-articular problems, such as fibrillation of the radial head (13). Because lateral epicondylitis may be part of a generalized arthropathy with additional joint symptoms, other blood studies, such as erythrocyte sedimentation rate and uric acid concentration, tests for rheumatoid disease, and complete blood count may be warranted.

Diagnosis of tennis elbow may be confounded by regional nerve involvement, referred to as radial tunnel syndrome (36). The deep branch of the radial nerve may be compressed (by pronation and flexion of the wrist) as it passes dorsal to the arcade of Frohse along the fibrous edge of the supinator muscle (11,29,45,53). Differential signs include increased pain with deep palpation of the radial head and isometrically resisted supination of the forearm, suggesting radial tunnel syndrome, as opposed to tenderness to palpation of the lateral epicondyle and isometrically resisted extension of the wrist, signifying true tennis elbow (29). Lee, as reported by Gunn (29), found increased action potentials during electromyographic studies of subjects with radial tunnel syndrome. Compression may be from abnormal fibrous bands in front of the radial head, the radial recurrent fan of vessels, and the sharp tendinous origin of the extensor carpi radialis brevis. Rarely, a ganglion or lipoma may cause compressive neuropathy. The posterior intersosseous nerve may be compressed where it enters the supinator muscle, and 30% of subjects have a well-defined arcade of Frohse, which makes compression neuropathy more likely. Pain is more diffuse in compression neuropathy than in tennis elbow, and tenderness is located in the fore-
arm musculature distal to the lateral epicondyle at the level of the radial head. Weakness of extension of the middle finger with the elbow extended can be an important diagnostic feature in the compressive neuropathy, but it must be differentiated from extensor carpi radialis brevis involvement (47). Compression of the posterior interosseous nerve as the cause of tennis elbow is rare. The intrinsic factors cited for lateral epicondylitis have been identified in Table 1. Other conditions that must be considered during the process of differential diagnosis are presented in Table 2.

Extrinsic Factors

The principal extrinsic factor to consider when evaluating a patient with complaint of elbow pain is cervical spine dysfunction. Any evaluation of the elbow and forearm should include an evaluation of the cervical area for possible radiculopathy or facet joint syndrome, especially when the pain is resistant to therapy directed at the elbow (11,25,28,29,40,53). The dermatomes and myotomes of the lateral epicondyle and the lateral forearm are supplied by the C 5–6 and C 6–7 nerve roots.

According to Lee (29), nerve root ischemia, secondary to improper posture, facet, disc, or other involvement can cause spontaneous firing of selected large unmyelinated fibers with resultant hyperaesthesia in the related dermatome. Infiltration of the muscle by connective tissue may result in rigidity noted during palpation and is perceived by the patient as a focal point of muscle tenderness that is aggravated by deep palpation. Trigger points in the segmentally innervated spinal musculature may occur. Submaximal contractions of the affected cervical muscles will not reproduce deep muscle pain, and there are usually no complaints of local cervical pain. No abnormal neurological signs are noted, and the exam rarely identifies a cervical contractile tissue lesion.

A more severe cervical radiculopathy will be characterized by segmental demyelination of selective nerve endings and decreased nerve conduction velocities (29). Deep muscle tenderness is increased, and a “fatiguing” weakness is noted in repeated testing of the wrist extensors. If denervation occurs, the collagen becomes weaker and more susceptible to microscopic and macroscopic tears. Muscle weakness and atrophy may be present if denervation has occurred. Submaximal contractions of the wrist extensors are painful. Finally, Kivi (25) cites psychogenic factors secondary to anxiety and depression to be possible causes of lateral epicondylar and forearm pain.

**Table 1.** Intrinsic factors cited as causative of lateral epicondylitis.

<table>
<thead>
<tr>
<th>Condition</th>
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<tbody>
<tr>
<td>Rheumatoid arthritis (blood tests, joint instability, limited motion, erythema, and generalized pain are diagnostic features) (11,25,53)</td>
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<tr>
<td>Posterior epicondylitis at triceps attachment to olecranon (40)</td>
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<tr>
<td>Tendinitis of long head of the biceps (due to insertion on the radius) (53)</td>
</tr>
<tr>
<td>Radial tunnel syndrome (arcade of Frohse) (43,47)</td>
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<tr>
<td>Tumor (of capitellum or in the supinator muscle) (54)</td>
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**Table 2.** Conditions to be considered in differential diagnosis of lateral epicondylitis.

<table>
<thead>
<tr>
<th>Condition</th>
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<tr>
<td>Overexertion of wrist extensor muscles (primarily ECRB muscle) (12,26,38)</td>
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<tr>
<td>Bursitis of wrist extensor subteniduous space (11,26,28,29,53)</td>
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<tr>
<td>Periosteal inflammation (11,25)</td>
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<tr>
<td>Capsular irritation of the radioumeral joint (28)</td>
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<tr>
<td>Pinched synovial fold (3,11,26)</td>
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<tr>
<td>Radial collateral ligament inflammation (38)</td>
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<tr>
<td>Annular ligament fibrosis (3,11,28)</td>
</tr>
<tr>
<td>Ectopic calcification of lateral epicondyle (25,28)</td>
</tr>
<tr>
<td>Radiocapitellar joint degeneration (40)</td>
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ECRB = Extensor carpi radialis brevis.
brace is a simple cock-up splint during the acute stage (10,11,25). The purpose of the cock-up splint is to put the wrist extensor mechanism at rest. The most frequently used brace is probably the tennis elbow strap or "counterforce armband" (14). This type of brace is advocated for controlling forces at the lesion site (27,28). Forearm support braces are used throughout the acute and chronic phases of the disease, and their mechanism of function is thought to result from counterforce control (19,37). The actual mode of action and its effect on muscle torque in normal subjects was studied by Stonecipher and Catlin (49), who found no improvement in isokinetic wrist extensor torque at 30°/sec but significant increases in torque development when tested at 120°/sec. In a study by Wadsworth et al (55), application of a counterforce armband was found to increase wrist extension and grip strength in the affected arm of patients with epicondylitis. This finding is in partial agreement with Stonecipher and Catlin (49) and Burton (6). It was postulated by Wadsworth et al (55) that this increased strength could result from the armband dispersing stress away from the lesion, thus reducing further tissue injury and related pain inhibition mechanisms. Pain decrease with armband use was not found to be statistically significant by Wadsworth et al (55).

Inflammation

Physical therapists often use ice and electrical stimulation in an attempt to diminish the inflammatory response associated with this condition. Nonsteroidal anti-inflammatory agents are usually prescribed for 2-3 weeks (28). No particular medication has been found to be superior, and the selection of the medication and its dosage will vary according to the patient's response (28,40). Steroid injections are often used if treatment by oral medication and therapeutic modalities has failed to reduce the patient's pain and inflammation (28,40). In a study comparing the effectiveness of early steroid injection with the use of splinting and oral medication in treating patients with lateral epicondylitis, Kivi found no significant difference in the treatment results (25). In a trial of acupuncture therapy in patients with lateral epicondylitis who had failed to respond to steroid injection, Brattberg (5) found that acupuncture therapy resulted in complete to marked improvement in more than 60% of the cases. Chi-square analysis of Brattberg's data indicated that acupuncture was significantly more effective than steroid therapy (5). Halle et al (20) conducted a study comparing the response of patients to four different treatments, including ultrasound, ultrasound with hydrocortisone phonophoresis, transcutaneous electrical nerve stimulation, and steroid injection all accompanied by the same home program of bracing, ice, and painful task avoidance. The results from this study showed no significant differences in the treatment outcome (20).

Tissue Healing

Tissue healing is thought to be enhanced by use of therapeutic modalities that promote increased circulation to the injured area (17). Both ultrasound and high-voltage galvanic stimulation are recommended to assist in this process (40). Patients should be encouraged to not overuse their extremity during the acute tissue healing phase and to avoid activities that aggravate their symptoms. Patients are reminded that avoidance of pain does not necessitate complete immobilization and that gentle, controlled stresses are important for the appropriate alignment of connective tissue as it heals. This concept is particularly important if the treatment involves the use of manipulative maneuvers such as Mill's or Cyriax's techniques (53). The tissue should not be allowed to heal in a shortened position as this may predispose the patient to recurrence of the condition (11). Passive and active-assisted stretching of the common wrist extensors should be undertaken to encourage proper tissue alignment during healing so that such recurrences are avoided.

Transverse or deep friction massage is often used by physical therapists for treating lateral epicondylitis. Cyriax believed this helped to prevent random binding of newly formed collagen fibers (11). Walker's (56) study, using deep friction massage on healing medial collateral knee sprains in rabbits, did not support this contention. Stratford et al (52) did not find deep friction massage superior to no massage in their study with patients with epicondylitis.

Muscle Conditioning

Improving fitness should be a key element in the rehabilitation effort. The treatment of the patient's pain and inflammatory response, while initially important, does not complete the therapeutic intervention. The patient's functional ability should be assessed as thoroughly as possible. Leach and Miller (28) reported that the involved extremity will often demonstrate a reduction in passive wrist flexion of 10-15° when compared with the noninvolved side. If such a reduction in flexion is identified, stretching exercises designed to improve the flexibility of the wrist extensor group should be instituted and continued until wrist range of motion is equal to the uninvolved side. The usual method of instituting strengthening exercises is by means of an intensity-graded protocol according to the patient's tolerance. These exercise programs should be started early in the treatment to assist with appropriate tissue remodeling. It is probably appropriate that early strength training should focus on low-load, high-repetition pro-
grams to avoid symptom aggravation. Strengthening programs may include a combination of isometric, isotonic, and isokinetic exercises. The recommended strengthening goal for competitive athletes is that their playing arm wrist extensor strength should be 10% greater than the nondominant arm, while a 5% differential is recommended for the recreational athlete (40). While clinical intuition and review of the existing literature suggest the proceeding general guidelines for strength training of patients with lateral epicondyritis, there is virtually no scientific evidence to document the efficacy of such efforts.

Controlling Force Loads

Controlling force loads will be vital both in the early and late treatment of lateral epicondyritis and is an important factor when considering preventative measures. Tennis patients with lateral epicondyritis should be encouraged to use a racquet with a mid- to large-size head, a lighter weight, and a reduced string tension by 3–5 lbs (30). The hand grip should also be the right size (37). A handle with too small of a diameter will require increased grasp effort, thus presumably increasing the stress upon the wrist extensor muscle attachment. The injured player should also play with new tennis balls, since old tennis balls require more stroke force to achieve the same velocity. Clay courts, if available, are also helpful because horizontal ball velocity is decreased (30). The injured player should also undergo a thorough assessment of his/her playing technique. Stroke patterns that need to be examined include the player’s use of weight transfer during all tennis strokes and the backhand stroke, in particular (28,37). In the occupational setting, an ergonomic analysis of task requirements is usually beneficial in determining which jobs may be likely to cause increased stress of the wrist extensor mechanism (12). Once identified, these jobs may then be altered to reduce the stress loads which may, in turn, decrease the incidence of job-related lateral epicondyritis. Assessment of playing technique and ergonomic analysis are important not only for treatment of injured clients but for preventing repetitive overuse injuries as well.

SURGICAL TREATMENT

Various reports indicate that approximately 10% of patients with lateral epicondyritis will be unresponsive to conservative methods (3,4,18,21). These patients offer a challenge to the clinician and may ultimately necessitate surgical intervention. A final approach prior to surgery is proposed by Wadsworth (53), who suggests that the Mill’s manipulation technique should be performed with the patient fully relaxed under local anesthesia. The technique is performed following an injection of 0.5 ml methylprednisolone and 0.5 ml of 2% xylocaine into the extensor carpi radialis brevis tendon. With the anesthetized patient in the supine position, the wrist fully flexed, and the forearm maximally pronated, the patient’s elbow is rapidly and forcefully moved from a position of full flexion to full extension. Wadsworth (53) reported that in over 100 resistant cases over the last 20 years, a repeat manipulation was necessary in only six patients and surgical intervention was needed in only one patient.

Many surgical procedures are currently advocated, with each technique reflecting the differing view concerning the condition’s etiology. In 1955, Bosworth (3) presented a study on the role of the annular ligament in tennis elbow. A follow-up study was published in 1965 to report further experience and compare results of various surgical techniques. Four operative techniques were performed in his study, which spanned the years of 1939–1964. The techniques were listed by Bosworth (3) as follows: 1) transverse division of the common extensor origin with distal displacement of annular ligament in 16 elbows (1939–1953); 2) transverse division of the extensor origin with distal displacement of the annular ligament and removal of the synovial fringe in two elbows (1949–1953); 3) transverse division of the extensor origin and resection of the annular ligament in 16 elbows (1943–1963); and 4) vertical incision of the extensor origin in line with its fibers, with resection of the annular ligament and repair of the common origin in 28 elbows (1953–1964). Bosworth reported good results with all techniques, although the technique involving division of the extensor origin and distal displacement of the annular ligament was abandoned secondary to prolonged periods of recovery. In recent years, numerous authors have published studies reporting the efficacy of the simple lateral release treatment first described by Bosworth (2,7,44).

Boyd and McLeod (4) are proponents of what is termed the Bosworth III procedure. This involves excision of the extensor muscle origin; bursa, if present; and the synovial fringe. Their report in 1973 claimed pain relief in all but a few patients. Full recovery was generally reported in 2–4 months.

Goldie (18) used a complete release of the common extensor tendon, which permits an approximate 1 cm distal muscle slide to a new resting length. He reported “excellent” results in 73% of cases, “good” results in 18%, and 9% were “failures” (18).

Garden (15) published an article in 1961 describing a simple surgical technique involving lengthening of the extensor carpi radialis brevis tendon just lateral to the wrist. He believed that the extensor carpi radialis brevis was predominantly responsible for the condition and that release of tension on this tendon would result in the resolution of symptoms.
In 1968, Carroll and Jorgensen (9) reported "poor" results using Garden’s procedure. In 1978, however, Stovell (50) claimed "excellent" results for 16 of 18 patients, with the technique supported for its simplicity, effectiveness, and short recovery period.

Nirschl and Pettrone (39) advocate a procedure in which the degenerated extensor carpi radialis brevis origin is resected, and decortication of the lateral epicondyle is accomplished. A 1987 report by Leach and Miller (28) supports this procedure after following it for a decade. They reported relief of pain symptoms in over 90% of the cases.

Spencer and Herndon (46) described a simple fasciotomy of the extensor origin as a surgical approach for lateral epicondylitis. They reported "excellent" or "good" results in 96% of the 23 patients studied. A long-term follow-up study was published on this technique by Posch et al (42), who reported "excellent" or "good" results in 31 of 35 patients. The authors recommended the simple fasciotomy because of its simplicity, minimal complications, and general rapid recovery of 3-4 weeks.

Kaplan (23) was the first to suggest that the radial nerve was involved, though not specifically entrapped, in the syndrome known as tennis elbow. His gross dissection study revealed that the radial nerve innervated nearly all of the tissues (including the periosteum) in the region of pain complaints by patients with lateral epicondylitis. Consequently, he proposed surgically interrupting most of the articular nerve supply to the lateral epicondyle to provide relief of symptoms for such patients. He reported three cases in which his denervation technique was successfully applied (23), but we are unaware of any report of a prospective, randomized clinical trial in which this procedure has been explored further.

Roles and Maudsley (43) proposed radial nerve entrapment as a possible cause of resistant tennis elbow. Compression of the radial nerve was believed to occur at four clinically diagnosable sites. The corrective surgical technique they described involves dividing the deep fascia and freeing the superficial radial nerve and posterior interosseous nerve along their courses. They reported "excellent" or "good" results in 19 of 20 cases, while Roles and Maudsley (43) reported "excellent" or "good" results in 35 of 38 cases.

This brief surgical review highlights the primary approaches currently being used in the intervention of resistant tennis elbow. As noted previously, the proponents for these various surgical techniques advocate the procedure on the basis of their understanding of the primary cause and focus of tissue of lateral epicondylitis. Conclusive data documenting superior efficacy of one or another of these procedures is, as yet, unavailable.

**SUMMARY**

In most cases, lateral epicondylitis is a self-limiting condition that will generally resolve within 1 year (15). However, the condition can be quite disabling and cause significant impairment of function. This impairment of function will most readily manifest itself as pain in the elbow and lateral proximal forearm associated with forceful gripping or wrist extension (repetitive microtrauma). Fortunately, the vast majority of patients (89-97.3%) respond readily to conservative or nonoperative treatment (4,10,25). For patients who fail conservative treatment, a wide variety of surgical procedures that demonstrate a high success rate exist (3,13,28,43,46). A vital component of any treatment program is patient counseling and task analysis to avoid reinjuring the extensor mechanism, along with a graded exercise program to provide controlled stresses to assist in tissue remodeling.

**REFERENCES**

LITERATURE REVIEW