**Background**

“Tennis elbow”, commonly referred to as lateral epicondylitis, is a chronic degeneration of the common extensor tendons (extensor carpi radalis brevis, extensor digitorum, extensor digiti minimi and extensor carpi ulnaris) at their attachment site at the lateral epicondyle of the humerus.1 Even though this condition is commonly referred to as “tennis elbow”, and was first reported in the literature in 1883 as “lawn tennis arm”, less than 10% of patients experiencing this condition actually play tennis.2 Lateral epicondylitis affects 1-3% of the general population, 15% of manual workers, and is more commonly experienced by adults between the ages of 45-54 with equal distribution among men and women.2,3,4

The term epicondylitis, and the associated suffix “-itis”, infers an inflammatory condition, but the more accurate term would be lateral epicondylosis to indicate the chronic, degenerative nature of the tendons.1 Histologic studies of the extensor tendons have identified fibroblastic degeneration and collagen disruption, which is indicative of tendinosis, as opposed to the presence of macrophages and neutrophils which occur with an inflammatory response.1 Therefore, “tennis elbow” and lateral epicondylitis will be referred to in this paper as lateral epicondylosis.1

**Anatomy**

The extensor carpi radalis brevis (ECRB), extensor digitorum (ED), extensor digiti minimi (EDM) and extensor carpi ulnaris (ECU) muscles originate on the lateral epicondyle of the humerus, and share a common extensor tendon. These tendons insert at different sites on the wrist and hand, but work together collectively to extend the wrist.2While pain from lateral epicondylosis is felt at the common extensor tendon at the lateral epicondyle, the ECRB is the most commonly affected muscle by this condition.1

All extensor muscles of the arm receive motor innervation from the radial nerve (C5-C8, T1).5 The poster interosseous nerve is the major branch of the radial nerve in the forearm, which travels in front of the lateral epicondyle of the humerus, and supplies motor innervation to the common extensor muscles.5 The lateral epicondyle lies within the C5-C7 dermatome, and receives sensory input from the lateral antebrachial cutaneous nerve, a branch of the musculocutaneous nerve. 5,6

**Etiology**

The development of lateral epicondylosis is not completely understood, but is associated with microtrauma from repetitive upper extremity activities, especially those requiring repeated wrist extension. 4,7Recreational examples of predisposing activities are poor technique with a backhand tennis stroke, use of a tennis racket with a grip that is too small, strings that are wound too tight, or using tennis balls that are wet and heavy.7 Occupational activities such as typing, painting, or using a screwdriver can also lead to the development of pain at the lateral epicondyle and common extensor origin.7This repetitive stress on the tendons triggers a degenerative process, leading to increased collagen cross-linkage and disruption, and potentially tissue failure and rupture.1

Lateral epicondylosis begins with an initial acute inflammatory response following repetitive microtrauma, which usually resolves with rest.1 During this phase, crepitus may be palpable over the lateral epicondyle and common extensor tendon. 7 However, when the patient continues to perform pain provoking activities, or rests and returns to activity without determining the underlying cause, a chronic condition develops due to failure of the tendon tissues to heal appropriately.5,8 This transition to chronic tendinosis involves angiofibroblastic hyperplasia, which is characterized by an invasion of fibroblasts within the collagen infrastructure, disorganized collagen orientation and vascular hyperplasia as the tissue attempts to repair itself. 1,2 While patients may seek treatment when the condition is in the inflammatory stage, it is most common to see patients after the condition has become chronic.1

The continued use of weakened tendon tissues can eventually lead to structural failure of the tendon, as the atrophied and disorganized collagen exhibits reduced stress-strain capabilities and can eventually rupture with continued loading.1Interestingly, the histological properties observed in the weakened tendon during tendinosis are very similar to those observed in a tendon following a corticosteroid injection.2

While the degeneration of the tendon from repetitive overuse of a tendon with atrophied and disorganized collagen is considered a primary cause of tendinosis, there are other theories as to how this process develops as well.1Following the initial onset of pain over the ECRB, patients may develop altered movement patterns to minimize symptoms, leading to under-use and stress-shielding of the ECRB.1This disuse may contribute to weakening of the tendon, and actually predispose it to injury, which has been reinforced by histological evidence of defects and necrosis as well as muscle regeneration attempts within the ECRB in patients with a long duration of lateral epicondylosis.1

In addition to these morphological changes in the tendon, particularly to the ECRB, there are neurosensory, motor, and neurotransmitter changes which occur during lateral epicondylosis.4 Studies have shown that sensory changes and pain could be traced to neurogenic inflammation at the origin of the ECRB, as well as an increase in neurotransmitters leading to increased pain response, and direct irritation from chemicals such as lactate.1,7These changes can lead to neurological changes in the peripheral nervous system that can ultimately lead to increased sensitivity within the central nervous system, which is one possible explanation for why 56% of patients with lateral epicondylosis report pain distal at locations distal to the elbow, such as the neck and shoulder.1,5 This could also be due to altered biomechanics in distal joint segments, such as the shoulder, secondary to elbow pain.1

**Diagnosis**

The most commonly observed symptoms of lateral epicondylosis are pain at the lateral epicondyle, which is reproduced by palpation and active wrist extension, but normal elbow range of motion.2,4 Symptoms usually develop gradually over time and coincide with a change in activities involving the upper extremity.2 Grip strength is usually reduced on the affected side, and patients may report pain with specific activities using the affected upper extremity, such as shaking hands, shaving, lifting a coffee mug, and lifting household items with an extended elbow.2The patient’s history and descripton of symptoms are also a useful tool when developing a diagnosis.7 A previous history of tennis elbow suggests a tendinosis, as do symptoms longer than 3 months in duration. 7

There are a variety of clinical tests which can be utilized by examiners to help aid in their development of a diagnosis. Cozen’s Test is an active test performed with the patient’s elbow stabilized by the examiner’s thumb on the patient’s lateral epicondyle.5 The examiner then instructs the patient to make a fist, and pronate the forearm, followed by radial deviation and extension of the affected wrist against manual resistance applied by the examiner. 5 A positive test result is a sudden onset of significant pain at the lateral epicondyle.5

Mill’s Test is a passive test performed with the examiner pronating the forearm, fully flexing the wrist and extending the elbow while palpating the lateral epicondyle.5 If pain is experienced over the lateral epicondyle, then the test is positive.5Psychometric properties such as validity, specificity and sensitivity are not known for Mill’s and Cozen’s Test, however.7

The Lateral Epicondylitis Test/Maudsley’s Test requires active extension of the middle phalanx against manual resistance applied distally to the proximal interphalangeal joint.5This produces stress on the extensor digitorum muscle-tendon unit, and if pain is experienced by the patient over the lateral epicondyle, the test is positive.5

The “chair lift test” is performed with an extended elbow and pronated forearm with a three-finger grip (thumb, index and middle finger). 1,9 This position of wrist flexion, ulnar deviation, and forearm pronation combined with forceful gripping and active wrist extension is believed to maximally load the common extensor tendon, and elicit pain in individuals with lateral epicondylosis.9A simulated version of the chair lift test demonstrated high interrater (ICCs 0.8 – 0.93) and intrarater reliability (ICC: 0.9-0.97) as well as a strong negative correlation between pain and force generation in individuals with lateral epicondylosis, as less force was produced in patients with the highest pain severity (Spearman’s rho: -0.78 to -1.0). 10While the force in this simulated version was dependent on the subject, and not the weight of the chair, this does lend some credibility to the use of the chair pick-up test in the clinical setting as a diagnostic tool for lateral epicondylosis.9,10

Given the paucity of psychometric data available for each of these tests, it appears most beneficial to perform 2-3 of the aforementioned tests and combine the results of each with the information gathered in the subjective portion of the initial evaluation to make a more accurate diagnosis.9

In addition to objective testing to develop a diagnosis, hematological tests can be utilized to determine if there are any inflammatory markers within the tissue, as well as plain radiographs to determine if the problem is due to osteoarthritis, osteochondritis dissecans or loose bodies within the elbow. 10 Ultrasound and magnetic resonance imaging (MRI) are useful to identify changes in the ECRB and affected tendons.7 While MRI can provide additional information about the tendon and joint capsule that other methods cannot, results correlate poorly with patient subjective reports of symptoms.1

*Differential Diagnosis*

 Radial tunnel syndrome(RTS) presents very similarly to lateral epicondylosis, and occurs when the posterior interosseous nerve is compressed in the radial tunnel at the proximal forearm. 11 The radial tunnel is comprised of the brachioradialis, the extensor carpi radialis longus (ECRL) and extensor carpi radialis brevis (ECRB) laterally; medially by the biceps tendon and the brachialis; and the capsule of the radiocapitellar joint and supinator muscle. 11 As the posterior interosseous nerve crosses the elbow, there are a variety of structures which it can become compressed by, but the most frequent site of entrapment occurs between the two heads of the supinator at the forearm, a region dubbed ‘the arcade of Froshe’.5,11

The causes of radial tunnel syndrome are very similar to those that lead to lateral epicondylosis, such as repetitive forearm pronation from using a screwdriver and repetitive manual labor.12 Pain is experienced during activity using the hand and wrist, and from palpation over the lateral epicondyle, and worsens with increased use.12 The primary difference in distinguishing between the two conditions clinically is that tenderness with lateral epicondylosis is localized to the attachment site of the common extensor tendons at the lateral epicondyle, whereas with radial tunnel syndrome the pain is approximately 2 inches more distally in the forearm, where the radial nerve penetrates the supinator muscle. 11,12 In addition, resisted wrist extension will produce pain in individuals with lateral epicondylitis, but not with RTS.1,11These two key differences necessitate the need for active listening as the patient describes the primary location of their pain as well as careful palpation and an understanding of muscle and nerve anatomy during the objective portion of the initial evaluation.

Additionally, the Rule-of-Nine Test has been proposed as a test to differentiate between radial tunnel syndrome and lateral epicondylosis. 13In order to perform this test, the examiner draws a large, square box over the anterior aspect of the proximal forearm, with the box divided 3 columns and 3 rows to include a total of 9 smaller equal squares.13 The columns are delineated as either lateral, medial or middle and rows are labelled 1,2,and 3 in a proximal to distal orientation. 13 The posterior interosseous nerve travels along the lateral column of the square in both the right and left upper extremity, and can be potentially used to specify radial tunnel syndrome due to the pain being specific to this area of the square, and rule-out lateral epicondylosis.13

**Physical Therapy Interventions for Lateral Epicondylosis**

Lateral epicondylosis is most commonly treated nonsurgically, with improvement reported in approximately 95% of individuals.2 The primary nonsurgical treatment options are activity modification, physical therapy, nonsteroidal anti-inflammatory drugs, bracing and corticosteroid injections.2 The treatment of lateral epiconylosis is focused on pain management, preserving and improving movement, grip strength and endurance, return to normal function and promoting tissue healing.1,7 Generally, avoiding the provoking activities and rest will lead to symptom resolution, however without understanding of the initial problem the condition may return once the patient returns to activity.1

*Exercise*

 Research suggests that physical therapy is the most effective treatment of lateral epicondylitis for long-term symptom resolution, but there is no consensus on the optimal intervention(s) to administer. 1,2,14Research is very limited on the isolated use of any particular physical therapy modality (i.e. exercise, ultrasound, massage, etc.) and its impact on lateral epicondylosis, but research on stretching and strengthening programs supports their efficacy at reducing pain and increasing strength in individuals with lateral epiconylosis. 14

Eccentric exercise training has become a popular treatment for tendinopathies, and while research demonstrates that it can be utilized successfully for patients with lateral epicondylosis, exercise regimens vary between studies, research is limited, and there does not appear to be a clear advantage of eccentric-only training compared to concentric and eccentric contractions.2, 9,15,16 Studies which report on eccentric training use differing protocols as outlined by Stanish and Curwin and Alfredson; the former utilizes both concentric and eccentric movements and the latter only eccentric.15

Martinez-Silvestrini et al. performed a randomized controlled trial which divided subjects into three groups: stretching only, concentric-only exercise and stretching, and eccentric-only exercise and stretching. 9Following 6-weeks of each intervention, all groups displayed significant improvements in grip strength, pain, and subjective function, but there no statistically significant differences between any of the groups.9Unfortunately, while these findings do suggest that active therapies can be beneficial, it does not promote one modality over another, nor does it refute the possibility that symptoms resolved due to the passage of time and avoidance of offending activities**.**

Pienimanki et al. randomized subjects into two treatment groups: those receiving pulsed ultrasound (0.3-0.7 W/cm3, 1:5 pulse ratio, frequency 1 MHz and duration 2 milliseconds) 2-3 times per week, and those who received wrist and forearm stretching, progressive isotonic strengthening exercise, and simulated occupational tasks (i.e. twisting a towel into a roll, moving buttons from one location to another, etc.).16 Following8-weeks, participants in the exercise group experienced a significant reduction in pain both at rest and during activity than in the ultrasound group. 16 The exercise group also experienced a 45% increase in isokinetic wrist flexion torque and 12% increase in isometric grip strength, compared to a 4% decline in wrist flexion torque and unchaged isometric grip strength in the ultrasound group.16

*Manual Therapy*

Manipulations are commonly used when other methods have not been unsuccessful.18Cyriax therapy is a common intervention for lateral epicondylosis which consists of deep tissue friction (DTF) massage and a low-amplitude, high-velocity trust manipulation (Mill’s manipulation).2,17 DTF is manually applied within tolerable limits of patient discomfort and performed specifically at the affected soft tissues at the lateral epicondyle in a transverse direction.17This is performed for 10-15 minutes with at least 48 hours between applications.17,18 The DTF prepares the tissue for Mill’s manipulation, which is applied with the patient’s elbow fully extended and the forearm pronated. 17,18 Cyriax advocated that this combination of DTF and manipulation be performed 3 times per week for 4 weeks, however research on the effectiveness of this intervention is inconclusive. 17,18 While there are a variety of manipulations prescribed for lateral epicondylosis (Kaltenborn’s, Stoddard’s, Mennell’s) which may be useful in symptom relief, they are not to be used as a stand-alone treatment. 18 Manipulations and mobilizations appear beneficial for pain reduction for lateral epicondylosis, but more research needs to be conducted to determine conclusive findings on their efficacy**.**14,19

*Additional Physical Therapy Interventions*

 While some research does suggest the use of ultrasound for individuals with lateral epicondylosis, there is not enough high quality evidence available to support or contest its use clinically as an isolated treatment.2,19 However, it may offer some benefit when used in conjunction with stretching, strengthening and manual therapies.2,19 Similarly, no consensus is available regarding the effectiveness of iontophoresis, electromagnetic field therapy, or laser therapies on lateral epicondylosis.2

**Non-Steroidal Anti-Inflammatories (NSAIDs)**

Findings from literature on the use of NSAIDs as a treatment of lateral epicondylosis is inconclusive, with conflicting results depending on the type of oral NSAID used.1 A Cochrane review on the use of NSAIDs for lateral epicondylosis concluded that the effect of topical NSAIDs on pain is inconclusive, as well.20 NSAIDs taken orally have the risk of gastrointestinal discomfort and diarrhea, and those applied topically may cause a skin rash.20

**Corticosteroid Injections** Research suggests that corticosteroid injections do offer better short-term pain relief (6 weeks) than rest and physical therapy in individuals with lateral epicondylosis, but not for the long-term (1 year), and individuals receiving them had a higher rate of symptom recurrence than those receiving physical therapy.2,14 Corticosteroid injections also carry the risk of collagen atrophy, skin depigmentation, common extensor tendon rupture, short-term elevation of blood glucose in patients with diabetes, and muscle wasting.1,2

**Surgical Interventions**

When patients fail to respond to conservative treatments, surgical intervention is often the next course of action.1 Open, arthroscopic and percutaneous procedures using a small (1 cm) incision are the most frequently described procedures, with open tendon release performed most frequently.1,2 Open release divides the junction between the extensor carpi radialis longus and the common extensor tendon, as well as detaching the extensor digitorum communis to expose the extensor carpi radialis brevis.2 The ECRB is then debrided and the richly vascular bone of the lateral epicondyle may or may not be punctured with small holes to induce bleeding into the area to promote tissue healing and repair depending on the surgeon’s preference.1,2 While there is no consensus regarding the optimal open surgical technique, research reports that 78-89% of patients report “good” to “excellent” results.1 Similarly, 91% of patients reported a complete resolution of symptoms following percutaneous release 3-years following the procedure; 87% of those who were treated arthroscopically reported satisfactory results at approximately 10-years following the procedure.1

**Summary**

Lateral epicondylosis is a degenerative condition of the common extensor tendon (tendinosis) which is characterized by pain with active wrist extension, palpation of the lateral epicondyle and reduced grip strength in the affected upper extremity. While commonly referred to as a lateral epicondylitis and tennis elbow, it is neither an inflammatory condition nor exclusive to individuals who play tennis. Examiners should pay particular attention to their findings from the subjective and objective portion of their examinations to delineate lateral epicondylosis from radial tunnel syndrome, especially with regards to the description, location and activities that produce pain. The vast majority of cases can be treated successfully with non-operative management, including a variety of physical therapy interventions as well as rest from the offending activities. However, determining what the predisposing factors are that have led to the development of the condition is imperative to prevent a reoccurrence of symptoms. Future research should include more randomized controlled trials that compare physical therapy interventions to rest from the offending activities to determine the magnitude of effects from physical therapy interventions.

For individuals who do not respond to conservative treatments, surgical options appear to have good results, although there is no clear, optimal technique which provides better results than others. Pharmacological and corticosteroid injections may provide short-term relief of pain, but have associated complications which must be considered and do not address the initial root problem that led to the development of lateral epicondylosis.

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