Radiological Overview of Lateral Epicondylitis Assessment Using Shear-wave Elastography

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ABSTRACT

Lateral epicondylitis (LE) is a degenerative disease process affecting 1% to 3% of the population between 40 and 45 years old. It was originally thought that the cause of lateral epicondylitis was an inflammatory process, which would then result in the symptoms. However, histological studies have demonstrated that, through repetitive microinjuries at the common extensor origin (CET) site, there is a degenerative process with gradual failure of repair in the extensor carpi radialis brevis (ECRB) tendon. Although it was originally described and associated with the act of playing tennis, the etiology of this pain in the lateral aspect of the elbow is more widespread and related to overuse of the CET though repetitive dorsiflexion and pronosupination exertion of the wrist. The initial diagnosis is by clinical suspicion. Imaging is further performed to help in evaluating disease extent, exclude other entities that cause lateral elbow pain, and for surgical planning. Various imaging modalities can be used to evaluate LE. Nowadays, additional imaging modalities are commonly needed to help complement a clinical diagnosis. Due to some limitation of x-ray and MRI, US, specifically with the application of elastography is gradually attracting public attention. Shear-wave elastography (SWE) measures the elastic properties of tissues, based on the well-established principle that shear waves propagates faster in healthy tendons than diseased ones so can be used in diagnosis of tendinopathy. This study aimed to review the different radiological assessment for lateral epicondylitis.

Keywords: Lateral Epicondylitis; SWE ; US ; MRI ; Common Extensor Origin

INTRODUCTION

Tennis elbow is the most common cause of elbow symptoms in patients presenting with elbow pain in general. The condition tends to affect men and women equally. The annual incidence is one to three percent in the United States **(1).** Despite the condition being commonly referred to as tennis elbow, tennis players make up only 10% of the patient population. Half of tennis players develop pain around the elbow, of which 75% represent true tennis elbow. It is more common in individuals older than 40 years of age. Smoking, obesity, a repetitive movement for at least two hours daily, and vigorous activity (managing physical loads over 20 kg) are risk factors in the general population for the development of this condition. The natural course of the condition is favorable with spontaneous recovery within one to two years in 80% to 90% percent of the patient **(2,3).**

The exact etiology of LE has not been well identified. However, it is commonly associated with repetitive microtrauma from excessive gripping or wrist extension, radial deviation, and/or forearm supination **(4).** The extensor carpi radialis brevis (ECRB) is the most frequently affected muscle. The pronator and other extensor carpal muscles are also commonly affected **(5).** In addition to the factor of excessive mechanical forces, the unique origin of ECRB in the lateral aspect of the capitellum places the tendon at risk for repeated undersurface abrasion during elbow extension and flexion **(6).**

Imaging modalities

Lateral epicondylitis is a disease entity that is diagnosed mainly by clinical suspicion. Imaging is not initially performed but it is helpful for evaluating disease extent, excluding other entities that cause lateral elbow pain, and for surgical planning. Various imaging modalities can be used to evaluate the condition, each with its own advantage, disadvantage, and application **(1)**.

1- Plain X-ray:

Routine views for evaluation of elbow pathology include anteroposterior (AP) and lateral views. Plain radiograph can exclude other differential diagnoses of LE e.g. osteochondritis dissecans, detect calcifications, local osteoporosis, and underlying bone fractures. In cases of long-standing LE, calcifications of ECRB insertion can be seen**.** Advantages of radiographic evaluation is that it is, cheap, easily accessible, and non-invasive. Drawbacks include the inability to detect tendon pathology and risk of exposure to ionizing radiation **(7)**.

2-Ultrasound Examination:

Ultrasound is considered an excellent method for diagnosis of lateral epicondylosis, with high sensitivity of about 80% & specificity of about 50% **(8).** Ultrasound has been considered an accessible , easy and risk-free for elbow evaluation. Considering the common extensor origin, anatomical landmarks e.g., lateral epicondyle & elbow joint with head of radius, make it easy to be orientated in this region. Ultrasound of the elbow has more advantages rather than other imaging methods e.g., MRI as it is less time consuming, has superior spatial resolution, is more cost-effective, and allow dynamic examination. Drawbacks include operator dependency, some technical limitations such as difficulties in contact with curved body surfaces, bone shadowing, and diminished ability to visualize deep structures. Furthermore, doppler settings including gain, wall filter, color priority, and pulse repetition frequencies can influence outcome in regard to color doppler activity. Various ultrasound techniques can be used to evaluate the elbow joint including grey scale (B-mode), Doppler, and elastography **(9)**.

- **Grey scale ultrasound (GUS):**

Measurement of the thickness of the common extensor tendon can be performed in different ways. In a study by **Krogh et al. (9)** reported two different ways of measuring the thickness of the CET were applied **(Figure 1).** Another study by **Ustuner et al. (10)** showed that common extensor tendon was thicker on the dominant side versus the non-dominant side at all three locations (humeral 4.60 versus 4.22 mm, articular 3.55 versus 3.23 mm, radial 3.17 versus 2.88 mm, $p < 0.001$) and gradually tapered from proximal to distal, moderate relation with age and BMI was present, most pronounced at the humeral location.

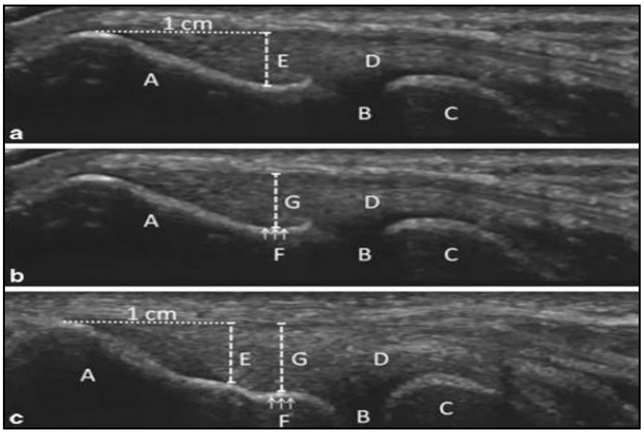

Fig. 1: Measuring the tendon thickness by ultrasound. Longitudinal sonogram illustrating two different methods; (a and b) for measuring the thickness of the common extensor tendon. Labels: Lateral epicondyle (*A*), radiohumeral joint (*B*), radial head (*C*), common extensor tendon (*D*), tendon thickness 1 cm distal form the attachment (E), and tendon thickness at “the plateau”

- **Sonographic grading scale of common extensor tendon lesion:**

For sonographic assessment of the degree of tendon affection, a grading scale was developed depending on echotexture grade **(Table 1) (11).**

Table (1): Sonographic assessment of tendon lesion (11).

Echotexture grading scale	
0	Normal
1a	Hypoechogencity in less than one-third of the tendon
1b	Hypoechogencity in between one-third and two-thirds of the tendon
1c	Hypoechogencity in more than two thirds of the tendon
2	Partial-thickness tear
3	Full-thickness tear

Doppler sonography:

The color Doppler activity is usually seen in an area limited proximally by the tip of the lateral epicondyle and distally by the humeroradial joint space. The outer border is the most superficial fibers, and the deep border is the bone. There are several ways to assess Doppler activity, yet no consensus has been reached regarding which method to use. Color Doppler activity is graded in a new ranking scale from grade 0–4. The grading is estimated in a 0.5-cm longitudinal part of the tendon with the maximal Doppler activity (region of interest, ROI). The scale is as follows: Grade 0: no activity, grade 1: single vessel, grade 2: Doppler activity in less than 25 % of the region of interest, grade 3: Doppler activity in 25–50 % of the region of interest, and grade 4: Doppler activity in more than 50 % of the region of interest **(9).**

Elastography:

Two main types of elastography are currently used in clinical practice, namely strain elastography and shear wave elastography. In comparison with strain sonoelastography, SWE is considered to be more objective and reproducible and allows direct assessment of tissue elasticity, with the possibility to obtain quantitative measurements without the need for manual compression. **Table (2)** summarized the main differences between strain elastography and SWE **(12)**.

Table (2): The differences between strain elastography and SWE (12).

Items	**Strain elastograghy**	**Shear wave elastography**
Type	Quasi-static elastograghy	Dynamic elastography
Stimuli characteristic	Mechanical force	Acoustic radiation force
Stimuli source	Manual compression/ inherent organ motion.	Focused ultrasound beam
Parameter assessed	Strain distribution	Shear wave propagation speed
Assessment method	Mainly qualitative	Quantitative
Operator-dependent	Yes	No
Depth of tissue	Superficial tissue	Superficial and deep tissue
Price	Less expensive	Expensive

Shear wave sonoelastography (SWE):

SWE detect the changes in tendon stiffness both qualitatively by color coded maps and quantitatively by measuring shear wave elasticity and shear wave velocity. SWE may act as an effective indicator for monitoring treatment response in tendinopathies, potentially leading to the establishment of more personalised and effective treatment plans **.** A primary limitation of SWE is depth of penetration. Shallow depths may be accommodated by applying a 5-mm layer of coupling US gel as standoff. The shape and size of the ROI for post-analysis is also limited on some scanners **(13)**. Most scanners require a timeout of a few seconds before the next acquisition, which prevents real-time dynamic imaging of structures in motion. Furthermore, SWE is sensitive to transducer pressure and angle. The shear modulus depends on the orientation of the probe relative to the examined structures **(14).**

There are currently three technical approaches for shear wave elastography **(Table 3)** including one-dimensional transient elastography (1D-TE), point shear wave elastography (pSWE), and two-dimensional shear wave elastography (2D-SWE) **(15)**. Recent studies in which elastography was used to evaluate the mechanical properties of tendons have reported that elastographic methods may detect the changes in tendon stiffness qualitatively and quantitatively, as well as monitor and guide ongoing treatments of tendinopathy. SWE is one of the main elastographic techniques **(16).** Shear waves propagate faster in healthy tendons than in those that are tendinopathic, and faster in contracted tendons and muscles than in those that are relaxed. Additionally, shear waves propagate faster along the long axis of healthy tendons than along the short axis **(14)**.

Table (3): Summary of shear wave imaging methods (15).

pSWE	2D-SWE	1D-TE
-Excitation method: dynamic stress by ARFI (acoustic radiation force impulse), in the normal direction, in asingle focal location. -Shear waves measured perpendicular to plane of excitation. -Shear wave speed (c_s) reported or converted in young's modulus (E) to provide quantitative estimate of tissue elasticity. -Operator can use B-mode ultrasound to directly visualize and select ROI (region of interest). -Does not show an image of stiffness -Can be performed on conventional ultrasound machine using standard ultrasound probe.	-Excitation method: dynamic stress by ARFI, in the normal direction, in multiple focal zones. -Shear waves measured perpendicular to ARFI application. -Multiple focal zones are interrogated in rapid succession, faster than the shear wave speed, creating near cylinderical shear wave cone, allowing real-time monitoring of shear waves in 2D for measurement of (c_s) or E and generation of quantitative elastograms. -Operator is guided by both anatomical and tissue stiffness information, has real time visualization of acolor box; quantitative elastogram superimposed on a B-mode image stiffness information -currently newest SWE method.	-Excitation method: dynamic stress by a mechanical vibrating device. -Shear waves measured parallel to excitation. -Stiffness estimated along ultrasonic A-line, in afixed region, neither user adjustable or image guided. -Operator selects imaging area using time motion ultrasound, based on multiple A-mode lines in time at different proximal locations forming low quality image. The same probe uses A-mode ultrasound to measure c_s and E is calculated. -First system commertially available. The most widely used and validated technique for assessment of liver fibrosis.

In another study of the Achilles, patellar and humeral epicondylar tendon, improvements in the VISA score, an index for the severity of tendinopathy, following 6-months of treatment were accompanied by an increase of 4.6 m/s in shear wave elastography values, indicating improved stiffness **(17).**

- ***Technique of SWE in examination of lateral epicondylitis:***

The examiner should be careful not to put pressure on the tendons because the SWV measurements could be inaccurate if the CET was pressurized by the transducer. The ROI (mean, 4.83 mm2; range, 2.85–6.12 mm2) is drawn on each

CET image at the lateral epicondyle on acolour-coded map generated by the ultrasound machine software. The ultrasound machine software provided the area, mean velocity in meters per second (m/s), and stiffness in kilopascals (kPa) for the ROI. For the color elastograms: red is usually defined for encoding hard consistency **(Fig. 2,3);** blue indicates soft consistency **(Fig. 4,5);** and green and yellow encode intermediate stiffness **(18).**

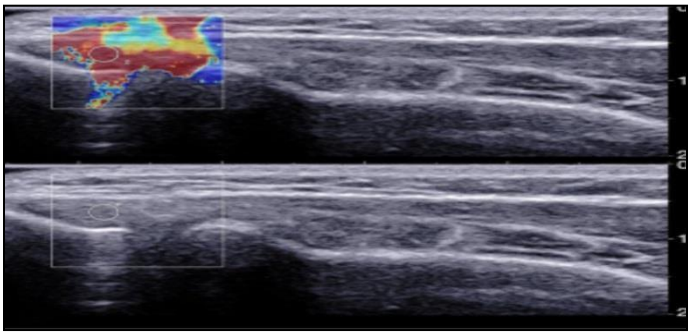

Fig. (2): SWE image of the healthy CETon longitudinal axis in a 36-year-old female patient with unilateral lLE. The bottom image is a longitudinal GUS scan of CET with superimposed color box borders for the SWE map, while there is a circular ROI for quantitative measurements on the top image. Quantitative SWE measurements show the Cmean is 13.6 m/s **(16).**

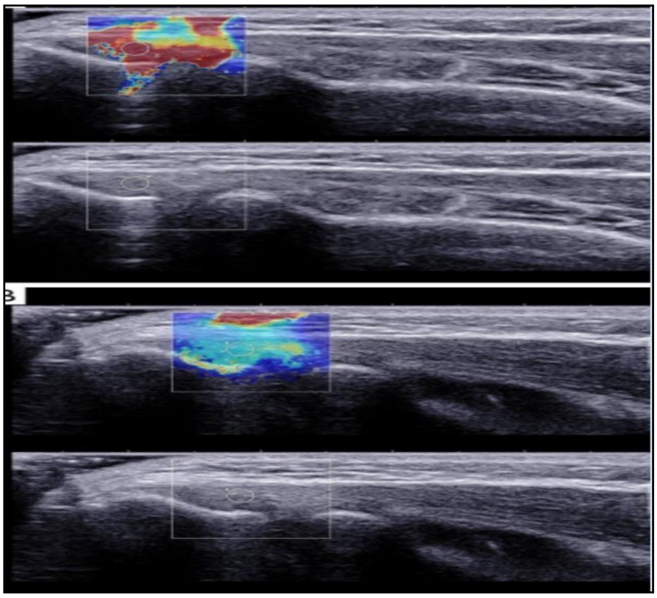

Fig. (3): SWE images of CET on longitudinal axis in a 31-year-old female patient. (A) SWE of the healthy CET showing a mostly red region indicating the stiff tendon structures. Quantitative SWE measurements show the Cmean is 15.7 m/s. (B) SWE of CET showing the most blue or green areas indicating the soft tendon structures. Quantitative SWE measurements show the Cmean is 8.6 m/s **(16).**

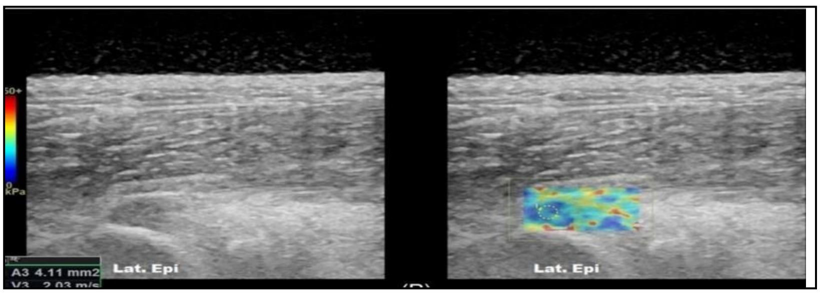

Fig. (4): Left GSU imaging revealed a localized hypoechoic area in the common extensor tendon. Right: a ROI was selected in the area. The shear wave elastography revealed a blue color within the focal green color that corresponded to the hypoechoic area. The stiffness was 12.33 kPa, and the shear wave velocity was 2.03 m/s. CET, common extensor tendon; ROI, region of interest **(19).**

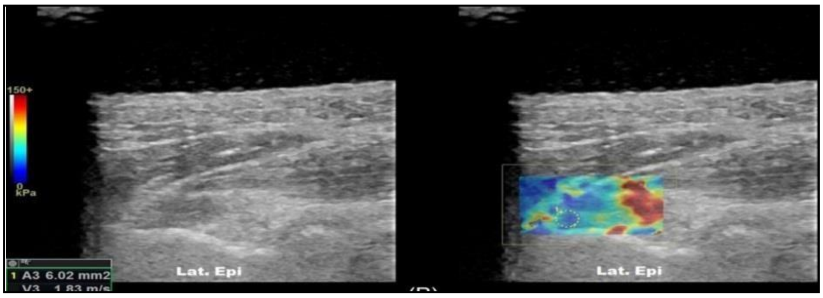

Fig. (5): A 60-year-old female with left lateral epicondylitis that lasted 7 month Left: gray-scale ultrasound imaging revealed a localized hypoechoic area in the common extensor tendon. Right: a ROI was selected in the area. The shear wave elastography revealed a focal blue color that corresponded to the hypoechoic area. The stiffness was 10.08 kPa, and the shear wave velocity was 1.83 m/s **(19).**

Therefore, SWE can quantify the severity of tendinopathy through ranking tendon stiffness from 0-15 m/s, or in units of kilopascals. In a study of the Achilles, humeral epicondylar and patellar tendons, a shear wave elastography value of less than 70 kPa (4.8 m/s) indicated disease, while values above this number highlighted good tendon health **(17).**

CONCLUSION:

SWE showed excellent reliability for the evaluation of CET elasticity and is superior to the GSU since it can evaluate the diseased tendon both qualitatively using color coded maps and quantitatively by measure of velocity and stiffness.

Regarding grey scale ultrasound features of lateral epicondylitis, the most encountered are focal areas of hypoechogenicity with a background of intrinsic tendinopathy, tendon swelling, calcification, and cortical irregularity and tendon tears.

Complementary shear wave evaluation following the non-operative management of some cases showed a significant increase in velocity and stiffness, which indicates that shear wave elastography can be used not only for diagnosis but also for follow up of cases after treatment.

No Conflict of interest.

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