Diagnostic Value of Musculoskeletal Ultrasound in Acute and Chronic Lateral Epicondylalgia

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ABSTRACT
Introduction: The literature suggests that abnormal sonographic findings of the common extensor origin (hypoechogeticity, neovascularity, calcifications, irregular margin, presence of adjacent fluid, irregular fibrillar pattern, thickness, tear) and of the lateral epicondyle (cortical irregularities) can be used to confirm the presence of Lateral Epicondylalgia (LE) in elbows which have been initially diagnosed using the clinical diagnosis for LE. The association of these abnormal sonographic findings and the initial clinical diagnosis for LE were studied. Methodology: The participants were recruited in Metro Manila (Philippines) through advertisements and referral by doctors and physiotherapists. LE was determined if participants reported lateral elbow pain on one elbow which was replicated by any of the Cozen’s, Mill’s, or Maudsley’s tests. Acuity of elbow symptoms was determined using six weeks since symptom onset as the time differentiating acute from chronic LE. A prospective blinded sonographic assessment of both elbows of participants was performed using a valid and reliable scanning protocol. Results: Fifty-one participants provided 55 symptomatic and 46 asymptomatic elbows (one elbow ineligible due to congenital shortening). Duration of elbow pain ranged from a day (acute) to 36 months (chronic). The hypoechogeticity of the common extensor origin was moderately associated with acute LE (sensitivity=67%, specificity=38%) and strongly associated with chronic LE (sensitivity=81%, specificity=64%). The calcifications of the CEO were found to be significantly associated with acute LE (DOR: 14.62) and chronic LE (DOR: 7.26) with p<0.05. Conclusion: Sonographic measures of hypoechogeticity and calcifications of
the common extensor origin may complement the findings from the elbow provocation tests in confirming a diagnosis of acute or chronic LE.

INTRODUCTION
Lateral Epicondylalgia (LE) is the most common cause of pain in the lateral aspect of the elbow affecting the common extensor origin (CEO). This condition is generally more common in individuals between 35 to 60 years of age albeit it can occur at any age. The incidence of LE in medical consultation ranges from 0.3 to 1.1% and in the working population from 2 to 4%. The mean number of lost workdays per year from elbow pain (including LE) is 2.3 to 3.9.

A clinical diagnosis for LE is dependent on reports of pain on the lateral epicondyle, lateral epicondylar tenderness, and positive response to any of the three provocation tests, namely the Cozen’s, Mill’s, or Maudsley’s test. These provocation tests are designed to stress the CEO and replicate the patient’s reports of lateral elbow pain. These provocation tests are easily applied on elbows of patients and are commonly used in clinical and research settings. Despite their practical use, there is no reported diagnostic validity in the current literature that is specific to each of these provocation tests. Additionally, there is limited evidence on their ability to identify specific elbow structures related to lateral elbow pain.

The poor diagnostic validity of Cozen’s, Mill’s, and Maudsley’s tests may be associated with less than adequate physiotherapy treatment outcomes for LE, as without a sound understanding of which structures are involved, physiotherapy treatment is likely to be non-specific. Consequently, suboptimal treatment outcomes are likely associated with workdays lost and residual symptoms.

The search for better clinical diagnosis of LE is associated with the increased use of musculoskeletal ultrasound (MSUS). Improvements in MSUS equipment and in frequencies of transducer heads (5 to 17 MHz) have yielded better quality ultrasound images. Better resolution on echotexture of muscles, tendons, and bones in ultrasound images are associated with improved diagnostic validity of MSUS in detecting the presence of LE. Additionally, real-time images demonstrating changes in size of nerves, tendons, and bones and the relationship of elbow structures are likely to improve the diagnostic validity of MSUS in the determination of LE.

Musculoskeletal ultrasound (MSUS) and Magnetic Resonance Imaging (MRI) are diagnostic equipment that demonstrate soft tissue contrast of anatomical structures within elbows containing abnormalities. Of the two diagnostic equipment, the MSUS is more practical to use in the clinics as it is more cost-effective than the MRI. The cost-effectiveness of MSUS has led to its increased use in healthcare practice since 2001. Despite MSUS not being as sensitive as MRI, its specificity is comparable with MRI. According to Shahabpour et al., MSUS might be adequate for diagnosing LE and MRI may be reserved for patients with symptoms whose MSUS findings are normal.

Appendix 1 reports the common abnormal MSUS findings in elbows with LE namely:

- hypoechochogenicity,
- neovascularity,
- calcifications,
- thickening,
- fibrillar changes,
- adjacent fluid, and
- tears of CEO and lateral epicondyle irregularities.

Hypoechogenicity of the CEO are ruptured collagens corresponding to histological findings of scar tissue with marginal areas of degeneration in the CEO. Calcifications of the CEO are irregularly-shaped foci of hyperechoic areas within the CEO, reflecting severity of the degeneration process. Neovascularity of the CEO is intratendinous hyperemia detected as colour-flow signal indicating failed attempts of the CEO to heal itself after repetitive elbow activities, reflecting inadequate blood supply in the CEO.

Lateral Epicondylalgia Based on Acuity of Elbow Symptoms
LE is generally classified into acute and chronic stages based on the duration of lateral elbow pain. Acute LE is described by patients as feeling of something “giving way” within the elbow during traumatic and forceful activities. It is characterised by tenderness and swelling of forearm extensor muscle with microscopic injuries within the CEO. Conversely, chronic LE
develops over time after repetitive and forceful handgrip activities. In chronic LE, the intensity of pain and its associated disability are less when compared to acute LE.\textsuperscript{28,30}

As reported in Appendix 1, the consensus in the literature as to the definitive cut-off point in the duration of elbow symptoms differentiating acute from chronic LE is lacking, as evidenced by the time frames given in the following studies: 1 week, 3 weeks, 6 weeks, and more than 4 weeks.\textsuperscript{22,31-37} Archambault et al and Soslowsky et al reported the presence of inflammatory markers in as early as six weeks in the acute stage of tendon injuries.\textsuperscript{38,39} Despite this, there is no consensus among authors on the use of the descriptors of acute or chronic LE. Additionally, figures on the diagnostic validity of MSUS findings specific to acute LE have not been clearly identified and reported in the current literature.

Our study sought to determine the diagnostic validity of eight abnormal MSUS findings of the CEO (hypoechoogenicity, neovascularity, calcifications, irregular margin, presence of adjacent fluid, irregular fibrillar pattern, thickness, tear), and one MSUS finding of the lateral epicondyle (cortical irregularities) to confirm the presence of LE in elbows which were initially diagnosed with LE using a clinical diagnostic approach. Based on the acuity of elbow symptoms, using six weeks as time differentiating acute from chronic LE, we investigated the association of these abnormal MSUS findings and the clinical diagnosis of LE.

**METHODOLOGY**

**Ethics**

This research was approved by the Ethics Review Board of the University of Santo Tomas (UST) (Ethics approval: IRB-AP210-D-LEPS) and the Human Research Ethics Committee of the University of South Australia (Ethics approval: 22328).

**Setting**

Physiotherapy Skills Laboratory and the Department of Physical Medicine and Rehabilitation of UST.

**Study Population**

Volunteer participants were recruited from January 2011 to September 2011 via a comprehensive campaign using advertisements, flyers, and social networking sites in a wide-ranging reference population reflecting private and public hospitals, private clinics, sport clubs, marketplace, factories, health centres, and schools in Manila, Philippines. Participants were also accepted from consecutive referral by doctors and by physiotherapists in Manila. This approach was taken because there was no available comprehensive register of individuals with LE from which to recruit participants randomly.

To be eligible for study inclusion, participants needed to report pain over the lateral elbow area regardless of duration of symptoms. Potential participants who reported pain over the lateral epicondyle or in the regions five centimeter proximal and five centimeter distal to the lateral epicondyle were eligible to participate in the study.\textsuperscript{9,9} Potential participants were excluded if they had current general body malaise, current diagnosis of cancer, previous or current fractures in arm/forearm/wrist, elbow osteoarthritis, recent blunt elbow trauma, cervical radiculopathy, peripheral neuropathy, stroke, previous surgery to elbow, or were pregnant.

**Reliability of the Examiners**

The sonologist had 20 years of practice in rehabilitation medicine and had been using MSUS for the past four years. The sonologist’s reliability in using MSUS on the elbow region was established through comparison with an expert Australian sonographer who had 20 years of experience in the use of MSUS.\textsuperscript{40} The sonologist and sonographer demonstrated perfect agreement (Kappa=1.0) on finding irregularities on the lateral epicondyle; moderate agreement (Kappa=0.60) on finding neovascularity in the CEO; and fair agreement on finding calcifications within the CEO (Kappa=0.53) and fluid around the CEO (Kappa=0.25).\textsuperscript{40} A research assistant, who was trained for more than three years in musculoskeletal assessment, performed the clinical examination.

**Study Processes**

**Initial Screening**

The purpose and mechanics of the study were explained to participants, and they signed a consent form. The provocation examinations of Cozen’s, Mill’s, and Maudsley’s tests were performed by the research assistant (working independently of the other researchers) by testing both elbows of consenting and eligible participants. Participants who had reproduction of pain in the lateral elbow by any of the three tests were classified as having LE. Elbows without pain were classified as asymptomatic. The history and activities aggravating the participants’ lateral elbow pain were recorded.
**Imaging and Interpretation**

A prospective blinded MSUS assessment by the sonologist was performed on both elbows of consecutive participants with LE using an ESaote MyLab 40 Family Ultrasound machine (ESaote Asia Pacific Diagnostic Private Limited) with a multi-frequency broadband transducer (up to 18 MHz). Because of a lack of time and funding, asymptomatic subjects were not imaged. The sonologist was blinded to the elbow with LE. An imaging protocol in obtaining optimal MSUS images of the CEO and lateral epicondyle that is valid and reliable was used in this study.40

Following the processes outlined in the research summarised in Appendix 1, MSUS measures of hypoechogenicity, neovascularity, calcifications, adjacent fluid, irregular fibrillar pattern, tendon thickness, and tear were taken, as well as irregularities on the margin of the CEO.12,17,21,22 The presence of a tear was indicated by a longitudinal split within the CEO (Figure 1). However, the sonologist in this study did not determine the extent of the tear. The CEO thickness was determined as “enlarged” if there was a 10% difference compared with the opposite side, as suggested in the studies of du Toit et al and Connell et al (Figure 2).12,17 To confirm the abnormal MSUS changes in the CEO and lateral epicondyle, longitudinal and transverse scans were obtained. For each participant, the provocation tests and the MSUS examination occurred within two hours, reducing the potential for the condition to change (maturation bias).12,41

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**Figure 1. Musculoskeletal Ultrasound Findings of the CEO of a 49-Year Old Female Participant with Right LE**

The upper green arrows indicate hyperechoic changes within the CEO. The lower green arrows indicate presence of tear within the CEO. Key: CEO, common extensor origin

**Figure 2. CEO Thickness of a 40-Year Old Female Participant with Right LE**
The CEO in the right elbows with LE was thicker compared to the CEO in the left elbow without LE. Key: CEO, common extensor origin; LE, Lateral epicondylalgia

Reference Standard
The reported presence of lateral elbow pain replicated by any one of the Cozen’s, Mill’s, or Maudsley’s tests was used as a reference standard in diagnosing LE in this study. These uncomplicated provocation tests were commonly used in the clinical practice and research studies.¹²

Statistical Analysis
The clinical diagnosis of LE, as defined by reproduction of pain by at least one provocation test, was the reference standard. The six week time point was used to differentiate acute from chronic LE. The diagnostic validity was calculated using data grouped into cells A-D similar to Table 1. Each MSUS finding was compared for case LE elbows and non-LE elbows. Cell A reports on true positive findings, and cell D reports on true negative findings (as determined by agreement by both diagnostic tests). Cells B and C report on false positive and false negative findings, respectively.

| Table 1. 2x2 Table for Abnormal MSUS Findings and Clinical Diagnosis of Lateral Epicondylalgia |
|----------------------------------|--------------------------|
| MSUS findings (+)               | LE (+)                   |
|                                 | A                        |
| MSUS findings (-)               | LE (-)                   |
|                                 | B                        |
|                                 | C                        |
|                                 | D                        |

Key: A, True Positive; B, False Positive; C, False Negative; D, True Negative; LE, Lateral epicondylalgia; MSUS, musculoskeletal ultrasound; (+), positive; (-), negative

The diagnostic validity was determined using MedCalc Version 11.3.0 (MedCalc easy-to-use statistical software, 2012-2013).² In detail, calculations of specificity, sensitivity, likelihood ratios, predictive values and diagnostic odds ratios were determined using the following formulae:²

Sensitivity= A/(A+C)
Specificity= D/(B+D)
Positive predictive value= A/(A+B)
Negative predictive value= D/(C+D)
Positive likelihood ratio= A/(A+C)/(B/(B+D))
Negative likelihood ratio= C/(A+C)/(D/(B+D))
Diagnostic odds ratio= (A/C)/(B+D)

RESULTS
From January 2011 to September 2011, fifty-four participants (39 female, 15 male) aged between 15 to 66 years (mean (SD): 41(13)) were included in the study. Three participants could not participate in the MSUS scan because of scheduling difficulties. Of the 51 available participants (102 elbows, 38 female, 13 male), one elbow was excluded from testing due to congenital shortening and flaccidity. Of the 101 available elbows, 55 elbows had LE and 46 elbows had no LE (Figure 3). Of the 55 symptomatic elbows, 49 were on the dominant side (43 on the right, four on the left, and one participant was ambidextrous).

The participants had lateral elbow pain ranging from 1 day to 36 months, affecting 47 of the dominant elbows. Acute LE was experienced by 24 participants (43.6%) and chronic LE by 31 participants (56.4%). No significant difference (p>0.05) in age between the acute and chronic LE groups was noted. Within both acute and chronic groups, women predominated. Table 2 reports the characteristics of the participants and elbows examined in this study.
Table 2. Characteristics of The Participants

<table>
<thead>
<tr>
<th></th>
<th>Acute (current LE pain &lt; 6 weeks)</th>
<th>Chronic (current LE pain &gt; 6 weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Male</td>
</tr>
<tr>
<td>Number of participants</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Age (in years) (mean, min-max)</td>
<td>40.8 (15 to 64)</td>
<td>40.6 (20 to 56)</td>
</tr>
<tr>
<td>Duration of elbow pain (in months) (mean, min-max)</td>
<td>0.46 (0.03 to 1.32)</td>
<td>0.49 (0.03 to 1)</td>
</tr>
<tr>
<td>Number of symptomatic elbows</td>
<td>24</td>
<td>5</td>
</tr>
<tr>
<td>Number of asymptomatic elbows</td>
<td>21</td>
<td>5</td>
</tr>
<tr>
<td>Dominant side affected</td>
<td>23</td>
<td>5</td>
</tr>
<tr>
<td>Right</td>
<td>20</td>
<td>4</td>
</tr>
<tr>
<td>Left</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Number of participants whose bilateral elbows were affected</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Key: LE, lateral epicondylalgia

Appendix 2 reports the estimates of diagnostic validity and confidence intervals of the nine abnormal MSUS measures for acute and chronic LE. Hypoechogeticity and calcifications of the CEO were the most useful predictors of acute and chronic LE. Hypoechogeticity of the CEO was the strongest predictor of LE, although it was better at predicting chronic rather than acute LE (Sns: 81% chronic, 67% acute; DOR: 7.41 chronic, 1.52 acute). Applying a high measure of specificity (of at least 80%), all other MSUS measures were strongly specific for acute LE except for hypoechogeticity of the CEO, and all MSUS measures were strongly specific for chronic LE except for hypoechogeticity of the CEO and cortical irregularities of the lateral epicondyly. Moreover, calcifications of the CEO was found to be significantly associated with acute LE (DOR: 14.62) and chronic LE (DOR: 7.26) with p<0.05. No adverse effects with either MSUS or clinical examination were reported.

DISCUSSION

This study reports on the diagnostic validity of abnormal MSUS findings in elbows with acute or chronic LE. MSUS measures, particularly hypoechogeticity and calcifications of the CEO, provide objective information that is relevant for both acute LE and chronic LE.

Hypoechogeticity of the CEO appears to be a stronger feature of chronic LE [Sns: 81 (64 to 91)] than acute LE [Sns: 67 (46 to 82)], reflecting a chronically overused tendon. An overused CEO may be associated with weakening of the extensor carpi radialis brevis (ECRB) and extensor digitorum communis (EDC) due to suboptimal repetitive contraction of these muscles, preventing the painful sensation at the elbow that accompanies handgrip in elbows with LE. Despite that calcifications are common features of chronic tendon degeneration, calcifications of the CEO are more significantly associated with acute LE (DOR: 14.62) than with chronic LE (DOR: 7.26). Its presence may be an initial attempt of the body to cope with stress by converting soft tissue structures to bony structures, implying the need to stop stressful handgrip activities as soon as pain is reported. The formation of calcifications may be an immediate response of the CEO to stress created by the contracting forearm extensor muscles in the elbow. It is part of the CEO tissue remodeling process that occurs in less than six weeks of injury. Calcifications may reflect the body’s attempt to functionally adapt to the mechanical load created by repetitive and forceful handgrip activities.

The hypoechogeticity of the CEO has the lowest specificity (64%) compared to the specificities reported in other studies, as shown in Appendix 1. The lower specificity reported could be secondary to the sole inclusion of non-LE elbows of case participants. Similar to our study, Struijs et al (2004) investigated the non-LE elbows of subjects with unilateral LE and registered...
the lowest specificity among the published studies with 25 or more participants (Appendix 1).\textsuperscript{45} This resemblance in results suggests that there may be MSUS presentations in non-LE elbows of case participants which may be typical to them compared to those seen in non-symptomatic elbows of healthy subjects.

Considering the significant associations between hypoechogenicity of the CEO, calcifications of the CEO, acute LE, and chronic LE, the replication of lateral elbow pain through the provocation tests should not be singularly used in diagnosing LE. Muscle fatigue or soreness may cause lateral elbow pain which may be replicated by Cozen’s, Mill’s, or Maudsley’s tests, thus potentially mimicking LE. To prevent this inaccurate diagnosis, the involvement of the CEO as determined by the MSUS, should complement the findings of the provocation tests used in diagnosing LE. Considering that MSUS is a simple, objective, inexpensive, and non-invasive way of confirming LE, the authors propose that MSUS presence of hypoechogenicity and calcification of the CEO be included in the diagnostic criteria for LE. Additionally, the presence of hypoechogenicity of the CEO as a valid diagnostic indicator for presence of chronic LE corroborates with the diagnostic validity reported for chronic LE in the systematic review by Dones et al (2014) [Sensitivity: 0.64 (0.56 to 0.72)] and specificity [Specificity: 0.82 (0.72 to 0.90)].\textsuperscript{14} The current study further reports that the hypoechogenicity of the CEO is likewise a valid diagnostic indicator for presence of acute LE.

**MSUS Findings and Physiotherapy Regimen**

Considering that hypoechogenicity of the CEO may likely be associated with weakening of the CEO, we suggest graded eccentric exercise.\textsuperscript{43} In the study of Croisier et al, 46 patients with chronic LE have received eccentric training exercises of the forearm wrist extensors, which resulted in a significant reduction of pain intensity, an absence of strength deficit on the involved side, an improvement of the tendon MSUS image, and marked improvement in disability status.\textsuperscript{46} In a study by Martinez-Silvestrini et al, eccentric exercise improved pain-free grip strength and functional independence of 27 participants without causing any worsening of elbow symptoms.\textsuperscript{47}

Considering that calcifications of the CEO are associated with acute LE and chronic LE, aggressive resistance exercises of the forearm extensor muscles should be avoided as these can potentially worsen symptoms associated with the calcifications of the CEO. Physiotherapy treatment such as forearm bracing, splints, taping, and adjusting handgrip size are suggested.\textsuperscript{48-54} Forearm bracing compresses the forearm extensor muscles, which is assumed to de-load the CEO of stress.\textsuperscript{54} Grimmer-Somers et al recommended the use of forearm bracing and taping as off-the-shelf management for LE.\textsuperscript{51} Adjusting handgrip size for optimal grip reduces the muscular force required for gripping a tool, protects the underlying elbow joint structures, and reduces the risk of developing cumulative trauma associated with repetitive tasks requiring high hand grip forces.\textsuperscript{52,53}

The results of this study were based on what we believe to be a wide representation of the general population with lateral elbow pain in Manila, Philippines. Participants for this study were recruited from a large reference population in an attempt to obtain broad representation of LE across a range of sectors in Manila, in the absence of a population register. The majority of the participants was self-referred and came directly from places outside health care institutions. For economic reasons, many of these participants preferred not to take leave from work for treatment or to consult a rehabilitation doctor despite the presence of their LE. This sample therefore represents a population of LE sufferers that are potentially underreported in the traditional medical literature.

**Limitations of the Study**

The non-LE elbows were compared to the LE elbows of case participants using MSUS measurements. A decision was made at the time that for pragmatic reasons (time and resources), MSUS studies would not be undertaken on non-symptomatic elbows of healthy subjects. This may be perceived as a limitation in our study. The non-LE elbows of the participants in our study may not mirror the non-symptomatic elbows of subjects diagnosed as not having LE. Moreover, similarity between sides within an individual has been reported as a confounder when the non-LE side has been used as the “control.”\textsuperscript{76} However, as this study specifically compared the diagnostic validity of MSUS finding with positive responses to Cozen’s, Mill’s, and Maudsley’s tests, we believe that we took the most appropriate sampling approach.\textsuperscript{56}

The intra-tester and inter-tester reliability of the sonologist was not tested in determining the presence of tear and thickness of the CEO, which may have resulted in measurement errors. Although the reliability of our sonologist is comparable to a skilled sonographer with 20 years of experience in the use of MSUS, the operator-dependent characteristic of MSUS use may limit the external generalizability of the results for CEO thickness and tear.
There is certainly a risk of self-selection bias in this study. However our sampling frame sought to include individuals who may not have been represented in the earlier published studies where recruitment occurred only in the treatment clinics and seen by health care professionals.\textsuperscript{12,17,22}

**IMPLICATIONS FOR PRACTICE**
Currently, the clinical diagnosis of LE is based on the use of provocation tests (Cozen, Mill, Maudsley) which are both gross and subjective. This study confirms the diagnostic value of incorporating MSUS measures of hypoechogenicity and calcifications of the CEO when objectively confirming the presence of LE. We suggest that any elbow which is clinically diagnosed with LE, of any duration, should be sonographically scanned to identify the soft tissue abnormality in the CEO. Knowledge of these MSUS results would guide healthcare professionals in designing therapeutic regimens conducive to CEO healing and potentially addressing in some way the heavy economic burden due to workday loss and residual impairments in LE elbows.

**IMPLICATIONS FOR RESEARCH**
Future studies recruiting participants from a comprehensive database (i.e. central registry for musculoskeletal complaints) should be conducted to compare the MSUS findings between healthy elbows of subjects without LE with elbows diagnosed with LE. Particularly, this study should establish that the non-LE elbow of a subject with unilateral LE had similar MSUS findings to the non-symptomatic elbows of healthy subjects.

**DECLARATION OF CONFLICT OF INTEREST**
This research has received funding from the Department of Science and Technology of the Republic of the Philippines. The authors declare no conflict of interest in the planning, collection, interpretation and writing of the study reported in this paper.

**FUNDING**
This study was funded by the Department of Science and Technology (DOST) of the Republic of the Philippines. The DOST has no role in the making of the study design, collection, analysis, and interpretation of the data, writing of the report, and in the decision to submit the paper for publication.

**REFERENCES**


In an attempt to understand better the pathology in elbows with LE, improvements and increased use of musculoskeletal ultrasound (MSUS) have proliferated since 2001.

Objectively detected pathology within the CEO and around the lateral epicondyle (Tarhan et al., 2009, du Toit et al., 2008, Levin et al., 2005).

### APPENDIX A

**Sensitivity and Specificity of MSUS Findings in Elbows with LE**

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<tbody>
<tr>
<td>N=px, elbows</td>
<td>32.38 8,8</td>
<td>52.52 17,22</td>
<td>8.8 76,72</td>
<td>41.41</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Age (in years)</td>
<td>Mean:52.6 Range:38-70</td>
<td>Mean:45</td>
<td>Mean(SD): 49.8 49.8</td>
<td>Mean:45</td>
<td>Mean:46 Range:38-63</td>
<td>Mean:45.6 Range:21-67</td>
<td>Mean(SD): 24.3,7,3 Range:16-36</td>
</tr>
<tr>
<td>Duration of symptoms</td>
<td>Mean:9 mos Range:6-120 mos</td>
<td>Mean:6.2 Range:1-72 mos</td>
<td>Mean:18 mos</td>
<td>Mean:7.5 mos Range:3 wks-2 yrs.</td>
<td>Mean:7.1 mos Range:1 day-9 yrs</td>
<td>Mean:2.2 mos Range:17 days to 9.8 mos</td>
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### Continuation on Sensitivity and Specificity of MSUS Findings in Elbows with LE

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<td></td>
<td></td>
</tr>
<tr>
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<td>Mean:45</td>
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<td>Mean:46 Range:38-63</td>
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</tr>
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<td>Mean:18 mos</td>
<td>Mean:7.5 mos Range:3 wks-2 yrs.</td>
<td>Mean:7.1 mos Range:1 day-9 yrs</td>
<td>Mean:2.2 mos Range:17 days to 9.8 mos</td>
</tr>
</tbody>
</table>

Key: LE, lateral epicondylalgia; mo(s), month(s); MSUS, musculoskeletal ultrasound; n, number; px, participants; Sns, sensitivity; Spc, specificity; wk(s), week(s); --, not reported

In an attempt to understand better the pathology in elbows with LE, improvements and increased use of musculoskeletal ultrasound (MSUS) have proliferated since 2001. In evaluating LE, MSUS has objectively detected pathology within the CEO and around the lateral epicondyle (Tarhan et al., 2009, du Toit et al., 2008, Levin et al., 2005).
### APPENDIX B

**Diagnostic Validity Expressed as Percentages (95% Confidence Intervals) for Musculoskeletal Findings in the Elbows of Participants with LE**

<table>
<thead>
<tr>
<th></th>
<th>Acute (current LE symptoms of &lt; 6 weeks)</th>
<th>Chronic (current LE symptoms of &gt; 6 weeks)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sns</td>
<td>Spc</td>
</tr>
<tr>
<td><strong>Common Extensor Tendon</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoechoeginity</td>
<td>67 (46-82)</td>
<td>38 (21-60)</td>
</tr>
<tr>
<td>Neovascularity</td>
<td>8 (2-26)</td>
<td>95 (77-100)</td>
</tr>
<tr>
<td>Calcifications</td>
<td>42 (24-61)</td>
<td>90 (71-97)</td>
</tr>
<tr>
<td>Margins</td>
<td>4 (1-20)</td>
<td>100 (85-100)</td>
</tr>
<tr>
<td>Adjacent fluid</td>
<td>4 (1-20)</td>
<td>100 (85-100)</td>
</tr>
<tr>
<td>Fibrillar pattern</td>
<td>8 (2-26)</td>
<td>95 (77-99)</td>
</tr>
<tr>
<td>Thickness</td>
<td>13 (4-31)</td>
<td>100 (85-100)</td>
</tr>
<tr>
<td>Tear</td>
<td>4 (1-20)</td>
<td>100 (85-100)</td>
</tr>
</tbody>
</table>

*Lateral Epicondyle* |

| Cortical irregularities | 30 (15-50) | 81 (60-92) | 64 (35-95) | 50 (35-66) | 1.53 (0.52-4.51) | 0.88 (0.63-1.22) | 3.94 (0.71-21.76) | 23 (11-40) | 76 (57-89) | 76 (29-77) | 54 (30-49) | 0.94 (0.36-2.44) | 1.02 (0.76-1.36) |

*Generate small but sometimes important shifts in probability

**p<0.05

Key: DOR, diagnostic odds ratio; LE, Lateral Epicondylalgia; NLR, negative likelihood ratio; NPV, negative predictive value; PLR, positive likelihood ratio; PPV, positive predictive value; Spc, specificity; Sns, sensitivity; __infinity

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