Original article

The diagnostic test accuracy of ultrasound for the detection of lateral epicondyritis: A systematic review and meta-analysis

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ABSTRACT

Background: The purpose of this study was to determine the diagnostic test accuracy of ultrasound for the detection of lateral epicondylitis.

Methods: An electronic search of databases registering published (MEDLINE, EMBASE, CINAHL, AMED, Cochrane Library, ScienceDirect) and unpublished literature was conducted to January 2013. All diagnostic accuracy studies that compared the accuracy of ultrasound (index test) with a reference standard for lateral epicondylitis were included. The methodological quality of each of the studies was appraised using the QUADAS tool. When appropriate, the pooled sensitivity and specificity analysis was conducted.

Results: Ten studies investigating 711 participants and 1077 elbows were included in this review. Ultrasound had variable sensitivity and specificity (sensitivity: 64%–100%; specificity: 36%–100%). The available literature had modest methodological quality, and was limited in terms of sample sizes and blinding between index and reference test results.

Conclusions: There is evidence to support the use of ultrasound in the detection of lateral epicondylitis. However, its accuracy appears to be highly dependent on numerous variables, such as operator experience, equipment and stage of pathology. Judgement should be used when considering the benefit of ultrasound for use in clinical practice. Further research assessing variables such as a transducer frequency independently is specifically warranted.

Level of evidence: Level II.

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1. Introduction

Lateral epicondylitis is one of the most commonly diagnosed elbow pathologies and has a population prevalence in 1.3% of the general population [1–6] and 7% in manual workers [7]. The most common features of lateral epicondylitis are pain and hyperalgesia [4,8,9]. While the initial diagnosis of lateral epicondylitis is generally performed through clinical assessment and patient history [10–12], literature has indicated the use of diagnostic imaging to assist with more complex cases [5,13,14]. In addition, ultrasound has gained support as a secondary diagnostic examination, supporting or refuting clinical examination findings to improve the accuracy of lateral epicondylitis diagnosis [10–12].

Ultrasound has been advocated as a diagnostic imaging modality for the detection of soft tissue injuries [15–18]. Literature has suggested that ultrasound has a growing place in modern health care [19,20]. However, no review has examined all the available literature on the diagnostic test accuracy of ultrasound for detecting lateral epicondylitis. Therefore, the purpose of this review was specifically to analyse the literature relating to the diagnostic test accuracy of ultrasound for the detection of suspected lateral epicondylitis.

2. Materials and methods

2.1. Search strategy

A PRISMA compliant systematic review method was adopted [21]. The primary search was conducted for the electronic databases: MEDLINE, EMBASE, CINAHL, AMED, Cochrane Library and Science Direct. These were searched: January 1990 to January 2013, to identify studies that used ultrasound as a diagnostic tool for identifying lateral epicondylitis.

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2.4. Study selection

All search results (titles and abstracts) were reviewed by one reviewer (SL) using the eligibility criteria. The full-texts of all potentially eligible papers were ordered and re-reviewed by one reviewer (SL), and verified by a second (TS). Full-text papers satisfying the criteria were included in the final review.

2.5. Data extraction

As with study eligibility, data was independently extracted from all included studies by one reviewer (SL), and verified by a second (TS). Data was extracted using a standard data extraction form. Data extracted included:

- study design;
- location study undertaken;
- sample size;
- gender;
- age range;
- cause of condition;
- severity and duration of symptoms; type of ultrasound machine used;
- frequency of ultrasound used;
- profession of clinician undertaking the ultrasound;
- length of experience;
- reference standard assessment;
- profession of clinician undertaking this assessment;
- assessment details;
- findings including, sensitivity, specificity, true positive, true negative, false positive, false negative values.

2.6. Methodological appraisal

All included studies were assessed for methodological quality using the quality assessment of diagnostic accuracy studies (QUADAS) tool [23]. This is a validated tool for the appraisal of diagnostic accuracy studies [24]. All included papers were appraised and verified by one reviewer (SL) and verified by a second (TS).

2.7. Data analyses

All studies were assessed for heterogeneity by observing the data extraction tables and sensitivity/specificity forest plots. When evidence of heterogeneity was demonstrated in respect to study characteristics, populations or interventions, the studies were assessed using a narrative approach. When there was minimal evidence of observed heterogeneity, pooled estimates of sensitivity and specificity, with 95% confidence interval (CI) were computed. Statistical heterogeneity among studies was assessed by a chi² test for heterogeneity and by calculating the I² statistic to highlight the effect of true variability [25]. A summary receiver operating characteristic plot (sROC) was calculated for the pooled dataset.

Analyses were conducted using the Review Manager 5.1 for Windows (The Nordic Cochrane Centre, Copenhagen, The Cochrane Collaboration, 2008).

3. Results

3.1. Search results

The PRISMA flow diagram summarising the search results is presented as Fig. 1. A total of 31 papers were identified from the search results. From these, 10 papers satisfied the eligibility criteria and were included in the review.

A secondary search was conducted for on-going trials and unpublished literature using the databases: Current Controlled Trials; WHO International Clinical Trials Registry Platform; Open Grey (System for Information on Grey Literature in Europe); UK National Research Register Archive; UKCRN Portfolio Database and the National Technical Information Service.

Reference lists for all included papers were reviewed to identify any further studies. Finally, all corresponding authors from the papers obtained were contacted to review the search results and identify any omitted papers.

The search strategy was independently performed by one reviewer (SL) and verified by a second (TS). An example of the MEDLINE search strategy is presenting in Box 1. This strategy was adapted for each individual search engine.

### Box 1: MEDLINE search strategy

<table>
<thead>
<tr>
<th>TERMS and BOOLEAN OPERATORS</th>
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<tbody>
<tr>
<td>1. Lateral epicondylitis</td>
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<td>2. Lateral epicondylagia</td>
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<tr>
<td>3. Tennis elbow</td>
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<tr>
<td>4. Lateral elbow tendinosis</td>
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<td>5. Lateral elbow tendinopathy</td>
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<td>6. Lateral elbow epicondylopathy</td>
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<tr>
<td>7. OR/1-6</td>
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<tr>
<td>8. Ultrasound</td>
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<td>9. Sonography</td>
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<td>10. US</td>
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<td>11. Ultrasoundography</td>
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<td>12. High intensity focused ultrasound</td>
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<td>13. Diagnostic imaging</td>
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<td>14. OR/8–13</td>
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<td>15. Arthroscopy</td>
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<td>16. Arthroscopic surgery</td>
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<td>17. OR/15–16</td>
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<tr>
<td>18. Sensitivity</td>
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<td>19. Specificity</td>
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<td>20. True positive</td>
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<td>21. False positive</td>
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<td>23. False negative</td>
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<td>24. OR/18–23</td>
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<td>25. AND/14,17,24</td>
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3.2. Critical appraisal results

A summary of the critical appraisal results is presented in Table 1. Overall, the quality of the reported studies was modest, following the QUADAS guidelines [23]. Nine of the papers obtained a clear representation of the scope of participants likely to be seen in practice. Only Maffulli et al. [26], based on the elbows of regular tennis players, showed selection bias. Connell et al. [1] state that participants referred, and included in the study, presented with only lateral elbow pain, no further eligibility criteria were discussed. The remaining nine papers gave varying levels of descriptions of selection criteria. A reference standard of clinical assessment was used within eight of the papers on living volunteers. Connell et al. [1] only mention the presence of lateral elbow pain and Jäen-Díaz et al. [6] did not use a reference standard. Only du Toit et al. [14] and Miller et al. [2] clearly state the timeframe between reference standard and index test. Nine papers did not show partial verification bias. However, in the case of Jäen-Díaz et al. [6], the study participants were selected on the basis that they had been referred by their general practitioner for reasons other than lateral epicondylitis and consequently were not given a reference standard.

Jäen-Díaz et al. [6] did not have a specific reference standard. The remaining nine studies showed clear verification of disease status prior to undergoing the index test. It is clear that in all ten papers that the reference standard (where present) was undertaken independently of the index test. Seven papers [1,2,6,10,12,14,27] provided a replicable description of the index test. Seven papers describe the process of initial diagnosis, generally utilising a clinical assessment to allow for the reproduction within practice or future studies. Jäen-Díaz et al. [6] did not employ a reference standard; and neither Connell et al. [1] nor Hee Lee et al. [12] provided a description of the reference standard. Seven studies confirmed blinding between those undertaking the reference standard, and those interpreting the ultrasound results. While du Toit et al. [14] state there was no blinding, Connell et al. [1] and Noh et al. [27] give no indication either way. The reference standard results (where stated) were interpreted without knowledge of the index test in all the ten eligible papers. None of the papers provided the type of clinical data that would be available in everyday practice to clinicians when the results were interpreted. Struijs et al. [28] state clearly that 15 participant’s images were judged unsuitable for evaluation. However, the remaining nine papers did not declare uninterpretable results. Both Struijs et al. [28] and Connell et al. [1] report withdrawals from their studies, respectively.

3.3. Study characteristics

The results of each study’s cohort characteristics are summarised in Table 2. In total, the ten studies recruited 574 symptomatic patients, 163 asymptomatic patients. In total, diagnostic results from ultrasound performed on 1077 elbows were identified.

Study and statistical homogeneity permitted four studies to be pooled through a meta-analysis [3,12,27,28]. The remaining papers either provided only partial data [1,6,10,14] or were too heterogeneous [2,26] for a meta-analysis, and were therefore synthesised narratively.
Table 1
QUADAS appraisal scores.

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</tbody>
</table>

QUADAS criteria
1. Was the spectrum of patients' representative of the patients who will receive the test in practice?
2. Were selection criteria clearly described?
3. Is the reference standard likely to correctly classify the target condition?
4. Is the time period between reference standard and index test short enough to be reasonably sure that the target condition did not change between the two tests?
5. Did the whole sample or a random selection of the sample, receive verification using a reference standard or diagnosis?
6. Did patients receive the same reference standard regardless of the index test result?
7. Was the reference standard independent of the index test?
8. Was the execution of the index test described in sufficient detail to permit replication of the test?
9. Was the execution of the reference standard described in sufficient detail to permit its replication?
10. Were the index test results interpreted without knowledge of the reference results?
11. Were the reference standard results interpreted without knowledge of the results of the index test?
12. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?
13. Were uninterpretable/intermediate results reported?
14. Were withdrawals from the study explained?

✓ : satisfied; √ : not satisfied; U: unclear.

3.4. Meta-analysis

The pooled sensitivity was 0.82 (95% CI: 0.76–0.87), and pooled specificity was 0.66 (95% CI: 0.60–0.72). This is represented in Fig. 2 ROC indicating a high sensitivity and a proportionally lower specificity. The position of the curve suggested a modest sensitivity and specificity where the curve is moderately near best. The forest plot in Fig. 3 indicates reasonable consistency in terms of sensitivity. However, as Fig. 3 indicates, in the study of Levin et al. [3], it appears as an anomaly for the specificity value in comparison to the other results.

3.5. Narrative synthesis

Four studies provided partial data on the diagnostic accuracy of their ultrasound assessments [1,6,10,14]. From these, sensitivity ranged from 0.80 [6] to 1.00 [10] and specificity, ranged from 0.63 [14] to 0.923 [6]. Connell et al. [1] did not provide a value for specificity.

Maffulli et al.’s [26] paper specifically observes the ultrasound images of elite tennis players. They reported a sensitivity of 0.93 in this population where clinical assessment was the reference standard.

Table 2
Table to depict the population characteristics of included studies.

<table>
<thead>
<tr>
<th>Study</th>
<th>Numbers</th>
<th>Gender M/F</th>
<th>Mean age (Years)</th>
<th>Duration of characteristics</th>
<th>Index test</th>
<th>Operator profession</th>
<th>Experience of operator (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connell et al. [1]</td>
<td>81</td>
<td>54/30</td>
<td>41</td>
<td>1 day–9 years</td>
<td>US (HDI 3000) 10 MHz</td>
<td>Sonograph + MSK radiologist</td>
<td>NS</td>
</tr>
<tr>
<td>du Toit et al. [14]</td>
<td>44</td>
<td>24/20</td>
<td>47.5</td>
<td>&gt; 3 months</td>
<td>Grey-Scale 17–5 MHz Power Doppler 1000 Hz/75 Hz Doppler 6–18 MHz Real-time SE 6–13 MHz</td>
<td>Sonograph</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>de Zordo et al. [10]</td>
<td>60</td>
<td>21/39</td>
<td>48.1</td>
<td>NS</td>
<td>US 12 MHz US 7.5–10 MHz US (HDI 5000) 12 or 13 MHz</td>
<td>Radiologist x2</td>
<td>Doppler – 6 SE – 3</td>
</tr>
<tr>
<td>Hee Lee et al. [12]</td>
<td>111</td>
<td>26/85</td>
<td>48.3</td>
<td>NS</td>
<td>US 12 MHz US 7.5–10 MHz</td>
<td>Radiologist</td>
<td>7</td>
</tr>
<tr>
<td>Levin et al. [3]</td>
<td>32</td>
<td>16/16</td>
<td>37.8</td>
<td>NS</td>
<td>US (HDI 5000) 12 or 13 MHz</td>
<td>Sonograph</td>
<td>6</td>
</tr>
<tr>
<td>Maffulli et al. [26]</td>
<td>41</td>
<td>39/2</td>
<td>24.3</td>
<td>17 days–9.8 months</td>
<td>Real-time US 5–7 MHz US (HDI 3000) 5–10 MHz</td>
<td>Radiologist</td>
<td>NS</td>
</tr>
<tr>
<td>Miller et al. [2]</td>
<td>17</td>
<td>8/6</td>
<td>37.5</td>
<td>NS</td>
<td>US (HDI 5000) 5–10 MHz</td>
<td>Orthopaedic surgeon</td>
<td>NS</td>
</tr>
<tr>
<td>Noh et al. [27]</td>
<td>54</td>
<td>25/29</td>
<td>43.5</td>
<td>&gt; 3 weeks</td>
<td>US 40 mm field of view</td>
<td>Orthopaedic surgeon</td>
<td>NS</td>
</tr>
<tr>
<td>Stuijs et al. [28]</td>
<td>57</td>
<td>NS</td>
<td>45.5</td>
<td>&gt; 6 weeks</td>
<td>US (SSD-900) 7.5 MHz</td>
<td>Sonograph</td>
<td>NS</td>
</tr>
</tbody>
</table>

NS: not stated; SE: sonoelastographic; US: Ultrasound

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Miller et al. [2] investigated the use of ultrasound versus MRI for the diagnosis of both lateral and medial epicondylitis. The combined reported sensitivity of the ultrasound was 0.73, while the specificity was 0.88. This population was referred following a clinical diagnosis as the reference standard.

4. Discussion

The findings of this review indicate that the diagnostic accuracy of ultrasound for detecting lateral epicondylitis is diverse with the sensitivity ranging from 64% to 100%. Specificity demonstrated a wider range of 36% to 100%.

There is a general consensus that the sensitivity of diagnostic ultrasound is greater than the specificity. Due to the fact that not all papers had control groups, or utilised the asymptomatic elbow of the participant as well, there is potential for spectrum bias. This may have affected the specificity and potentially sensitivity negatively, lowering the possible diagnostic test accuracy of the ultrasound tested. There was no explanation within any paper to determine why this occurred or what previous literature has discovered.

The majority of the papers included in this review concluded that the use of ultrasound was beneficial to assist with the detection of lateral epicondylitis [1,10,12,14,26,27]. Amongst these, specificity range from 76.5% to 100% and specificity from 76.2% to 100%.

Apart from Maffulli et al.’s [26] study, none of the papers highlighted the occupation of their participants. It was unclear whether any control groups had been in jobs that may have increased their susceptibility to lateral epicondylitis [4]. This paucity of information on participant occupation may affect the generalisation of these findings to clinical practice.

Five papers [2,3,6,10,12] gave no indication of symptom duration, while Connell et al. [1] included participants with symptom durations from 1 day to 9 years. This range has the potential to result in a substantial scope, in terms of the levels of degeneration and changes that might be seen at the tendon of the participant being investigated. No studies have assessed this in lateral epicondylitis. However, Kayser et al. [29] reported an increased difficulty in detecting chronic Achilles tendon pathology compared to those in acute stages. While this study may not be directly transferable to the elbow, it is an area considered as a cause of bias previously [29]. It is necessary to understand the process of degeneration and discover whether images from ultrasound are more accurate in the acute or chronic stages. This information could potentially help to guide practice and highlight the specific time frame when diagnostic imaging may be most appropriate.

The literature related to the ultrasound operator profession and expertise on the accuracy of the findings is an area that has been under-researched, across a range of tendinopathies. While some papers make generalised commentary that this link exists [30,31], other investigations consider the levels of experience and training of the professional, rather than the title of the profession itself [32,33]. McKiernan et al. [34] noted that many operators do not have the skills required to achieve accurate results. However, Sandmeier and Renström [35] and Allen et al. [36] concluded that it is both the experience and profession of the ultrasound operator, which are key factors between inter- and intra-observer reliability.

The studies themselves included four different professions of ultrasound operator as shown in Table 2. Three employed a radiologist [10,12,26], four used a sonographer [3,6,14,28]; one paper an orthopaedic surgeon [27]; one with a sonographer and musculoskeletal radiologist [1]; and the final paper [2] did not note the profession of the operator. When looking at the profession of these operators in comparison to the sensitivity and specificity findings from the investigations, there appears to be little comparison between the two. The highest diagnostic test accuracy of ultrasound has been determined by three different professionals within three of the papers [10,14,27], of which the sonographer also showed the lowest diagnostic test accuracy in two of the remaining papers [3,28]. Consequently, within this review, ultrasound does not appear to be operator dependant, although this is an interesting aspect of diagnosis, which could have further investigation. With regard to the experience of the operators, only half of the papers disclosed this information (Table 2) and there would appear to be no obvious correlation between these results.

Throughout the papers studied, the variability of equipment used is extensive. Whilst technology has improved: machines, transducers and frequencies have become more accurate [30]. As such, the variability between machines could be considered as a reflection of typical clinical practice. However, this may also be considered a confounding variable.

When considering the type of ultrasound, the papers included within this study utilised, two of the studies compared two different types of ultrasound, grey-scale versus power Doppler, and power Doppler vs sonoelastography, respectively [10,14]. The remaining eight papers utilised real-time ultrasound with varying frequencies (Table 2). Rasmussen et al. [37] reported that high frequency transducers (7–15 MHz) are optimal for tendon injury detection.

![Fig. 2. sROC plot for ultrasound for the detection of lateral epicondylitis.](image-url)
imaging. This is in line with all of the papers included, which have a frequency range that includes at least part of this range (Table 2).

The gold standard reference test for this study would have been surgical observation. However, this was not used in these studies. While the use of a clinical assessment is the typical approach to diagnosing lateral epicondylitis in clinics, due to its relative simplicity [14], it is subjective depending on the clinician performing the test. While there is yet to be found a more appropriate means than clinical diagnosis within clinical practice, open or arthroscopic surgery is still considered the gold standard reference test for the diagnosis of this pathology [38][39]. Clinical assessment is the most commonly used method of diagnosis; nevertheless, it allows room for bias and heterogeneity within the results [40].

5. Conclusions

The use of ultrasound in the detection of lateral epicondylitis is recommended with caution since its accuracy appears to be highly dependent on numerous variables. Current evidence emphasises the advantages of the non-invasive, cheap, quick and accessible nature of diagnostic ultrasound compared to MRI or arthroscopy. Nonetheless, ultrasound requires extensive skill and experience to operate effectively. The increased use of ultrasound for the detection of lateral epicondylitis in clinical practice indicates the growing recognition of its potential. Further, high quality research based on multicentre studies is now required to develop the evidence-base on ultrasound’s application in diagnosis of this condition.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

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Further reading
