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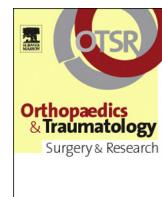
Original article

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

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ARTICLE INFO

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search of databases registering published (MEDLINE, EMBASE, CINAHL, AMED, Cochrane Library, ScienceDirect) and unpublished literature was conducted to January 2013.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 a transducer frequency independently is specifically warranted.
Level of evidence: Level II.

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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Box 1: MEDLINE search strategy.

TERMS and BOOLEAN OPERATORS
1. Lateral epicondylitis
2. Lateral epicondyalgia
3. Tennis elbow
4. Lateral elbow tendinosis
5. Lateral elbow tendinopathy
6. Lateral elbow epicondylopathy
7. OR/1–6
8. Ultrasound
9. Sonography
10. US
11. Ultrasonography
12. High intensity focused ultrasound
13. Diagnostic imaging
14. OR/8–13
15. Arthroscopy
16. Arthroscopic surgery
17. OR/15–16
18. Sensitivity
19. Specificity
20. True positive
21. False positive
22. True negative
23. False negative
24. OR/18–23
25. AND/7,14,17,24

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.

2.2. Eligibility criteria

2.2.1. Inclusion criteria
The inclusion criteria include:

- participants who presented with persistent lateral elbow pain with suspected lateral epicondylitis were included;
- both male and female, athletic and non-athletic individuals;
- participants with recurrent as well as first-time lateral epicondylitis.

2.3. Exclusion criteria

The exclusion criteria include:

- studies were excluded if they were written prior to January 1990 due to heterogeneity in imaging techniques and equipment [22];
- studies whose populations were solely paediatrics (< 16 years of age);
- animal or cadaver studies;
- papers published in non-English languages;
- studies using therapeutic rather than diagnostic ultrasound.

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 chi^2 test for heterogeneity and by calculating the I^2 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.
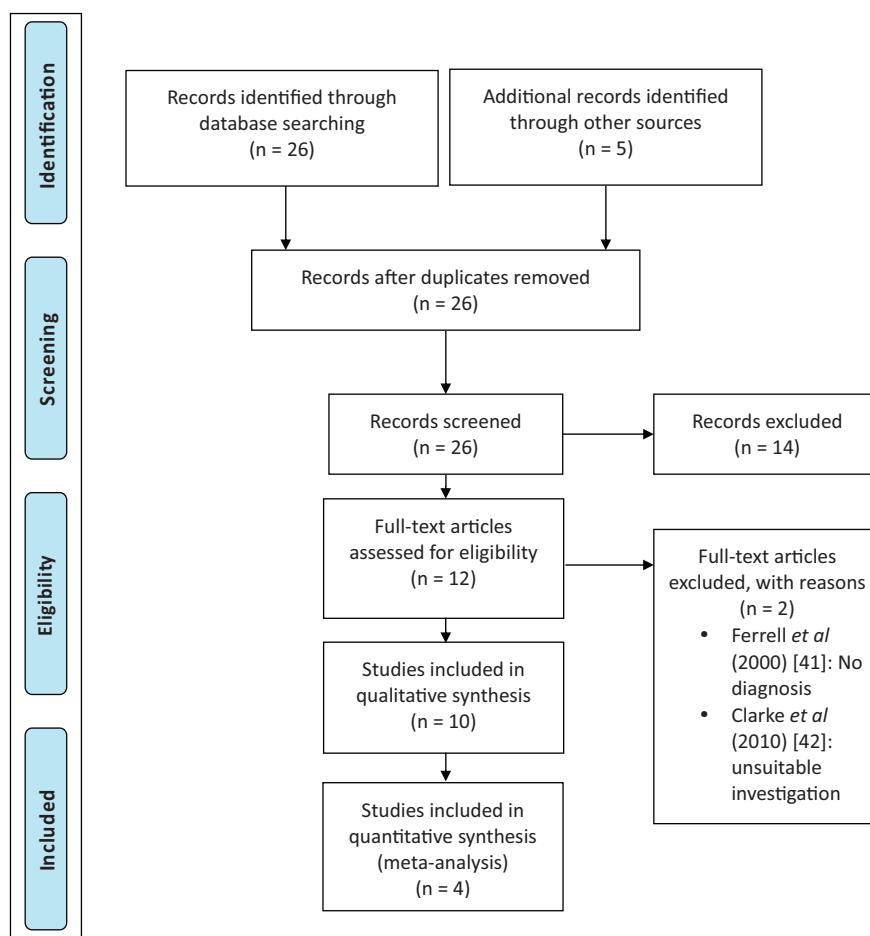
Fig. 1. PRISMA flow diagram to depict the search strategy results.

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 Jaén-Diaz 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 Jaén-Diaz 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.

Jaén-Diaz 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. Jaén-Diaz 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.

QUADAS criteria	Connell et al. [1]	du Toit et al. [14]	de Zordo et al. [10]	Hee Lee et al. [12]	Jaén-Diaz et al. [6]	Levin et al. [3]	Maffulli et al. [26]	Miller et al. [2]	Noh et al. [27]	Stuijs et al. [28]
1.	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓
2.	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓
3.	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
4.	U	✓	✗	✗	✗	✗	✗	✓	✗	U
5.	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓
6.	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓
7.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
8.	✓	✓	✓	✓	✓	✗	✗	✓	✓	✗
9.	✗	✓	✓	✗	✗	✓	✓	✓	✓	✓
10.	U	✗	✓	✓	✓	✓	✓	✓	U	✓
11.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
12.	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗
13.	✗	✗	✗	✗	✗	✗	✗	✗	✗	✓
14.	✓	✗	✗	✗	✗	✗	✗	✗	✗	✓

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 results of the reference standard?
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 largely 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.

Study	Numbers	Gender M/F	Mean age (Years)	Duration of characteristics	Index test	Operator profession	Experience of operator (years)
Connell et al. [1]	81	54/30	41	1 day–9 years	US (HDI 3000) 10 MHz	Sonographer + MSK radiologist	NS
du Toit et al. [14]	44	24/20	47.5	> 3 months	Grey-Scale 17–5 MHz Power Doppler 1000 Hz/75 Hz	Sonographer	> 20
de Zordo et al. [10]	60	21/39	48.1	NS	Doppler 6–18 MHz Real-time SE 6–13 MHz	Radiologist ×2	Doppler – 6 SE – 3
Hee Lee et al. [12]	111	26/85	48.3	NS	US 12 MHz	Radiologist	7
Jaén-Diaz et al. [6]	240	120/120	44.4	NS	US 7.5–10 MHz	Sonographer	6
Levin et al. [3]	32	16/16	37.8	NS	US (HDI 5000) 12 or 13 MHz	Sonographer	5
Maffulli et al. [26]	41	39/2	24.3	17 days–9.8 months	Real-time US 5–7 MHz	Radiologist	NS
Miller et al. [2]	17	8/6	37.5	NS	US (HDI 3000) 5–10 MHz	N/S	NS
Noh et al. [27]	54	25/29	43.5	> 3 weeks	US 40 mm field of view	Orthopaedic surgeon	NS
Stuijs et al. [28]	57	NS	45.5	> 6 weeks	US (SSD-900) 7.5 Mhz	Sonographer	NS

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

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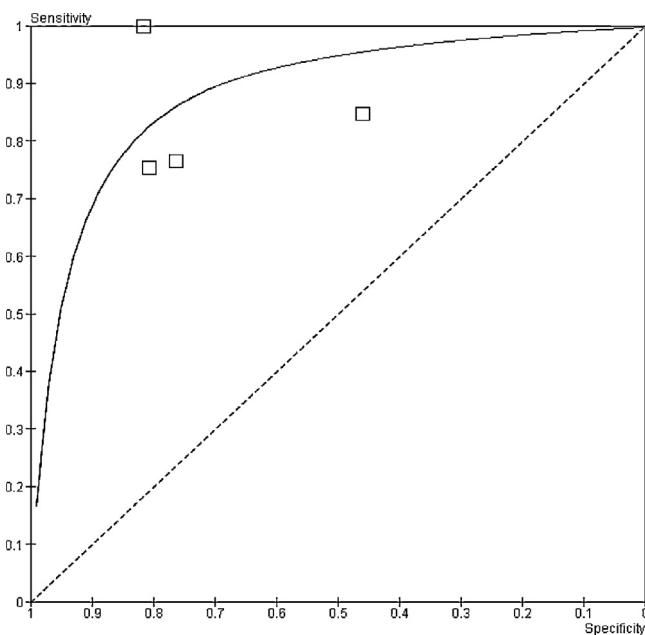
Fig. 2. sROC plot for ultrasound for the detection of lateral epicondylitis.

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, sensitivity 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

Study	TP	FP	FN	TN	Sensitivity	Specificity
Hee Lee 2011	39	15	12	48	0.76 [0.63, 0.87]	0.76 [0.64, 0.86]
Levin 2005	61	52	11	44	0.85 [0.74, 0.92]	0.46 [0.36, 0.56]
Noh 2010	27	5	0	22	1.00 [0.87, 1.00]	0.81 [0.62, 0.94]
Stuijs 2005	43	11	14	46	0.75 [0.62, 0.86]	0.81 [0.68, 0.90]
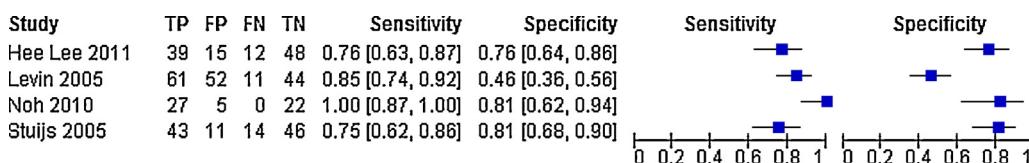
Fig. 3. Forest plot depicting the sensitivity and specificity of ultrasound for detection of lateral epicondylitis.

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.

References

[1] Connell D, Burke F, Coombes P, McNealy S, Freeman D, Pryde D, et al. Sonographic examination of lateral epicondylitis. AJR Am J Roentgenol 2001;176:777–82.
[2] Miller T, Shapiro M, Schultz E, Kalish PE. Comparison of sonography and MRI for diagnosing epicondylitis. J Clin Ultrasound 2002;30: 193–202.
[3] Levin D, Nazarian L, Miller T, O'Kane PL, Feld RI, Parker L, et al. Lateral epicondylitis of the elbow: US findings. Radiology 2005;237:230–4.
[4] Shiri R, Viikari-Juntura E, Varonen H, Heliövaara M. Prevalence and determinants of lateral and medial epicondylitis: A population study. Am J Epidemiol 2006;164:1065–74.
[5] De Smedt T, de Jong A, van Leemput W, Lieven D, van Glabbeek F. Lateral epicondylitis in tennis: update on aetiology, biomechanics and treatment. Br J Sport Med 2007;41:816–9.
[6] Jaén-Diaz JI, Cerezo-Lopez E, Lopez-de Castro F. Sonographic findings for the common extensor tendon of the elbow in the general population. J Ultrasound Med 2010;29:1717–24.
[7] Solheim E, Hegna J, Oyen J. Extensor tendon release in tennis elbow: results and prognostic factors in 80 elbows. Knee Surg Sport Traumatol, Arthrosc 2011;19:1023–7.
[8] Vincenzo B, Wright A. Lateral epicondylalgia I: epidemiology, pathophysiology, aetiology and natural history. Physic Ther Review 2009;1:23–34.
[9] Wolfe SW. Green's Operative Hand Surgery. 6th ed. Oxford, UK: Churchill Livingstone, Elsevier; 2010.
[10] De Zordo T, Lill SR, Fink C. Real-time sonoelastography of lateral epicondylitis: comparison of findings between patients and healthy volunteers. AJR Am J Roentgenol 2009;193:180–5.
[11] National Institute for Health Clinical Excellence. Managing long-term sickness absence and work incapacity for work–Published Clinical Guidelines [Online]; 2009. Available from: http://www.nice.org.uk/PH19 [Accessed 30th August 2012].
[12] Hee Lee M, Cha JG, Jin W. Utility of sonographic measurement of the common tendon in patients with lateral epicondylitis. AJR Am J Roentgenol 2011;196:1363–7.
[13] Poltawski L, Jayaram V, Watson T. Measurement issues in the sonographic assessment of tennis elbow. J Clin Ultrasound 2010;38:196–204.
[14] du Toit C, Stieler M, Bisset L, Vincenzino B. Diagnostic accuracy of power Doppler ultrasound in patients with chronic tennis elbow. Br J Sport Med 2008;42:872–6.
[15] Gibbon WW, Cooper JR, Radcliffe GS. Distribution of sonographically detected tendon abnormalities in patients with a clinical diagnosis of chronic Achilles tendinosis. J Clin Ultrasound 1998;28:61–6.
[16] Smith TO, Back T, Toms AP, Hing CB. Diagnostic accuracy of ultrasound for rotator cuff tears in adults: A systematic review and meta-analysis. Clin Radiol 2011;66:1036–48.
[17] Hashefi M. Ultrasound in the diagnosis of noninflammatory musculoskeletal conditions. Semin Ultrasound, CT, MRI 2011;32:74–90.
[18] Callaghan MJ. A physiotherapy perspective of musculoskeletal imaging in sport. Br J Radiol 2012;85:1194–7.
[19] Grassi W, Filippucci E, Busilacchi P. Musculoskeletal ultrasound. Best Pract Res Clin Rheumatol 2004;18:813–26.
[20] Lew HL, Chen CPC, Wang T-G, Chew K. Introduction to musculoskeletal diagnostic ultrasound: examination of the upper limb. Am J Phys Med Rehabil 2007;86:310–21.
[21] Moher D, Liberati A, Tetzlaff J, Altman D. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA Statement. PLOS Med 2009;6:e1000097.
[22] Hoskins P, Martin K, Thrush A. Diagnostic Ultrasound: Physics and Equipment. Cambridge, UK: Cambridge University Press; 2010.
[23] Whiting P, Ruties AW, Reitsma JB, Bossuyt P, Kleijen J. The development of QUADAS: a tool for the quality assessment of studies if diagnostic accuracy included in systematic reviews. BMC Med Res Methodol 2003;3:25.
[24] Leeflang MMG, Deeks JJ, Gatsonis C, Bossuyt P. Systematic reviews of diagnostic test accuracy. Ann Intern Med 2008;149:889–97.
[25] Deeks JJ, Higgins JPT, Altman DG. Analysing data and undertaking meta-analysis. In: Higgins J, Green S, editors. Cochrane Handbook for Systematic Reviews of Interventions: Cochrane Book Series. Chichester, UK: Wiley-Blackwell; 2011.
[26] Maffulli N, Regine R, Carrillo F, Capasso G, Minelli S. Tennis elbow: an ultrasonographic study in tennis players. Br J Sport Med 1990;24:151–5.
[27] Noh KH, Lae Moon Y, Jacir AM, Kim KH, Gorthi V. Sonographic probe induced tenderness for lateral epicondylitis: an accurate technique to confirm the location of the lesion. Knee Surg Sport Traumatol, Arthrosc 2010;18:836–9.
[28] Struijs PAA, Spruyt M, Assendelft WJJ, van Dijk CN. The predictive value of diagnostic sonography for the effectiveness of conservative treatment of tennis elbow. AJR Am J Roentgenol 2005;185:1113–8.
[29] Kayser R, Mahlfeld K, Heyde CE. Partial rupture of the proximal Achilles tendon: a differential diagnostic problem in ultrasound imaging. Br J Sport Med 2005;39:838–42.
[30] Klauser AS, Peetrons P. Developments in musculoskeletal ultrasound and clinical applications. Skeletal Radiol 2010;39:1061–71.
[31] Lenton PH, Primack S. Advances and utility of diagnostic ultrasound in musculoskeletal medicine. Curr Rev Musculoskel Med 2008;1:24–31.
[32] Delle SA, Riente L, Bombardieri S. Limits and perspectives of ultrasound in the diagnosis and management of rheumatic diseases. Mod Rheumatol 2008;18:125–31.
[33] Le Corroller T, Cohen M, Aswad R, Pauly V, Champsaur P. Sonography of the painful shoulder: role of the operator's experience. Skeletal Radiol 2008;37:979–86.
[34] McKiernan S, Chiarello P, Warren-Forward H. Diagnostic ultrasound use in physiotherapy, emergency medicine, and anaesthesiology. Radiography 2010;16:154–9.
[35] Sandmeier R, Renström P. Diagnosis and treatment of chronic tendon disorders in sports. Scandin J Med Sci Sport 1997;7:96–106.
[36] Allen GM, Drakonaki EE, Tan ML, Dhillon M, Rajaratnam V. High-resolution ultrasound in the diagnosis of upper limb disorders: a tertiary referral centre experience. Ann Plastic Surg 2008;61:259–64.
[37] Rasmussen OS. Sonography of tendons. Scandin J Med Sci Sport 2000;10:360–4.
[38] Oakley SP, Portek I, Szomor Z, Appleyard RC, Ghosh P, Kirkham BW, et al. Arthroscopy – a potential "gold Standard" for the diagnosis of chondropathy of early osteoarthritis. Osteoarthritis Cartilage 2005;13:368–78.
[39] Crawford R, Walley G, Bridgman S, Maffulli N. Magnetic resonance imaging versus arthroscopy in the diagnosis of knee pathology, concentrating on meniscal lesions and ACL tears: a systematic review. Br Med Bull 2007;84:5–23.
[40] Boyer MI, Hastings H. Lateral tennis elbow: "is there any science out there?". J Shoulder Elbow Surg 1999;8:481–91.

Further reading

Ferrell WR, Balint PV, Sturrock RD. Novel use of laser Doppler imaging for investigating epicondylitis. Rheumatology 2000;39:1214–17.

Clarke AW, Ahmad M, Curtis M, Connell D. Lateral elbow tendinopathy: correlation of ultrasound findings with pain and functional disability. Am J Sport Med 2010;38:1209–14.