EDITOR'S CHOICE

# A systematic review of ultrasonography in osteoarthritis

H I Keen,[1] R J Wakefield,[2] P G Conaghan[2]

► Additional supplementary fig 1 is published online only at http://ard.bmj.com/content/vol68/issue5

[1] School of Medicine and Pharmacology, University of Western Australia, Perth, Australia; [2] Section of Musculoskeletal Disease, Leeds Institute of Molecular Medicine, University of Leeds, Leeds, UK

Correspondence to: Dr H I Keen, School of Medicine and Pharmacology, Royal Perth Hospital, Level 3, MRF Building, Rear 50 Murray Street, Perth, WA 6000, Western Australia; helen.keen@uwa.edu.au

Accepted 23 January 2009

## ABSTRACT

**Background:** Ultrasonography has been increasingly utilised to aid the understanding and management of rheumatic conditions. In recent years there has been a focus on the validity and utility of ultrasonography in demonstrating joint pathology, although this has largely focused on inflammatory arthritis.

**Aims:** To undertake a systematic review of the published literature evaluating ultrasonography as an assessment tool in osteoarthritis.

**Methods:** Medline and Pubmed were searched to identify original manuscripts, published before June 2008, utilising ultrasonography to assess the joints of cohorts of subjects with osteoarthritis. Data were extracted from manuscripts meeting the inclusion criteria, with a particular focus on the pathology imaged, the definitions used, scoring systems and their metric properties.

**Results:** Forty-seven studies were identified that utilised ultrasonography to assess structural pathology in osteoarthritis. Doppler function was only assessed in 10 studies and contrast agents in one. There was heterogeneity with regard to the pathology examined, the definition of pathology, quantification and the reporting of these factors. There was also a lack of construct and criterion validity and data demonstrating reliability and sensitivity to change.

**Conclusions:** Whereas there is increasing evidence of the validity of ultrasonography in detecting structural pathology in inflammatory arthritis, more work is required to develop standardised definitions of pathology and to demonstrate the validity of ultrasonography in osteoarthritis.

Osteoarthritis has traditionally been imaged with conventional radiographs. However, in recent years, novel imaging techniques such as ultrasonography have been utilised to obtain a better understand of this disease. Although the application of ultrasonography to inflammatory diseases has been common and widespread, it has been applied to osteoarthritis less frequently.

Two recent systematic reviews by Joshua and colleagues[1 2] examined the validity of ultrasonography as an outcome measure according to the principles of truth and discrimination; components of the OMERACT filter. The first addressed the validity and reproducibility of ultrasonography in assessing synovitis only;[2] the second, power Doppler in musculoskeletal disease.[1] These reviews demonstrated that most of the work validating ultrasonography has been undertaken in inflammatory diseases, such as rheumatoid arthritis, and has largely studied the hand, knee or ankle joints. A minority of work examined in these systematic reviews pertained to either synovitis or power Doppler signal in osteoarthritis. In the first review, 10 of the 54 manuscripts reviewed utilised ultrasonography to assess synovitis in osteoarthritis.[2] Six of the 53 manuscripts reviewed in the second review article utilised Doppler signal in osteoarthritis.[1]

There are no published systematic reviews focusing on the application of ultrasonography to osteoarthritis. We wanted to examine the published literature to assess the role of ultrasonography in assessing structural pathology in osteoarthritis, and to examine the validity of ultrasonography as an assessment tool in osteoarthritis, with particular respect to the performance metrics of these tools. To do this, a systematic review was undertaken. The function of this review is to update the literature reviews by Joshua and colleagues,[1 2] with a focus on osteoarthritis, and to broaden the search to include ultrasonography-detectable pathologies other than synovitis and Doppler signal, including tendon and ligament disorders, cartilage pathology and cortical pathology including osteophytosis. In addition, definitions of pathologies and scoring systems utilised in osteoarthritis were examined.

## METHODS

Pubmed was searched for articles first published between 1955 and June 2008. The search was limited to humans and English language. The search terms were "[ultrasound or sonography] and osteoarthritis". The titles and abstracts of the 244 manuscripts identified were reviewed. Medline was searched using [MESH subject heading "ultrasonography" or the keyword "ultrasonography"] and [MESH headings "osteoarthritis" or "osteoarthritis, knee" or "osteoarthritis, hip" or the keyword "osteoarthritis"]. The search was limited to humans and English language. A total of 148 articles was identified. Of the articles identified, 147 were duplicates, therefore the titles and abstracts of 245 articles were assessed with regard to inclusion and exclusion criteria. Articles were excluded if they were not original articles pertaining to the use of B-mode ultrasonography in the assessment of a joint in a cohort of subjects with a diagnosis of osteoarthritis at baseline. Review articles (n = 48), case reports (n = 15), letters (n = 1), position statements (n = 1), recommendations (n = 2), practice audits (n = 1), pictorial reviews (n = 1), studies ex vivo (n = 7) and second reports (n = 2) were excluded. In addition, articles that utilised ultrasonography only for guiding injections and did not report any validity data or findings of the ultrasonography examination were excluded (n = 6). Manuscripts utilising

Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

ultrasonography to measure only rotational angles were also excluded (n = 3). Of the remaining articles, 58 did not assess a cohort with a diagnosis of osteoarthritis at baseline, 46 did not utilise B-mode ultrasonography and 16 did not examine a joint structure. An additional nine publications were identified by experts in the field and searching the bibliographies of recent review articles. Therefore 47 manuscripts were included in this review (see supplemental fig 1 available online only and table 1). Data were extracted and inserted into a spreadsheet developed for this review based on similar published reviews.[1 2]

This covered descriptive aspects of trial methodology, a description of the ultrasonography-detected findings in osteoarthritis cohorts, issues relating to the validity of ultrasonography in assessing osteoarthritis, the relationship between ultrasonography findings and symptoms of osteoarthritis and the clinical utility of ultrasonography in osteoarthritis.

**Table 1** Description of the studies identified utilising ultrasonography to assess joints in a cohort with osteoarthritis

| First author (reference no) | Year | No with osteoarthritis | Definition of osteoarthritis cohort described | Comparator group examined | Joint region imaged | Doppler |
|---|---|---|---|---|---|---|
| Fam[3] | 1982 | 50 | U | Y | Knee | N |
| Aisen[4] | 1984 | 7 | N | Y | Knee | N |
| Baratelli[5] | 1986 | 16 | N | Y | Hip | N |
| McCune[6] | 1990 | 9 | N | Y | Knee | N |
| Iagnooco[7] | 1992 | 60 | U | Y | Knee | N |
| Jonsson[8] | 1992 | 6 | N | Y | Knee, hip | N |
| Martino[9] | 1993 | 18 | N | Y | Knee | N |
| Lennox[10] | 1994 | 25 | N | Y | Knee | N |
| Ostergaard[11] | 1995 | 2 | N | Y | Knee | N |
| Arslan[12] | 1999 | 10 | N | Y | SI joint | P |
| Monteforte[13] | 1999 | 126 | Y | Y | Knee | N |
| Baratto[14] | 2000 | 10 | N | N | C spine | N |
| Iagnocco[15] | 2000 | 57 | Y | Y | Hand | N |
| Schmidt[16] | 2000 | 10 | Y | Y | Knee | C |
| Giovagnorio[17] | 2001 | 2 | Y | Y | Knee | P |
| Qvistgaard[18] | 2001 | 41 | Y | N | Knee, hip | N |
| Reardon[19] | 2001 | 12 | N | Y | Hip | N |
| Walther[20] | 2001 | 13 | N | Y | Knee | P |
| Falsetti[21] | 2002 | 100 | N | Y | Shoulder | N |
| Walther[22] | 2002 | 24 | U | Y | Hip | P |
| Falsetti[23] | 2003 | 265 | U | Y | Foot | N |
| Filippucci[24] | 2003 | 2 | N | Y | Hand, knee, foot | N |
| Monteforte[25] | 2003 | 14 | N | N | C spine | N |
| Tarhan[26] | 2003 | 58 | Y | Y | Knee | N |
| Karim[27] | 2004 | 19 | N | Y | Knee | N |
| D'Agostino[28] | 2005 | 600 | Y | N | Knee | N |
| Iagnocco[29] | 2005 | 110 | U | N | Hand | N |
| Naredo[30] | 2005 | 90 | Y | Y | Knee | N |
| Pourbagher[31] | 2005 | 10 | N | N | Hip | N |
| Yoon[32] | 2005 | 26 | N | N | Knee | P |
| Acebes[33] | 2006 | 30 | N | N | Knee | N |
| de Miguel Mendieta[34] | 2006 | 101 | Y | N | Knee | N |
| Jan[35] | 2006 | 36 | Y | N | Knee | N |
| Jung[36] | 2006 | 51 | Y | N | Knee | N |
| Kristoffersen[37] | 2006 | 71 | Y | Y | Knee | C |
| Mandl[38] | 2006 | 32 | Y | Y | Hand | N |
| Qvistgaard[39] | 2006 | 100 | Y | N | Hip | N |
| Su[40] | 2006 | 18 | N | N | Hip | N |
| Tarasevicius[41] | 2006 | 33 | N | N | Hip | N |
| Altinel[42] | 2007 | 61 | U | N | Knee | N |
| Atchia[43] | 2007 | 10 | N | N | Hip | N |
| Lee[44] | 2007 | 42 | N | Y | Knee | N |
| Robinson[45] | 2007 | 120 | U | N | Hip | B |
| Keen[46] | 2008 | 37 | Y | N | Hand | N |
| Keen[47] | 2008 | 7 | N | N | Hand | P |
| Kim[48] | 2008 | 30 | Y | N | Knee | N |
| Song[49] | 2008 | 41 | Y | Y | Knee | P |

Including study details, the joint region scanned and whether information regarding the image acquisition, definition of pathology and scoring system were described. B, both colour and power Doppler; C, colour Doppler; C spine, cervical spine; E, described elsewhere; N, no; P, power Doppler; SI, sacroiliac; U, unclear; Y, yes.

Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

The performance metrics were evaluated using criterion and construct validity, reliability and responsiveness to change. Criterion (or direct) validity is determined by comparing the technique with a gold standard.[50] For the purpose of this review, this was considered a comparison against either direct macroscopic or microscopic visualisation of the pathology, for example by arthroscopy, examination during surgery, or histopathological examination. Construct (or indirect) validity is determined by comparing the technique against other modalities known to measure the same pathology; for example, comparing ultrasonography-detected synovitis against magnetic resonance imaging (MRI) or computed tomography (CT)-detected synovitis.[50] Comparison against MRI, scintigraphy, conventional radiography, clinical examination, laboratory tests and bone mineral density were all considered measures of construct validity.

Reproducibility is intrinsic to both the validity of a technique as an outcome in clinical trials and also to its ability to demonstrate changes over time. Reproducibility is generally determined through examining inter and intra-observer reliability. For this review, both were subanalysed according to whether the assessments were made through repeated image acquisition or re-reading stored images. In addition, responsiveness to changes with time were also recorded, as these examine discrimination and also further address construct validity.[50] A brief summary of the findings of each manuscript was included.

## RESULTS

### Characteristics of the studies

Forty-seven articles published between 1982 and 2008 were included in the review. The findings are summarised in table 1. The majority of studies were published after 2000. The knee has been examined more extensively than other joints, followed by the hip, hand, foot, tempromandibular joint and sternoclavicular joint. The definition of osteoarthritis was not consistent and was not specified in approximately half the papers. American College of Rheumatology criteria were often used to identify clinical disease. Radiographic criteria were also commonly used, using different Kellgren Lawrence or Altman grades to define the cohort. Other studies used diagnostic criteria specific to their study, such as a combination of clinical symptoms, signs, the American College of Rheumatology criteria and radiographic criteria. Some manuscripts used terms such as ''clinical diagnosis'' or ''typical changes'' without further clarification. It was also common for no definition to be provided.

### Technical aspects of ultrasonography machines and image acquisition reported in the studies

The vast majority of studies employed grey-scale ultrasonography, and most (42, 89%) reported the transducer characteristics. Doppler, either power (six, 13%) or colour (three, 6%) were used in 10 studies, and contrast was examined in only one study. The Doppler specifications were reported in five, were unclear in one and were not reported in one manuscript.

The majority (40, 85%) of manuscripts provided some description of the probe and joint position during image acquisition; however, there was variability between studies imaging the same joint region as to how the images were acquired.

### Pathologies imaged and scoring systems

The pathologies examined most commonly were effusion, followed by synovial thickening or hypertrophy, cartilage parameters, vascularity, Baker's cysts, osteophytes, tendon and ligament abnormalities, meniscal changes, bursitis, erosions and panniculitis. Definitions of the imaging appearance of the pathology imaged were provided in approximately half of the

**Table 2** Validity of ultrasonography-detected cartilage pathology described in the manuscripts, including definitions, scoring systems, comparator and results

| First author (reference no) | Pathology imaged | Definition in manuscript | Scoring system | Comparator | Results |
|---|---|---|---|---|---|
| de Miguel Mendieta[34] | Meniscal lesion | Y | Present or absent | Symptoms | N/A |
| Naredo[30] | Meniscal extrusion | Y | Present or absent | Clinical examination<br>CR<br>Symptoms | Meniscal displacement associated with higher pain scores, medial joint pain and worse radiographic grade |
| Giovagnorio[17] | Typical signs of arthritis (including cartilage thinning) | Y | Present or absent | Clinical examination<br>Laboratory | Ultrasonography findings did not correlate with laboratory or clinical findings |
| Keen[46] | Joint space narrowing | Y | Present or absent | Radiography | Ultrasonography detected more joint space narrowing than radiography |
| Kim[48] | Cartilage | N | NS | Scintigraphy | No correlation |
| Iagnocco[7] | Cartilage thickness | Y | Measured in mm | N/A | N/A |
| Jonsson[8] | Cartilage thickness | Y | Measured in mm | MRI<br>Radiography | No comparison made due to technical difficulties |
| Jung[36] | Cartilage thickness | N | Measured in mm | Laboratory biomarkers | N/A |
| Martino[9] | Cartilage thickness | N | Measured in mm | Pathology | Good correlation between ultrasonography measurements and histology |
| McCune[6] | Cartilage thickness<br>Cartilage clarity<br>Cartilage sharpness | N<br>N<br>N | Measured in mm<br>7-Point scale<br>7-Point scale | Pathology | Good correlation between ultrasonography measurements and histology |
| Monteforte[13] | Cartilage thickness | N | NS | N/A | N/A |
| Ostergaard[11] | Cartilage thickness | N | Measured in mm | MRI | Moderate correlation between ultrasonography and MRI |
| Tarhan[26] | Cartilage sharpness | N | 7-Point scale | MRI | Reasonable correlation between ultrasonography and MRI detected cartilage sharpness and clarity |

CR, conventional radiography; DE, described elsewhere; MRI, magnetic resonance imaging; N, No; N/A, not applicable; NS, not stated; Y, Yes.



Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

**Table 3** Validity of ultrasonography-detected tendon and ligament pathology described in the literature, including definitions, scoring systems, comparator and results

| First author (reference no) | Pathology imaged | Definition in manuscript | Scoring system used | Comparator | Results |
|---|---|---|---|---|---|
| Altinel[42] | Patella tendon | NS | 4-Point scale | N/A | N/A |
| Falsetti[23] | Enthesitis | Y | 4-Point scale | CR | Good agreement between ultrasonography and CR for enthesophytes and erosions |
| | Plantar fasciitis | Y | 4-Point scale | | |
| Falsetti[21] | Enthesitis | Y | Present/absent | Clinical examination | Ultrasonography detected more disease than clinical examination or CR |
| | Enthesophytes | N | Present/absent | CR | |
| | Tenosynovitis/tendinosis | N | Present/absent | | |
| Kim[48] | Patella tendon | N | NS | Scintigraphy | No correlation |
| | Medial and lateral collateral ligaments | N | NS | | |
| Lennox[10] | Diameter of quadriceps muscle | N | Measured in mm | N/A | N/A |
| Monteforte[13] | Thickness of patella and quadriceps tendons | N | Measured in mm | N/A | N/A |
| Naredo[30] | Tendon and ligament lesions | DE | NS | Clinical examination | No abnormalities found |
| | | | | CR | |
| | | | | Symptoms | |
| Reardon[19] | Quadriceps muscle thickness | N | NS | N/A | N/A |
| Su[40] | Posterior structure tears | N | Graded as fully continuous, partly continuous or fully discontinuous | N/A | N/A |
| Yoon[32] | Anserine tenobursitis | Thickness of PA | Measured in mm | Clinical examination | Ultrasonography detected pathology in only two of 26 with the clinical syndrome |
| | | Bursitis >2 mm | Present or absent | | |
| | | Thickening of tendon | Measured in mm | CR | |
| | | Loss of normal fibrillations | Present or absent | | |

CR, conventional radiography; DE, described elsewhere; N, No; N/A, not applicable; NS, not stated; PA, pes anserinus; Y, Yes.

studies, and again, no standard definition of pathology was used across the studies (tables 2, 3, 4 and 5). The ultrasonography appearance of cartilage, when defined, was generally considered a sonolucent or anechoic band overlying cortex. Cartilage thinning was the most common pathology examined, although clarity and sharpness was also measured, although definitions of these abnormalities were not given.[6 26] Tendon and ligament pathologies were also rarely defined. Enthesitis was examined by one group,[21 23] with definitions encompassing features of heterogeneous hypoechogeneicity, tendon thickening, cortical irregularities (erosions and enthesophytes) and oedema, although the Doppler signal was not examined in these studies. Cortical irregularities have similarly rarely been defined. Erosions have been defined in one study,[29] and osteophytes in two studies.[46 47] Synovial pathologies, including synovial hypertrophy, effusion and Doppler signal, were most often studied and usually defined. As a definition of synovial hypertrophy and effusion has been published by the OMERACT ultrasonography group,[51] which can be used in future studies, the definitions used in previous published manuscripts are perhaps less interesting than other aspects of the imaging. For example, in reviewing the articles it became clear that there was no

**Table 4** Validity of ultrasonography-detected cortical pathology described in the literature including definitions, scoring systems, comparator and results

| First author (reference no) | Pathology imaged | Definition in manuscript | Scoring system used | Comparator | Results |
|---|---|---|---|---|---|
| Falsetti[21] | Acromial irregularity | N | Present/absent | CR | Of the nine with ultrasonography-detected pathology, eight had CR pathology |
| Kim[48] | Bony spurs | N | NS | Scintigraphy | Correlation between ultrasonography-detected osteophyte length and scintographic uptake |
| Keen[46] | Osteophytes | Y | Counted | CR | Ultrasonography detected more osteophytosis than radiography |
| Keen[47] | Osteophytes | Y | 4-Point scale | N/A | N/A |
| Qvistgaard[39] | Osteophytes | N | 4-Point scale | Radiography | Weak correlation between ultrasonography findings and Kellgren CR score |
| Robinson[45] | Osteophytes | N | 4-Point scale | Clinical symptoms | Ultrasonography findings did not correlate with symptoms |
| | | | | Clinical response | |
| Jung[36] | Osteophyte length | Y | Measured in mm | Laboratory biomarkers | Osteophyte length correlates with biochemical markers |
| Iagnocco[7] | Erosions | Y | Present or absent | CR | Ultrasonography detected erosions in 16/101 subjects |
| | | | | | CR detected erosions in 22/101 subjects |
| Ostergaard[11] | Erosions | N | Counted | MRI | Ultrasonography detected 38% of MRI erosions |

CR, conventional radiography; DE, described elsewhere; MRI, magnetic resonance imaging; N, No; N/A, not applicable; NS, not stated; Y, Yes.



Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

standardisation with regard to the positioning of the joint, planes in which images were obtained and the scoring of synovial pathologies. Eleven of the studies examining synovitis clearly differentiated between synovial hypertrophy and effusion, whereas in 12 studies they were either considered together or it was unclear. In addition, some studies required an arbitrary minimal thickness of synovial hypertrophy and effusion[28 30 44] before considering the pathology to be present. The scoring systems used were usually reported, but again demonstrated great variety, being either dichotomous, ordinal or continuous (tables 2, 3, 4 and 5).

### Validity of ultrasonography

Most studies addressed the construct validity of ultrasonography (n = 27), with little examination of criterion validity (n = 9). Two studies found reasonable correlation between ultrasonography-detected cartilage thickness and histological cartilage thickness[6 9] and one study demonstrated reasonable correlation between ultrasonography-detected cartilage thickness and MRI.[11] A paucity of information is available about the construct validity of ultrasonography-detected qualitative cartilage changes (table 2), and quantitative changes were limited to measurements of thickness, as unlike MRI, it is difficult to utilise ultrasonography to detected total volumes. Tendon and ligament changes were usually compared against clinical examination, with varying results. For example, little correlation was found between ultrasonography and clinical diagnoses of anserine tenobursitis,[32] whereas there was good correlation between ultrasonography and clinical and radiographic changes of enthesitis at the shoulder and foot.[21 23]

The validity of ultrasonography in detecting cortical irregularities was infrequently studied (table 4), with ultrasonography being found to be more sensitive to osteophytosis than radiography in the small joints of the hand,[46] but less sensitive to erosions.[29] This was thought partly to be because osteophytes overhanging erosions may shadow underlying erosions preventing visualisation by ultrasonography. It may also be related to the positioning of the erosions. Whereas rheumatoid erosions tend to be peri-articular, osteoarthritis erosions, as seen radiographically, may be within the central portion of the joint and inaccessible with ultrasound.

Ultrasound performs comparably to MRI in detecting effusion, synovial hypertrophy and popliteal cysts (tables 2, 3, 4 and 5). The validity of ultrasonography-detected cartilage changes has only been assessed in comparison with MRI or histology at the knee joint (table 2). Ultrasonography was more sensitive and specific than clinical examination in detecting effusion and synovial hypertrophy, although this has been examined exclusively at the knee joint (table 5). The knee joint has also been the focus of comparison between ultrasonography-detected synovial pathology and MRI and arthroscopy.[11 27] The ability of ultrasonography to detect synovitis changes has been examined at the hip,[22] and fluid aspiration has been compared with ultrasonography-detected effusions in the hip and hand.[15 39]

No consistent relationship between clinical symptoms and ultrasonography-detected pathology is found in this review, although symptomatic joints tend to have more ultrasonography-detected pathology than controls/healthy joints.

### Reproducibility of ultrasonography

A minority of studies reported any reproducibility data, although when reported it was reasonably good. Intra-reader acquisition was reported in three studies, intra-reader reporting was reported in four, inter-reader acquisition was reported in three and inter-reader reporting was reported in two.

### Discriminate validity of ultrasonography

Only eight studies examined the ability of ultrasonography to detected changes over time. Those studies, the joints, interventions and pathologies studied are presented in table 6.

The general trends were a reduction in pathology with time after therapy, although only one of the studies was a randomised controlled trial, the others being observational case series.

## DISCUSSION

This review demonstrates that since the start of the new millennium there has been increasing evidence of the application of ultrasonography to osteoarthritis. However, for ultrasonography to be fully useful in assessing therapies and responses, it first needs to be validated as an outcome tool. In this review, we have identified manuscripts that use ultrasonography to evaluate osteoarthritis and demonstrated that further work is required to validate ultrasonography in osteoarthritis.

Generally, the descriptions of ultrasonography technicalities, such as information about the machine and probe specifications and the position of the scan in obtaining images was adequately described. The quality of reporting of the pathologies imaged, their definitions and scoring was less well described and, when present, demonstrated marked heterogeneity between studies. There are no well accepted definitions of ultrasonography pathology in osteoarthritis, although definitions of synovial hypertrophy, effusion, tenosynovitis, enthesitis and erosion have been developed by the OMERACT ultrasonography group for use in inflammatory arthritis.[51] These definitions were applied to osteoarthritis in some publications,[46 47] but not routinely, which may reflect the fact that the recommendations were only published in late 2005. In addition, the validity of applying definitions developed for inflammatory arthritis to osteoarthritis needs consideration.

The scoring systems utilised were also not always described, and again demonstrated marked heterogeneity, generally being dichotomous, ordinal (based on qualitative, semiquantitative or quantitative domains) or continuous scales (such as simple numeric counts or measuring in millimetres). Most of the literature examined pathology in grey scale, with a paucity of publications utilising Doppler or contrast agents. The OMERACT ultrasonography group has recently been working towards recommendations for a scoring system for synovitis in inflammatory arthritis, which will soon be published. This is too new to see reflected in the published literature; however, again, whether this is applicable to osteoarthritis needs consideration.

Whereas ultrasonography appears to be more sensitive for the detection of synovitis in osteoarthritis than clinical examination, with reasonable sensitivity compared with MRI or histology, there is little evidence to confirm the validity of ultrasonography in detecting bony pathology in osteoarthritis, and the evidence regarding the detection of cartilage pathology is largely limited to the detection of focal cartilage thickness. The clinical utility of ultrasonography in detecting cartilage in vivo is questioned, as the physical properties of ultrasonography make load-bearing cartilage difficult to image reliably due to acoustic shadowing. This review has also highlighted a paucity of information on the responsiveness of ultrasonography in

Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

**Table 5** Validity of ultrasonography detected synovial pathology described in the literature including definitions, scoring systems, comparators and results

| First author (reference no) | Structure imaged | Definition of imaging appearance of pathology | Scoring system | Comparator | Results |
|---|---|---|---|---|---|
| Acebes[33] | Baker's cyst | N | Maximal area calculated in two planes using software | Clinical examination | Clinical and ultrasonography parameters decrease after therapy |
| | Synovial hypertrophy | N | Maximal area calculated in two planes using software | Symptoms | |
| Arslan[12] | Vascular flow (RI) | Y | RI | CT | All osteoarthritis subjects had sacroilitis on CT; however, only 50% had Doppler flow on ultrasonography |
| Atchia[43] | Hip joint | DE | DE | N/A | N/A |
| Baratelli[5] | Joint capsule thickness | Y | Measured in mm | N/A | N/A |
| D'Agostino[28] | Synovial hypertrophy | Y | Present or absent | Clinical examination | Synovitis found more commonly with ultrasonography than CE although there was a strong association between ultrasonography synovitis and clinical effusion |
| | Effusions | Y | Present or absent | CR | Ultrasonography synovitis associated with KL grade >2 |
| | | | | Symptoms | Ultrasonography synovitis was associated with early morning stiffness and sudden aggravation of pain in past 2 weeks |
| de Miguel Mendieta[34] | Effusion | Y | Present or absent | Symptoms | Symptomatic knees were more likely to demonstrate effusion and Baker's cyst than asymptomatic knees |
| | Bursitis | Y | Present or absent | | |
| | Baker's cyst | Y | Present or absent | | |
| Fam[3] | Popliteal cysts | Y | Present or absent | CR | Ultrasonography found cysts in 29/100 knees |
| | | | | Arthrogram | Arthrogram used to confirm two cysts |
| | | | | Symptoms | Ultrasonography popliteal cyst correlated with increasing radiographic grade cysts in 17/36 knees with KL grade >2, but only 12/64 knees with KL grade 2 |
| Giovagnorio[17] | Vascularity | Y | Present or absent | Clinical examination | GS findings not correlated with laboratory markers or CE |
| | Synovial thickening, effusion. | N | Present or absent | Laboratory biomarkers | PD signal related to ESR |
| Iagnocco[15] | Effusion | Y | Measured in mm | Aspiration of fluid | Ultrasonography is able to detect joint effusion |
| Jan[35] | Synovial sac thickness | N | Measured in mm | Symptoms | Pain correlated with ultrasonography-detected sac thickness |
| Jung[36] | Capsular distension | Y | Measured in mm | Laboratory biomarkers | Subjects with capsular distension and effusion have higher levels of COMP and HA |
| | Effusion | Y | Measured in mm | | |
| | Synovial proliferation | Y | Present or absent | | |
| Karim[27] | Synovitis | Y | 4-Point scale (based on morphology) | Clinical examination | Ultrasonography has higher sensitivity and specificity than CE compared with arthroscopy |
| | Effusion | Y | Present or absent | Direct visualisation | |
| Keen[47] | Synovitis | Y | 4-Point scale | N/A | N/A |
| | Vascularity | Y | 4-Point scale (semiquantitative) | | |
| Kim[48] | Effusion | Y | Measured in mm | Scintigraphy | Ultrasonography-detected effusion correlated with uptake in medial femoral and tibial condyles |
| | Synovitis | Y | U | | |
| Kristoffersen[37] | Synovial hypertrophy | Y | NS | Clinical examination | N/A |
| | Fluid | Y | NS | Symptoms | |
| | Hyperaemia | Y | RI | | |
| Lee[44] | Synovial proliferation | Y | Present or absent | Biochemical markers | Synovial proliferation not associated with biochemical markers |
| Naredo[30] | Bursitis | Y | NS | Clinical examination | Ultrasonography effusion was associated with higher VAS pain at rest and on motion |
| | Effusion | Y | NS | CR | |
| | Popliteal cyst | Y | NS | Symptoms | |
| Ostergaard[11] | Effusion | Y | Measured in mm | MRI | Ultrasonography detected 100% of effusions, 100% Baker's cysts, 57% synovial thickening |
| | Synovial thickness | Y | Measured in mm | Clinical examination | Ultrasonography and MRI showed moderate correlation with synovial membrane thickness and effusion |
| Qvistgaard[39] | Synovial profile | Y | 3-Point scale (semiquantitative) | Fluid aspiration | No correlation between fluid aspiration and fluid on ultrasonography |
| | Effusion | Y | 3-Point scale (semiquantitative) | | |
| | Global synovitis | N | 3-Point scale (semiquantitative) | | |

Continued

Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

**Table 5** Continued

| First author (reference no) | Structure imaged | Definition of imaging appearance of pathology | Scoring system | Comparator | Results |
|---|---|---|---|---|---|
| Robinson[45] | Effusion | Y | Present or absent | Clinical symptoms | Ultrasonography did not predict clinical response |
| | Capsular thickness | Y | Measured in mm | Clinical response | Ultrasonography findings did not correlate with symptoms |
| | Vascularity | N | Present or absent | | |
| Schmidt[16] | Synovial thickness | N | 3-Point scale based on measurement in mm | Clinical examination | No agreement between CE and ultrasonography in detecting synovitis |
| | | | | Direct visualisation | Agreement between GS ultrasonography and arthroscopy as to presence of villi was 80–85% |
| | | | | Histology | All knees with histological pannus had Doppler signal within hypoehcoic synoial hypertrophy |
| Song[49] | Effusion | Y | 4-Point scale based on measurement in mm | Clinical examination | Effusion found by ultrasonography in 78%, by MRI 81% |
| | Synovial hypertrophy | Y | 4-Point scale based on measurement in mm | MRI | No correlation between lateral recess effusion and MRI |
| | Vascularity | N | 4-Point scale semiquantitative | | Poor correlation between contrast enhancement and MRI |
| Tarasevicius[41] | Capsular distension | Y | Measured in mm | N/A | N/A |
| Tarhan[26] | Synovial hypertrophy | Y | 4-Point scale based on measurement in mm | MRI | Synovial thickening (ultrasonography 34%, MRI 50%) |
| | | | | | Popliteal cysts (ultrasonography 40%, MRI 35%) |
| | Effusion | Y | 4-Point scale based on measurement in mm | Clinical examination | Increased changes with increasing radiographic grade |
| Walther[22] | Synovial thickness | N | 4-Point scale, based on measurement in mm | Histology | PD valid in detecting vascularity of synovium |
| | Effusion thickness | Y | 4-Point scale, based on measurement in mm | | |
| | Vascularity | Y | 4-Point scale and software | | |
| Walther[20] | Synovial thickness and effusion | N | 4-Point scale, semiquantitative | Histology | Good correlation between PD signal and histological vascularity scores |

CE, clinical examination; COMP, cartilage oligomeric matrix protein; CR, conventional radiography; CT, computed tomography; DE, described elsewhere; ESR, erythrocyte sedimentation rate; GS, grey scale; HA, hyaluronic acid; KL, Kellgren Lawrence; MRI, magnetic resonance imaging; N, No; N/A, not applicable; NS, not stated; PD, power Doppler; RI, resistive index; U, unclear; VAS, visual analogue scale; Y, Yes.

osteoarthritis and a lack of information about the feasibility of this imaging technique. Furthermore, there is a paucity of reliability data presented in the literature with regard to inter-reader and intra-reader reliability in image acquisition and the scoring of stored images.

This review has limitations. First, only two databases were searched, meaning that some manuscripts may have been missed. However, the two databases searched are arguably the most utilised in medical literature searches and the extensive duplication of manuscripts found was reassuring. Second, we limited the search to studies utilising ultrasonography in osteoarthritis, excluding studies that imaged joint pathologies in other joint diseases only. If the validity of ultrasonography in detecting synovial, cortical, cartilage and tendon changes in other joint diseases (ie, rheumatoid arthritis) can automatically be applied to osteoarthritis, then the scope of this review is

**Table 6** Studies demonstrating changes in ultrasonography-detected pathology in response to intervention

| First author (reference no) | Joint | Intervention | Findings |
|---|---|---|---|
| Acebes[33] | Knee | Intra-articular steroids | Popilteal cyst size and wall thickness decreased after therapy |
| Baratto[14] | C spine | Low power modulated laser stimuli | Reduction in soft tissue thickness with therapy |
| Iagnocco[15] | Hand | Intra-articular saline | Ultrasonography can demonstrate capsular distension post-intra-articular saline |
| Jan[35] | Knee | Repetitive short-wave diathermy | Decrease in suprapatella sac thickness in the treatment group, but not in control group |
| | | | Decrease in pain index after therapy correlated with decrease in synovial sac thickness |
| Monteforte[25] | C spine | Laser therapy | Subcutaneous tissue thickness reduced after laser therapy |
| Reardon[19] | Knee | Observation post-surgery | No significant increase in quadriceps thickness<br>Symptomatic side remained significantly thinner than other side |
| Su[40] | Hip | Observation post-total hip replacement | Posterior structure integrity improved with time |
| Tarasevicius[41] | Hip | Observation post-total hip replacement | Capsular distension at 6 months improves at 12 months |

C spine, cervical spine.

Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

limited. However, it may not be correct to assume that validity and reproducibility in one disease implies validity and reproducibility in another. These metrics are likely to be influenced by disease-specific factors, such as the degree of pathology, distribution of pathology, subtle differences in pathologies and response to therapy. For example, a manuscript examined in this review found ultrasonography less sensitive than radiography to cortical erosions in osteoarthritis of the small joints of the hand,[29] whereas it is well accepted that ultrasonography is more sensitive to erosions in the small joints of the hand in rheumatoid arthritis.[52] This is thought to be a result of osteophytes (a pathognomonic feature of osteoarthritis but not rheumatoid arthritis) obscuring ultrasonography visualisation of erosions in osteoarthritis.

A further issue to consider regarding this review is that its evaluation of the role of ultrasonography in osteoarthritis is limited by being systematic (with strict inclusion and exclusion criteria) and focusing on published evidence but excluding, for example, pictorial reviews that may provide insight into the way the ultrasonography appearance of pathology in osteoarthritis has been defined by some experts. The reason for excluding such reports was that although the definitions they included may have good face validity, the further validity or reliability of these definitions cannot be assessed from the published literature. Investigation of valuable information contained in such publications will be warranted in devising consensus definitions.

Another limitation (albeit a reflection of the published literature, rather than a methodological problem in this review) is that most of the studies included were undertaken with ultrasonography machines with now outdated technology. Modern imaging technology may have better sensitivity, specificity and further aid our understanding of osteoarthritis; it has recently been hypothesised that the pathology of the finger collateral ligaments may play a causal role in osteoarthritis,[53] but these ligaments may have been difficult to identify with early high-resolution ultrasonography technology. This review may need updating in the near future, given that the OMERACT[51] definitions were published relatively recently, machine technology is improving rapidly, and international organisations such as OMERACT and OARSI are developing research agendas focusing on ultrasonography in osteoarthritis.

Ultrasonography is an imaging technique that may be useful in the diagnosis and management of osteoarthritis, both in clinical trials and in practice. Application of this imaging methodology to osteoarthritis has aided the understanding of the disease process, the relationship between structure and symptoms and may aid in the assessment of future therapies. Whereas previous reviews have demonstrated reasonable validation of ultrasonography in inflammatory arthritis,[1 2] further work is required to validate ultrasonography as an outcome tool in osteoarthritis.

**Competing interests:** None.

## REFERENCES


1. **Joshua F,** Edmonds J, Lassere M. Power Doppler ultrasound in musculoskeletal disease: a systematic review. *Semin Arthritis Rheum* 2006;**36**:99–108.
2. **Joshua F,** Lassere M, Bruyn G, Szkudlarek M, Naredo E, Schmidt W, *et al*. Summary findings of a systematic review of the ultrasound assessment of synovitis. *J Rheumatol* 2007;**34**:839–47.
3. **Fam AG,** Wilson SR, Holmberg S. Ultrasound evaluation of popliteal cysts on osteoarthritis of the knee. *J Rheumatol* 1982;**9**:428–34.
4. **Aisen AM,** McCune WJ, MacGuire A, Carson PL, Silver TM, Jafri SZ, *et al*. Sonographic evaluation of the cartilage of the knee. *Radiology* 1984;**153**:781–4.
5. **Baratelli M,** Parrini L. Ultrasonography in the study of pathological conditions of the hip. *Ital J Orthopaed Traumatol* 1986;**12**:233–7.
6. **McCune WJ,** Dedrick DK, Aisen AM, MacGuire A. Sonographic evaluation of osteoarthritic femoral condylar cartilage. Correlation with operative findings. *Clin Orthop Relat Res* 1990;**254**:230–5.
7. **Iagnocco A,** Coari G, Zoppini A. Sonographic evaluation of femoral condylar cartilage in osteoarthritis and rheumatoid arthritis. *Scand J Rheumatol* 1992;**21**:201–3.
8. **Jonsson K,** Buckwalter K, Helvie M, Niklason L, Martel W. Precision of hyaline cartilage thickness measurements. *Acta Radiol* 1992;**33**:234–9.
9. **Martino F,** Ettorre GC, Angelelli G, Macarini L, Patella V, Moretti B, *et al*. Validity of echographic evaluation of cartilage in gonarthrosis. Preliminary report. *Clin Rheumatol* 1993;**12**:178–83.
10. **Lennox IA,** Cobb AG, Knowles J, Bentley G. Knee function after patellectomy. A 12- to 48-year follow-up. *J Bone Joint Surg Br* 1994;**76**:485–7.
11. **Ostergaard M,** Court-Payen M, Gideon P, Wieslander S, Cortsen M, Lorenzen I, *et al*. Ultrasonography in arthritis of the knee. A comparison with MR imaging. *Acta Radiol* 1995;**36**:19–26.
12. **Arslan H,** Sakarya ME, Adak B, Unal O, Sayarlioglu M. Duplex and color Doppler sonographic findings in active sacroiliitis. *Am J Roentgenol* 1999;**173**:677–80.
13. **Monteforte P,** Rovetta G. Sonographic assessment of soft tissue alterations in osteoarthritis of the knee. *Int J Tissue React* 1999;**21**:19–23.
14. **Baratto L,** Capra R, Farinelli M, Monteforte P, Morasso P, Rovetta G. A new type of very low-power modulated laser: soft-tissue changes induced in osteoarthritic patients revealed by sonography. *Int J Clin Pharmacol Res* 2000;**20**:13–16.
15. **Iagnocco A,** Coari G. Usefulness of high resolution US in the evaluation of effusion in osteoarthritic first carpometacarpal joint. *Scand J Rheum* 2000;**29**:170–3.
16. **Schmidt WA,** Volker L, Zacher J, Schlafke M, Ruhnke M, Gromnica-Ihle E. Colour Doppler ultrasonography to detect pannus in knee joint synovitis. *Clin Expert Rheumatol* 2000;**18**:439–44.
17. **Giovagnorio F,** Martinoli C, Coari G. Power Doppler sonography in knee arthritis—a pilot study. *Rheumatol Int* 2001;**20**:101–4.
18. **Qvistgaard E,** Kristoffersen H, Terslev L, Danneskiold-Samsoe B, Torp-Pedersen S, Bliddal H. Guidance by ultrasound of intra-articular injections in the knee and hip joints. *Osteoarthritis Cartilage* 2001;**9**:512–17.
19. **Reardon K,** Galea M, Dennett X, Choong P, Byrne E. Quadriceps muscle wasting persists 5 months after total hip arthroplasty for osteoarthritis of the hip: a pilot study. *Intern Med J* 2001;**31**:7–14.
20. **Walther M,** Harms H, Krenn V, Radke S, Faehndrich TP, Gohlke F. Correlation of power Doppler sonography with vascularity of the synovial tissue of the knee joint in patients with osteoarthritis and rheumatoid arthritis. *Arthritis Rheum* 2001;**44**:331–8.
21. **Falsetti P,** Frediani B, Filippou G, Acciai C, Baldi F, Storri L, *et al*. Enthesitis of proximal insertion of the deltoid in the course of seronegative spondyloarthritis. An atypical enthesitis that can mime impingement syndrome. *Scand J Rheumatol* 2002;**31**:158–62.
22. **Walther M,** Harms H, Krenn V, Radke S, Kirschner S, Gohlke F. Synovial tissue of the hip at power Doppler US: correlation between vascularity and power Doppler US signal. *Radiology* 2002;**225**:225–31.
23. **Falsetti P,** Frediani B, Fioravanti A, Acciai C, Baldi F, Filippou G, *et al*. Sonographic study of calcaneal entheses in erosive osteoarthritis, nodal osteoarthritis, rheumatoid arthritis and psoriatic arthritis. *Scand J Rheumatol* 2003;**32**:229–34.
24. **Filippucci E.** Sonographic training in rheumatology: a self teaching approach. *Ann Rheum Dis* 2003;**62**:565–7.
25. **Monteforte P,** Baratto L, Molfetta L, Rovetta G. Low-power laser in osteoarthritis of the cervical spine. *Int J Tissue React* 2003;**25**:131–6.
26. **Tarhan S,** Unlu Z. Magnetic resonance imaging and ultrasonographic evaluation of the patients with knee osteoarthritis: a comparative study. *Clin Rheumatol* 2003;**22**:181–8.
27. **Karim Z,** Wakefield R, Quinn M, Conaghan P, Brown A, Veale D, *et al*. Validation and reproducibility of ultrasonography in the detection of synovitis in the knee: a comparison with arthroscopy and clinical examination. *Arthritis Rheum* 2004;**50**:387–94.
28. **D'Agostino M.** EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part 1: prevalence of inflammation in osteoarthritis. *Ann Rheum Dis* 2005;**64**:1703–9.
29. **Iagnocco A,** Filippucci E, Ossandon A, Ciapetti A, Salaffi F, Basili S, *et al*. High resolution ultrasonography in detection of bone erosions in patients with hand osteoarthritis. *J Rheumatol* 2005;**32**:2381–3.
30. **Naredo E,** Cabero F, Palop MJ, Collado P, Cruz A, Crespo M. Ultrasonographic findings in knee osteoarthritis: a comparative study with clinical and radiographic assessment. *Osteoarthr Cartilage* 2005;**13**:568–74.
31. **Pourbagher MA,** Ozalay M, Pourbagher A. Accuracy and outcome of sonographically guided intra-articular sodium hyaluronate injections in patients with osteoarthritis of the hip. *J Ultrasound Med* 2005;**24**:1391–5.
32. **Yoon HS,** Kim SE, Suh YR, Seo YI, Kim HA. Correlation between ultrasonographic findings and the response to corticosteroid injection in pes anserinus tendinobursitis syndrome in knee osteoarthritis patients. *J Korean Med Sci* 2005;**20**:109–12.
33. **Acebes JC,** Sanchez-Pernaute O, Diaz-Oca A, Herrero-Beaumont G. Ultrasonographic assessment of Baker's cysts after intra-articular corticosteroid injection in knee osteoarthritis. *J Clin Ultrasound* 2006;**34**:113–17.
34. **de Miguel Mendieta E,** Cobo Ibanez T, Uson Jaeger J, Bonilla Hernan G, Martin Mola E. Clinical and ultrasonographic findings related to knee pain in osteoarthritis. *Osteoarthr Cartilage* 2006;**14**:540–4.
35. **Jan MH,** Chai HM, Wang CL, Lin YF, Tsai LY. Effects of repetitive shortwave diathermy for reducing synovitis in patients with knee osteoarthritis: an ultrasonographic study. *Phys Ther* 2006;**86**:236–44.


Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.

36. **Jung YO,** Do JH, Kang HJ, Yoo SA, Yoon CH, Kim HA, *et al*. Correlation of sonographic severity with biochemical markers of synovium and cartilage in knee osteoarthritis patients. *Clin Exp Rheumatol* 2006;**24**:253–9.
37. **Kristoffersen H,** Torp-Pedersen S, Terslev L, Qvistgaard E, Holm CC, Ellegaard K, *et al*. Indications of inflammation visualized by ultrasound in osteoarthritis of the knee. *Acta Radiol* 2006;**47**:281–6.
38. **Mandl LA,** Hotchkiss RN, Adler RS, Ariola LA, Katz JN. Can the carpometacarpal joint be injected accurately in the office setting? Implications for therapy. *J Rheumatol* 2006;**33**:1137–9.
39. **Qvistgaard E,** Torp-Pedersen S, Christensen R, Bliddal H. Reproducibility and inter-reader agreement of a scoring system for ultrasound evaluation of hip osteoarthritis. *Ann Rheum Dis* 2006;**65**:1613–19.
40. **Su E,** Mahoney C, Adler R, Padgett D, Pellicci P. Integrity of repaired posterior structures after THA. *Clin Orthop Relat Res* 2006;**447**:43–7.
41. **Tarasevicius S,** Kesteris U, Kalesinskas RJ, Wingstrand H. Dynamics of hip joint effusion after posterior soft tissue repair in total hip arthroplasty. *Int Orthop* 2006;**30**:233–6.
42. **Altinel L,** Kose KC, Degirmenci B, Petik B, Acarturk G, Colbay M. The midterm effects of diabetes mellitus on quadriceps and patellar tendons in patients with knee arthrosis: a comparative radiological study. *J Diabetes Complications* 2007;**21**:392–6.
43. **Atchia I,** Birrell F, Kane D. A modular, flexible training strategy to achieve competence in diagnostic and interventional musculoskeletal ultrasound in patients with hip osteoarthritis. *Rheumatology (Oxford)* 2007;**46**:1583–6.
44. **Lee YA,** Kim JY, Hong SJ, Lee SH, Yoo MC, Kim KS, *et al*. Synovial proliferation differentially affects hypoxia in the joint cavities of rheumatoid arthritis and osteoarthritis patients. *Clin Rheumatol* 2007;**26**:2023–9.
45. **Robinson P,** Keenan AM, Conaghan PG. Clinical effectiveness and dose response of image-guided intra-articular corticosteroid injection for hip osteoarthritis. *Rheumatol (Oxford)* 2007;**46**:285–91.
46. **Keen HI,** Wakefield RJ, Grainger A, Hensor EMA, Emery P, Conaghan PG. Can ultrasonography improve on radiographic assessment in osteoarthritis of the hands? A comparison between radiographic and ultrasonographic detected pathology. *Ann Rheum Dis* 2008;**67**:1116–20.
47. **Keen HI,** Lavie F, Wakefield RJ, D'Agostino MA, Hammer HB, Hensor EMA, *et al*. The development of a preliminary ultrasonographic scoring system for features of hand osteoarthritis. *Ann Rheum Dis* 2008;**67**:651–5.
48. **Kim HR,** So Y, Moon SG, Lee IS, Lee SH. Clinical value of (99 m)Tc-methylene diphosphonate (MDP) bone single photon emission computed tomography (SPECT) in patients with knee osteoarthritis. *Osteoarthritis Cartilage* 2008;**16**:212–18.
49. **Song IH,** Althoff CE, Hermann KG, Scheel AK, Knetsch T, Schoenharting M, *et al*. Knee osteoarthritis efficacy of a new method of contrast-enhanced musculoskeletal ultrasonography in detection of synovitis in patients with knee osteoarthritis in comparison with magnetic resonance imaging. *Ann Rheum Dis* 2008;**67**:19–25.
50. **Ostergaard M,** Wiell C. Ultrasonography in rheumatoid arthritis: a very promising method still needing more validation. *Curr Opin Rheumatol* 2004;**16**:223–30.
51. **Wakefield RJ,** Balint PV, Szkudlarek M, Filippucci E, Backhaus M, D'Agostino MA, *et al*. Musculoskeletal ultrasound including definitions for ultrasonographic pathology. *J Rheumatol* 2005;**32**(12):2485–7. [erratum appears in *J Rheumatol* 2006;**33**:440].
52. **Wakefield R,** Gibbon W, Conaghan P, O'Connor P, McGonagle D, Pease C, *et al*. The value of sonography in the detection of bone erosions in patients with rheumatoid arthritis: a comparison with conventional radiography. *Arthritis Rheum* 2000;**43**:2762–70.
53. **Tan AL,** Toumi H, Benjamin M, Grainger AJ, Tanner SF, Emery P, *et al*. Combined high-resolution magnetic resonance imaging and histological examination to explore the role of ligaments and tendons in the phenotypic expression of early hand osteoarthritis [see Comment]. *Ann Rheum Dis* 2006;**65**:1267–72.



**Take advantage of BMJ Journals' remarkable catalogue of titles with Related Collections**

No busy professional has time to browse through all pertinent journals to find relevant articles, but with Related Collections you no longer have to. Follow the "Related Collections" link from any article and use the "Show Collections from other Journals" to expand your search across all BMJ Journals. Or simply follow the "Browse by topic" link on the home page. By setting up your own collections and receiving email alerts every time an article is added to your chosen area, you can build up your own significant body of knowledge.


Ann Rheum Dis: first published as 10.1136/ard.2008.102434 on 14 April 2009. Downloaded from http://ard.bmj.com/ on March 20, 2024 by guest. Protected by copyright.