A systematic review of ultrasonography in osteoarthritis

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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 understanding 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

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
Arsilan 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.

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 ²⁴	Meniscal lesion	Y	Present or absent	Symptoms	N/A
Naredo ³⁰	Meniscal extrusion	Y	Present or absent	Clinical examination CR	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	Symptoms Clinical examination 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	No comparison made due to technical difficulties
Jung ³⁶	Cartilage thickness	N	Measured in mm	Radiography	N/A
Martino ⁹	Cartilage thickness	N	Measured in mm	Laboratory biomarkers Pathology	Good correlation between ultrasonography measurements and histology
McCune ⁶	Cartilage thickness	N	Measured in mm	Pathology	Good correlation between ultrasonography measurements and histology
	Cartilage clarity	N	7-Point scale		
	Cartilage sharpness	N	7-Point scale		
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.

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	
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 hypoechogenicity, 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 scintigraphic 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 Clinical response	Ultrasonography findings did not correlate with symptoms
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
Ostergaard ¹¹	Erosions	N	Counted	MRI	CR detected erosions in 22/101 subjects
					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.

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 detect 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 tenosynovitis,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 detect 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

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

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
Schmidt ¹⁶	Vascularity	N	Present or absent	Clinical examination	No agreement between CE and ultrasonography in detecting synovitis
	Synovial thickness	N	3-Point scale based on measurement in mm	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 hypoechoic synovial 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%)
	Effusion	Y	4-Point scale based on measurement in mm	Clinical examination	Popliteal cysts (ultrasonography 40%, MRI 35%)
Walther ²²	Synovial thickness	N	4-Point scale, based on measurement in mm	Histology	Increased changes with increasing radiographic grade
	Effusion thickness	Y	4-Point scale, based on measurement in mm		PD valid in detecting vascularity of synovium
Walther ²⁰	Vascularity	Y	4-Point scale and software		
	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	Popliteal 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
Monteforte ²⁵	C spine	Laser therapy	Decrease in pain index after therapy correlated with decrease in synovial sac thickness
Reardon ¹⁹	Knee	Observation post-surgery	Subcutaneous tissue thickness reduced after laser therapy
Su ⁴⁰	Hip	Observation post-total hip replacement	No significant increase in quadriceps thickness
Tarasevicius ⁴¹	Hip	Observation post-total hip replacement	Symptomatic side remained significantly thinner than other side
			Posterior structure integrity improved with time
			Capsular distension at 6 months improves at 12 months

C spine, cervical spine.

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 OMERACT⁵¹ 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.

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REFERENCES

- Joshua F, Edmonds J, Lassere M. Power Doppler ultrasound in musculoskeletal disease: a systematic review. *Semin Arthritis Rheum* 2006;**36**:99–108.
- 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.
- Fam AG, Wilson SR, Holmberg S. Ultrasound evaluation of popliteal cysts on osteoarthritis of the knee. *J Rheumatol* 1982;**9**:428–34.
- 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.
- Baratelli M, Parrini L. Ultrasonography in the study of pathological conditions of the hip. *Ital J Orthopaed Traumatol* 1986;**12**:233–7.
- 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.
- Iagnocco A, Coari G, Zoppini A. Sonographic evaluation of femoral condylar cartilage in osteoarthritis and rheumatoid arthritis. *Scand J Rheumatol* 1992;**21**:201–3.
- Jonsson K, Buckwalter K, Helvie M, Niklason L, Martel W. Precision of hyaline cartilage thickness measurements. *Acta Radiol* 1992;**33**:234–9.
- 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.
- 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.
- 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.
- Arsilan 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.
- Monteforte P, Rovetta G. Sonographic assessment of soft tissue alterations in osteoarthritis of the knee. *Int J Tissue React* 1999;**21**:19–23.
- 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.
- 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.
- 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.
- Giovagnorio F, Martinoli C, Coari G. Power Doppler sonography in knee arthritis—a pilot study. *Rheumatol Int* 2001;**20**:101–4.
- Qvistgaard E, Kristoffersen H, Terslev L, Danneskiold-Samsøe 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- Filippucci E. Sonographic training in rheumatology: a self teaching approach. *Ann Rheum Dis* 2003;**62**:565–7.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- 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.
- de Miguel Mendieta E, Cobo Ibanez T, Usón Jaeger J, Bonilla Hernan G, Martín Mola E. Clinical and ultrasonographic findings related to knee pain in osteoarthritis. *Osteoarthr Cartilage* 2006;**14**:540–4.
- 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.

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.

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